B – Resource Statement

4 Physical Characteristics

4.1 Geography

The location and boundaries of the Kaipara River catchment are shown in Map 1. The catchment drains an area of 270 square kilometres extending from the foothills of the Waitakere Ranges in the south and Riverhead Forest in the east to the Kaipara Harbour in the north. For the purposes of water resource management, eight sub-catchments (shown in map 1) have been delineated.

Part of the southern catchment (an area of approximately 20 km^2) is located within the boundaries of Waitakere City. From these elevated headwaters, the river flows north as the Kumeu River into Rodney District, within which the main part of the catchment lies. North of Kumeu Township the river flows in a westerly direction, to be met by the Ararimu and Tikokopu Streams which drain the north eastern part of the catchment.

The confluence of these streams, just upstream of Waimauku, marks the upper limit of the Kaipara River proper. The River continues to flow west, being joined by smaller tributaries such as the Waimauku Stream and Wharauroa Stream, until at Woodhill the northerly flow resumes. Downstream of Woodhill, the Lower Kaipara River meanders through an increasingly wide floodplain towards Helensville. North of Helensville, the river is joined by the remaining two tributaries of note, the Awaroa and Moau Streams, before meeting the Kaipara Harbour at Parakai.

4.2 Geology and Hydrogeology

Map 2 is a schematic representation of the catchment geology based on New Zealand Geological Survey maps. The basement geology of the catchment comprises Miocene aged Waitemata Group sedimentary rocks. These rocks form the hills in the east and south of the catchment. Two units are distinguished: interbedded sandstones and mudstones are the dominant rock type, while weakly consolidated conglomerates are also present. The conglomerates are largely found in the area under Riverhead Forest and in the hills to the south of Helensville, as far as Woodhill.

More recent Pleistocene and Holocene deposits of the Kaihu and Tauranga Groups dominate the remaining surface geology of the catchment. The elevated western part of the catchment comprises dune sands and gravels . These dune formations extend beyond the catchment to the north to form Kaipara South Head. The major river valley floodplains of the catchment, particularly those of the Kumeu River, Ararimu Stream and Lower Kaipara River have been subject to the deposition of clays, silts, alluvium and peat.

The Waitemata Group rocks and dune sands are the two main aquifers within the catchment. The Waitemata Group rock aquifer acts largely as a semi-confined groundwater system due to the layered nature of the sedimentary rocks. The aquifer receives recharge directly from the infiltration of rainfall in areas of higher elevation where these rocks outcrop at the surface. In low lying areas conditions may be confined beneath low permeability alluvial materials.

Groundwater flow is predominantly through fracture zones in the rocks, occurring from areas of higher elevations towards the major streams. As a result of the varied nature of fracturing and layering, the hydraulic properties of the aquifer can vary considerably over short distances, both horizontally and vertically. Bore yields reflect these variations, with low yields where fracturing is widely spaced or poorly connected. In general, the aquifer transmissivity is very low, when compared to other aquifers.

Groundwater abstraction from the Waitemata Group rock aquifer is concentrated in the southern part of the catchment, reflecting the high level of demand from horticulture in this area. More detail on the groundwater resource in this area can be found in the Kumeu-Hobsonville Groundwater Resource Assessment Report (ARC, July 1995).

The sand and gravel deposits in the western part of the catchment form a complex aquifer, with recharge occurring in the elevated highly permeable dune sands forming the catchment boundary to the west. Within these sands, perched water tables and springs occur where intercollated less permeable deposits form flow barriers. Recharge from the dune sands flows east towards the floodplain of the Kaipara River. The sand horizons in this area are overlain by low permeability estuarine sediments which act as a confining layer. The water table sits relatively close to the ground surface throughout this low lying area and, in some bores, artesian flow occurs. Groundwater abstraction from the sands is greatest in the Rimmer and Fordyce Rds area, again reflecting the distribution of horticulture.

Differences in the characteristics of these two main aquifers are of consequence for the surface water hydrology of the catchment. In particular, the higher permeability and pattern of groundwater flow in the dune sands results in the discharge of water more freely from this aquifer. This is reflected in the higher baseflows recorded in streams in the west compared to other parts of the catchment. The conglomerates in the east of the catchment also provide higher baseflows than typical Waitemata Group rocks, with low flows in the Ararimu Stream, for instance, higher than in typical Waitemata catchments. A more detailed discussion of stream low flows is presented in chapter 6.

4.3 Soils, Topography and Land Capability

The distribution of soil types in the Kaipara River catchment is shown in map 3 while map 4 shows the variation in slope. A key to map 3 is presented in Appendix I. This names the soil types and presents a brief description of the composition and characteristics of each soil. There are five broad groups of soil type within the catchment:

Soils of flood plains

These soils, in particular the Whakapara clay loam (KWF), relate to recent alluvial deposition and are generally moderately to well drained. However, the mottle phase of the Whakapara clay loam (KWFm), which occurs in the floodplain of tributaries in the upper catchment, are poorly drained.

Soils of estuarine flats and former lake beds

The soils around the mouth of the Kaipara River mouth are characterised by clay and clay loam complexes (KKP). To the west of the river mouth and into the coastal sand dune area, the soils have a higher peat content (KKPy) although these soils are also imperfectly to very poorly drained.

Soils of coastal sand dune complexes

The western fringe of the catchment is dominated by Red Hill (KRLH and KRL1) and Pinaki (KPN and KPNH) soil types of the coastal sand dunes. These soils, having a high sand content, are well drained.

Soils of undulating terraces and lowlands

The soils in the lowlands around Huapai and Kumeu are characterised by well to moderately well drained water sorted soils (KC1 and KC1A). South of Kumeu the Waipu peaty silt loam occurs (KYUy) which is imperfectly to very poorly drained.

Soils of rolling and hilly land

The soils throughout the steeper land found in the north east of the catchment are dominated by Mahurangi (KMV and KMVH) sandy loams which are imperfectly to very poorly drained. To the west as far as the boundary of the main Kaipara River floodplain, the better drained Whangaripo (KWR, KWRH and KWReh), and Warkworth (KWA and KWAH) soil types dominate. The main soils in the remaining elevated areas of the catchment, in the foothills of the Waitakere Ranges, are of the Cornwallis (KCW and KCWH) and Waitakere (KYT and KYTH) groups. These soils are well to moderately well drained.

Land use capability classes are presented in Map 5. A key to Map 5 is presented in Appendix I. This describes the characteristics of land in each class, along with its potential uses and susceptibility to degradation. A brief summary of this information is given below.

Of the eight classes of land use capability, classes I, V and VIII are not present in the Kaipara catchment. The land of greatest productive potential in the catchment is class II, with class VII being of lowest capability.

Class II land is found throughout areas of lower land with gentle topography in the Kumeu area and to the west of the Kaipara River north of Woodhill. These areas are highly suited to intensive cropping and horticulture, with local variations in wetness and soil quality the main limiting factors. Class III land occurs in areas of slightly more rolling topography, for instance in the lower foothills of the Waitakere Ranges and the lower slopes of land in the Ararimu valley, and is also suited to cropping, with grazing on steeper slopes. However, class III land in the dune sands in the west of the catchment is less suited to arable farming due to the potential for soil erosion when cultivated, and seasonal soil moisture deficiencies.

Class IV and VI land occurs in areas of rolling to moderately steep slopes throughout the foothills of Waitakere Ranges and the hills in the north east of the catchment. A range of soil types are present and susceptibility to erosion can vary widely depending on slope. Much of the class IV land in the catchment is under pasture. Both Riverhead and Woodhill Forests are largely on class VI land. In the latter case, the land comprises unstable dune sands and weakly developed soils which are susceptible to wind erosion.

Class VII land is found only at the extreme north west of the catchment. Although comprising older stable dune sands, the steeper slopes in this area make it susceptible to severe gully erosion as well as severe to extreme wind erosion. This area is not forested.

4.4 Climate

The Kaipara River catchment is located within an area described as the A1 climate class by the New Zealand Meteorological Service (1983) in its classification of New Zealand's climates. This climate group experiences warm humid summers and mild winters, with a winter maximum in the distribution of rainfall. The mean air temperature is 15 ^{0}C, this varying between monthly means of 11^{0} C in July and 19^{0} C in January. Prevailing winds are south westerly with occasional strong gales from the east or north-east.

Rainfall is variable across the catchment, largely due to topographic influences. Mean annual rainfall increases in a southerly direction, from 1292 mm at Helensville to 1341 mm at Woodhill Forest and 1387 mm at Waimauku, in the approximate centre of the catchment. Rainfall is at a maximum in the more elevated southern part of the catchment, with an annual mean of 1894 mm at Waitakere, whilst the longest record in the catchment, at Riverhead Forest, has an annual mean of 1448 mm.

5 Heritage

5.1 Cultural Heritage

5.1.1 A Summary History Of The Human Occupation And Modification Of The Kaipara River Catchment

Introduction

The Kaipara River catchment has a history of human occupation that extends back over at least seven centuries. The history is predominantly related to Maori occupation, although the catchment has European historical associations that date back nearly 180 years. The human occupation and modification of this extensive catchment is reflected by present day vegetation patterns; and a complex mosaic of archaeological sites, historic structures and trees, place names, and historical and cultural associations.

Throughout the long period of human occupation the Kaipara River Catchment and its water bodies have been extensively modified as a result of direct or indirect human influences. In the pre European era this modification was most intense in the lower catchment on either side of the river between Rewiti and the river mouth near Helensville. Following the beginning of organised European settlement in the 1850s the catchment was however modified in its entirety.

A basic knowledge of the history of this cultural modification is essential if the natural and physical resources of the Catchment are to be fully understood and sustainably managed as required by the RMA 1991.

The Pre European Era

Most of the Catchment, as defined in this study, is the ‘ancestral land’ of the Te Taou hapu of Ngati Whatua who still maintain a marae beside the Kaipara River at Rewiti just north of Waimauku. Te Kawerau a Maki also have historical associations with much of the catchment, and in particular with the Kumeu River sub catchment.

This brief historical account has been produced in consultation with representatives of both Iwi. It is not however a definitive account of the relationship that they hold with the study area. The complexities of the relationship that the two Iwi hold with the wider catchment is beyond the scope of the study, and is for them to describe. In the same regard this study is not a detailed account of the European historical associations with the Catchment. The aim of this account is to give a general background to the direct and indirect human modification of the Kaipara River Catchment, as can be ascertained from the archaeological and historical record.

The archaeological survey record in the Catchment is incomplete and largely confined to its north western sub catchments. A general picture of pre European occupation and modification of the Catchment can however be gleaned from known archaeological site distribution, aerial photographs and the historical record. The vegetation patterns illustrated on early survey plans dating from the 1850s and 1860s indicate that while Maori occupation was focused around the lower reaches of the river, the wider catchment was modified in some way by human influences in the pre European era.

The extent of the Maori relationship with the Kaipara River Catchment is clearly illustrated by the mosaic of traditional Maori place names that were applied throughout its area (see Map 6). All of the hills and ridges had specific names, as did all of the waterways including even the smallest tributaries. The high points that encircle the catchment still provide reference points for the identity of the local Iwi. They are important in themselves and are also important as 'nga matapuna o te awa', the 'headwaters or sources of the river'.

In the south stands the catchment's highest point Pukematekeo (336 m.). It is located at the southern end of the northern foothills of the Waitakere Ranges which are of major significance to Te Kawerau a Maki. Known traditionally as Nga Rau Pou a Maki (the many posts of Maki), the northern foothills include Huranui, Maungakarikari, Papatawhara and Te Pou a Maki. The catchment is bounded in the south east by the ridge known as Pukewhakataratara. Further down river are the important landmarks of Te Korekore in the west, and Whatati, Pukeharakeke, Kahutopuni, Te Ahu and Pukeatua in the east. Immediately to the north of Rewiti Marae is Tauwhare, a hill of major significance to the Te Taou hapu of Ngati Whatua.

The lower Kaipara River and its tributaries are bordered by numerous named high points. To the west of the river on the consolidated dune country are Pukewera, Rarapuka, Pahunuhunu, Puketutu and Purerua. The eastern side of the river is dominated by the high ridge known as Paehoka which drops to Pukekorari south of Helensville. Standing above the Kaipara River mouth is the impressive flat topped hill of Otamateanui and a series of high points including Patukuri and Kaikai.

The name Kaipara appears to have applied traditionally to the Harbour and in particular to its southern arm. The Kaipara River itself had many different names that applied to its component parts. For example the meandering bends in the river near Helensville were known as Tungoutungou while the section near the main river bridge was known as Te Pu a Tangihua. Further upriver were the shoals known as Kaiwaka, and the meander north of Rewiti which was known as Tua te tua.

Each tributary had its own name which gave it a unique identity, and mauri or spiritual essence, which is still seen by Tangata Whenua as being of fundamental importance in their management. Some of the traditional names of the tributaries reflect the physical qualities of the streams and their catchment eg Waikoukou, Mangakura, and Te Awaroa. Others like Mangatoetoe, Ahukaramuramu, Te Ararimu, Waimauku and Nga Kiriparauri were named because of natural resources associated with them. A number were named because of their historical or cultural associations e.g. Pakinui, Kumeu, Waipatukahu, Nga Tahanga, Wharauroa and Rakauwhatia.

Over many centuries the Tangata Whenua developed an intimate knowledge of, and an association with, the entire catchment. They utilised its resources and had both direct and indirect influences on its ecology. From the earliest period of Maori settlement the catchment would have been by two indirect cultural influences. The kiore or Polynesian rat impacted on birds, insects and reptiles, and also influenced regeneration patterns by eating seeds on the forest floor. The most intensive modification of the catchment was however resulted from the development of kainga (settlements) and maara (cultivations).

The archaeological and historical record indicates that main occupation and cultivation areas were located on either side of the Kaipara River above the swampy ground between Reweti and Te Awaroa (Helensville). The ongoing use of fire to clear land in the development of settlements and cultivations undoubtedly caused the greatest modification of the catchment in the pre European era. Earthworks undertaken in the formation of kainga and pathways, and numerous rua (food storage pits) also modified the catchment. The rich array of food, medicines and building materials in the adjoining forest was also harvested. In the vicinity of kainga the forest was modified through the planting of groves of trees such as puriri, taraire, kowhai and karaka in order to provide food and to attract birds. The extensive wetlands associated with the floodplain were harvested for inanga, kokopu, koura, eels, kakahi (freshwater mussels) and waterfowl. Raupo, reeds and harakeke (flax) were taken as building and weaving material. A wetland near Ohirangi known as Te Tareminga was used in ancient times as a place to trap moa (Sheffield 1963:25).

All of these valued resources, including the Kaipara River itself, were protected by pa (fortifications) which are still of extreme significance to the Tangata Whenua of the district. The eighteen pa known to be located within the catchment are in the main located on the high country bordering the lower Kaipara River between Reweti and Helensville. The construction of pa and the other forms of pre European environmental modification would have had a significant impact on the ecology, landforms and water bodies in the Catchment.

The water bodies of the Catchment were all perceived as having their own mauri (spiritual essence) and were used in a carefully regulated way depending on the nature of their mauri. Every kainga drew water from named puna (springs), roto (lakes), manga (streams) and awa (rivers). The Kaipara River itself was the source of numerous natural resources and it provided an extremely important transport route between the Kaipara Harbour and the overland portage to Rangitopuni.

Thus in the pre European era, environmental change within the Kaipara River Catchment was significant, although it was gradual and largely confined to the mid and lower catchment area. The nature and extent of pre European environmental change was illustrated by the vegetation patterns found in the Catchment immediately prior to European settlement. These patterns were mapped in detail by J. Beever using the first survey plans for the district compiled in the 1860s and 1870s. Large expanses of fern and manuka were found near the Kaipara River in the mid and lower Catchment. The high country east of the river between Helensville and Riverhead remained largely clothed in ‘kauri forest’, as did the western and southern edges of the Kumeu sub catchment.

The flood plain of the upper and lower Catchment retained dense kahikatea dominated swamp forest and extensive flax and raupo wetlands. Extensive wetlands were also to be found along both sides of the main floodplain between Reweti and Helensville with a particularly large expanse of swamp known as Kaituna being located between Bradley and Rimmer Roads. On its northern edge there was a permanent ‘freshwater lake’(Sheffield 1963: 18) which is no longer present. Another large fresh water lake, known as ‘Wharepapa’, was also located to the south of Bradley Road at the head of the Pahunuhunu Valley. This lake was large enough to be “offered as a water supply for Helensville by Mr.

A. Dewar, as early as 1884, but the offer was not accepted." Lake Wharepapa was drained for farm development in the early twentieth century.

The Post European Era

The first recorded European visit to the study area was made by the C M S missionary Reverend Samuel Marsden who made an inspection of the Kaipara Harbour entrance in July 1820. Marsden reported that, "there are three fresh-water rivers…upon whose banks the finest spars are to be met with" (Elder 1932:271). Marsden's visit stimulated European interest in the timber resources of the Kaipara River Catchment although they were not to be exploited for several decades.

The Catchment continued to be modified by Maori occupation in the early 1800s. Marsden noted that the kainga on the lower Kaipara River had extensive cultivations, and that cats and pigs were common. In 1842 the Rev. William Colenso crossed the south eastern edge of the catchment which he described as 'barren country'. He commented on the lack of inhabitants in the area, and noted that near the Kaipara River, "the pine forests…were burning furiously", an occurrence that he saw as commonplace (CMS London Records, Feb 1842).

In 1844-45 the flat land between Kumeu and Riverhead was acquired by private European purchasers and some timber was cut and taken to Brereton's Riverhead Mill. Between 1851 and 1859 the Crown purchased much of the southern and eastern portion of the Catchment. This opened the way for the beginning of half a century of timber milling which was to have a significant long term impact on the water bodies of the district. In 1854 the Crown issued 'timber licences' to David Archibald in the Kumeu area, William Blake in the Waikoukou Valley, and James Maxwell in the Ararimu Valley. Their operations, which included the construction of a driving dam and a water powered mill, would have caused significant siltation in the Ararimu and Kumeu sub catchments, as well as in the downstream area. The Wilkins brothers were to continue milling the Waikoukou Valley until the mid 1880s.

In 1862 John McLeod established a timber mill at Te Awaroa (Helensville). He initially milled the adjoining Te Awaroa sub catchment, and then secured timber cutting rights on the Maori land extending down the eastern side of the Kaipara River as far as the Wharauroa sub catchment. In the 1880s McLeod's Mill, reformed as the Helensville Timber Co., milled the Kiwitahi Block east of Woodhill and the Tikokopu and Wharauroa Blocks. The area continued to be milled by the Kauri Timber Co. until 1892.

This large scale milling operation had a major impact on the lower Kaipara River Catchment. The Awaroa, Mangakura, Wharauroa, Tikokopu and Waikoukou sub catchments were cut over, and many timber camps and bullock roads were constructed within them. Numerous driving dams were constructed to 'float' timber to the Kaipara River, with the course of the lower Tikokopu Stream being significantly modified to assist in this process. Timber booms were erected in the Kaipara River at Ohirangi near the Mangakura Stream outlet and logs were rafted and towed to Helensville mills, or to waiting ships.

Much of the forest in the upper Kumeu River sub catchment was not accessible for milling until the construction of the Auckland Helensville railway link in 1881. A great deal of the forest cover had simply been burnt during land clearance for farms from as early as 1853, and many farmers sold totara and puriri for fence posts, building and wharf piles. In the late nineteenth century Hunter Brothers operated a mill on their Taupaki property where they milled timber from the high country extending north to Waimauku. These operations in conjunction with the development of pasture obviously had a significant impact on the Kumeu sub catchment and the downstream water bodies. The Taupaki and Kumeu areas began to experience regular major winter flooding in the early nineteenth century. A substantial part of the Catchment was also dug over for kauri gum, including many of its wetland areas. The wetlands and stream margins were also modified through the harvesting of flax which was processed at the many small flax mills located throughout the district.

The main long term modification of the catchment's water bodies and water table resulted from land clearance and drainage undertaken in the development of agriculture. European settlement began in the Kumeu sub catchment in 1853 and by 1870 pastoral farms had been developed throughout the Catchment. Store cattle were run on most properties, however with the development of the Harkins Point- Helensville railway (1875) and the Auckland Helensville rail link (1881) dairying became the predominant land use on easier country. Dairy production intensified with the opening of the Ambury&English Creamery, Woodhill (1894), the Waitemata Dairy Co Creamery, Waimauku (1904), and the Kaipara Co-op Dairy Co Factory, Helensville (1911).

The development and intensification of pastoral farming over the next 50 years was to have a significant impact on water flows and water tables in the Catchment. Wells and ponds had been excavated since European settlement began. In the early 1900s bores were sunk on most farms. On W. Smith's property at Ohirangi for example, a bore produced, "an amazing flow of 7000 gallons a day." (Sheffield 1963:168) Substantial drainage works were undertaken on the floodplain, in particular after the introduction of drag-lines in the 1920s. This work had a particular impact on water tables and water bodies in the lower catchment on the alluvial lowland bordering the river between Reweti and Helensville.

In the 1920s exotic forestry operations also began to impact on the water tables and water bodies in the Catchment. In 1926 the Crown developed the Riverhead State Forest on the marginal farmland which had made up the abortive Riverhead Homestead Settlement. Woodhill State Forest was developed by the Crown from 1934 as part of a project to stabilise the vast area of mobile sand dunes located to the west of the lower Kaipara River Catchment. These two exotic forests are still in production.

From the early 1900s the growing borough of Helensville had begun to experience water shortages. Several sources were inspected and in 1913 a concrete water supply dam was constructed on the upper Mangakura Stream just south of the town. This impoundment yielded just 25,500 gallons per day which became insufficient for Helensville's needs within a decade. Investigations into the possibility of taking underground water from the sand country west of Te Pua were undertaken in 1930, however "the iron and other mineral contents of such water made it unsuitable" (Ibid.:218). In 1934 a second larger dam was constructed on the Mangakura Stream greatly increasing storage capacity. The construction of a larger lower level earth dam on the Mangakura Stream was proposed from the mid 1950s and commissioned in 1964 raising total storage capacity to approximately 107,000cu m. In 1975 a pumping station utilising the underground water resources of the sandhills area was finally constructed near Bradley Road, Wharepapa.

From the early 1900s the Catchment was faced with a water problem of a different kind. Timber milling, agricultural development and the introduction of exotic weed species had modified stream and river bed profiles and runoff flows in the Catchment. From 1918 there was regular inundation of the floodplain and there has been major flooding of farmland and townships on 20 occasions since that time. The worst flood on record occurred in July 1979 and there has been a major flood as recently as 1996.

In 1930 the Kaipara River Board was formed with the specific aim of dealing with the problem of flooding especially in the lower Catchment. A dragline was used to straighten bends in the Kaipara River north of Woodhill, and a number of stopbanks were constructed. In the late 1950s and early 1960s the former Waitemata County Council undertook river improvement works, "with the aim to reduce the duration of flooding of farmland to no more than three days" (ARA 1989: 2). This work included channel straightening and cleaning, and the construction of diversions and stop banks. The Kaipara River Flood Management Plan 1989 proposed major channel diversions and improvements on the lower Kaipara River , and the construction of flood berms at Kumeu and a flood diversion channel at Taupaki.

Dairying declined in importance from the 1960s and there are now only 32 dairy farms located in the Catchment. Farm subdivision for lifestyle and horticultural blocks has accelerated in recent decades, especially in the Kumeu River sub catchment. This process has been accompanied by population growth throughout the Catchment, and an expansion in residential and commercial development, particularly in the Kumeu-Huapai and Waimauku areas. A significant industrial node dominated by the Particle Board Factory has also developed at Huapai-Kumeu.

The expansion of market gardening, orcharding and viticulture raised water demand dramatically from the 1970s. In conjunction with residential, commercial and industrial development it has led to a proliferation of bore installation and farm dam construction in the last two decades. In 1988 the Auckland Regional Authority identified and designated the Campbell Road Impoundment as the preferred future bulk water source for the Auckland region. This scheme would involve extracting water from the Kaukapakapa River and the combined flows of the Ararimu, Waikoukou, and Tikokopu Streams. It has a potential mean safe yield of 90,000 cu m /d which would have a significant impact on the availability of water in the downstream catchment.

Conclusion

The landforms, ecology and water bodies of the Kaipara River Catchment have been modified in their entirety over many centuries of human occupation and resource use. Over the centuries human associations have developed with the natural resources of the Catchment which has been left with a rich array of places and areas of historical and cultural significance reflecting both the Maori and European occupation of the land. A knowledge of the history of the use of the Catchment's water bodies and water resources is essential if these resources are to be managed sustainably into the future.

5.1.2 Archaeology of the Kaipara River Catchment

Introduction

The physical remains of past occupation and use of the Kaipara River and its tributaries are varied. The remnants of Maori occupation are evident in the landscape by earthworks (e.g. pa, storage pits, and terraces) and the remains of resource gathering and subsistence activities (shell middens, taro and karaka groves). The early European industrial and commercial activities are also documented in the land by the remains of structures such as sawmills, buildings, flourmills, and wharves. However, our knowledge about historic places and areas within the catchment is very limited. Archaeological site survey has been confined to a few locations. No sites have been investigated using scientific techniques and a synthesis of the primary heritage information sources (archaeology, oral traditions and historic accounts) has not been compiled. Where surveys have taken place, a number of sites have been recorded. This discussion looks at the existing historic place information within the extent of completed survey within the catchment.

Distribution Map

Map 7 shows the distribution of recorded historic places and areas. It is important to note that it also shows the areas that have been surveyed for such sites. The absence of data for a particular area should not be taken to mean that it contains no historic places. Most areas remain to be surveyed for such sites.

The majority of site surveying was done in the 1970s. Legislation as this time defined archaeological sites as any specific location that retained material evidence of past human activity and that through archaeological techniques could provide evidence for the exploration, occupation, settlement and development of New Zealand. This definition was limited to archaeological sites that were more than 100 years old (Historic Places Amendment Act 1975). The Historic Places Act 1980 also retained this definition.

The implications of this past legislation has meant that a number of historic buildings, structures and areas associated with the early European phase of settlement within the region have gone unrecorded. Changes to the legislation in 1993 extended the definition in a minor way to encompass those sites "*associated with human activity that occurred before 1900*" (Historic Places Act 1993) to include Maori-European contact sites. However large scale systematic survey of these site types has not yet been undertaken.

To date 174 items of cultural heritage significance have been recorded within the Kaipara River catchment: 150 archaeological sites, 7 historic buildings and structures, 12 maritime sites, two botanical sites and 3 historic sites reported by Hayward and Diamond in 1977. These different categories of heritage places is based on the Cultural Heritage Inventory, a database of heritage sites within the Auckland region which has been compiled by the Auckland Regional Council over the last 8 years. The map legend identifies these different categories with a range of colours.

Archaeological Site Survey

Within the Kaipara River catchment, systematic archaeological site survey has been limited to three specific areas. These are shown as shaded areas on the distribution map covering (a) parts of the north-west sub-catchments inland from Woodhill Forest, (b) part of the Riverhead Forest and (c) the Waikoukou Stream valley.

Simon Best recorded numerous archaeological sites during a survey for the New Zealand Historic Places Trust in 1975. This survey was conducted on the north western side of the catchment, extending from Rimmer Road in the north to Hamilton Road in the south, and inland to State Highway 16. A total of 164 archaeological sites were identified (Best, 1975). Fourteen pa sites in the area were considered to be especially important archaeologically. These sites are located on the north-south aligned ridges along the western boundary of the Kaipara River catchment. These pa sites represent defended high points inland from Muriwai Beach.

In 1975 Jennifer Leighton undertook archaeological site survey in the area west of Parakai recording 37 sites. Extensive surveying for archaeological sites has also been undertaken in the wider Kaipara area by Wynne Spring-Rice. Most of this work has focussed on the southern Kaipara peninsula from South Head to Woodhill. However, only a few of these sites are located within the catchment boundary as defined on the map.

Archaeological site survey was not resumed until the late 1980s when a large scale project was undertaken by the Auckland Regional Authority to ascertain suitable locations for future bulk water supply for the Auckland Region. Preliminary archaeological surveys were undertaken in 1988 by Ian Lawlor at three locations within the Kaipara catchment. Two surveys were undertaken in the Riverhead Forest, where three archaeological sites were recorded, and an additional survey was completed along the Waikoukou Stream valley where a further 9 sites were recorded.

The most recent work has been undertaken by consultant archaeologists surveying small blocks of land around Helensville for residential subdivision development proposals. Only a few sites were identified during these surveys. Authorities were granted by the Historic Places Trust to modify these sites for development activities (see reports by Clough and Associates, Best, and Bioresearches). Investigations found only limited evidence of past human occupation in these areas. Other archaeological work has focused on monitoring forestry operations within the Woodhill Forest.

Maritime Sites

Historic records relating to the coastal environment of the Auckland Region were researched for evidence of our maritime heritage. This project identified sites within the coastal marine area for which the ARC is directly responsible. This work was reported (Taylor, 1994), sites were evaluated, and a sample have been scheduled for protection and preservation in the Regional Plan: Coastal. However, the Kaipara was one area where exhaustive research did not take place due to the large scale of the area and the high density of sites. Further work in the Kaipara Harbour was recommended as part of this study (Taylor, 1994: 74). Twelve sites have been recorded at the mouth of the Kaipara River and are located within the Kaipara

River catchment and include 4 sawmills, a hulk, 2 wharves, a flour mill, a flax mill, a boom, and 2 bridges (See Table 5.1).

Historic Areas, Buildings, Places, Objects and Structures

Details of seven historic buildings located within the Kaipara River catchment are given below in Table 5.2. Information has been gathered by the ARC relating to historic areas, buildings, places, objects and structures and are recorded in the Cultural Heritage Inventory, however these places are not formally recorded on any national inventory. Protection of these sites is predominantly achieved by inclusion in District Plans. The buildings that are listed below have been noted because of their historical associations and are of local importance.

Table 5.2: Historic Buildings recorded in the Kaipara River Catchment

CHI No.	Metric Easting	Metric Northing	Location	Site Type	Name(s)
54	2639600	6500550	Rogan Avenue Helensville	DWELLING	Te Makiri
695	2640100	6501700	20 Commercial Rd, Helensville.	JUSTICE	Helensville Courthouse
1179	2647690	6482250	Across the road from Waitakere Primary School, Waitakere	SCHOOL HALL	Waitakere School Hall
1184	2649427	6482256	15 Amreins Road, Waitakere	DWELLING	Betula Hill
1185	2648864	6481791	82 Mc Entee Road, Waitakere	DWELLING	Villa
1187	2648182	6482454	29 Township Road, Waitakere	EX STORE	"Cottage Gardens"
1188	2648173	6482259	Waitakere	PUBLIC HALL	Waitakere Public Hall

Many historic places recorded in the Waitakere area resulted from intensive survey work of Jack Diamond and Bruce Hayward (1978). They reported and mapped large numbers of historic sites although these were never been formally recorded within the New Zealand Archaeological Association Site Record File due to the legislative restrictions at the time. This work focused on sites relating to the industrial, commercial and domestic activities of early European settlement. A total of 683 sites were identified and reported and have been included into the ARC Cultural Heritage Inventory. Remains of the once extensive network of tracks and tramlines in the Waitakeres extend into the Kaipara River catchment and are shown on the site distribution map.

Rodney District Council is currently research into historic places within the district. As part of this work, further places of heritage significance may be identified within the Kaipara River catchment.

Historic Flora and Botanical Sites

Historic flora and botanical sites are those places and areas which have significant historic associations. The map shows that to date there has been only one place formally identified within the Kaipara River catchment, a rimu tree planted in 1923 when the Waitakere Primary School opened. It is believed that considerably more vegetation of historic significance is located with in the catchment, particularly where historic structures have been recorded. Rodney District Council is currently undertaking research into a number of historic trees that

Table 5.1: Maritime sites recorded in the Kaipara River Catchment

CHI No.	Metric Easting	Metric Northing	Site Type	Name(s)	Description
187	2640100	6502300	SAWMILL/WHARF/ BOOM	John McLeod Issac McLeod McLeods Mill	Coastal sawmill. Mill was established opposite the Te Awaroa Maori village. It became the focal point for the surrounding region. The name of Helensville came from John McLeod's name for his home "Helens Villa" after his wife. The township grew around the mill. By the mid-1860's McLeods ran sailing cutters from Helensville around the Kaipara. The most notable cutter was the PAI MARIRE. McLeod's had their own wharf and used it to export timber and unload coal for the mill's steam engines. In 1882 McLeod's joined with other investors in forming the Helensville Timber Company. The old mill was closed. Remains of the boom are assumed to exist.
189	2640100	6502500	SAWMILL	Charles West's sawmill Charles S. West	Large coastal sawmill built in 1917 which continued to operate until recent times using native timber and more recently P.radiata from the Unahirere Block near Helensville. Charles West was the son of Arthur West who had the earlier timber factory and mill in Helensville.
446	2639850	6501500	SAWMILL/WHARF/ BOOM	Helensville Timber Company's Mill Helensville Timber Company Wharf Kauri Timber Company	Sawmill . The new single storied mill stood on the lower land and the northern edge of Te Horo Pa, adjacent to the Kaipara River at Helensville South. In 1886 the Kauri Timber Co. purchased the Helensville Timber Co and ran until 1892 when the 'timber boom' was over and the Kauri Timber Co. concentrated its milling operations in Freeman's Bay in Auckland. Logs were towed to the boom (which was located on the opposite side of the river) from the Ohirangi Boom by steam launch from where they were winched into the mill. The boom stretched almost across the river. A deep cutting was required for the railway siding which is still used by the Dairy Company.
447	2639500	6499900	BOOM	Ohirangi Boom	Boom. Logs were floated down the river to the Ohirangi Timber Boom from where they were rafted and towed by steam launch to the Helensville Timber Co mill boom and then winched into the mill.
505	2640050	6502100	BRIDGE		Railway bridge for the extension from Helensville South to Helensville North of the railway. Made in the foundry of Charles Spinley in 1881.
507	2640050	6502250	WHARF	Railway wharf	In 1881 the railway was extended to Helensville north, near the site of McLeod's mill, and a new large station, engine shed, goods shed and wharf were also erected. SEE 501
508	2640050	6502400	FACTORY (FISH)/WHARF		In 1882 a John Wilson built new premises beyond the north railway terminus, between the main road and the river. It also had a wharf on the Kaipara river. The machinery could process 3000 one pound tins a day. Principal fish used was mullet, but kahawai, snapper, flounder and pilchards were also canned. In 1884 it passed to Mr. L.Masefield who applied for a slaughterhouse license and continued the business for some years. Marked on SO 4699 (1888)
510	2639920	6502300	FLAX MILL	Henry Ballans	Flaxmill ?1880s
522	2639300	6502100	BRIDGE	Te Horo Point Bridge Helensville Bridge	In 1882 the first bridge was built across the Kaipara River at Te Horo Point where the ferry had been. It was 12 foot wide, railed swing bridge with totara piles, some up to 50 feet in length. At the centre was a pivot stand for the swinging mechanism which opened 2 22 foot openings for ships to pass through. Concrete bridge across the Kaipara River 210x24 feet opened in October 1915.
524	2639910	6501500	FLOURMILL	Bates	A large 3 storied flourmill worked for a short time in the early years. It stood on a high bank between the railway and the river, south of the South Rail station. It was managed by Mr Bates. Grain was brought from the South Island by vessels. It was pulled down after a good many years by Alfred Brecroft.
846	2639820	6501500	SAWMILL	Coulthards	Sawmill in operation from 1902-1908 mainly cutting kahikatea and rimu. Coulthards had a licence to float timber on the Kaipara River and reused the old Helensville log boom.
919	2638700	6500900	HULK		More research is required to identify the name of the vessel. Rudder, bottom, and lower stem visible in reedy paddock.

have been identified in the Helensville area to ascertain their heritage significance. This could increase the number of trees with historical associations recognised in the district plan.

Discussion

Appendix II lists all recorded historic places and areas within the Kaipara catchment. The majority of historic places that have been surveyed and recorded are associated with Maori occupation. A fewer number of places associated with the historical period have been recorded. This is a product of both the criteria that bound the formal recording of archaeological sites to those places which were in use before 1900 and the lack of formal survey and recording work undertaken.

The map highlights the fact that a large portion of the catchment remains to be surveyed for heritage places. Most of the archaeological sites associated with Maori occupation are located on either side of the lower Kaipara River north of Waimauku. Historical accounts indicate intensive use of the area to the east of the Kaipara River by Maori where there are currently no sites recorded. It is expected that the same density of sites is to be found in the eastern sub-catchments as in the north-western surveyed areas, especially in the lower reaches of the Kaipara River up to the point where the river was navigable by canoe and boat.

The Kaipara was an area of extensive occupation and settlement by Maori and was also an important focus of 19^{th} century European settlement. Helensville itself formed an important gateway to the Kaipara River. The human history of the area has been well documented by Murdoch (1988), a brief summary of which is provided in section 5.1.1 of this report. Many of the original settler families still occupy properties in the catchment and the district is has a rich layer of historic places and areas that reflect its post European heritage. The Tangata Whenua groups associated with the catchment have retained their associations with its hills, waterways and traditions to this day. This relationship must be recognised and provided for in managing the catchment's present day resources.

Future Use

The Resource Management Act requires particular regard to be had to the 'recognition and protection of the heritage values of sites, buildings, places, or areas'. But despite intensive use of the river and its catchment by both Maori and European alike, over 90 percent of the catchment remains to be systematically surveyed, so it is difficult to make judgements about whether future development will affect historic places or areas. The priority areas for archaeological survey would be the eastern side of the Kaipara River and the ridges and valleys of the major sub-catchments. Future growth around Helensville, Waimauku, Woodhill and other places should also be targeted for survey work.

Any large scale earthworks or development has the potential to adversely affect archaeological sites or historic places and areas. Excavating earth from borrow areas, dam and road construction and vegetation removal all have the capacity to destroy, damage or modify archaeological sites or historic places and areas, as would an increase in arable crop farming as a result of increased irrigation.

To progress what we currently know about the cultural heritage of the Kaipara River catchment future use and development should take into account heritage values. All consent applications to dam streams and creeks, take water and carry out earthworks should be assessed to see if historic places and areas will be adversely affected by the proposed activities. Archaeological survey work should also be promoted where major developments are proposed.

5.2 Natural Heritage

5.2.1 Introduction

The Kaipara River catchment is an integral part of both Rodney and Kaipara Ecological Districts. Virtually the entire catchment is modified and in pasture or small rural settlements and developments. The location of rural centres at Waimauku, Helensville, Huapai and Kumeu within the catchment boundaries pose threats to the natural values of these areas. Domestic pets, for instance, threaten the continued existence of native birds in the area, while gardens are often a source of exotic weeds. Discharges throughout the catchment can compromise water quality (see section 6.2) and impact on the natural values associated streams and wetlands.

The high level of modified landscapes throughout the catchment has resulted in the loss of indigenous vegetation cover in the past, leaving only a limited number of isolated forest fragments. Few ecological corridors appear to exist in the catchment that provide linkages between these forest remnants. The largest forest areas in the Kaipara and Rodney Ecological Districts are Woodhill Forest and Riverhead State Forest. These pine plantations border the Kaipara River catchment and pose the threat of pines self sowing in native forest and scrub remnants.

Despite these threats, the catchment provides an important habitat for many species, including some that are rare or endangered (For example, the rare fern *Loxsoma cunninghamii* and the threatened Australasian bittern). Fish communities in the Kaipara River include shortfinned eels, Inanga, black mudfish in swamp areas, longfinned eels, shortfinned eels and banded kokopu in the lower eastern catchment; and in the main river channels, longfinned eels, shortfinned eels, mullet and flounder (see section 7.2 for more detail).

Although the Kaipara Harbour lies beyond the boundaries of the catchment, it is important to note its status as an area of international significance. This status is primarily due to its importance as a nesting site for international migratory birds. Many of these nesting sites are in the estuarine areas of the harbour. The Kaipara River is the main source of freshwater to some of these estuarine habitats and therefore has a significant influence on salinity gradients, water quality, sediment budgets and flushing abilities in these parts of the harbour.

5.2.2 Data Sources

The following summary describes documented natural heritage sites within the Kaipara River catchment as of January 1999. A brief description of each site is provided, with an indication of the site locations shown on Map 8.

The information has been taken from several sources held by the ARC and listed in the bibliography. This has been reviewed in the light of draft reports on recent ecological surveys of the Kaipara and Rodney Ecological Districts. The ecological significance of some of the sites mentioned in these drafts are under revision, with several sites considered to be of greater ecological significance than previously thought. Further sites of natural heritage value may be documented in the final reports on these surveys, and it is probable that there are other sites of significant natural value within the catchment that are yet to be identified.

The significance of each of the sites documented here is based on their presence and ranking in national, regional and district surveys. This is according to the following criteria (see bibliography for sources):

International

- Listed in Geopreservation Inventory, WERI, ARPS, Appendix B of the RPS, and Draft Appendix B Notes as sites of International Significance.
- SSWI sites of outstanding significance

National

- Listed in Geopreservation Inventory, WERI, ARPS, Appendix B of the RPS and Draft Appendix B Notes as sites of National Significance
- SSWI sites of high significance

Regional

- Listed in Geopreservation Inventory, WERI, ARPS, Appendix B of the RPS, Rodney PNA and unpublished ARC lists as being of Regional Significance
- SSWI sites of Moderate-High significance

District or Local Significance

- Listed in Geopreservation Inventory, WERI, Rodney PNA and unpublished ARC lists as being of District or Local Significance
- SSWI sites of moderate and potential significance
- Not identified in any source as being of Regional or higher significance

The following summary groups sites according to the subcatchments shown in map 1. A description is also given of sites in the vicinity of the Kaipara Harbour beyond the catchment outlet.

5.2.3 Description of Natural Heritage Sites by Sub-catchment

Kumeu River

The Kumeu River sub-catchment (including the Upper Kumeu River) is one of the two major headwaters of the catchment and is characterised by broad valleys with extensive alluvial soils separated by low, rolling hills. The area is predominantly rural with main land uses being pastoral farming and widespread horticultural development (Wildlife Services, 1989). Little information is available regarding the riparian values of the river or any of its tributaries, other than the following.

Taupaki Riverine Remnant

An area of lowland manuka-kanuka forest on alluvium has been identified as a Priority Vegetation Site in the Rodney Ecological District PNAP Survey Report (1992). This site occurs along the Kumeu River near Taupaki.

Matua Rd Bush

This site consists of alluvial podocarp forest extending up a scarp. The forest has a healthy canopy containing kahikatea, totara, titoki and manuka. This vegetation creates a link between the Riverhead Pine forest and the Kumeu River habitat. Some of the forest has been fenced off from stock, and this area is now actively regenerating. Common native birds are present, including kereru, tui, fantail and grey warbler. This site has been identified as a SSWI site (P249) of 'moderate' ecological value.

Hinau Rd Bush (partly located within Waimauku subcatchment)

This area of native vegetation is one of the larger forest patches in the Kaipara River catchment. It consists of kauri-podocarp forest with puriri, kohekohe and kanuka . Stands of taraire also occur scattered throughout the forest. Common forest birds and kereru are present. This site has been selected as a SSWI of 'Moderate' ecological value (P130). Some of the forest is protected by bushlot covenant while the rest is privately owned in many lots (Julian et al., 1998).

Auckland University Reserve - Waimauku

This is a Scientific Reserve owned by Auckland University, consisting of 15 ha of remnant kauri forest. The reserve has been identified as a SSWI of 'Potential' value (P138).

Ararimu Stream

The Ararimu Stream is the second major headwater catchment of the Kaipara River. The catchment consists of narrow, steeply sided valleys which dissect the hill country north of Waimauku. The sub-catchment as defined here includes the Waikoukou Stream but not the Tikokopu Stream. The area is rural in character with extensive areas of exotic afforestation and pastoral farming (Wildlife Services, 1989). Two valley systems form the upper reaches of the Ararimu River - these are referred to here as 'Campbell Road' and 'Chatham Road'. Both of these valley systems are largely within the Riverhead Forest pine plantation.

Pastoral farming has heavily influenced the Waikoukou Stream valley with the majority of its catchment still used for this purpose. The remaining area is generally reverting to shrubland dominated by either gorse or kanuka after the cessation of farming in these areas (Green, 1988). Patches of forest within the valley provide examples of regenerating complex, southern Rodney riparian forest (Cutting, 1989).

A characteristic of the Waikoukou Stream is the occurrence of flax (*Phormium tenax*) along its banks, which provide a local food source for nectar feeding birds such as tui during the flowering season. In several places along the stream are small, thin strips of raupo swamp. However, these wetlands are considered to be of limited wildlife value.

Campbell Road

Ninety four per cent of the Campbell Road valley system is covered by pine forest (Green, 1988). This has reduced native vegetation to 20m wide riparian strips, which represent approximately 4 - 6 km (8 - 12 ha) of stream side vegetation. This vegetation is generally a mixture of tree ferns such as ponga (*Cyathea dealbata*) and mamaku (*Cyathea medullaris*), together with cabbage trees, pate (*Schefflera digitata*), putaputaweta (*Carpodetus serratus*) and hangehange (*Geniostoma rupestre*). Scattered broom (*Carmichaelia aligera*) and mahoe (*Melicytus ramiflorus*) are also present. While these streams remain intact, they represent an extensive network of native vegetation (and hence also a corridor or refuge for wildlife) in an otherwise exotic forest (Mitchell, 1988). Although presently unconfirmed, it is expected that the threatened North Island fernbird are present in the valley (Cutting, 1989).

Chatham Rd

The Chatham Rd valley system is 74% covered with pine plantation forest (Green, 1988), and many of the stream banks support narrow bands of native riparian vegetation. However, in the understorey of the pine forest within the Chatham Rd valley there is a greater abundance of indigenous flora than is found at Campbell Road. This vegetation provides a habitat for native birds such as silvereye, grey warbler and fantail (Green, 1988).

Ararimu Swamp

In the upper reaches of the Ararimu Stream within the Chatham Road valley is a long thin strip of freshwater wetland. This wetland is approximately 850 m in length, with a total area of 2 ha. The thick shrub areas on the periphery of the swamp are dominated by tree ferns, manuka and cabbage trees, while the wetter areas support an association of raupo, *Baumea rubiginosa*, *Polygonum decipiens*, *Juncus prismatocarpus* and *Isachne globosa*. This is a good, representative example of a north Auckland freshwater wetland. Spotless crake and the threatened North Island fernbird have been confirmed present in the wetland (Green, 1988; Mitchell, 1988; Cutting, 1989).

Riverhead State Forest Biological Reserve/Riverhead Ecological Area

Further downstream of the Chatham Road and Campbell Road valley systems is a regionally significant indigenous forest remnant. This forest extends over 12.4 ha and is considered to be the last sizeable stand of indigenous forest remaining within Riverhead Forest. The remnant is noted for its considerable diversity of plant associations and forest types, with examples of kanuka-*Gahnia* associations, complex podocarp forest, various stages of regenerating scrub-hardwood forest and coastal forest. The rare fern *Loxsoma cunninghamii,* is also present. This site has been identified as a SSWI, and is included in Appendix B of PARPS (#74) and the Department of Conservation's Conservation Management Strategy (CMS #165).

Davis' Property

The confluence of the Waikoukou Stream and the Tikokopu Stream occurs on the Davis' property. At this point a deep channel is formed, the banks of which are scattered with indigenous trees. The most substantial area of native riparian vegetation occurs on the true left bank where there is a line of old totara, matai and a number of *Pennantia corymbosa*. The largest of the totara is 1.5m d.b.h. These areas are inundated during times of high flow, and it is considered that any change in the water levels of this area of the stream channel could have a major effect on this vegetation (Mitchell, 1988).

Matua Valley Vineyards

The Waikoukou Stream runs through the Matua Valley Vineyards property. The true right bank has occasional scattered native trees such as totara (*Podocarpus totara*) and kowhai (*Sophora microphylla*). The true left bank has a mixture of pines and the occasional native tree (Mitchell, 1988). There are two small patches of indigenous forest close to the Waikoukou Stream.

The first forest area (Q10 453943) has a canopy of approximately 5 - 8m in height that is dominated by kahikatea (*Dacrycarpus dacrydioides*) and totara *(Podocarpus totara)*. Also scattered throughout the remnant are (*Prumnopitys taxifolia*), miro (*Prumnopitys ferruginea*), kauri (*Agathis australis*), rimu (*Dacrydium cupressinum*), kowhai, titoki (*Alectryon excelsa*) and kawaka (*Libocedrus plumosa*). The second forest fragment (Q10 452941), is in better condition than the first, with a more closed, 18m high canopy of similar species mix. In both patches, stock have grazed the understorey reducing opportunities for further regeneration, albeit suppressing weed growth (Mitchell, 1988). A previous study by Mitchell (1988) noted that raising the water level by 1m or more, or by taking peak flows, would be unlikely to have any impact on these two stands.

Maber's Farm

The Maber's Farm is located on the western side of the Waikoukou Stream valley. This property is now largely cleared of native vegetation and is under intensive pasture. Mitchell (1988) deduced from aerial photographs that from 1981 - 1988 approximately 28 ha of scrub and treeland were cleared from the western side of the valley. Remaining areas of native vegetation include stand of ricker kauri at Q10 465976 (Mitchell, 1988).

Stevens Property

This property is intensively farmed, and it is estimated that at least 5 ha of indigenous regenerating forest has been cleared since 1981 (Mitchell, 1988). This site is noted for the presence of *Dicksonia fibrosa, Cyathea smithii* and Hall's totara *(Podocarpus hallii)*. This site is close to the northern limit for *Dicksonia fibrosa,* while *Cyathea smithii* and Hall's totara are not usually found at such a low altitude. This suggests that the Waikoukou Stream may have an unusually cold environment and formerly it would have supported a rather different flora than the surrounding areas. It is thought that if these forest patches were left to regenerate, they could develop into a very interesting community (Mitchell, 1988).

Ararimu/Waikoukou Valley (new PVS)

This site consists of a large area of regenerating kanuka (*Kunzea ericoides*) forest that extends over approximately 140 ha. Although highly dominated by kanuka, the canopy also contains manuka and mamaku, together with scattered kahikatea and cabbage trees (*Myrsine australis*), putaputaweta, lancewood (*Pseudopanax crassifolius*), ponga, and wheki (*Dicksonia squarrosa*). Totara, kauri and other podocarp seedlings are also a common canopy component, with tanekaha and totara are regenerating well in the understorey. This vegetation is the third largest area of kanuka forest on lowland hill country in the entire Rodney Ecological District. A range of forest bird are present in this forest, including kereru. It has been selected as a Priority Vegetation Site in the PNAP revision, and is ranked as a SSWI of 'Moderate' significance (Mitchell, 1988; Julian et al., 1998).

Tikokopu Stream

Little detailed information is available regarding the ecological values of the Tikokopu Stream. Cutting (1989) however notes the presence of 'classic' riparian vegetation along the banks of this river which could be significantly effected by raising the water level of the stream.

Waimauku Sub-catchment

Downstream of Waimauku the Kaipara River flows through a stable, meandering, steep-sided channel, similar to that of the Kaukapakapa River. Riparian vegetation is generally sparse with patches of native forest and scrub scattered along the river bank. For example, totara stands with a mixed understorey of towai, kowhai, cabbage tree, kahikatea, mamaku, manuka, willow and blackberry occur in places (Wildlife Services, 1989).

Head Wharauroa Stream Bush

One of the best examples of riparian totara forest in the Rodney Ecological District occurs at the head of the Wharauroa Stream. The forest contains a mixture of Hall's totara, miro, rimu, tanekaha, kauri and a range of broadleaved species such as mapou and maire. Continued grazing of the understorey by stock however, is limiting the regeneration potential of this site. Various birds have been observed using this habitat including fantail, grey warbler, kereru and white faced heron. This site has been identified as a SSWI of 'Potential' ecological value (P479) and has additional value as a link to riparian vegetation further downstream. It is privately owned.

Wharauroa Stream

This site has been selected as a Recommended Area for Protection (RAP #27) in the Rodney Ecological District PNAP Survey, and is identified as a Site of Natural Significance (CMS #147) by the Department of Conservation (1995). It includes a long, narrow 13 ha riparian strip along the Wharauroa Stream. Numerous small patches of secondary kauri and kahikatea-kohekohe-taraire occur along the stream banks. One of the largest kahikatea in the Auckland Region is found here. Areas of dense regenerating manuka and kanuka scrub link some of the more developed forest areas. The lineal extent of this vegetation, and the link it provides to other forest sites further to the north, gives this site added value. Common native forest birds use the Wharauroa Stream forest, including fantail, tui, grey warbler and silver eye. Tui and kereru are present in good numbers, and kaka have also been reported. The RAP contains part of the Taylor Road Bush SSWI site (P416), which has been recommended to be updated from its current 'Potential' status to 'Moderate' (Julian et al., 1998). Parts of the Wharauroa Stream vegetation are protected within a bushlot covenant and the Colin Kerr-Taylor Memorial Reserve, but most of the area remains unprotected.

Lake Paekawau

Lake Paekawau is one of the Muriwai dune lakes, it is 95% open water, with the remaining 5% being in raupo (*Typha orientalis*). The lake margins are mainly in pasture, although a small amount of bush is present (refer below). The nationally rare dabchick was observed at the lake in the past, along with good numbers of paradise duck (observed in 1986, 1991) and some black shag (1991). The lake is on private land, and has been selected as a SSWI of 'Potential' value (P199).

Lake Paekawau Shrublands

On a ridgetop above Lake Paekawau is an area of kanuka forest. The ridgetop is formed by young, less stable dunes. The forest understorey contains a diverse range of regenerating plants such as kowhai, nikau, pigeonwood, hangehange, mapou, akeake, cabbage tree and lowland totara. This site is considered to be of at least regional significance. It is under private ownership (Davis, 1998).

Small Lake

Known only as 'Small Lake', this site has been identified as a SSWI of 'Potential' value (P615). Fifty per cent of the lake vegetation consists of algae, with the margins supporting areas of *Carex* and willows. Spotless crake have been observed using the lake, which is considered to be good water fowl habitat.

Unnamed Wetland, Waimauku Stream north of State Highway 16

Royal Forest and Bird Protection Society (1998) undertook an ecological assessment of a wetland on the Waimauku Stream immediately north of SH 16. Three types of wetland were identified, covering a total area of 20 hectares, as summarised below:

Type I - Raupo and Crack Willow dominated wetland following the course of the Waimauku stream. This is the most extensive type.

Type II - Raupo and Cabbage Tree wetland plant association following a channel flowing from a spring in an area of bush to the north-west of the main stream.

Type II - rainwater seepage and flood water fed wetland adjacent to the main channel.

The assessment indicates that Koura, Inanga and eels are present, while a diverse invertebrate community and Banded Kokopu are also expected to be present. Non-native fish include Rudd and Carp. A wide range of native and non-native birds have been reported, including the threatened native Bittern, Banded Rail and Spotless Crake.

The wetland has not previously been identified by the ARC as having Regional significance, and is not recorded on the Department of Conservation's 'Sites of Special Wildlife Interest' database. However, given the extent of the wetland, the wetland could be of Regional significance as it provides a sizeable area of habitat for native wetland bird and fish species, including threatened species.

Lower Kaipara River

Downstream of Davidson Road, the river becomes saline and tidal. The flats adjoining the river have been drained, and oversown with introduced grasses. They are intensively developed and are grazed by cattle (Wildlife Services, 1989). There would appear to be no areas of ecological significance in this area of the Kaipara River catchment.

The lower reaches of the Kaipara River are largely estuarine, with saltwater influences found as far as 12 - 16 km from the river mouth (Dibble, 1984). Upstream of Helensville, the riparian vegetation generally consists of introduced grasses such as floating sweet grass, Pampas and fescue. Downstream of Helensville the Kaipara River broadens to a wide intertidal river system with steeply sloping margins. Mangrove forest becomes common above the mean high water mark. The adjoining flats have been drained and developed (Wildlife Services, 1989).

Woodhill School Bush I, II, & III

Three ecologically significant areas of vegetation have been identified in the PNAP Survey of the Kaipara Ecological Region near Woodhill School. Previously the SSWI site (P425) was the only recognised site of significance in this area.

Woodhill School Bush I

An area of kanuka/nikau-treefern forest is divided into two fragments by a driveway at this site. The forest extends over the midslope of an old stable duneland. Tall kanuka rise above a mixed canopy of ponga and nikau, while the understorey contains further nikau, tree ferns and *Gahnia lacera*. Together this vegetation forms a dense community, which is considered to be of at least regional significance. Part of the site contributes to the Woodhill School Bush Reserve, with the remainder being in private ownership (Julian et al., 1998).

Woodhill School Bush II

The second forest patch near Woodhill School is also located on an old stable duneland. This mixed podocarp-broadleaf forest has a high level of naturalness and is thought to be either original or in a very advanced stage of regeneration. The forest has healthy structure with a canopy dominated by kahikatea, totara, puriri, kanuka and titoki. This forest is considered to be of at least regional significance (Julian et al., 1998).

Woodhill School Bush III

This site consists of a very healthy patch of kauri-kanuka forest on an old stable duneland. The forest has a high level of naturalness and is in the advanced stages of secondary succession. The kauri and kanuka form a dense stand of forest, together with some lowland totara, puriri and kanuka. The kauri tends to be more abundant on the higher ridges, with kanuka on the hillslopes and kahikatea in the gullies. This vegetation is under private ownership and is of at least regional significance (Davis, 1998).

Woodhill School Scrub

A midslope area that runs parallel to State Highway 16 supports a patch of manuka scrub. Despite being fairly weed infested with gorse and Pampas grass, the scrub is still considered to be at least regionally significant. Regenerating indigenous species are apparent within the scrub (Julian et al., 1998).

Mangakura Stream

The Mangakura Stream catchment has been selected as a Recommended Area for Protection (RAP 26) in the PNAP survey of the Rodney Ecological District. It has been identified as a SSWI of ‘Moderate’ ecological value (P232). The entire catchment is covered with secondary forest containing kauri, rewarewa, rimu, puriri, kanuka and nikau. This vegetation is protected as the valley forms the water supply catchment for Helensville. Common forest bird species are present.

Bradley Road Swamp

Bradley Road swamp is a large, 6-10 ha wetland of at least regional significance. The wetland occurs at the bottom of a valley on an alluvial flat. It has a diverse vegetation structure consisting of a raupo canopy with scattered, emergent manuka and cabbage trees. Other species present include flax, *Carex, Coprosma* and various ferns. This vegetation is thought to be original. Pukeko, fantail, spotless crake and paradise duck are among the birds that have been observed in the swamp. Bradley Road Swamp has been identified as a SSWI of ‘Moderate’ ecological value (P44) and has been selected as a Site of Natural Significance by the Department of Conservation (CMS #143). The wetland is on private land and is not protected (Julian et al., 1998).

Te Horo Marginal Strip

This site is managed by the Department of Conservation (DoC #496). It consists of a 0.03 ha strip of land along the right bank of the Kaipara River, below the Kaipara Dairy Company. Some mangroves are present and mallards and grey ducks have been observed at this site.

Awaroa Stream

Inland Road Bush

This site consists of two forest remnants that are heavily grazed. Although species such as kauri, rimu, taraire and nikau are present in the canopy, little regeneration is occurring. Common skink are present. Inland Road Bush has been identified as a SSWI ‘Potential’ value (P146). It is privately owned.

Awaroa Stream Marginal Strip

Awaroa Stream Marginal Strip is managed by the Department of Conservation (DoC #495). The site consists of a 0.09 ha area on the northern bank of the Awaroa Stream. It is heavily modified, with ground cover being either metalled or pasture. A car ramp occupies part of the area.

Moau Stream

Rimmer Road Bush

This site contains a small area of regenerating kauri forest. Other species present include puriri, karaka and nikau. The understorey has been grazed for many years and little regeneration of native flora is occurring. The bush is on private land, and has been identified as a SSWI site of ‘Potential’ value (P367).

Fordyce Road Wetland

Fordyce Road wetland occurs within a Rodney District Council reserve at the bottom of a valley on an alluvial flat. The swamp is in an excellent, healthy condition and has a high degree of naturalness. The vegetation consists of a raupo-*Baumea*-*Schoenus* reedland. Bird species present include kingfisher, tui, fantail and grey warbler. Breeding pairs of the threatened Australasian bittern have been observed in the wetland. This site has been identified as a 'Moderate-High' value SSWI and a Site of Natural Significance by DoC (CMS #140) (1995).

Fordyce Road Kanuka Treeland

Bordering the Fordyce Road wetland is an area of kanuka treeland. This site has a low level of naturalness as it is not fenced off from stock and regular grazing by cattle, sheep and horses occurs. The understorey of the treeland is therefore largely composed of exotic grasses. However the presence of *Melicope ternata* in the treeland is unusual. The treeland is considered to be of at least regional significance (Julian et al., 1998).

Kaipara Harbour

The Kaipara River empties into the Kaipara Harbour which is an area of International ecological significance (Appendix B # 21, ARC, 1995). The river mouth is an outstanding habitat for bird life, supporting a huge number of waders. 25,000 birds have been recorded here at any one time (ARC, 1995). The confluence of the Kaipara and Kaukapakapa Rivers also occurs at this point. For this reason the immediate ecological values of the estuarine area of the Kaukapakapa River have been included in this report.

An important ecotone joins the Kaipara River mouth to the Kaukapakapa River. This ecotone begins at the seaward end with an extensive area of mangroves (the largest expanse of mangroves in the Auckland Region) that in places has a width of greater than 200m. This mangrove forest then grades into a large rush meadow, saltmarsh and estuarine wetland complex. Extensive *Salicornia* meadows, reeds (*Juncus* and *Carex* species), wetlands interspersed with manuka, mingimingi and flax species, provide a range of habitat types and vegetation sequences representative of coastal wetlands in the region. These wetlands are considered to be of national importance. This vegetation continues inland to the foothills of the kauri forest of the Kaukapakapa Scientific Reserve, which provides the terrestrial component of the ecotone (Wildlife Services, 1989) (Refer below for further details of the Reserve).

Parakai Geothermal Field

The largest and hottest thermal water resource in the Region occurs at the Parakai Geothermal field (Appendix B # 45)(ARC, 1995). It has been identified as being of regional significance in the Geopreservation Inventory, and highly vulnerable to complete destruction or major modification by humans (Kenny and Hayward, 1996). The geothermal field has also been identified as a Site of Natural Significance in Appendix B of the Proposed Regional Policy Statement (#45; ARC, 1995) and the Conservation Management Strategy (CMS # 141; DoC, 1995).

Kaukapakapa Estuary Scientific Reserve

The lower Kaukapakapa River area supports diverse habitats types including forest, shrubland, raupo wetlands, saltmarsh and mangrove forests (described above). A number of threatened bird species have been observed in this area including Australasian bittern, banded rail and North Island fernbird (Cutting, 1989).

The Kaukapakapa Estuary Scientific Reserve is located north of the river estuary and extends from sea level to 158 m, and covers 210 ha in total. Included is the saltmarsh and terrestrial section of the ecotone described above. The terrestrial vegetation ranges from kahikatea-swamp maire to kauri-broadleaf forest, providing habitat for a range of species including a colony of shags and other nesting birds. This site has been identified as an area of considerable ecological value, and has been recommended as a Priority Place for Protection(PPP 25) in the Rodney PNAP Survey (RAP 25). The reserve is also included as a significant site in Appendix B of PARPS (# 43) and DoC's Conservation Management Strategy (# 144). It is ranked as a SSWI of 'Moderate-High' value. The reserve is managed by the Department of Conservation.

6 The Surface Water Resource

6.1 Stream Hydrology

6.1.1 Introduction

Hydrology is concerned with the study of the natural water cycle, or the processes by which water is transferred between the atmospheric, surface and sub-surface environments. The evaluation of surface water resource availability focuses on only one component of the cycle, river flows, and in particular low flows during summer when water demand is generally greatest.

A study of the low flow hydrology of the Kaipara River catchment was undertaken prior to the development of the 1989 water allocation and management plan (ARWB, 1989). The focus of the study was to estimate key low flow indicators as a measure of water availability in each sub-catchment.

In the intervening 10 year period since the plan was published, additional measurements of flow have been made throughout the catchment, some of these at continuous flow recording sites. The collection of this data has allowed a full review of the catchment low flow hydrology to be undertaken, such that certain key low flow estimates have been revised. The results of the review are documented in full in a separate report (ARC, 1999) and are summarised below.

The estimation of low flows is only one component of the study of river flows. At the other end of the hydrological scale are river flood flows, which while having little influence on the allocation of water, are of key importance for engineering design and land use planning. The flood flows of the catchment have previously been investigated in the preparation of the Kaipara River Flood Management Plan (Beca Carter Hollings and Ferner Ltd, 1989).

6.1.2 Low Flow Hydrology - Terminology

Low flow hydrology involves the statistical analysis of river flow data to establish estimates of flows which will occur during periods of dry weather of varying severity. In general terms, the analysis techniques available include:

- Flow frequency analysis - this involves estimating the magnitude of flows which will occur, on average, only once in any given number of years.

- Flow duration analysis - this involves estimating the probability of flows above or below a given threshold.

Although the linkages between these components of low flow analysis are close, each plays a distinct role in establishing the characteristic pattern of flows in a catchment. Key indicators of this pattern include:

- the five year low flow of one-day duration - this is the flow which is expected to occur, on average, for one day once every 5 years. It is represented by the symbol Q_5.

- the mean annual low flow of one-day duration - this is the flow which is expected to occur, on average, for one day once every 2.33 years. It is represented by the symbol $Q_{2.33}$. The 'return period' of the mean annual flow is not 1 year, due to the skewed nature of the statistical distribution of flow data.

- the specific yield - this is a measurement of flow per unit of land area (usually $l/sec/km^2$) which is a useful indication of the variation in low flows in response to differences in geology or land use within or between catchments. Specific yields are also estimated for different return periods, key ones again being those for the 5 year and mean annual one day events (SD_5 and $SD_{2.33}$).

- flow duration curves - these represent the distribution of all flows (low and high) and are a useful indication of the variability between winter and summer conditions. If flows fall within a fairly restricted range for most of the time then there is generally a strong 'baseflow' (groundwater fed) component which helps to maintain flows during periods of low rainfall.

6.1.3 Previous Research

In 1975 the Auckland Regional Water Board (ARWB) commissioned a preliminary study of water resources within the Auckland Region (Tonkin & Taylor, 1975). The results of the study included a one in five year one day duration low flow map for the Kaipara River catchment which clearly differentiated between western and eastern areas. The specific discharge (SD_5) in the western part of the catchment, including Woodhill and Waimauku, was estimated to be 2.2 $l/s/km^2$, in comparison with 1.6 $l/s/km^2$ in the eastern part of the catchment.

In 1976/77 the ARWB commenced a more detailed study of the catchment, installing rainfall and stream flow recorder sites, mapping geological features, and implementing a water quality programme (Brabant, 1979). Demand for water was increasing due to localised urban growth and general horticultural development, particularly in Kumeu and Waimauku. Around the same time, a separate study was undertaken by the Bulk Water Department of the Auckland Regional Authority (ARA) to investigate the Waikoukou Stream for a potential bulk water supply scheme (ARWB, 1981).

Data collected through the late 1970s and early 1980s was used in the development of the 1984 Freshwater Report and Interim Management Plan for the Kaipara River catchment (ARWB, 1984). One in five year flows were estimated from data collected during the drought of 1982/83 and showed a clear link with variations in geology across the catchment. The estimated SD_5 specific discharge varied from 1.5 $l/s/km^2$ in the Waimauku Plateau and western sand hills to 0.0 $l/s/km^2$ in areas of recent alluvial deposits.

Further Bulk Water Supply investigations were undertaken in the late 1980s to assess the potential of sites within the Ararimu Stream catchment to supplement Auckland's existing water supply. This involved undertaking hydrological investigations on the stream during the summer of 1987-88 and analysis of this data along with that collected from the Waimauku flow recorder site on the main Kaipara River. On the basis of this analysis, the estimated 5 year low flow at Waimauku was estimated to be around 70 l/sec. This estimate, however, was based on flow records which were significantly influenced by upstream abstractions. The 'natural' Q_5 (adjusted for pumping effects) was considered to be closer to 100 l/sec (KRTA Limited and Tonkin & Taylor Limited, 1988).

In 1989, the ARWB's 1984 Interim Management Plan was superceded by a Water Allocation and Management Plan (ARWB, 1989) which elaborated further on the catchment hydrology in reviewing water availability and allocation. The total Q_5 discharge from catchment was estimated to be 245 l/sec, this being calculated by totalling the predicted runoff from each of over 30 small sub-catchments. The 1989 plan also re-stated they key findings of the previous hydrological analysis, including that:

- during summer low flows, the Kumeu River provides the largest component of flow to the Kaipara River under natural conditions, although abstractions have the potential to significantly reduce this input;

- the impact of out-of-stream water users makes it difficult to estimate 'natural' stream flows;

- under natural conditions, the Ararimu River contributes slightly less than the Kumeu River to the flow of Kaipara's main channel; and

- the Waipatukahu Stream catchment which drains both the Waimauku Plateau and the Western Sand Country, yields a considerably higher SD_5 than any other part of the catchment.

6.1.4 Hydrological Data Collection

Background

The Auckland Regional Council (ARC) collects flow data from automatic recorder sites and also undertakes manual flow gaugings at sites throughout the catchment. The location of these sites are shown on maps 9 and 10. Automatic sites are equipped with instruments to record water levels at 15 minute intervals. Flows are then calculated from a 'rating curve' which represents the relationship between flows and water levels at the site. The sites are gauged regularly in order to update the rating curves associated with them. Gauging sites are often in remote areas of the catchment and are monitored at irregular intervals during the dryer periods of the year.

Flow Recorder Sites

The lack of sufficient data was a barrier to preliminary hydrological investigations during the 1970's and early 1980's. In order to overcome this problem, the ARWB responded by progressively installing sites between 1977 and 1984. These are listed in table 6.1, along with additional sites installed by the Ministry of Works and Development (MWD) and the National Institute of Water and Atmospheric Research (NIWA) for separate sub-catchment studies.

Table 6.1- Flow recorder sites in the Kaipara River catchment

Site Name	Site No.	Record Commenced	Recording Authority	Reason for Installation
Kumeu Stream at NZ Particle Board	45301	20/5/77 - 27/3/98 (closed)	ARC	Consent condition for water right 760958 to monitor sewage discharge.
Kaipara River at Waimauku	45311	9/10/78 - current	ARC	Major river.
Kumeu Stream at Maddrens	45315	2/12/83 - current	ARC	Water resource monitoring, water quality.
Waikoukou Stream at Longlands	45346	5/7/85 - ?	NIWA	Irrigation investigations, water supply investigations.
Wharauroa Stream at Moffats	45347	17/7/85 - 20/1/93 (closed)	MWD	Irrigation investigations, water supply investigations.
Kaipara River at Davidsons Bridge	45309	12/2/60 - 27/11/62	MWD	Water resource monitoring
Kumeu River at Kays Stream	45318	11/12/83 - 21/4/85 (closed)	ARC	Water quality
Ararimu Stream at Old North Rd.	45326	14/12/83 - current	ARC	Bulk Water Supply Investigations
Waimauku Stream at Willocks	45334	31/8/80 - 20/7/82	ARC	Water resource monitoring

The first site was installed on Huapai Stream at Particle Board in 1977. New Zealand Particle Board Limited applied for a water right to discharge treated domestic sewage into the Huapai Stream (Right No. 760958). In order to comply with a special condition of the water right, the company constructed a V-notch weir and water level recorder near the effluent outfall. The water behind the weir was used for emergency fire fighting and was often emptied by staff so that the flow record is of only limited value.

In 1978, the ARWB installed a flow recorder on the Kaipara River at Waimauku. Five years later in 1983, flow recorder sites were installed on the Ararimu Stream at Old North Road Bridge, and another on the Kumeu Stream at Maddrens for bulk water and water quality investigations respectively. Data from each of these three sites, which the ARC continues to operate, has been used in the review of the catchment hydrology presented here. A brief description of each site and the associated flow records are given below.

Kaipara River at Waimauku (site 45311)

Flows at this site, which has a catchment area of 155.4 km^2, have been recorded since October 6^{th} 1978. There are only 207 days of missing record, these relating to equipment malfunction and site upgrades. During the years immediately following installation of the site, weed and debris affected the recording of levels. Weed and debris can elevate water levels, and result in an overestimate actual stream flow. Regular field checks by ARC officers now minimise this problem and the flow estimates reported here are not considered to be significantly influenced by weed and debris affects. Reviews of the rating curve in May 1983 and March/April 1987 resulted in an intensive gauging programme to improve the accuracy in the rating curve at the medium to low flow range.

Kumeu Stream at Maddrens (site 45315)

The recorder site at Maddrens measures the flow of the Kumeu River, which has a catchment area of 47.6 km^2 at this point. Flow records commenced on December 12^{th} 1983. Weed has also affected water levels at this site, particularly during summer months when flushing flows occur only infrequently. There are a total of 150 days of missing record of duration 1 day in 31 days. The site has been subject to a series of equipment upgrades but few major changes have taken place since records commenced.

Ararimu Stream at Old North Road (site 45326)

Flow records from the Old North Rd recorder site, which has a catchment area of 66.8 km^2, began on December 14^{th} 1983. There are significant gaps in the record, with the largest break in the record occurring between May 1986 and October 1990 when the site was closed. The site was re-commissioned and re-located on the other side of the stream in October 1990.

Flow Gaugings

Flow gaugings are important for maintaining the accuracy of automated flow sites and for estimating flows on streams which are not monitored continuously. There are 47 gauging sites throughout the catchment (see maps 9 and 10). The distribution of these sites reflects the demand for information by previous studies of water availability and water quality. Streams in the Waimauku Plateau area have been intensively gauged as a result of the concentration of water abstractions in this area. The concentration of sites in the Ararimu Stream catchment reflects the Bulk Water Supply investigations of the late 1980s.

Gauging sites are monitored irregularly, with their distribution in time reflecting the development of previous water allocation plans. The Interim Management Plan of 1984 for example, is based on a series of gaugings during 1982-83. Since the early 1990s a summer low flow programme has operated with between 6 and 10 sites now gauged each year.

6.1.5 Low Flows at Recorder Sites

Background

The data from each of the three recording sites has been analysed for its flow duration and flow frequency characteristics. Whilst section 6.1.2 provides a brief explanation of these terms, a full description of the methodology employed is given in the report on the review of the catchment hydrology (ARC,1999).

Flow Duration Curves

The flow duration curves shown in figure 6.1 are similar to each other, in that inflection points are evident at high and low percentiles. These points are useful for characterising the flow regime of each stream, as they serve to distinguish the range of ‘normal’ flows and the proportion of time which flows may be considered to be representative of ‘drought’ or ‘flood’ conditions.

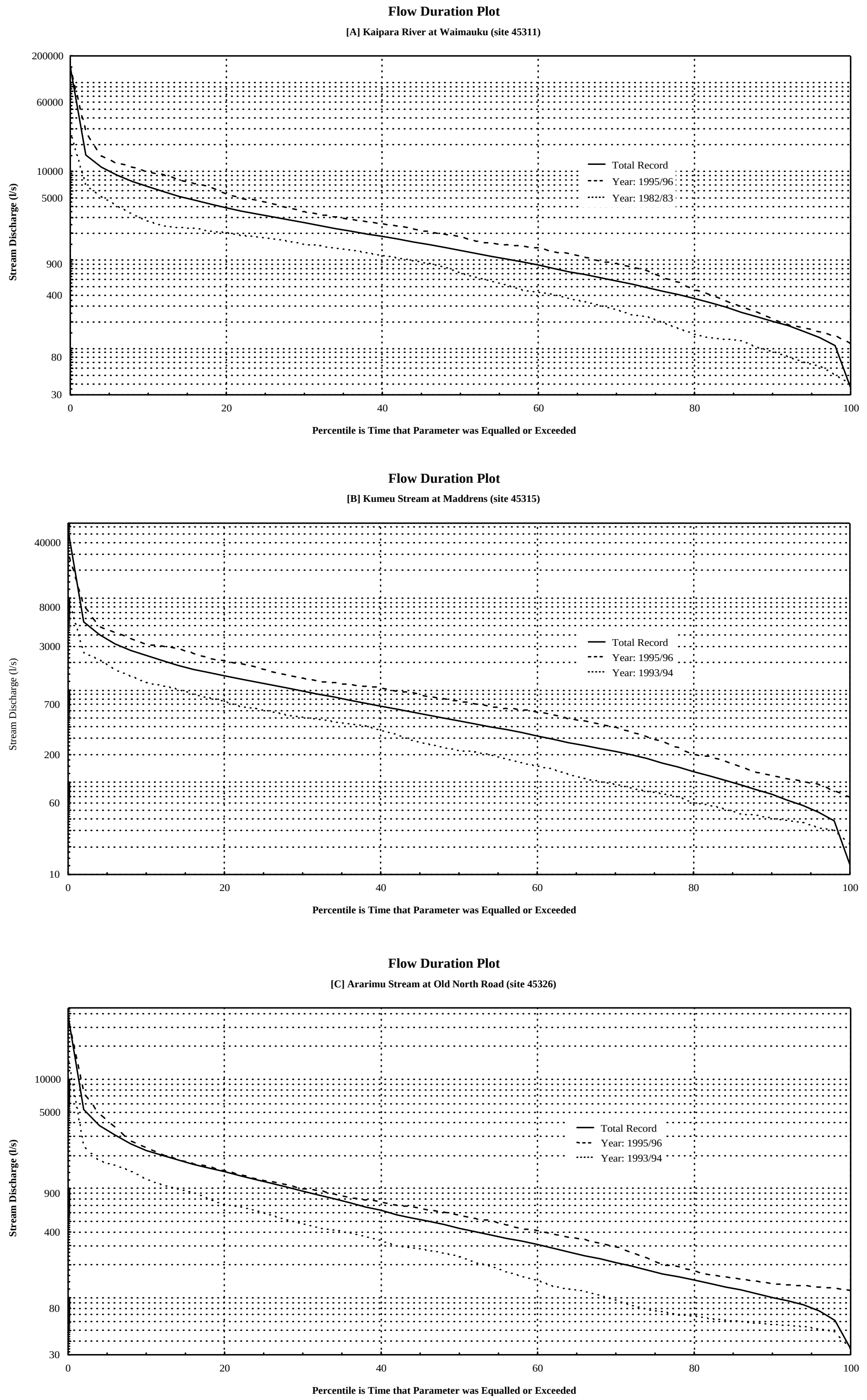

Flow Duration Plot
[A] Kaipara River at Waimauku (site 45311)
Stream Discharge (l/s)
200000
60000
10000
5000
900
400
80
30
0
20
40
60
80
100
Percentile is Time that Parameter was Equalled or Exceeded
Total Record
Year: 1995/96
Year: 1982/83
Flow Duration Plot
[B] Kumeu Stream at Maddrens (site 45315)
Stream Discharge (l/s)
40000
8000
3000
700
200
60
10
0
20
40
60
80
100
Percentile is Time that Parameter was Equalled or Exceeded
Total Record
Year: 1995/96
Year: 1993/94
Flow Duration Plot
[C] Ararimu Stream at Old North Road (site 45326)
Stream Discharge (l/s)
10000
5000
900
400
80
30
0
20
40
60
80
100
Percentile is Time that Parameter was Equalled or Exceeded
Total Record
Year: 1995/96
Year: 1993/94

Figure 6.1

The plots indicate that, in the records of the Waimauku (site 45311) and Maddrens (site 45315) sites, around 20 % of low flows lie beyond an inflection. In the record of the Old North Road site (site 45326), the only around 4 % of low flows are beyond the inflection such that ‘drought’ flows occur much less frequently. The flow duration curves therefore indicate that baseflows to the Ararimu stream are more significant than in the Kumeu River or Kaipara at Waimauku in maintaining flows during periods of prolonged dry weather.

The flow duration curves plots also show curves for the 1982/83 and 1995/96 hydrological years. In the former case, which was a drought year of some note, the distribution of flows was significantly below that for the period of record as a whole. The reverse is true in the case of the 1995/96 duration curve, which reflects the fact that conditions were wetter than average during this period.

In comparison with other catchments, the Kaipara River is characterised as having a relatively ‘flashy’ flow regime because flows vary across a wide range. Figure 6.2 compares flow duration curves for the three flow recorder sites against curves for two external sites. These curves are adjusted for catchment area. In comparison with the three sites in the Kaipara catchment, the curve for the Whangamaire Stream is relatively flat, indicating that there is less variability in the flows of this catchment. Low flows in the Whangamaire are maintained by a strong baseflow component sourced from springs throughout the catchment. In contrast, the Rangitopuni Stream is characterised as a ‘flashy’ stream in that flow variability is greater, being more responsive to individual rainfall events and with relatively insignificant baseflows.

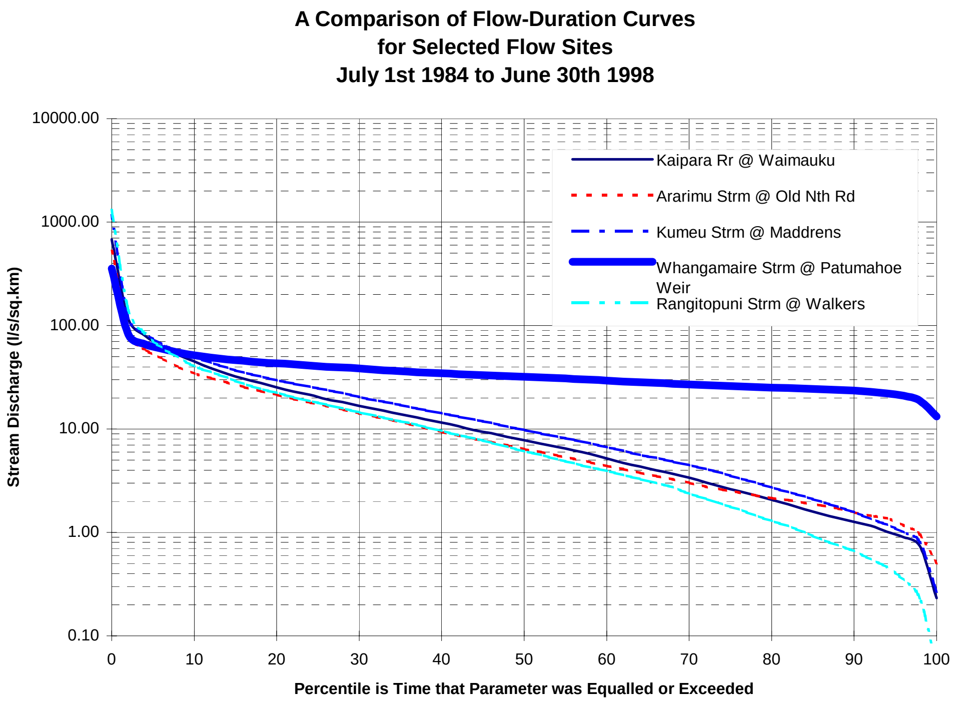


Figure 6.2

This comparison demonstrates the importance of geology in determining the flow characteristics of a catchment. Whilst the Whangamaire Stream drains a high yielding volcanic aquifer, the Rangitopuni catchment is dominated by sedimentary rocks of extremely low permeability. Similar contrasts in geology occur within the Kaipara River catchment (see section 4.1 - geology), and this impacts on low flows as revealed by previous studies and confirmed in the estimates of flows from different sub-catchments presented below (see section 6.1.6).

Low Flow Frequency

Flow frequency analysis involves ranking the series of (in this case) lowest daily flows occurring in each year of the hydrological record. A statistical distribution is then fitted to the ranked series and from this, estimates of the flows associated with any specified return period can be made. The mean annual and five year low flows of one day duration estimated by this method are presented in table 6.2.

Table 6.2 - Estimated Low Flows at Recorder Sites

Site	$Q_{2.33}$ (l/sec)	Q_5 (l/sec)	$SD_{2.33}$ (l/sec)	$SD_{2.33}$ (l/sec)
Kaipara at Waimauku	124*	90*	0.8*	0.58*
Kumeu at Maddrens	36*	26*	0.75*	0.55*
Ararimu at Old North Rd	70	48	1.05	0.72

* 'naturalised' flows - raw data adjusted for pumping effects

In estimating the $Q_{2.33}$ and Q_5 of the Kaipara River at Waimauku and the Kumeu River at Maddrens, the flow frequency analysis was performed on the raw data set. Close inspection of the flow records indicates the likely magnitude of abstractions upstream of each site, with a daily pumping cycle of falling and then rising flows often apparent. The values of $Q_{2.33}$ and Q_5 presented in table 6.2 have been adjusted upwards on the basis of the magnitude of pumping effects based on this inspection of data from low flow periods. However, pumping effects are not apparent in the record of the Ararimu Stream and no adjustment has been made to the estimates made from the raw data at this site. The estimated specific discharges of the Ararimu Stream are higher than those for the other two sites, confirming the results of the flow duration analysis in indicating the relative importance of baseflows in this part of the catchment.

6.1.6 Low Flows by Subcatchment

Overview

Mean annual and five year low flows have been estimated for each of eight subcatchments of the Kaipara River catchment. In certain cases there are variations in the estimated flows between individual streams within each sub-catchment. These estimates are derived from relationships established between flows measured on each stream during manual gaugings and those recorded concurrently at the continuous recorder sites. On the basis of this relationship and the Q_5 or $Q_{2.33}$ estimated from the continuous flow recorder data, it is possible to estimate Q_5 and $Q_{2.33}$ at each individual gauging site, and also SD_5 or $SD_{2.33}$ for the subcatchment within which each gauging site is located.

The estimated low flows and specific discharges for each subcatchment are listed in Table 6.3. One in five year specific discharges range from 1.50 l/s/km^2 in the Waimauku subcatchment to 0.39 l/s/km^2 in the Kumeu River subcatchment. During periods of low flow, the Waimauku and Lower Kaipara subcatchments combine to contribute nearly 50% of the total flow at the catchment outlet, emphasising the importance of differences in the geology of the eastern and western parts of the catchment.

Table 6.3 - Estimated Low Flows by Subcatchment

Sub-catchment	**Area (km^2)**	**$Q_{2.33}$ (l/s)**	**Q_5 (l/s)**	**$SD_{2.33}$ ($l/s/km^2$)**	**SD_5 ($l/s/km^2$)**
Upper Kumeu	43.72	37.66 (11.29%)	28.44 (11.86%)	0.86	0.65 (*0.62)
Kumeu River	38.19	23.96 (7.18 %)	14.91 (6.22%)	0.63	0.39 (*0.57)
Waimauku	38.84	81.35 (24.38%)	58.31 (24.32%)	2.09	1.50 (*1.51)
Ararimu Stream	51.84	49.95 (14.97%)	40.30 (16.81%)	0.96	0.78 (*0.42)
Lower Kaipara River	48.24	81.72 (24.50%)	59.10 (24.65%)	1.69	1.23 (*1.19)
Tikokopu Stream	22.37	22.37 (6.71%)	13.42 (5.60%)	1.0	0.60 (*0.45)
Awaroa Stream	10.86	10.86 (3.26%)	6.51 (2.71%)	1.0	0.60 (*0.50)
Moau Stream	13.60	25.48 (7.65%)	18.84 (7.86%)	1.87	1.39 (*1.37)
Total	**267.65**	**333.56**	**239.80 (*221.45)**	**1.24**	**0.89 (*0.83)**

Notes

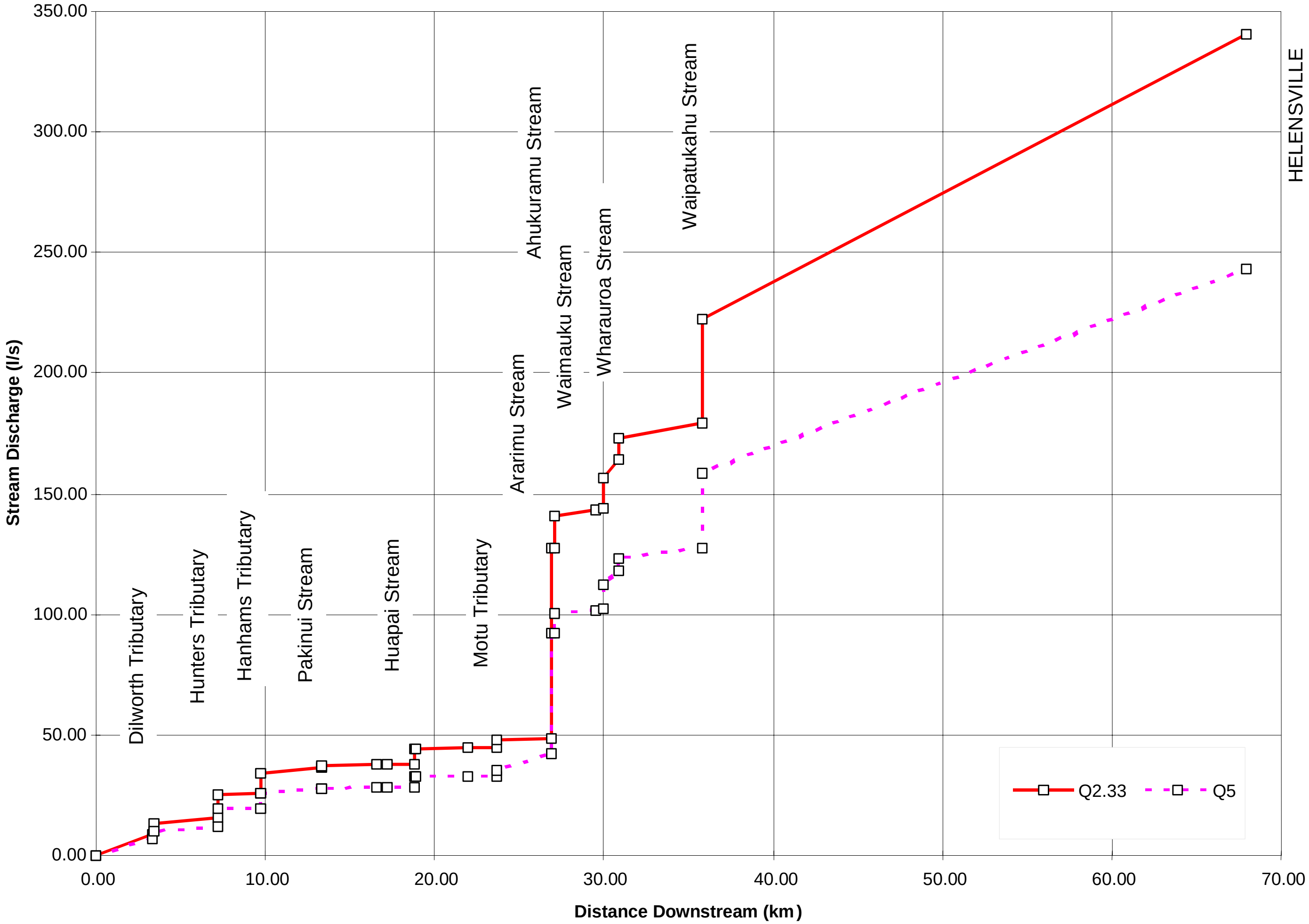
Percentages represent proportion of total flow at catchment outlet.

*** previous estimates, ARWB 1984**

In general, these estimates of the spatial variability of flow are relatively consistent with those of previous studies. Notable exceptions are the revised flow estimates for the Kumeu River, which are lower than those of the 1984 study, and the Ararimu and Tikokopu Streams, which are higher than previously estimated. Variations within each sub-catchment are described below.

Figure 6.3 presents low flow profiles for the catchment, representing the way in which estimated flows increase with distance downstream from the headwaters. The profiles clearly indicate where the flow in the main river is boosted by inflow at confluences with major tributaries, in particular the Ararimu, Ahukuramu, Waimauku and Waipatukahu Streams. The flow from these and other minor tributaries combines to produce estimated $Q_{2.33}$ and Q_5 flows of **333.56** and **239.80** l/s at the outlet of Kaipara River.

Figure 6.3 - Kaipara River
$Q_{2.33}$ and Q_5 Low Flow Profiles



Upper Kumeu River Sub-catchment

The Upper Kumeu River sub-catchment covers the southern most headwaters of the catchment. It can be divided into two broad regions of flow as shown in Maps 9 and 10, with lowland reaches yielding less than the western tributaries and reaches above Waitakere Bridge.

Based on gaugings at Waitakere Road on Hanhams tributary, specific discharges in the western part of the sub-catchment are estimated to be 1.40 and 1.07 l/s/km^2 for $SD_{2.33}$ and SD_5 events respectively. These values are considered to be representative of western tributaries and the area above Waitakere Bridge because of the consistent geology and topography through this the area.

Low flows from the eastern Pakinui Stream are lower, reflecting the alluvial nature and low lying topography in this area. Based on gaugings at Nelsons Rd, specific discharges in the Pakinui Stream sub-catchment are estimated to be 0.10 and 0.05 l/s/km^2 for $SD_{2.33}$ and SD_5 events respectively.

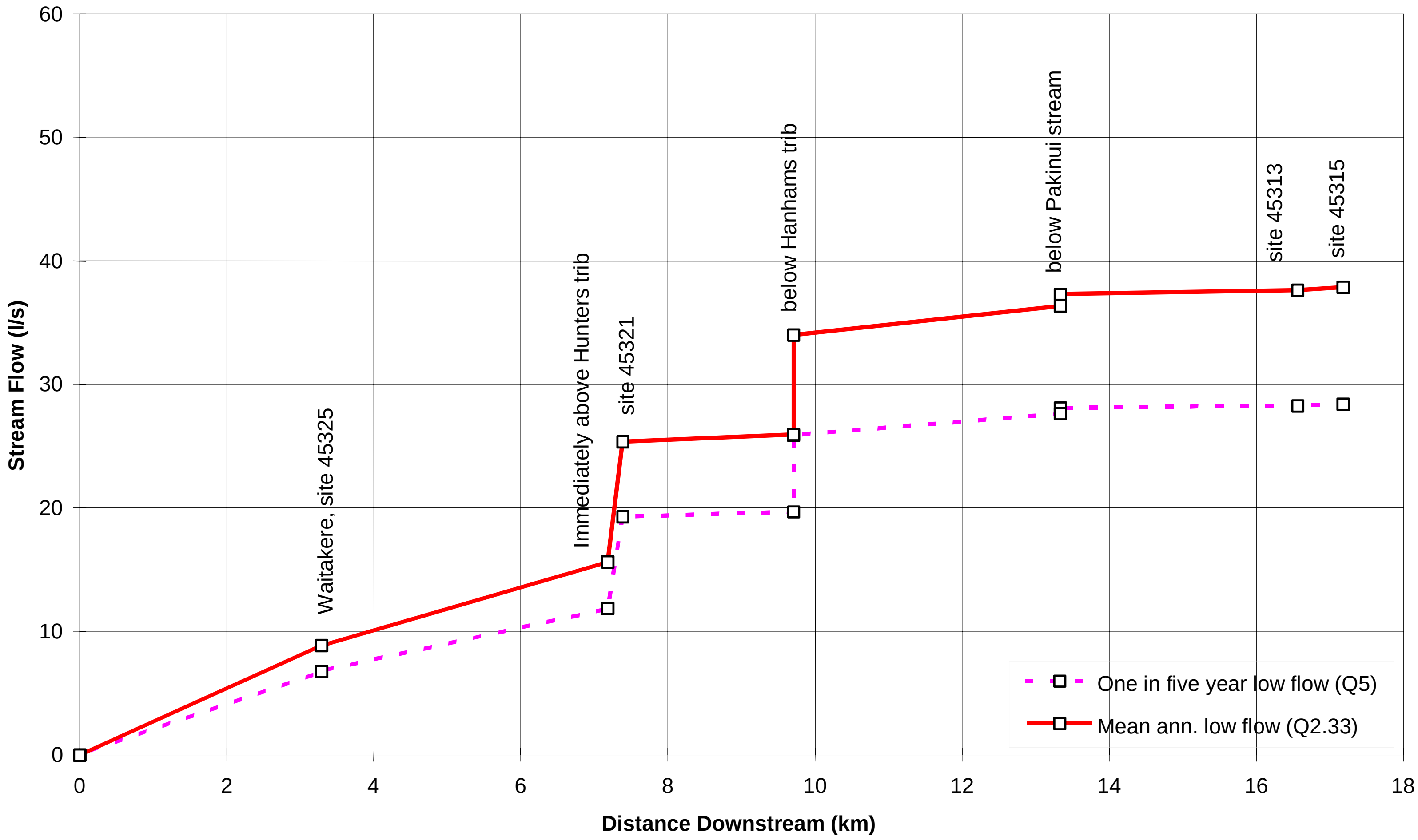
Figure 6.4 presents low flow profiles for the sub-catchment, and confirms the relatively minor contribution that the Pakinui Stream makes to the total flow of the sub-catchment, which is measured at the Maddrens flow recorder site. The estimated low flows from each of the two areas, when combined, are consistent with flows estimated from the flow frequency analysis for the Maddrens recorder site ($Q_{2.33}$ and Q_5 estimates of 36 and 26 l/s respectively, as described in section 6.1.5).

Kumeu River Sub-catchment

The Kumeu River sub-catchment lies to the north of the Upper Kumeu sub-catchment, and covers the area drained by the Ahukuramu, Motu and Huapai Streams. The upper reaches of these streams discharge from areas of Waitemata sedimentary rocks to an area of alluvial clays and silts in the low lying parts of the sub-catchment. Variations in the estimated specific discharges reflect these geological differences. The estimated $SD_{2.33}$ and SD_5 flows at gauging site 45329 on the Huapai Stream are 1.03 and 0.70 l/s/km^2 whilst further down stream at site 45301, an ex-recorder site, specific discharges are estimated to be 0.87 and 0.58 l/s/km^2. Below site 45301, the catchment area comprises of silts and clays and is therefore be expected to yield similar specific discharges to Pakinui Stream of 0.09 and 0.05 l/s/km^2. A similar pattern occurs in the neighbouring Ahukuramu catchment with estimated specific discharges at site 45314 on Awa Road of mean annual and one in five year specific discharges of 0.79 and 0.55 l/s/km^2 respectively.

On the basis of these gaugings, two areas of differing specific discharges are distinguished on maps 9 and 10. Estimated yields of $SD_{2.33}$ of 0.90 and SD_5 of 0.60 l/s/km^2 are representative of the Ahukuramu catchment and upper Huapai and Motu Streams. The estimated mean annual and one in five year yields of the remaining area of alluvial clay and silt are 0.10 and 0.05 l/s/km^2 respectively. The relative contributions of each of the three main tributaries is shown in figure 6.3 (main Kaipara River profile).

Figure 6.4 - Upper Kumeu River
$Q_{2.33}$ and Q_5 Low Flow Profiles



As a whole, the Kumeu River sub-catchment yields lower quantities of water per unit area than the Waimauku and Upper Kumeu sub-catchments, with $Q_{2.33}$ and Q_5 flows of 23.96 l/s and 14.91 l/s respectively. This reflects the high proportion of alluvial deposits in the sub-catchment. The low flow profiles for the Kaipara River (figure 6.3) indicate way in which each of the tributaries contributes to the overall flow in this catchment.

Waimauku Sub-catchment

The Waimauku sub-catchment includes the main Kaipara River between Waimauku and Woodhill and the tributaries which drain into this section of the river from both the north and south. The main tributaries are Waimauku Stream, Waipatukahu Stream and Wharauroa Stream. The geology of the sub-catchment comprises Waitemata sedimentary rocks north of the main river with sands and gravels forming the Waimauku Plateau in the south.

The streams of the Waimauku sub-catchment have been gauged in many places, allowing more detailed analysis of the variation in stream yields than in other sub-catchments. Estimated yields are highest in the upper headwaters of the streams draining the Waimauku Plateau. Specific discharge estimates fall further down these stream catchments, and are lowest in the streams north of the main river. Table 6.4 summarises the specific discharges estimated for different parts of the sub-catchment.

Table 6.4 - Specific discharges estimated for selected gauging sites, Waimauku subcatchment

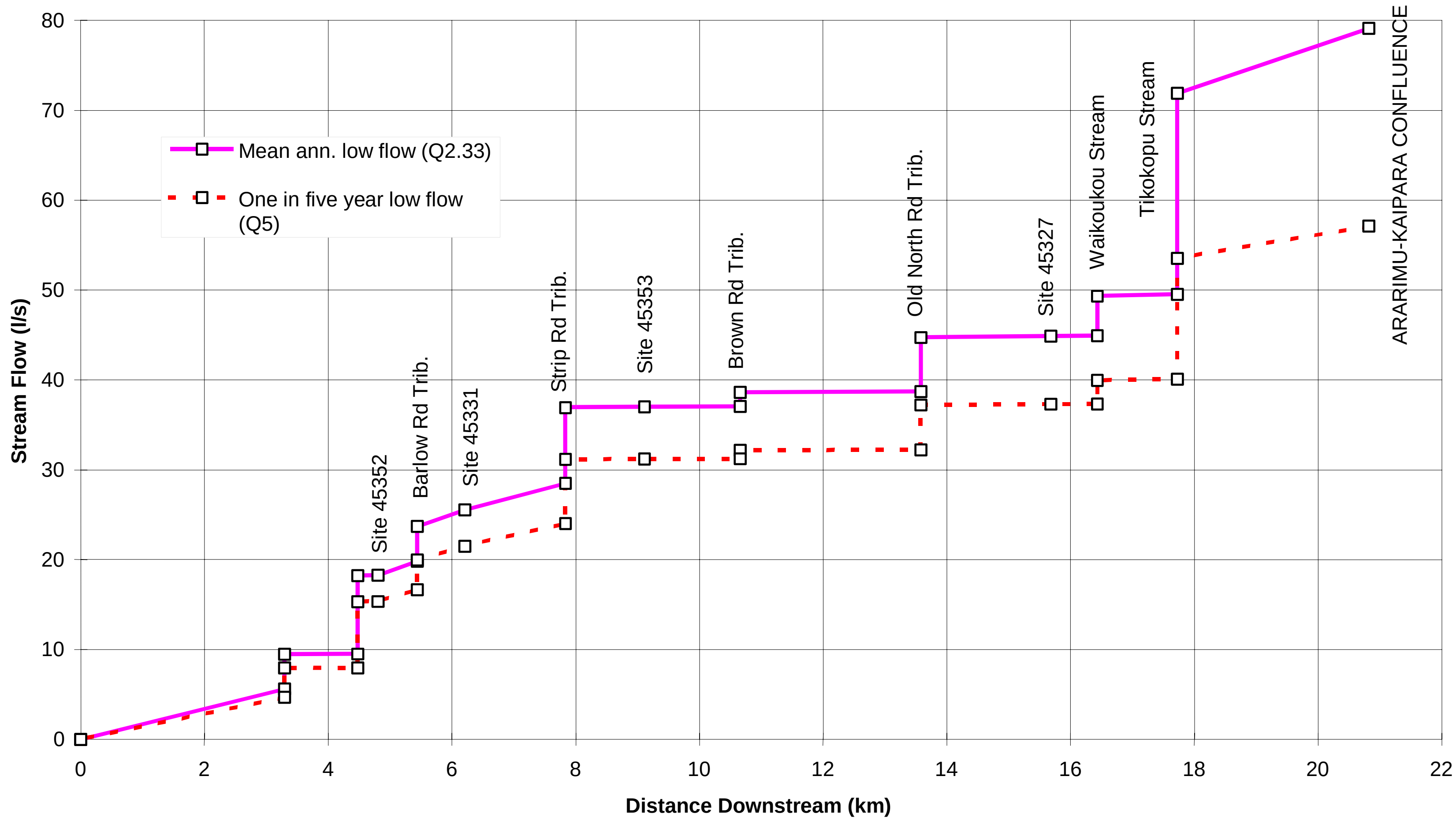
Stream	$SD_{2.33}$ (l/s/km^2)	SD_5 (l/s/km^2)
Waimauku Stream headwaters, upstream of gauging site 45338	3.57	3.08
Waimauku Stream, upstream of gauging site 45334	2.58	2.0
Waipatukahu Stream headwaters, upstream of gauging site 45339	4.6	3.7
Waipatukahu Stream western tributaries	3.1	2.05
Waipatukahu Stream eastern tributaries and lower southern tributaries	2.0	1.5
Wharauroa Stream and northern tributaries	1.0	0.6
minor northern tributaries (alluvial area)	0.1	0.05

When combined, these various tributaries yield $Q_{2.33}$ and Q_5 flows of 81.35 l/s and 58.31 l/s respectively. The low flow profiles for the Kaipara River (figure 6.3) indicate the way in which each of the tributaries contributes to the overall flow in this catchment.

Ararimu Subcatchment

The Ararimu subcatchment as defined here includes not only the Ararimu valley but also the Waikoukou Stream catchment upstream of Old North Rd (into which the Ararimu Stream flows). The major part of flow is contributed by the eastern tributaries which originate within Riverhead Forest. Yields in these tributaries at gauging sites on Blackwood, Campbell, Barlow and Strip Rds are estimated to be 1.30 and 1.10 l/s/km^2. In a mean annual and one in

Figure 6.5 - Ararimu Stream
Q2.33 and Q5 Low Flow Profiles



five year event respectively. The remainder of the subcatchment, including Waikoukou Stream and the western and lower eastern tributaries of the Ararimu Stream is estimated to yield a $SD_{2.33}$ of 1.0 and a SD_5 of 0.60 l/s/km^2. The low flow profile for the subcatchment, presented in figure 6.5, presents the relative contribution of each tributary (including the Tikokopu subcatchment). $Q_{2.33}$ and Q_5 flows from the subcatchment as a whole are estimated to be 49.95 and 40.3 l/s.

Tikokopu Stream Subcatchment

The Tikokopu Stream meets the Ararimu/Waikoukou Stream approximately 100 metres above the Old North Rd recorder site. From gaugings collected at one site in the sub-catchment estimated yields are a $SD_{2.33}$ of 1.0 and a SD_5 of 0.60 l/s/km^2. These are identical to yields estimated for the eastern and southern Ararimu subcatchment, which is of similar geology.

The estimated flows at the subcatchment outlet are 22.37 and 13.42 l/s for the mean annual and one in five year event respectively. Combining these with the estimated flows for the Ararimu subcatchment gives a $Q_{2.33}$ of 72.3 l/s and a Q_5 of 53.7 l/s. These compare well with flows estimated for the Old North Rd flow recorder site (slightly upstream of the subcatchment outlet) from the flow frequency analysis (see section 6.1.5) of 70 l/sec and 48 l/sec respectively. As a further check, the combined flows from the Ararimu, Tikokopu, Kumeu and Upper Kumeu Rivers calculated by summing the estimated flows from each area within these subcatchments is estimated to be a $Q_{2.33}$ of 133.9 l/sec and a Q_5 of 97.1 l/sec. These compare well with flows estimated for the Kaipara River at Waimauku (downstream of Waikoukou / Kumeu confluence) from the flow frequency analysis of 124 l/sec and 90 l/sec respectively.

Lower Kaipara River Subcatchment

Flows in the Lower Kaipara River and its tributaries are difficult to assess because of there have been few gaugings in this subcatchment. The estimated low flows are therefore assumed to be the same as those in adjacent subcatchments of similar geology. The area to the west of the main river comprises dune sands and gravels, similar to the Waimauku subcatchment, suggesting specific discharge values of 2.00 and 1.50 l/s/km^2 for the mean annual and one in five year event respectively in this part of the catchment. Waitemata sedimentary rocks dominate the area east of the main river, as in the Tikokopu subcatchment, indicating that specific discharges of $SD_{2.33}$ of 1.0 and a SD_5 of 0.60 l/s/km^2 are representative of this area.

Awaroa Stream Subcatchment

The Awaroa Stream has not been gauged, and specific discharges can only therefore be estimated on the basis of the geology of the subcatchment. Again, Waitemata sedimentary rocks dominate the subcatchment, as in the Tikokopu subcatchment, so that specific discharges of $SD_{2.33}$ of 1.0 and a SD_5 of 0.60 l/s/km^2 are considered to be representative of this area.

Moau Stream Sub-catchment

The Moau Stream sub-catchment includes not only the Moau Stream itself but also a small area to the east of the mouth of the Kaipara River. Neither part of the sub-catchment has been gauged and the estimated low flows are therefore assumed to be the same as those in adjacent sub-catchments of similar geology. The area to the west of the main river comprises dune sands and gravels, similar to the Waimauku sub-catchment, suggesting specific discharge values of 2.00 and 1.50 $l/s/km^2$ for the mean annual and one in five year event respectively in this part of the catchment. The minor eastern tributaries drain Waitemata sedimentary rocks, as in the Tikokopu sub-catchment, indicating that specific discharges of $SD_{2.33}$ of 1.0 and a SD_5 of 0.60 $l/s/km^2$ are representative of this area.

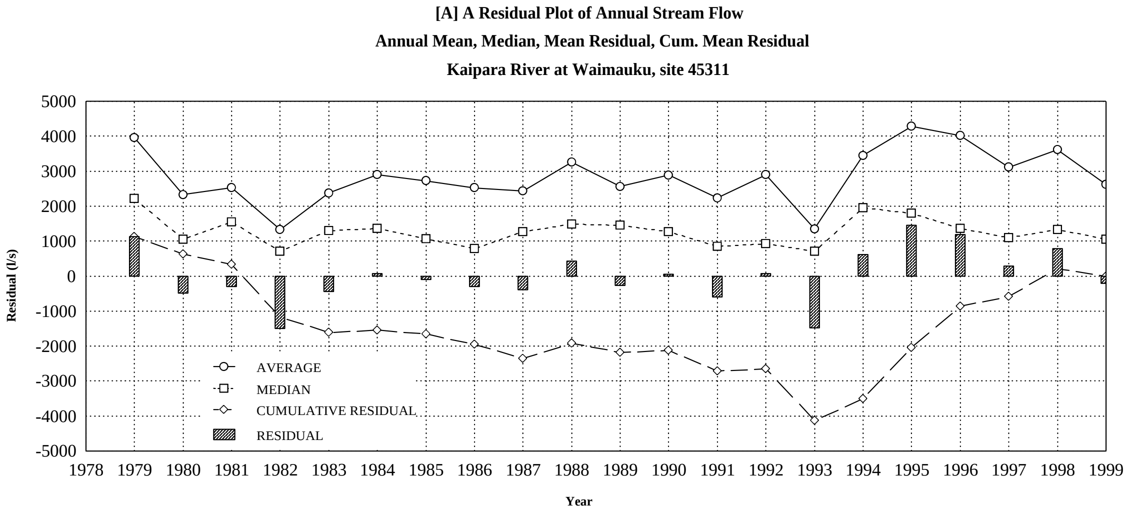
6.1.7 Long Term Variations in Flow

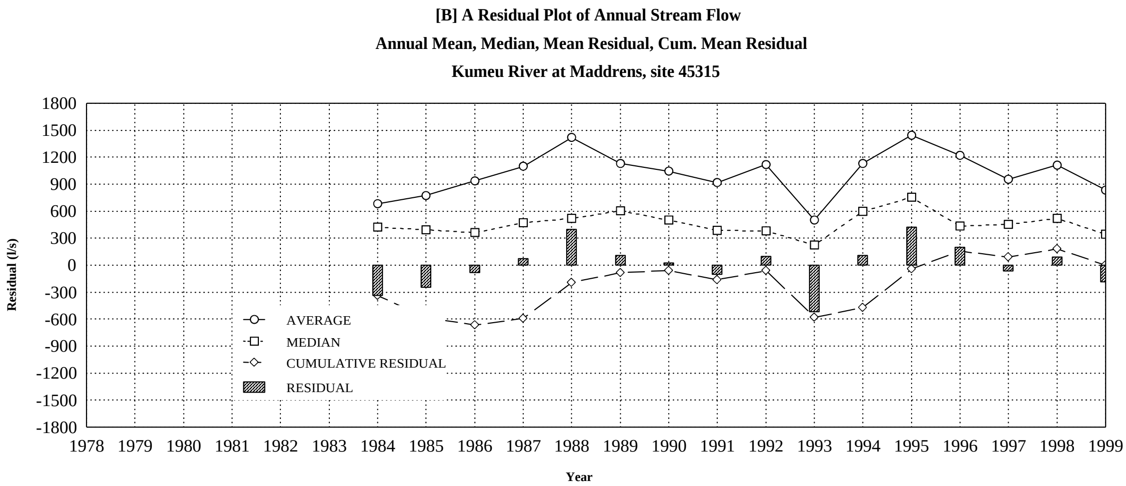
Long term changes in river flow can be of consequence for water allocation. A pattern of falling flows can result in reduced water availability whilst increasing flows can have the reverse effect. Comparison of average flows from year to year over the period of record provides a general indication of any long term trends.

Figure 6.6 presents variations in stream flow over the period of record at each of the three recorder sites. In addition to mean and median flow annual flows, the plots show ‘residuals’ which represent the difference between the mean flow in each year and the mean flow over the period as a whole. The ‘cumulative residual’ plot is indicative of any long term trends.

Although years of higher and lower than average flow are clearly visible, the plots do not appear to indicate long term trends in flow. However, on the basis of the Waimauku data, the flow record can be broken into three periods; 1979 to 1983, 1983 to 1993, and 1993 to 1999. The first section is characterised by a fall from above average flows in 1979 to below average flows in 1982-83. Between 1983 and 1993 annual flows remained close to average, until 1993 which coincided with the Auckland water shortage. The most recent period is characterised by above average flows.

These features of the flow record correspond with variations in rainfall, which in turn are the result of synoptic scale processes in the atmosphere. The Southern Oscillation is a synoptic-scale process involving a shift in position of Hadley cells across the equatorial Pacific. This process is represented by an index, known as the SOI, which describes east-west sea-surface pressure differences. It has a significant effect upon rainfall, and hence stream flow, in New Zealand. El Nino weather patterns are closely linked with periods of negative SOI, and these tend to result in below average rainfall in the Auckland Region.


[A] A Residual Plot of Annual Stream Flow
Annual Mean, Median, Mean Residual, Cum. Mean Residual
Kaipara River at Waimauku, site 45311
Residual (l/s)
AVERAGE
MEDIAN
CUMULATIVE RESIDUAL
RESIDUAL
Year


[B] A Residual Plot of Annual Stream Flow
Annual Mean, Median, Mean Residual, Cum. Mean Residual
Kumeu River at Maddrens, site 45315
Residual (l/s)
AVERAGE
MEDIAN
CUMULATIVE RESIDUAL
RESIDUAL
Year

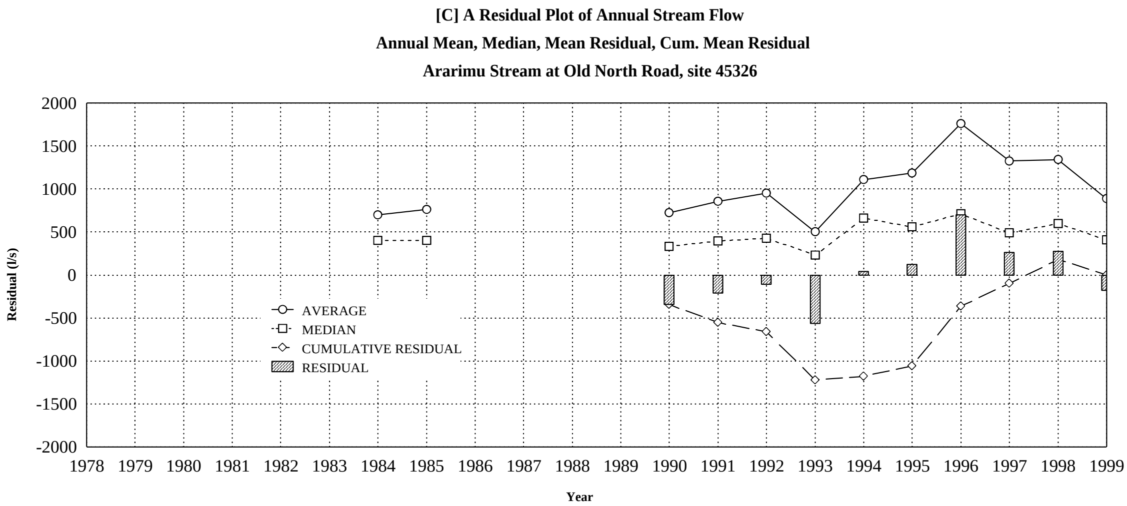

[C] A Residual Plot of Annual Stream Flow
Annual Mean, Median, Mean Residual, Cum. Mean Residual
Ararimu Stream at Old North Road, site 45326
Residual (l/s)
AVERAGE
MEDIAN
CUMULATIVE RESIDUAL
RESIDUAL
Year

Figure 6.6

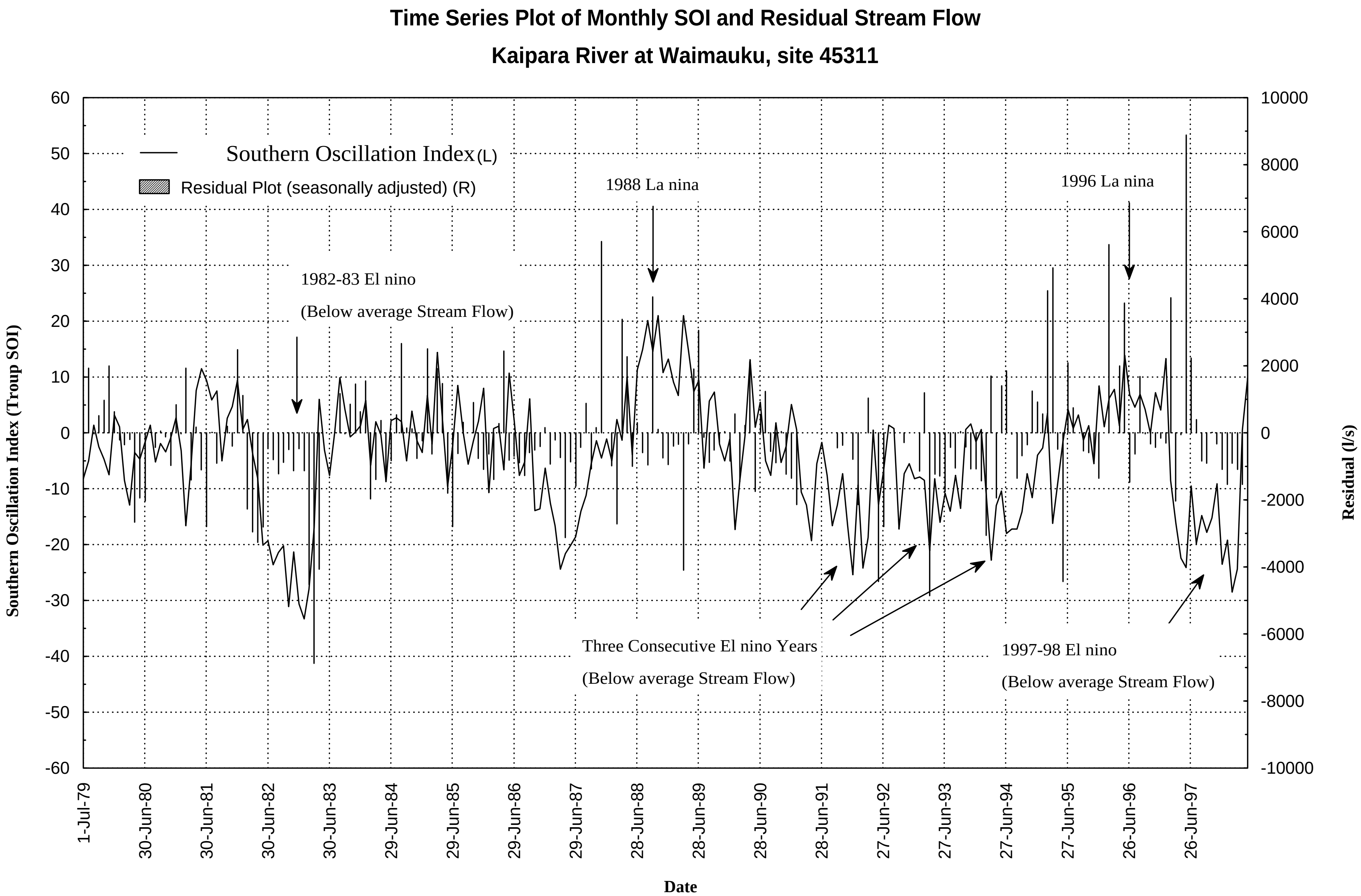

Time Series Plot of Monthly SOI and Residual Stream Flow
Kaipara River at Waimauku, site 45311
Southern Oscillation Index (L)
Residual Plot (seasonally adjusted) (R)
1988 La nina
1996 La nina
1982-83 El nino
(Below average Stream Flow)
Three Consecutive El nino Years
(Below average Stream Flow)
1997-98 El nino
(Below average Stream Flow)
Southern Oscillation Index (Troup SOI)
Residual (l/s)
Date
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
1-Jul-79
30-Jun-80
30-Jun-81
30-Jun-82
30-Jun-83
29-Jun-84
29-Jun-85
29-Jun-86
29-Jun-87
28-Jun-88
28-Jun-89
28-Jun-90
28-Jun-91
27-Jun-92
27-Jun-93
27-Jun-94
27-Jun-95
26-Jun-96
26-Jun-97

Figure 6.7

Figure 6.7 presents a residual plot of stream flow at Waimauku along with the SOI. The timing of El Nino and La Nina (periods of positive SOI) events can be seen to correspond with variations in the pattern of flow. The drought events of 1982, 1993 and 1997 coincide with negative SOI El Nino phases. The link between streamflow and La Nina phases appears to be less clear, suggesting that this phase tends to have a less marked impact on the Region's climate.

The Southern Oscillation index has been calculated for the period from 1876 to the present. Analysis of this appears to indicate a shift since 1972 from a La Nina to a El Nino dominated period, which suggests that the period of record at Waimauku coincides with a relatively dry climatic period. While it is unclear whether or not this will continue, it is apparent that El Nino phases have become more frequent and more intense in recent years.

6.2 Stream Water Quality

6.2.1 Introduction

The water quality of the Kaipara River and its tributaries has been monitored under a number of programs over the past 20 years. The results of this monitoring have shown that there are significant variations in water quality within the catchment, this largely reflecting differences in land use with the nature of runoff and discharges varying between forested, rural and urban catchments.

Generally, stream water quality in catchments dominated by native forest is high, due to the ability of the vegetation to absorb nutrients and minimise surface runoff. In exotic forested catchments, nutrient levels are higher and there can be elevated organic matter, colour and tannins, depending on the nature of the operations and land use in the vicinity of the watercourse.

Runoff in rural catchments can be compromised due to heavy fertiliser use and animal waste discharges. This can result in stream water being high in nutrients, bacteria and organic matter with associated depressed dissolved oxygen levels. During higher flows, high sediment loading can also be apparent as a result of poor land management practices. Herbicides and pesticides can also be present, either through direct runoff or from groundwater inflows.

In urban and industrial areas stream water quality is influenced principally by the types of discharges entering the stream. The most frequently occurring are non-point source stormwater discharges which can carry a range of pollutants from road run off and the disposal of contaminants to stormwater drains. Stormwater discharges can be high in bacteria, some trace metals and phenols. Point discharges include those from sewage treatment plants and from industry. The former are high in BOD, nutrients and bacteria, while the latter may involve a whole range of contaminants, both from continuous/regular point sources (authorised and unauthorised) and from accidental spills. In both rural and urban areas where there is no reticulated sewerage network, septic tanks can also contribute point discharges where they are poorly designed, located or maintained.

The extent to which the receiving water is affected by any of these sorts of discharges is determined by the degree of dilution or the assimilative capacity of the stream. This capacity can be compromised during periods of low flow, or as a result of over abstraction of stream water. The setting of minimum flows below which water abstractions are restricted can help to maintain an appropriate degree of dilution.

6.2.2 Water Quality Monitoring

The 1989 Kaipara River Catchment Management Plan (ARWB, 1989) reported on water quality at 22 sampling sites throughout the Kaipara River catchment. The majority of sites were sampled only a limited number of times as part of water quality studies undertaken in the early 1980s (data presented in Appendix III). There has been no catchment wide program of sampling since that time.

However, the water quality of the Kumeu River has continued to be monitored on a monthly basis as part of the ARC's long term baseline monitoring program. The monitoring site was relocated to Weza Lane in 1993 to avoid the influence of discharges from Kumeu and Huapai townships and associated rural industries on water quality.

Table 6.5 presents a summary of the sampling results over the period August 1993 to March 1997. The full results of sampling over this period are contained in Appendix III, along with a comparison of the concentrations of selected parameters with those at other sites throughout the Region.

Table 6.5 - Summary of Water Quality Monitoring Results, Kumeu River at Weza Lane.

Parameter (units)	Minimum	Median	Maximum
PH	6.4	7.1	7.7
Temperature (^{o}C)	7.4	15.5	22.0
Non-filtrable residue (mg/l)	5.6	13.0	49.0
Turbidity (ntu)	6.5	13.0	54.0
Chloride (mgCl/l)	19.7	29.9	38.8
Conductivity (mS/m)	12.8	16.5	20.9
Total Phosphorus (mgP/l)	0.04	0.08	0.190
Soluble Phosphorus (mgP/l)	0.008	0.02	0.05
Nitrate (mgN/l)	0.061	0.466	1.407
Ammonia (mgN/l)	0.003	0.046	0.215
BOD (mgO/l)	<2	<2	3.0
Total Coliforms (cfu/100ml)	490	2300	17000
Faecal Coliforms (cfu/100ml)	230	790	5000
Dissolved Oxygen (%)	52	82	93
Black Disk (m)	0.12	0.42	1.86

Compared to streams in other catchments in the Region sampled in the baseline monitoring program, the water quality parameters presented in table 6.5 rank approximately mid-range and are consistent with other mixed land use rural catchments. Comments on specific parameters are presented below.

Temperature

The results show a seasonal cycle in water temperature, which reflects the variation in air temperature through the year. The median temperature is similar to other rural streams where there has been widespread clearance of riparian vegetation, and is higher than that in other streams such as the Cascades Stream and Mahurangi River, where a greater proportion of the catchment is forested. The removal of riparian vegetation reduces shading with consequential increased water temperatures, particularly during summer. Elevated stream temperatures can result in reduced dissolved oxygen carrying capacity of the water, which can be critical for sensitive organisms, particularly where saturation levels are already reduced.

Dissolved Oxygen Saturation

This also follows a seasonal cycle, being inversely related to water temperature. DO provides a measure of the stream's ability to support aquatic life, with levels in the range 40-60% likely to stress sensitive organisms. DO levels in the Kumeu River are predominantly above this range, although are less than in more 'pristine' streams (such as Cascades) which are not subject to rural discharges and runoff. These discharges can promote the excessive growth of oxygen-demanding vegetation, which can in turn suppress the availability of oxygen for other instream organisms. DO levels can also be low in response to the over abstraction of water where this limits the assimilation capacity of the stream.

Biochemical Oxygen Demand

BOD provides a measure of the presence of organic matter. Elevated concentrations of oxygen demanding organic matter can result in depressed dissolved oxygen concentrations. Rivers with BOD of greater than 5.0 mg/l are considered polluted. The results of the monitoring in the Kumeu River are consistently below this value.

Conductivity

Conductivity provides an estimate of the total dissolved solids and can therefore indicate the level of inorganic contamination of the stream water. The results of the baseline monitoring indicate that the level of inorganic contaminants in the Kumeu River is relatively low, relating to the lack of urban development in the upper catchment.

pH

A value of 7 is typical for freshwater. Lower values can reflect high concentrations of heavy metals (as in an urban situation) or the occurrence of swampy conditions where the breakdown of organic material releases volatile acids. These affect the carbonate/bicarbonate balance and lowers pH. Elevated values of pH reflect increases in photosynthetic activity, typically in streams with limited riparian vegetation, where macrophytic vegetation is abundant. In these conditions the higher rate of carbon dioxide absorption affects the carbonate/bicarbonate balance to produce more alkaline conditions. In rural areas this effect can be exacerbated by elevated nutrient levels which promote macrophyte growth.

Water Clarity

Several of the parameters listed in table 6.5 relate to water clarity. Turbidity is a measure of the passage of light through water, with high values indicating poor passage of light which is a limiting factor in the ability of aquatic plants to photosynthesise. Black disc transparency is a measure of the horizontal water clarity, with a distance of 1.6 m being the critical measure for acceptable water clarity for recreational uses of streams. Non-filtrable residue is a measure of the suspended solids in the water, comprising silt, silica, clay and non-living organic material. Suspended solids not only reduce light penetration but also provide a media for pollutants to attach to. The Kumeu River is ranked below the mid-range of all sites sampled in terms of water clarity, as measured by these parameters. The relatively high suspended solid loading is typical of rural catchments where poor land management, including the removal of riparian vegetation and the incursion of stock into stream beds, results in high levels of sediment entering the stream, especially during rain events.

Microbiological Indicators

The measurement of total and faecal coliforms provides an indication of the microbiological quality of the stream water. Total coliforms include naturally occurring bacteria found in soils and decaying vegetation, along with faecal coliforms. High levels of total coliforms do not therefore necessarily reflect contamination of stream water. Faecal coliforms are a more restricted subset of bacteria which better reflect the discharge of faecal matter in stream water. The levels of faecal coliforms found in the Kumeu River are typical of rural catchments, resulting from the discharge of animal waste into the stream water.

Nutrients

Nutrient loading of streams in rural areas can occur where there is excessive discharge of waste and fertilisers, and can result in the proliferation of algae and macrophytes with several potentially detrimental effects. These include choking and reduced drainage efficiency, loss of amenity values, physical habitat reduction and reduced suitability of water for stock and irrigation. Nutrients measured in the baseline monitoring program are ammonia, nitrate, total phosphorus and soluble phosphorus. The concentrations of each of these parameters in the Kumeu River is again typical for a mixed use rural catchment. The levels of toxic constituents such as ammonia are below the levels at which they affect instream biota or stock.

6.2.3 Catchment Variations in Water Quality

The results of sampling in the early 1980's indicated significant variations in water quality from that recorded at the long term monitoring site. The water quality near the catchment outlet in the Lower Kaipara at Helensville was the most degraded, with increased levels of nutrient and sediment loading and a higher faecal coliform count compared to concentrations in the Kumeu River. This reflected the input of further discharges from rural runoff and waste discharges in the lower catchment, in particular due to greater concentration of dairy shed discharges in this part of the catchment, along with discharges from sewage treatment plants in Kumeu, Huapai and Helensville. The current distribution of discharge permits and dairy shed discharges are shown on map 11. Sewage treatment plants continue to operate at Huapai and at Helensville, with discharges from the latter tidally phased to prevent the treated effluent being carried upstream on an incoming tide.

In contrast, the monitoring demonstrated that the water quality of the tributaries in the north-western sub-catchments was relatively good compared to that of the main river. Lower concentrations of suspended solids, nutrients, BOD and faecal coliforms were recorded, particularly in the Ararimu Stream where a significant proportion of the catchment is forested.

The water quality of the Ararimu Stream was also described in the 1988 Bulk Water Supply Study (KRTA Limited and Tonkin & Taylor Limited, 1988b). The results of samples taken over the period January 1978 to March 1981 are presented in Appendix III and, although generally good, they indicate elevated levels of tannins, colour, chemical oxygen demand, iron and manganese. These relate to sawmilling and the natural leaching of decomposing vegetation in the forested part of the catchment. Variations in turbidity were noted during biota surveys for the Bulk Water Supply Study (KRTA Limited and Tonkin & Taylor Limited, 1989), with clearer water in riffle areas where the stream bed comprises a rock/gravel substrate, in contrast to more turbid waters in reaches of mud / clay substrates.

Further sampling of key water quality parameters was undertaken in the early 1990s as part of Phase II of the Future Bulk Water Supply Studies (McBride et al, 1991). These studies provide much valuable information and analysis on the relationship between flows, water quality and the functioning of aquatic ecology in the Ararimu Stream and the main Kaipara River. The key points are summarised here and in section 7.2 of this report, which deals with aquatic ecology.

The studies involved intensive surveys of water quality, undertaken during periods of high summer temperatures and low flows. Maximum water temperatures increased from 19.5 ^{o}C in the Ararimu Stream to 26.7 ^{o}C in the Kaipara River, coinciding with a reduction in the shading provided by riparian vegetation. Dissolved oxygen levels were lowest in the Kumeu River upstream of the confluence with the Ararimu Stream, whilst diurnal variations in DO were greatest at the poorly shaded reaches of the Kaipara River where prolific macrophyte growth occurred. Surveys of the Ararimu Stream downstream of Old North Rd found it to be 75% shaded by riparian vegetation, with 10% of the water surface covered by aquatic plants. This contrasts with the Kaipara River between Davidson’s and Kiwitahi Rd bridges, where only 20% of the channel was shaded, and 57% of the water surface was covered by aquatic plants.

The results of this intensive sampling were used to model the relationship between flows, temperature and dissolved oxygen and to recommend minimum flows in relation to the construction of a water supply dam in the upper reaches of the Ararimu Stream. The results of this work are discussed further in section 6.3.

6.2.4 Recent Monitoring

Certain water quality parameters were monitored continuously at the following seven sites in the catchment during May/June 1998 and April/May 1999:

- Kumeu River upstream of Pakinui Stream confluence (map reference Q11 498881)
- Kumeu River upstream of Huapai Stream confluence (map reference Q10 488912)
- Ararimu Stream at Old North Rd recorder site (map reference Q10 453944)
- Ararimu Stream at Campbell Rd (map reference Q10 495991)
- Kaipara River at Waimauku recorder site (map reference Q10 438921)
- Waimauku Stream at Muriwai Rd (map reference Q10 430908)
- Tributary of Kaipara River opposite Twin Peaks Rd (map reference Q10 397957)

The monitoring was undertaken with two data sondes which were rotated among the sites, being deployed at each for a period of ten to fifteen days. Temperature, turbidity, conductivity, pH and dissolved oxygen were measured to provide data to assist with analysis of the relationship between flow, water quality and instream habitat. The data is presented graphically in Appendix III.

The key results of this monitoring are:

Diurnal variations

As expected, water temperature, pH and dissolved oxygen tend to follow a diurnal cycle, peaking during the afternoon and reaching a minimum at night time. Variations in the dissolved oxygen saturation reflect changes in plant respiration between night and day. The level of pH follows the same diurnal cycle, peaking during the day when photosynthetic activity (and hence carbon dioxide absorption) is greatest.

Variations over period of monitoring

The key fluctuations over the period of monitoring at each site correspond with increased stream flow in response to rainfall events. The datasonde monitoring recorded the following effects:

- Turbidity peaks, due to increased sediment runoff during and following storm events.

- Conductivity falls, indicating the greater dilution of dissolved solids resulting from the increased flows in the stream.

- pH falls, as the effect of the absorption of carbon dioxide by plant photosynthesis becomes less significant during higher flows.

Variations between sites

The datasonde data confirms that the water quality of the Ararimu Stream is relatively good with lower temperatures and turbidity and higher dissolved oxygen than at most other sites. The water quality in the main Kaipara River at Waimauku was of similar quality, whilst further upstream in the Kumeu River temperatures and turbidity were higher and dissolved oxygen lower. This suggests that the relatively good quality water which enters the main river from the Ararimu catchment is effective in diluting the higher sediment and nutrient loadings from the upstream Kumeu River catchment.

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The water quality in the Waimauku Stream is similar to that in the Kumeu, although with lower dissolved oxygen, possibly due to poor aeration due to the presence of a large number of dams on the stream which reduce flow velocities. Dissolved oxygen may also be depleted due to the presence of oxygen demanding macrophytes in the lower reaches of the stream. Temperatures were also slightly elevated, again possibly relating to the proliferation of dams on the stream.

Fluctuations in Turbidity

There were fluctuations in turbidity at several of the sites which did not relate to rainfall events. The fluctuations tended to follow a pattern of a succession of 'spikes', at some sites (in particular the Waimauku Stream) following a diurnal pattern interspersed with periods of relatively stable turbidity. These fluctuations probably correspond to stock incursions into the stream above each site, with the regular movement of stock at certain times of day accounting for the consistency in turbidity measurements between days.

6.3 Analysis of Flow, Water Quality and Habitat Relationships

6.3.1 Introduction

As described in the previous sections, the monitoring of water quality at sites in the Kaipara River catchment has established that, in some places, the following effects occur during periods of low flow in the summer months:

- the elevation of water temperatures; and
- the lowering of dissolved oxygen levels.

Both of these effects can result in conditions which become limiting to the functioning of aquatic ecosystems. During periods of low flows, ecological functioning can also be affected by changes in instream habitat conditions, such as:

- the reduction in flow velocity; and
- the reduction in channel water depth and width.

An analysis has been performed to establish the flows below which the life supporting capacity of streams in the Kaipara River catchment may be affected, based on these water quality and habitat indicators (ARC, 2000). The analysis shows that, during most summers, flows in the Kaipara River catchment fall below these 'environmental flows'. By reviewing the historical flow record for the Waimauku recorder site, the analysis has assessed the frequency and duration of flows below the estimated environmental flow at this point in the catchment.

The methods, results and implications of the analysis are summarised below.

6.3.2 Method

Background to WAIORA

The relationship between flows, instream habitat and water quality was modelled using software developed by the National Institute of Water & Atmospheric Research (NIWA) for the Auckland Regional Council. The software, Water Allocation Impacts On River Attributes (Version 1.1), is given the acronym WAIORA, which can be interpreted to mean healthy water. WAIORA is described in full in the model user manual (NIWA, 1998) and related technical report (ARC, 1998).

For any flow at a given site, WAIORA predicts

- channel water geometry and velocity;
- mean and maximum water temperatures;
- minimum dissolved oxygen; and
- total ammonia,

providing that certain data has been collected and input into the model. WAIORA predicts these habitat and water quality parameters for any given flow. By varying the flow, it is possible to determine the flow required to ensure that the following habitat and water quality guidelines will be met:

- Minimum stream depth of 0.1 m;
- Maximum reduction in stream width of 30 %;
- Minimum velocity of 0.3 m/sec;
- Maximum increase in maximum daily temperature of 3 ^{o}C;
- Maximum daily temperature of 26 ^{o}C; and
- Minimum dissolved oxygen of 6 mg/l.

Additional guidelines also relate to maximum ammonia levels. These vary with the input data, depending upon habitat, temperature and pH values. The guidelines listed above are suggested in WAIORA help files, and are based on research in New Zealand and overseas on the habitat and water quality requirements of aquatic biota.

Input Data

Input data was collected at six of the seven sites listed in section 6.2.4. Data collection involved two visits to each of the sites to be modelled. During the first visit, stream cross sections were measured and flow gauged. The follow up visit involved a second gauging and measurements to determine changes to the channel cross section at the new flow. Observations were also made of stream shading. The collection of this information was concurrent with the installation of data sondes to collect the water quality data against which the model was calibrated.

The following data was input to all model runs:

- Flow, mean width and mean depth at the first gauging.

- Flow, mean width and mean change in depth at the second gauging.
- Reach length to next significant tributary or change in channel characteristics.
- Stream shading upstream and downstream.
- Published meteorological data.

Data had been collected at the six sites in the months of April to June, during which stream flows and temperatures were not at their lowest. In order predict minimum flows during and hotter mid-summer conditions, the model was first calibrated with the field data and published meteorological data for the month of May, and then re-run with meteorological data for the month of February.

6.3.3 Results

The results of the modelling indicate that, during periods of low flow and mid-summer climatic conditions, water velocities at each of the six sites will not meet the guideline value. This reflects the low elevation and shallow gradients of the streams modelled, most of which are subject to flooding during periods of higher flow.

Accepting that the velocity guideline can not be met, the analysis indicates that dissolved oxygen is the critical factor in determining the minimum flow at which all other guidelines are satisfied. Generally all other guidelines will be met at lower flows than those required to maintain DO levels at 6mg/l or higher. A summary of the predicted minimum environmental flows for each of the six sites is presented in table 6.6.

Table 6.6 – Summary of Results of WAIORA modelling

Site	Minimum Flow (l/sec)	Minimum flow as % of 1 in 5 year low flow	Minimum flow as % of mean annual low flow
45311 - Kaipara River at Waimauku	184	204 %	148 %
45326 - Ararimu Stream at Old North Rd	146	304 %	209 %
45357 - Kumeu River upstream of Huapai Stream confluence	38	138 %	103 %
45358 - Kumeu River upstream of Pakinui Stream confluence	113	422 %	320 %
45359 - Waimauku Stream at Muriwai Rd	20	168 %	130 %
45360 - unnamed tributary opposite Twin Peaks Rd	101	No reliable estimate of 1 in 5 year low flow	No reliable estimate of mean annual low flow

The results of the modelling indicate that the Kaipara River at Waimauku, and the lower reaches of the river downstream, are subject to significant DO stress during periods of low flow. The predicted minimum flow required to meet all guidelines is around double the 1 in 5 year low flow.

In contrast, the Ararimu Stream, which is subject to greater reaeration and lower water temperatures (as a result of greater shading) is not likely to be susceptible to significant DO stress. Although, the predicted minimum flow is three times the 1 in 5 year low flow, at lower flows (such as the 1 in 5 year low flow) DO levels do not drop as far as those at corresponding flows in the Kaipara River at Waimauku.

The other sites modelled are likely to exhibit DO stress between these two extremes. The lower reaches of the Kumeu River (represented by the site upstream of the Huapai Stream confluence) and the Waimauku Stream both have relatively low rates of reaeration and respiration, but exhibit smaller diurnal fluctuations in DO than the Kaipara River. However, reductions in reaeration during droughts, along with elevated respiration, can reduce night time DO levels. Recognising the low risk of DO stress, the predicted flow required to meet the WAIORA guidelines is significantly less than double the 1 in 5 year low flow in both cases.

In contrast, the modelling exercise indicated that relatively high minimum flows are needed to meet the guidelines in the upper Kumeu River (represented by the site upstream of the Pakinui stream confluence) and the unnamed tributary opposite Twin Peaks Rd in the lower Kaipara River catchment. The calibrated values of the model indicate that these streams have moderate reaeration rates but relatively high rates of respiration and photosynthetic activity. They have a moderate risk of DO stress.

6.3.4 Comparison with Previous Studies

A previous modelling study of the relationship between flow and water quality was undertaken as part of investigations for a future bulk water supply reservoir in the Ararimu Stream valley (McBride et al, 1991). The results of the 1991 study correspond closely with those of the WAIORA modelling exercise reported here. In particular, the authors found that the maintenance of acceptable dissolved oxygen levels were critical to the setting of a minimum flow, and that the main risk of DO stress occurred in the main Kaipara River. In order to maintain a satisfactory DO regime, the study recommended a minimum flow of 200 l/sec at the Waimauku recorder site, with no abstractions allowed until flow had increased beyond 300 l/sec. This latter recommendation reflects the fact small freshes after periods of low flow can temporarily cause depressed DO levels due to increased turbidity.

DO levels in the Ararimu Stream were found to be less affected by low flows, due to the greater shading reducing macrophyte growth and maintaining lower water temperatures. The study indicated that this relatively low risk of DO stress extends downstream, beyond the confluence with the lower Kumeu River. A minimum flow of 90 l/sec at the Old North Rd recorder site was considered to correspond with the recommended minimum flow of 200 l/sec at Waimauku.

6.3.5 Occurrence of Flows Below the Below the Environmental Minimum

An analysis of the historical flow record for the Kaipara River at Waimauku has been performed to establish the frequency and duration of flows below 180 l/sec, which is approximately that predicted by the WAIORA analysis as the minimum flow required to meet water quality and habitat guidelines (other than velocity). At this stage the analysis has not been repeated for the other sites modelled.

Analysis of Historical Flow Record

The number of days in each year of the historical flow record that flow has fallen below 180 l/sec is shown in table 6.7. The years are ranked from most to least days

Table 6.7 – Historical flows below 180 l/sec in the Kaipara River at Waimauku

	Number of days of flow below 180 l/sec
1982-83	83
1986-87	70
1997-98	59
1998-99	54
1993-94	47
1981-82	46
1994-95	38
1992-93	32
1985-86	26
1991-92	25
1990-91	25
1995-96	25
1987-88	24
1984-85	19
1980-81	17
1996-97	13
1978-79	7
1988-89	0
1979-80	0
1983-84	0
1989-90	0

Figures 6.8, 6.9. and 6.10 shows the distribution of days with flow below the minimum in each of a dry, middle ranked and wet year. In the driest summers, such as 1982/3, flow was naturally less than 180 l/sec for long periods of time (more than 2 months in total). In middle ranked summers (neither very dry nor very wet), such as 1991-92, flow was naturally less than 180 l/sec for approximately 1 month in total. In the wettest summers flow did not naturally fall below 180 l/sec.

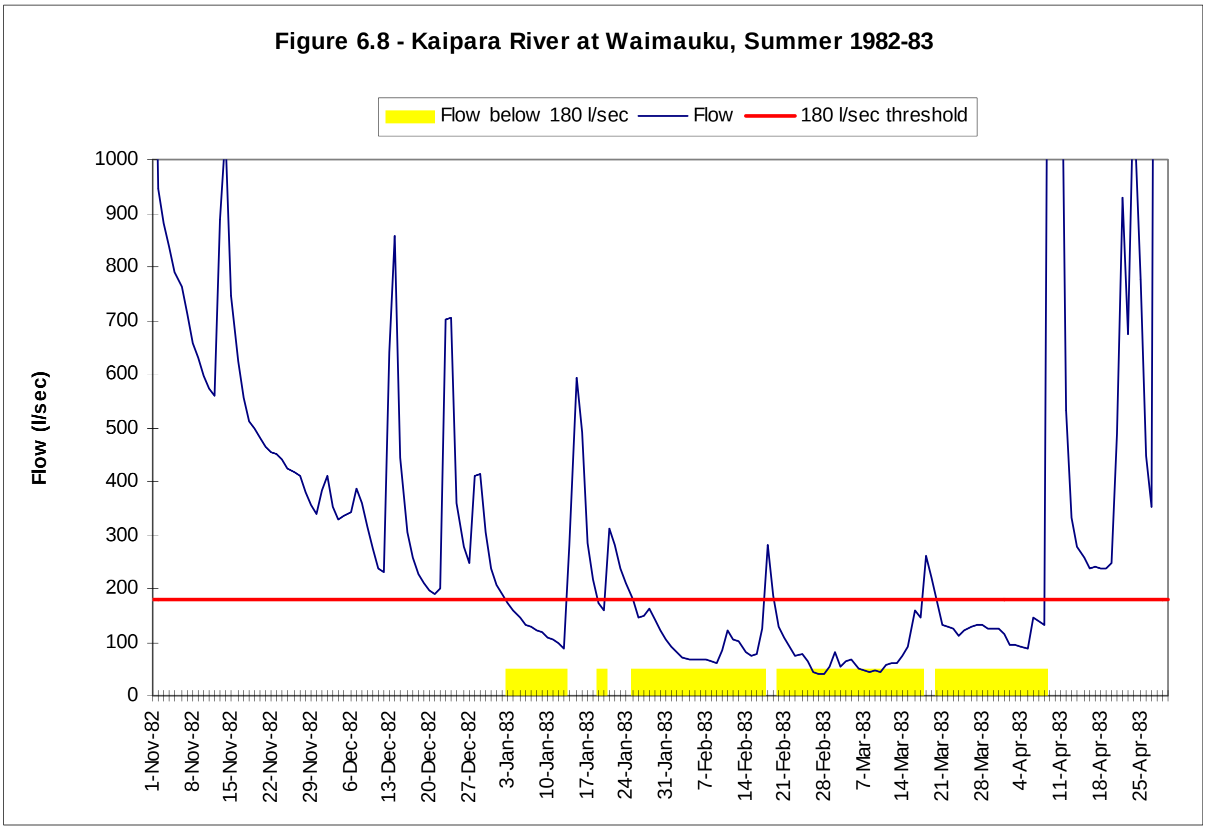


Figure 6.8 - Kaipara River at Waimauku, Summer 1982-83
Flow below 180 l/sec
Flow
180 l/sec threshold
Flow (l/sec)
1000
900
800
700
600
500
400
300
200
100
0
1-Nov-82
8-Nov-82
15-Nov-82
22-Nov-82
29-Nov-82
6-Dec-82
13-Dec-82
20-Dec-82
27-Dec-82
3-Jan-83
10-Jan-83
17-Jan-83
24-Jan-83
31-Jan-83
7-Feb-83
14-Feb-83
21-Feb-83
28-Feb-83
7-Mar-83
14-Mar-83
21-Mar-83
28-Mar-83
4-Apr-83
11-Apr-83
18-Apr-83
25-Apr-83

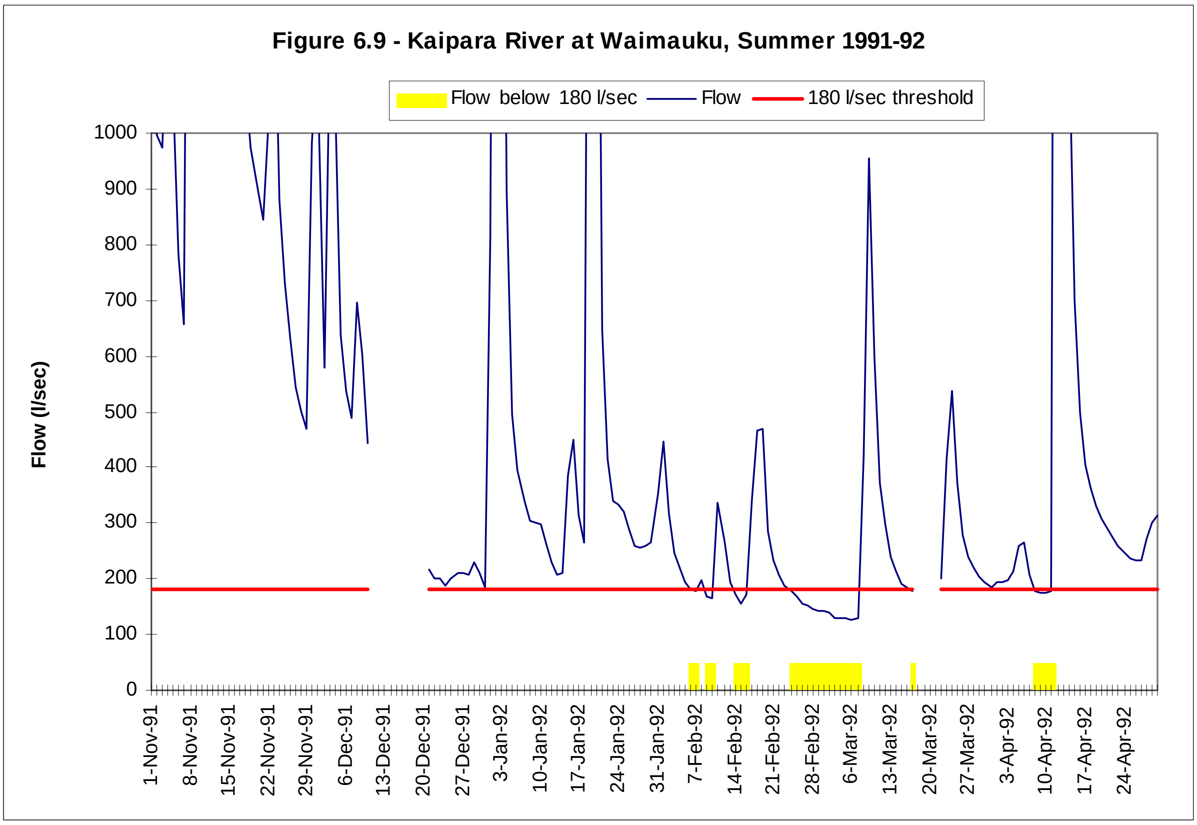
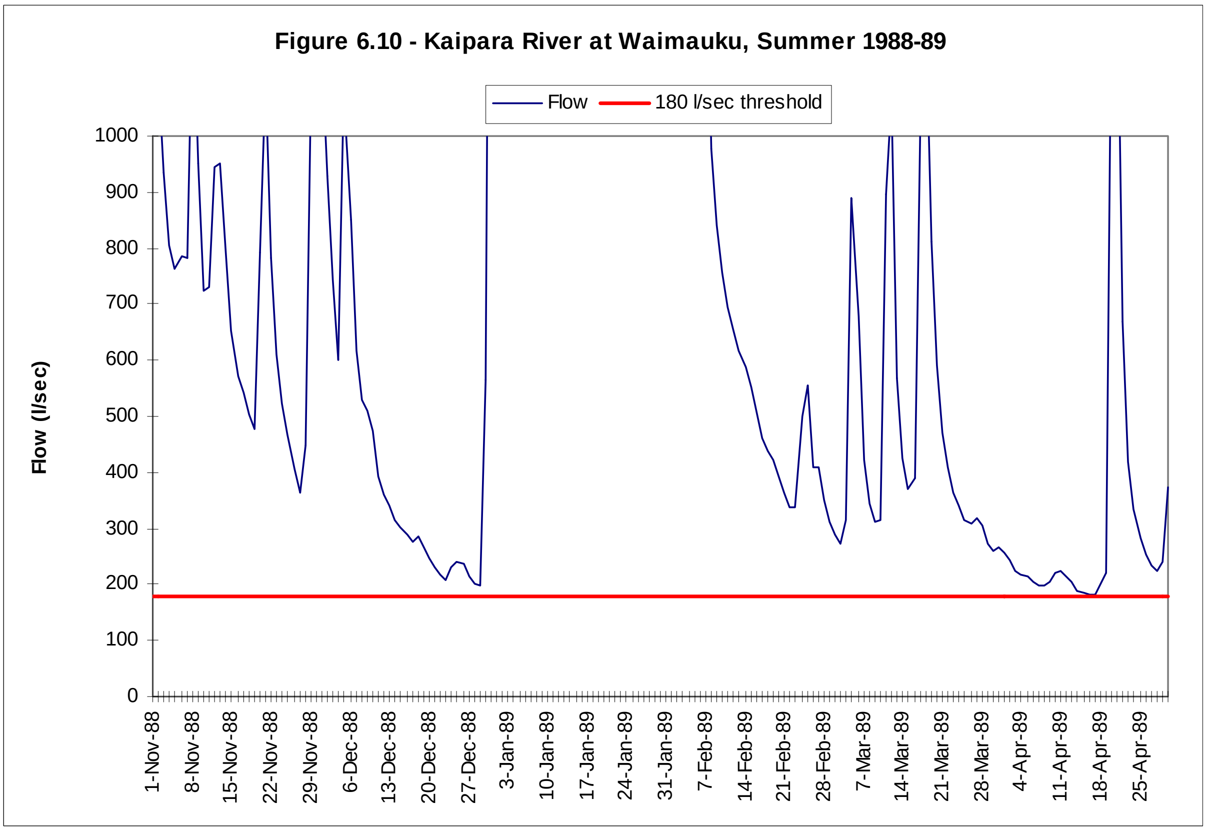


Figure 6.9 - Kaipara River at Waimauku, Summer 1991-92
Flow below 180 l/sec
Flow
180 l/sec threshold
Flow (l/sec)
1000
900
800
700
600
500
400
300
200
100
0
1-Nov-91
8-Nov-91
15-Nov-91
22-Nov-91
29-Nov-91
6-Dec-91
13-Dec-91
20-Dec-91
27-Dec-91
3-Jan-92
10-Jan-92
17-Jan-92
24-Jan-92
31-Jan-92
7-Feb-92
14-Feb-92
21-Feb-92
28-Feb-92
6-Mar-92
13-Mar-92
20-Mar-92
27-Mar-92
3-Apr-92
10-Apr-92
17-Apr-92
24-Apr-92



Probabilities

On the basis of historical flows, the probability or 'risk' of flows falling below 180 l/sec in the future can be predicted. There are two components to this risk:

- the number of consecutive days (duration) that flows fall below the 180 l/sec threshold; and

- the regularity within a specified number of years (frequency) that low flow events of a given duration will occur.

These two components of risk have been examined through a statistical analysis of flow records, using a technique termed 'spell flow analysis.' The analysis of flow records using spell flow analysis techniques is fully described in Institute of Hydrology (1980). The results of the spell flow analysis are presented in table 6.8.

The results indicate, for example, that:

- On average, once in every 10 years (10% of all years, or a probability of 0.1) flow will fall below 180 l/sec for a period of 28 or more consecutive days;

- On average, once in every 5 years (20% of all years, or a probability of 0.2) flow will fall below 180 l/sec for a period of 22 or more consecutive days; and

- On average, once in every 2 years (50% of all years, or a probability of 0.5) flow will fall below 180 l/sec for a period of 13 or more consecutive days.

Table 6.8 – Results of spell flow analysis, Kaipara River at Waimauku

Proportion of years with flow below 180 l/sec for the specified, or longer, duration (%)	Number of consecutive days with flow at or below 180 l/sec
10	28
20	22
30	19
40	16
50	13
60	10
70	8
80	5
90	1

6.3.6 Summary and Further Work

The WAIORA analysis indicates that guideline values of key water quality and habitat parameters, and most notably dissolved oxygen, will not be met during periods of low flow in most summers.

The analysis was based on predictions of likely February flow, water quality and habitat conditions made from a model calibrated using data collected in the months of April to May. In order to validate the model predictions it is essential that monitoring of water quality and habitat parameters is undertaken at each of the sites during January/February low flow conditions.

7 Instream Values of the Surface Water Resource

7.1 Introduction

The value of a water body includes both:

- the values associated with the quantity and quality of water *in situ* (in its natural location); and
- the value of that water for uses elsewhere.

Instream values fall into the first of these categories, being those associated with water flowing in a watercourse. They include ecological, cultural, and amenity (eg recreational and landscape) values. The following description of the instream values of the Kaipara River and its tributaries is the result of a review of ecological surveys and consultation with Tangata Whenua and the community.

Out of stream values include the economic value of water abstracted from a stream for purposes such as irrigation, industrial uses and stock drinking water supply. A description of the demand for water from the Kaipara River catchment for abstractive uses is presented in chapter 8.

7.2 Aquatic Ecology

7.2.1 Macroinvertebrates

The recorded distribution of macroinvertebrates is consistent with variations in water quality and riparian shading within and between sub-catchments. Sampling programs have been undertaken for Bulk Water Supply investigations (KRTA Limited and Tonkin & Taylor Limited, 1989 and McBride et al, 1991).

These studies found that the most diverse macroinvertebrate community is present in the Ararimu Stream. Small numbers (or moderate abundances) of ‘high quality’ indicators such as mayfly, blackfly and caddisfly larvae are present, these species requiring well oxygenated water.

Lower species densities have been recorded in the Waikoukou Stream, Tikokopu Stream and Kumeu River, with gastropods and caddisfly the dominant species. Gastropods were also found to dominate the invertebrate fauna of the Lower Kaipara River, along with freshwater shrimps which are tolerant of a range of water quality conditions. High densities of freshwater mussels were found at sites in the Kumeu River, Ararimu Stream and Kaipara River. These may play an important role in the purification of the river system filtering significant quantities of organic matter from the stream water (McBride et al, 1991).

In general terms, macroinvertebrate diversity and abundance was found to increase with lower velocities although there are some variations from this relationship depending on the time of year (McBride et al, 1991).

7.2.2 Fish

The results of fish surveys undertaken in the Kaipara River catchment are held on the National Freshwater Fisheries database. The surveys include those carried out in the early 1980s for the Bulk Water Supply Study (KRTA Limited and Tonkin & Taylor Limited, 1989) and the 1989 catchment water allocation and management plan (ARWB, 1989). Subsequent surveys in were undertaken throughout the catchment in 1991 (McBride et al, 1991) and 1994. The results of all recorded fish surveys undertaken in the catchment are presented in appendix IV).

In addition, whitebait surveys were undertaken for Bulk Water Supply Studies in 1986-7 and 1990 (KRTA Limited and Tonkin & Taylor Limited, 1989; and McBride et al, 1991).

These results of the various surveys are collated below, listing the species (including Koura, freshwater crayfish) recorded in each sub-catchment. In each case, species are listed in order of the frequency of occurrence, from most to least common (other than the whitebait records).

Ararimu sub-catchment

- Common bully (*Gobiomorphus cotidanus*)
- Shortfin eel (*Anguilla australis*)
- Longfin eel (*Anguilla dieffenbachii*)
- Koura (*Paranephrops*)
- Inanga (*Galaxias masculatus*)
- Redfin bully (*Gobiomorphus huttoni*)
- Torrentfish (*Cheimarrichthys fosteri*)
- Banded kokopu (*Galaxias fasciatus*)
- Crans bully (*Gobiomorphus basalis*)
- Common smelt (*Retropinna retropinna*)

Whitebait

- Inanga (*Galaxias masculatus*)
- Banded kokopu (*Galaxias fasciatus*)
- Giant kokopu (*Galaxias argenteus*)
- Koaro (*Galaxias brevipinnis*)
- Short jawed kokopu (*Galaxias postvectis*)
- Shortfin eel (*Anguilla australis*)
- Longfin eel (*Anguilla dieffenbachii*)
- Common smelt (*Retropinna retropinna*)
- Redfin bully (*Gobiomorphus huttoni*)
- Common bully (*Gobiomorphus cotidanus*)

Upper Kumeu sub-catchment

- Shortfin eel (*Anguilla australis*)
- Koura (*Paranephrops*)
- Longfin eel (*Anguilla dieffenbachii*)

- Common bully (*Gobiomorphus cotidanus*)
- Banded kokopu (*Galaxias fasciatus*)
- Inanga (*Galaxias masculatus*)
- Goldfish (*Carassius auratus*)
- Crans bully (*Gobiomorphus basalis*)

Tikokopu sub-catchment

- Shortfin eel (*Anguilla australis*)
- Longfin eel (*Anguilla dieffenbachii*)
- Common bully (*Gobiomorphus cotidanus*)
- Crans bully (*Gobiomorphus basalis*)

Waimauku sub-catchment

- Longfin eel (*Anguilla dieffenbachii*)
- Koura (*Paranephrops*)
- Shortfin eel (*Anguilla australis*)
- Banded kokopu (*Galaxias fasciatus*)

Whitebait (Kaipara River at Waimauku)

- Inanga (*Galaxias masculatus*)
- Banded kokopu (*Galaxias fasciatus*)
- Giant kokopu (*Galaxias argenteus*)
- Shortfin eel (*Anguilla australis*)
- Longfin eel (*Anguilla dieffenbachii*)
- Common smelt (*Retropinna retropinna*)
- Bullies (undifferentiated)

Kumeu sub-catchment

- Shortfin eel (*Anguilla australis*)
- Inanga (*Galaxias masculatus*)
- Koura (*Paranephrops*)

Whitebait

- Inanga (*Galaxias masculatus*)
- Banded kokopu (*Galaxias fasciatus*)
- Giant kokopu (*Galaxias argenteus*)
- Koaro (*Galaxias brevipinnis*)
- Short jawed kokopu (*Galaxias postvectis*)
- Shortfin eel (*Anguilla australis*)
- Bluegilled bully (*Gobiomorphus hubbsi*)
- Common bully (*Gobiomorphus cotidanus*)

Lower Kaipara sub-catchment

- Inanga (*Galaxias masculatus*)
- Banded kokopu (*Galaxias fasciatus*)

The most common species throughout the Kaipara River catchment are eels and Koura, both of which are tolerant of a wide range of habitat conditions. The presence and abundance of other species is more indicative of the variations in water quality and other habitat parameters between the various sub-catchments.

The Ararimu Stream has the highest species diversity with Common bully, Inanga and Torrentfish recorded in more than one survey whilst other species (Crans bully, Banded kokopu and Common smelt) have been recorded only once. There is also moderate species diversity in the Upper Kumeu sub-catchment, with Inanga, Banded kokopu and Crans bully recorded at sites on tributaries in the headwaters of the catchment. These species have not been recorded, however, in the main river itself, which has a lower species diversity consistent with the Kumeu River and Waimauku sub-catchments downstream.

Although only two species have been recorded in the Lower Kaipara River, reflecting the poor suitability of the lower river for adult fish, whitebait surveys have recorded a high diversity in juvenile fish (KRTA Limited and Tonkin & Taylor Limited, 1989) in the main Kaipara River at Waimauku. However, the fact that adult fish species diversity is low throughout much of the catchment upstream indicates that the degree of whitebait migration upstream from these lower reaches of the river is poor, other than to the Ararimu Stream and some tributaries of the Upper Kumeu River where the instream habitat and food supply are relatively good. These streams are typically are well shaded, have a rock or gravel substrate and good water quality. Similar streams throughout the catchment that have not been surveyed are likely to have similarly diverse fauna.

Where streams run through areas of farmland the factors of poor water quality and lack of shade combine to produce conditions which are limiting to most species, especially during periods of summer low flows. Over abstraction of water can exacerbate poor water quality and high temperatures, to not only limit the habitat availability in such streams, but also to prevent migration to reaches of better habitat upstream.

The absence of some fish species in parts of the catchment not only reflects habitat availability but also the presence of barriers to migration. Whilst species such as Banded kokopu and eels are able to climb natural barriers such as waterfalls, others, such as Inanga, are not. The presence of artificial barriers, such as dams, weirs and culverts, without adequate provision for fish passage, can prevent even climbing species from migrating upstream.

The numbers of fish present not only varies spatially, but also over time, especially in relation to the migration at certain times of year. Migrations occur in response to high flows, high tides and phases of full moon (McBride et al, 1991). In spring and early summer, large numbers of juvenile fish (whitebait) make their way upstream. The whitebait surveys undertaken at sites on the Kaipara River, Kumeu River and Ararimu Stream in the late 1980s and early 1990s recorded peak upstream migrations between late September and mid-November.

Downstream migrations are more variable, both in terms of the timing and stage of lifecycle. Adult eels, inanga and smelt migrate downstream in autumn whereas other species, including bullies and banded kokopu, move downstream as larvae in either autumn or spring (McBride et al,1991).

7.3 Values of Tangata Whenua

7.3.1 Introduction

The description of the history of human occupation of the Kaipara River catchment in section 5.1.1 indicates a long and complex relationship between Maori and the land in this area. Two iwi are recognised as tangata whenua: Ngati Whatua through out the majority of the catchment; and Te Kawerau a Maki in the area occupied by the southern headwaters of the river.

Representatives of both iwi have produced documents describing issues, concerns and values in relation to resource management issues, including water management. In addition, consultation with Ngati Whatua on specific issues associated with water resource planning in the Kaipara River catchment has been undertaken in the past.

7.3.2 Consultation and Iwi Statements

Ngati Whatua

As part of ARA Bulk Water Supply study of the late 1980s, a cultural assessment report was commissioned in relation to the proposed scheme to construct a dam at Campbell Rd and to abstract water from the Ararimu Stream (KRTA Limited and Tonkin and Taylor, 1989). The report documents consultation undertaken at that time, including the outcome of huis with local Marae and with Te Runanga O Ngati Whatua, and of site visits involving local kaumatua.

The consultation identified three broad themes in the description of the association between Maori and the natural water bodies of the area:

1. Kaimoana - the nurturing, protection and management of water bodies which provide food is integral to maintaining the honour and mana of the iwi.

2. Cultural and Spiritual Associations - in the Maori world view, water and its use are closely interwoven with cultural and spiritual matters.

3. Social Associations - during peace times, increased population could put pressure on the available resources, necessitating the rules of ‘Rahui,’ determining what, when and how much could be taken.

Specific issues raised during the consultation included concerns over:

- impacts on eel and kewai migratory routes;

- a possible reduction in the supply of kaimoana for manuhiri, including tuna, kaarahi, inanga, kewai and watakirhi (water cress);
- the placement of obstructions in water courses; and
- pollution, including the return of sewage to water courses.

Te Hao o Ngati Whatua are consultants for the tangata whenua of five marae on resource management issues. In their statement to the ARC on the preparation of the Regional Policy Statement and Regional Plan: Coastal (Te Hao o Ngati Whatua, 1993), Te Hao documented issues relating to the management of water resources. These include:

Issues relating to policy, planning and resource consents:

- these processes to reflect the Crown's presumed ownership of rivers, water and other taonga that Ngati Whatua never willingly gifted or sold;
- the allocation of resources under these processes to take into account the implications of Treaty Claims;
- policy making and the assessment of effects of resource consent applications to include the past and present effects on Tangata Whenua;
- resource consent procedures to ensure the active protection of significant areas; and
- effective opportunities for the participation of Tangata Whenua in resource consent procedures.

Issues relating to water quality and activities in the catchment of the Kaipara Harbour:

- prevention of the adverse effects of sewage, rural runoff and discharges, and stormwater on the mauri of ancestral waters;
- no more direct sewage or effluent discharges into water, and in particular into the tributaries of the Kaipara Harbour, be approved or renewed;
- concern over the effects of using hazardous substances on adjacent waterways;
- the protection of waahi tapu and other cultural heritage sites;
- Ngati Whatua to be involved in monitoring in the catchment of the Kaipara Harbour.

Te Kawerau a Maki

The Kawerau a Maki Trust Resource Management Statement (Kawerau a Maki Trust, 1995) discusses Kaitiakitanga, processes to be followed in plan and policy development and in resource consent applications, and matters of resource management significance to the Trust. Objective 4.4.1 is to give effect to the Trust's role as Kaitiaki in the management and conservation of water, and related policies address the Trust's concerns with regard to water which are:

- to protect the mauri of all natural waterways;
- to protect and enhance the food producing capacity of natural waterways;
- to protect and enhance the life supporting capacity of natural waterways; and
- to promote water conservation and efficient use of water.

7.4 Amenity Values

7.4.1 Introduction

The Resource Management Act 1991 defines amenity values as

"those natural or physical qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes."

The cultural values of tangata whenua are considered separately in section 7.3. This section therefore focuses on the recreational and landscape values of people and communities throughout the catchment. Consultation with the local community of the Kaipara River catchment has played a key role in identifying these values and the issues which are perceived as threats to those values.

7.4.2 Consultation Process

Consultation with the Kaipara catchment community has been undertaken in a number of ways:

- three public meetings held in October 1997 at Waimauku for the following audiences:
  - the general farming community;
  - consent holders, horticulturalists and market gardeners;
  - the general community;

- a survey attached to a newsletter sent to all property owners in the catchment in July 1997 (approximately 6,000)

- a more detailed land and water use survey sent to all owners of properties greater than 3 hectares (1,615 properties) in summer 1997/98, described in more detail in section 8.2.

There was a high response rate to the detailed land and water use surveys: in seven of the eight subcatchments over 50% of owners or occupiers responded to the survey. Overall, 42% of these also indicated resource, environmental and management concerns and/or values.

The two other means of consultation prompted a much lower response rate. The three public meetings were attended by a total of 50 members of the local community whilst only 101 replies were received in response to the newsletter survey (less than 2 % of mail out).

7.4.3 Results

The results of consultation are described in detail in Appendix V and are summarised below.

Major Values

The largest number of responses identifying values came from the more populous Upper Kumeu, Kumeu, Waimauku and Lower Kaipara sub-catchments, with several also from the Tikokopu and Ararimu. Those from the Moau, Awaroa and Lower Kaipara relate to maritime pursuits, reflecting their proximity to the Kaipara Harbour.

Picnicking, eeling, fishing and tramping are the top four recreational uses, with duck shooting, swimming, sea fishing and boating, general enjoyment and kayaking the other very popular activities. Other water-based activities, horse riding and camping were also cited.

Activities have strong geographical associations. Eeling is most popular in the Waimauku sub-catchment while freshwater fishing is equally popular in the Waimauku and Upper Kumeu sub-catchments. Tramping is most popular in the Upper Kumeu, reflecting the presence of the Waitakere Ranges, and the same applies to swimming in streams. Tramping is also popular in the Waimauku sub-catchment, again possibly because of its proximity to the Waitakeres.

Duck shooting is most popular in the Lower Kaipara, with adherents also from the Waimauku, Upper Kumeu and Kumeu.

Picnicking is the most widespread pursuit: it was the only one mentioned in each of the eight sub-catchments. General enjoyment as a resource use was most frequently cited in the Ararimu, Kumeu and Upper Kumeu sub-catchments.

Specific areas valued

An interesting finding is that respondents were almost equally split between local and global affiliations in nominating their most valued area: 47 cited their own property or local area, while 45 cited the entire catchment as being of value to them. These two themes attracted a significantly higher response that the next most valued areas, which are also generic rather than geographic: nearby bush and forest; stream surrounds and streamside parks, and parks and reserves generally.

Leading the list of geographic locations valued by the community are Muriwai, the Waitakere Ranges, the Cascades, Bethells and other West Coast beaches, followed by the Kaipara Harbour, other waterfalls and the Parakai hot pools. The geographic spread of specific locations is also interesting: of the 38 respondents citing places in the Waitakere Ranges - West Coast area, 37 are from the Upper Kumeu sub-catchment. Similarly, of the 15 who nominated Muriwai, 12 are from Waimauku - the gateway to Muriwai. Other more local sites were also nominated only by people from within their own sub-catchment.

The only nominations made in every sub-catchment were local and global: their own property or local area and the entire catchment. This seems to indicate that while people value what they know well, they are also very aware of the impact of wider, potentially adverse, influences on their local values.

Generic statements about the values of ‘parks’ or ‘reserves’ are also revealing, as they indicate a general appreciation of local amenity values. That is, although people make journeys to specific destinations for various types of recreation, or are aware of particular areas of great value, they spend most of their leisure or non-work time at home or locally, and consequently value a high quality local environment.

Major Concerns and Issues

Concerns in general order of importance are:

- flooding and the related issues of river clearance, blockages, weeds and willows
- water quality
- water availability
- sewage
- growth
- riparian management, fish habitat and bush protection and bird habitat
- rubbish in streams and rivers
- use of chemicals

Flooding and related issues attracted by far the highest proportion of all responses to resource concerns, especially in the Upper Kumeu, Lower Kaipara, Waimauku and Kumeu sub-catchments, and also in the Awaroa. Water quality is the next most frequently cited issue and was of particular concern to respondents in the Kumeu, Waimauku, Upper Kumeu and Lower Kaipara subcatchments.

Water availability and the allocation process is of concern in the Kumeu, Waimauku, Upper Kumeu and Ararimu subcatchments. This reflects the high level of demand on both surface and groundwater resources in these sub-catchments which, historically, have had the highest concentrations of water rights/permits. There are restrictions on the taking of groundwater in the Kumeu area and have been restrictions on the taking of surface water under the previous water allocation plan for the Kaipara catchment.

Growth is also an important issue in the Waimauku, Upper Kumeu and Kumeu sub-catchments, reflecting increasing rural-residential and more intensive subdivision development. Concern about Auckland's growth generally may also affect those in Kumeu-Huapai, which have a growing function as commuter settlements. The inter-related issues of sediment, riparian management, fish habitat and bush and bird habitat are most frequently cited in the Waimauku, Kumeu, Upper Kumeu and lower Kaipara sub-catchments, but also appear in responses from the Awaroa, Tikokopu and Ararimu sub-catchments.

8 Demand for the Surface Water Resource

8.1 Introduction

There are a range of competing demands for consumptive use of the surface water resources of the Kaipara River catchment. While the most widespread use of water is for stock, in certain areas of the catchment large volumes of water are taken for irrigation and municipal water supply.

This chapter describes the variations in water demand across the catchment, including a comparison of surface water use with that of groundwater. Trends which may influence water demand are identified, along with a number of important proposed developments in the catchment which could be of consequence for water demand and availability in the future.

8.2 Land and Water Use

8.2.1 Background to Land and Water Use Survey

A land and water use survey of the Kaipara River catchment was undertaken during the summer of 1997/98. All owners of properties greater than 2 hectares in size were sent a questionnaire asking for details of land use and sources of water. The size limit of 2 ha was chosen to exclude residential properties in areas such as Helensville and Kumeu townships which, although large in number, occupy only a small proportion of the total area of the catchment.

In addition, respondents were invited to describe values, issues and concerns with regard to management of the water resources of the Kaipara River catchment. More detail on this latter aspect of the survey is presented in section 7.4.

Reponses were received from 61 % of all the property owners surveyed, with these properties covering 66 % of the catchment as a whole. More detail on the spatial variability in the response rate is presented in table 8.1.

Table 8.1 - Response to land and water use survey, by sub-catchment

Sub-Catchment	Number of Responses	Area of property covered by responses (hectares)	Area surveyed as % of sub-catchment area
Ararimu	76	4,287	81
Awaroa	15	713	70
Kumeu River	259	1,670	61
Lower Kaipara	86	3,602	75
Moau	49	765	54
Tikokopu	48	1,132	47
Upper Kumeu	294	2,259	52
Waimauku	163	3,275	84
Total Catchment	1,616	17,703	66

Although land use and water demand is therefore unknown for 34 % of the catchment, the survey results do provide a clear indication of:

- Patterns of land use and possible future trends
- Current water demand, the distribution of demand and possible future trends
- Community concerns and values (see section 7.4.3)

8.2.2 Survey Assumptions

The survey asked property owners to specify land use as one of fifteen classes (including ‘other’). These are listed in table 8.2. In addition to specifying the area or percentage of the total property under each type of land use, respondents were also asked to specify the number of stock units. The combined information on areas irrigated and stock numbers allows the estimation of total water demand from that property. These estimates were based on the guideline water use quantities, also presented in table 8.2. Water demand was then summed for each group of land use types by sub-catchment and for the catchment as a whole.

In addition, the survey allowed respondents to specify a water source for each use on the property, including domestic consumption. This allows the total demand for water from streams, dams, groundwater and rainwater collection to be estimated.

Table 8.2 - Land and water use survey classes

Land Use Groups (as in summary results and diagrams)	Land Use Classes (as on survey questionnaire)	Water Use Guideline	Comment
Dairy	Dairy	70 l/day drinking water, 70 l/day washdown	assumes lactating cows *
Beef/Sheep	Beef	45 l/day	dry stock, including calves*
	Sheep	4 l/day	including lambs*
Native Bush	Native Bush/Forest		
Exotic Forestry	Exotic Forestry		
Horticulture	Orchard	25 m^3/ha/day	ARC guidelines
	Market Garden	35 m^3/ha/day	ARC guidelines
	Glass/Plastic House	40 m^3/ha/day	ARC guidelines
Lifestyle	Lifestyle		Under 5 hectares, insufficient stock to form an economic unit.
Other	Vacant/bare land		Land area which is either in domestic use or not in use at all.
	Piggery	25 l/day	assumes lactating sows *
	Poultry	30 l/day per 100 birds *	
	Other		including other stock: deer, horses, goats, ostriches, etc.
	Domestic	1 m^3/household/day	

* Sources: Farm Technical Manual, 1991; Facts and Figures for Farmers, 1987.

8.2.3 Results - Land Use

Table 8.3 presents the surveyed areas under each type of land use for the catchment as a whole and by sub-catchment. Figure 8.1 represents this information graphically.

Table 8.3 - Surveyed land use, by sub-catchment

	Catchment	Ararimu	Awaroa	Kumeu River	Lower Kaipara	Moau Stream	Tikokopu	Upper Kumeu	Waimauku
Lifestyle	32.7%	8.0%	5.7%	28.2%	18.2%	41.1%	52.3%	69.2%	32.6%
Exotic Forestry	26.2%	80.0%	5.2%	5.5%	22.0%	3.6%	2.0%	4.7%	7.0%
Beef/Sheep	15.7%	5.4%	68.6%	3.5%	21.1%	0.0%	22.7%	2.5%	32.0%
Dairy	11.2%	1.8%	3.1%	11.1%	23.6%	47.2%	9.1%	6.1%	8.4%
Native Bush	4.7%	3.2%	3.4%	3.2%	7.4%	0.3%	3.6%	7.6%	4.6%
Horticulture	3.7%	1.3%	1.2%	15.5%	1.5%	2.1%	0.3%	3.6%	3.8%
Other Stock	3.2%	0.1%	0.0%	19.1%	2.7%	0.0%	10.0%	1.4%	7.3%
Other	2.7%	0.3%	12.7%	13.9%	3.5%	5.6%	0.0%	4.8%	4.4%

The land use of the Kaipara River catchment as a whole falls into three broad classes, each of which occupies approximately one third of the area surveyed. These are:

- Agricultural use; dominated by drystock and dairy farming, and also including horticulture.
- Forest cover; mainly exotic forestry, but also including native bush.
- Lifestyle blocks; including low intensity, small scale pastoral land use and some residential areas.

There is a significant degree of variation from this overall pattern of land use with well defined spatial agglomerations of certain land uses in each of the sub-catchments.

The Upper Kumeu catchment is dominated by lifestyle living. This can largely be explained by its relative proximity to the Auckland urban area. To the north, in the Kumeu River catchment, there is greater emphasis on the productive use of land, with over 15 % of the area surveyed under horticulture. Orchards and vineyards are particularly significant, in terms of land area. The importance of horticulture in the Kumeu River sub-catchment reflects the prime land use capability of this area (see section 4.3) along with the proximity to the Auckland market. There is also a significant proportion of ‘other’ land in this catchment, reflecting the presence of the residential areas of Kumeu and Huapai.

Horticulture is also important in the Waimauku sub-catchment, although with a greater emphasis on market gardening and glass house crops the actual proportion of the land under horticulture is less than in the Kumeu sub-catchment. Drystock (beef/sheep) farming is also important, occupying approximately one third of the land area of the Waimauku sub-catchment.

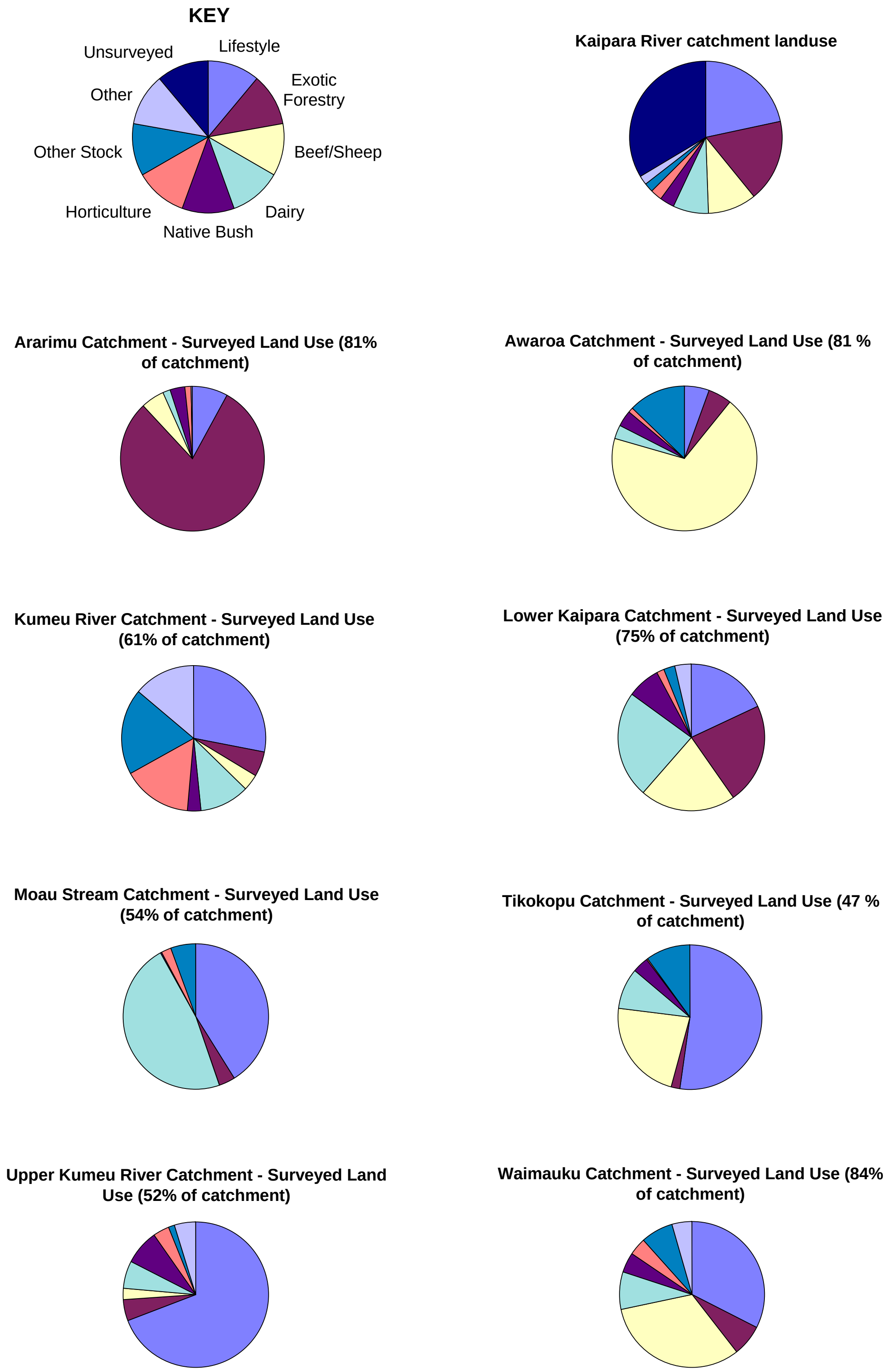


Figure 8.1 - Surveyed land use, by sub-catchment

Further north, in the Awaroa sub-catchment drystock farming dominates to a much greater extent, occupying around 70 % of the area surveyed. The greater emphasis on extensive agriculture reflects the poorer land use capability in this area. In the Ararimu sub-catchment, where the largest tracts of poor quality land occur, the landscape is dominated by exotic forestry.

Dairy farming is of most significance in the Lower Kaipara River and Moau sub-catchments, reflecting the availability of low lying better quality land toward the catchment outlet. Lifestyle blocks are also of significance in these areas, due to the proximity to Helensville. These variations are of consequence for water demand.

A small number of respondents surveyed gave an indication of proposed changes in land use. The vast majority of these related to the subdivision of current properties into smaller lifestyle or residential blocks.

The most notable other possible change is an increase in the area of glass house crops, particularly in the Kumeu sub-catchment. A smaller number of respondents in this area propose to increase the areas of orchard/vineyards and market garden cultivated. Throughout the remaining sub-catchments there were individual responses indicating isolated cases of increased crop areas or numbers of stock, but no major trends in agriculture are evident.

However, one apparent trend is the planting of trees and native bush regeneration, particularly in the Upper Kumeu catchment. This reflects the predominance of lifestyle blocks in this catchment, with productive land uses of relatively minor significance compared to elsewhere in the catchment.

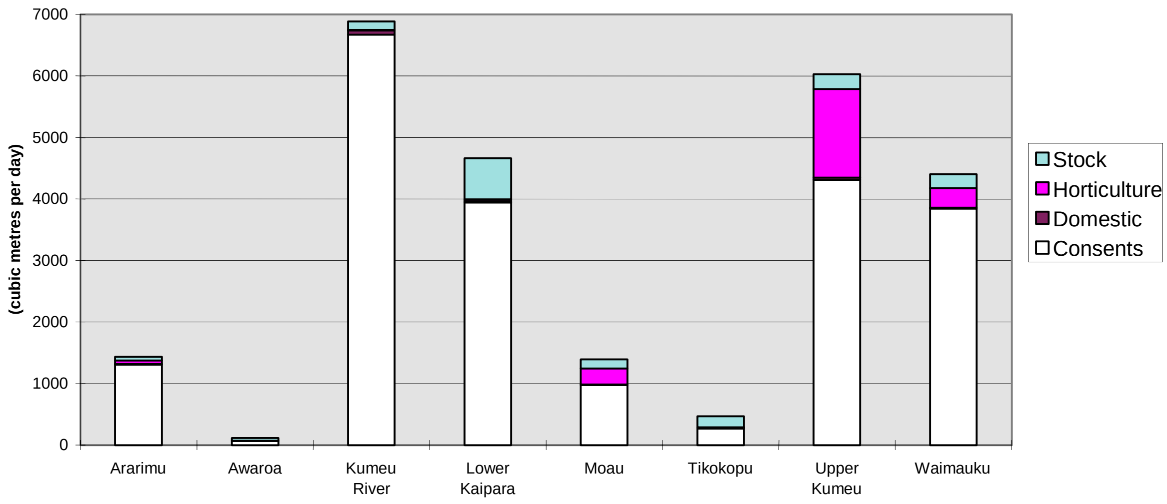
8.2.4 Results - Water Demand

The pattern of water demand estimated from the survey results is presented in figures 8.2 to 8.6. Water demand for stock, horticultural and domestic use has been estimated from the results of the survey, multiplied by a scaling factor reflecting the proportion of unsurveyed land in each sub-catchment. Note that the horticultural water demand does not include the demand of any existing consent holders who were surveyed.

The consented water demand is shown as a separate category, and was calculated by summing the daily allocations on all consents held at the time of the survey (summer 1997/98). This does not necessarily reflect the current or future consented demand, as it is likely that some expired consents will not be replaced while others may be replaced with changed allocations. The quantities which can be allocated will not be known precisely until the water allocation management strategy has been finalised and adopted, and consents processed accordingly. The distribution of consents to take and dam surface water held at the time of the survey is shown in map 12.

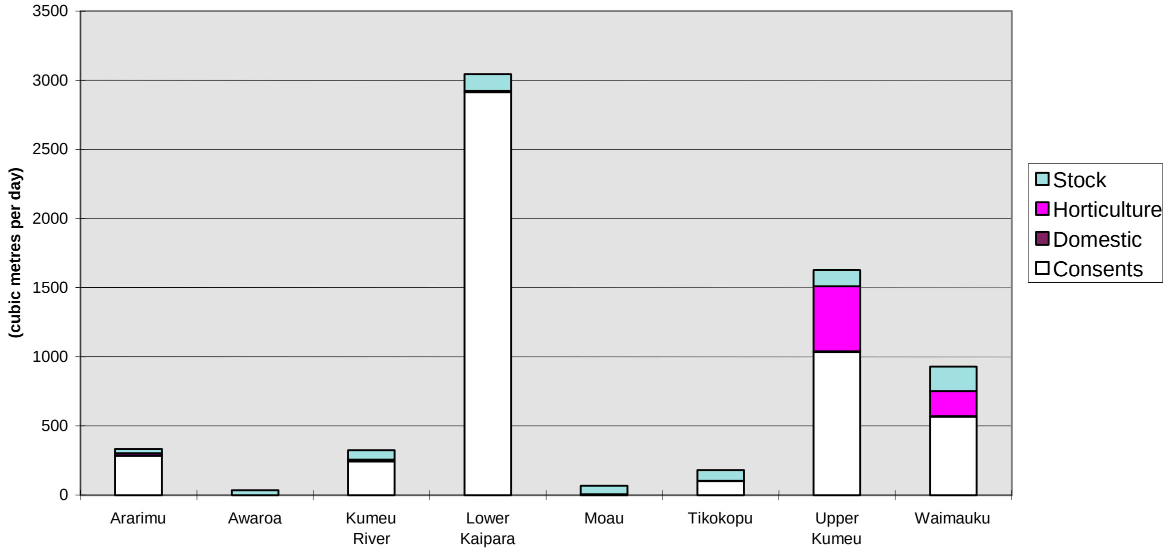
The estimated demand from all sources is shown in figure 8.2. The four sub-catchments of the Kumeu River, the Upper Kumeu, Waimauku and the Lower Kaipara stand out as the major areas of demand, reflecting the distribution of population and economic activity within the catchment.

Figure 8.2 - Estimated Water Demand from All Sources



The estimated demand from streams is shown in figure 8.3. Demand is significantly greater in the Lower Kaipara than in any other sub-catchment, reflecting the abstraction of water for Helensville public water supply along with a number of large consents for horticultural irrigation. Demand for stream water is also relatively high in the Upper Kumeu and Waimauku sub-catchments, reflecting the concentration of horticulture in these areas.

Figure 8.3 - Estimated Water Demand - Streams



Demand for water from dams is of most significance in the Waimauku sub-catchment, again reflecting the concentration of horticulture in this area (see figure 8.4). The abstraction of water from dams is also important in the Lower Kaipara sub-catchment, both for consented purposes and as a source of stock water, with this being the predominant area of dairy farming in the catchment.

Figure 8.4 - Estimated Water Demand - Dams

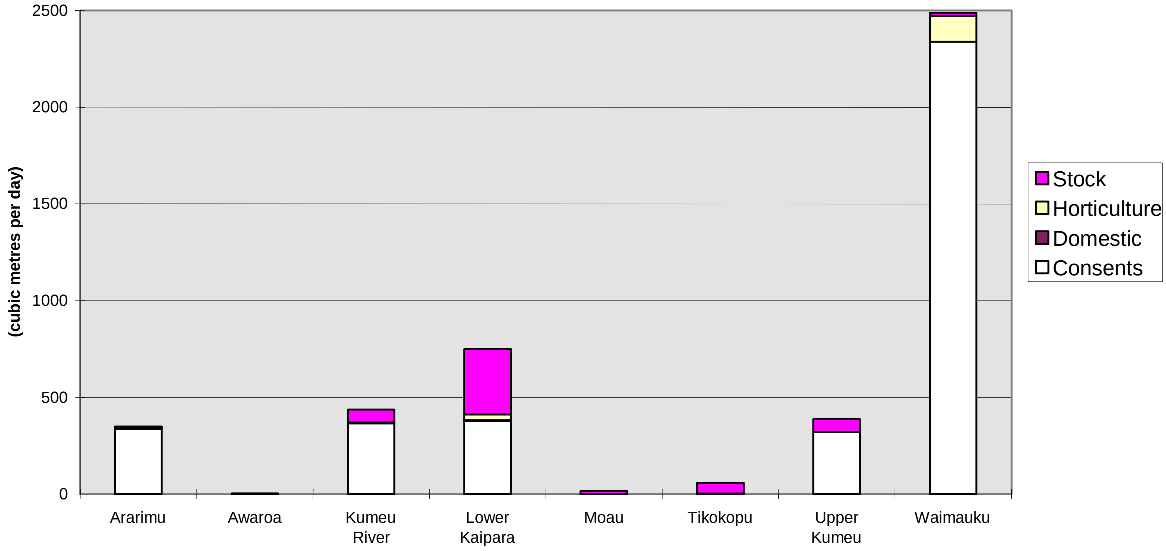
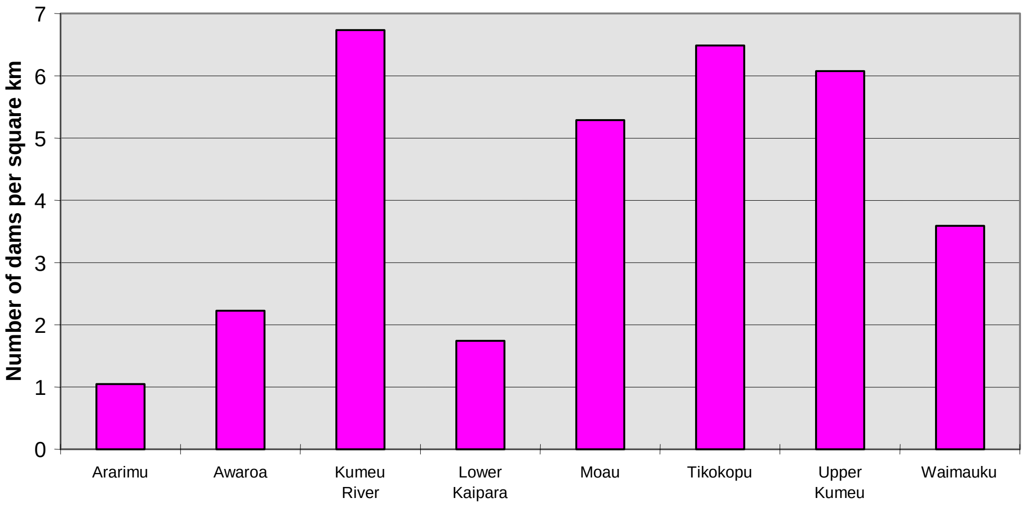


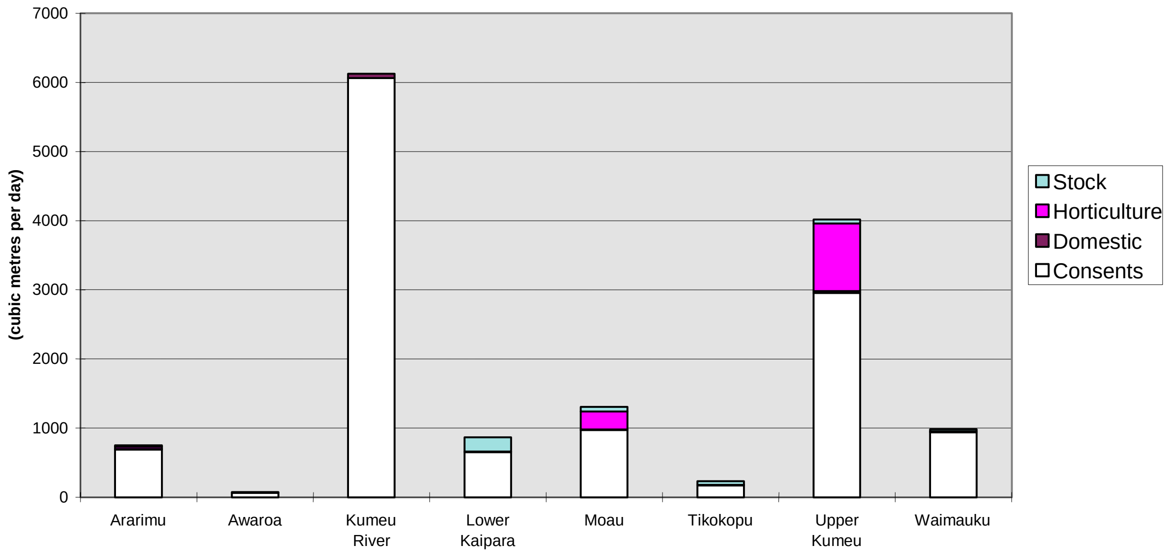
Figure 8.5 - Dam density (estimated from survey returns)



It is interesting to compare the pattern of demand for water from dams with the distribution of dams in the catchment. Figure 8.5 shows the density of dams (number of dams per square kilometre) in each sub-catchment. Despite the fact that demand for water from dams in the Waimauku sub-catchment far exceeds that in any other catchment, four other sub-catchments have a greater density of dams. The higher density of dams in each of the Upper Kumeu, Kumeu, Moau and Tikokopu sub-catchments can be explained by the predominance of lifestyle land use in these areas. Typically, this form of land use is accompanied by the construction of large numbers of small dams for ornamental purposes or to supply small quantities of stock water. Hence the relatively low demand for water from dams in these sub-catchments, despite the high density of dams. The proliferation of small dams associated with the growth of lifestyle land use is of relevance in examining possible future pressures on the resource.

Demand for groundwater is greatest in the Kumeu sub-catchment (see figure 8.6). This not only reflects the concentration of horticulture in this area, but also the fact that demand for water from other sources (streams and dams) is relatively low compared to the neighbouring Waimauku sub-catchment. The higher demand for surface water in Waimauku, and groundwater in Kumeu, reflects the relative availability of surface and groundwater and previous allocation policies.

Figure 8.6 - Estimated Water Demand - Groundwater



The average instantaneous rate of abstraction of surface water (or average combined pump rate) for stock and domestic uses has been estimated for each sub-catchment. These estimates, presented in table 8.4, are equivalent to the total daily demand for stock and domestic uses expressed in litres per second per unit area of land. The presentation of this information in these units allows stock and domestic uses to be taken into account when estimating the surplus water available for allocation to consents.

The possible future trends in land use, identified in section 8.2.3, do not appear to indicate any significant increase or decrease in demand for water from surface water resources. The majority of respondents who indicated a desire to subdivide their properties indicated that they expected rainwater / tank water to meet the needs of new properties resulting from the subdivision.

Respondents proposing to increase the area of glasshouse crops indicated that the additional irrigation demand would largely be taken from rainwater collection or bore water. There was more emphasis on surface water (both streams and dams) as sources for other types of horticultural expansion and for increased stock numbers, although given the very low number of responses on the subject of future water demand, no predictions on the future pattern of water demand have been made on the basis of this data.

Table 8.4 - Estimated abstraction rates for stock and domestic water uses by sub-catchment

		Streams		Dams		Total surface water	
Sub-catchment	Catchment area (km^2)	Demand (m^3/day)	Average abstraction rate (l/sec/km^2)	Demand (m^3/day)	Average abstraction rate (l/sec/km^2)	Demand (m^3/day)	Average abstraction rate (l/sec/km^2)
Ararimu	51.8	34	0.008	8	0.002	42	0.009
Awaroa	10.9	34	0.036	4	0.005	39	0.041
Kumeu River	38.2	73	0.022	72	0.022	145	0.044
Lower Kaipara	48.2	131	0.031	345	0.083	476	0.114
Moau	11.9	63	0.061	15	0.015	78	0.076
Tikokopu	22.3	81	0.042	56	0.029	136	0.071
Upper Kumeu	43.7	121	0.032	66	0.017	187	0.050
Waimauku	38.8	178	0.053	17	0.005	195	0.058

The trend of ongoing subdivision of properties is likely to lead to increased numbers of small dams. As indicated in section 8.2.4, the greatest density of dams appears to correspond with areas where a relatively high proportion of the land is occupied by lifestyle properties. While an increase in the number of small dams in the catchment may not have much influence on the total quantity of water taken, a trend of this sort does have the potential to significantly alter the flow regime of the river and its tributaries.

8.3 Future Influences on Water Availability and Demand

8.3.1 Future Bulk Water Supply

The Future Bulk Water Supply Study (KRTA Limited and Tonkin & Taylor Limited, 1988a) identified, as the preferred option for a new water supply source for Auckland, the construction of an earth dam in the Campbell Rd valley, Riverhead Forest. The proposed scheme envisaged the abstraction of water from the Ararimu Stream at Waikoukou Valley, downstream from the dam. Water would then be pumped to the dam from where a delivery line running east to Albany would meet with the existing water supply network. A subsequent phase of the proposed scheme would involve the abstraction of additional water from the neighbouring Kaukapakapa River for storage in the Campbell Rd dam.

Following a further assessment of potential bulk water supply sources, the Campbell Rd dam scheme was superceded by the proposed Waikato Pipeline (Watercare Services Ltd, 1995). However, in recognition that the projected growth in Auckland's population will necessitate the development of further bulk water source in the future, the 1995 study identified the proposed Campbell Rd dam scheme as the next preferred option for a future water source.

The effects of the development of the proposed dam on the water resources of the Kaipara River catchment would include loss of habitat in the Campbell Rd tributary and an altered flow regime in the Ararimu Stream and Kaipara River downstream of the confluence with the main river. The 1988 study identified the potential for a deterioration in the water quality of the main Kaipara River due to reduced inflows, and hence dilution, from the higher quality waters of the Ararimu Stream.

The scheme, as proposed in 1988, would involve the storage of 27 million cubic metres of water to meet a daily demand of 90,000 m^3. The water availability study for the proposed scheme (KRTA Limited and Tonkin & Taylor Limited, 1988b), determined that of this, up to 55,000 m^3/day could be taken from the Ararimu Stream. (Lower yields of 80,000 m^3/day total and 44,000 m^3/day from the Ararimu were presented in the subsequent Watercare review). Abstractions would be confined to periods of higher flows with a residual flow of 90 l/sec at the Ararimu intake site proposed in order to ensure adequate dilution of discharges into the main river.

8.3.2 Auckland Regional Growth Strategy and Structure Plans

The Auckland Regional Growth Strategy recommends that, of the projected growth in the population of the Auckland region over the next 50 years, up to 130,000 additional people should be accommodated in rural areas (Auckland Regional Growth Forum, 1999). The strategy envisages that much of this growth, of the order of 55,000 people, will occur in six rural towns including Kumeu and Helensville.

In order to service this additional population, the strategy identifies major infrastructural improvements, including:

- satellite water treatment plants to serve the western metropolitan area and Kumeu-Huapai;
- a new water supply for Helensville; and
- a new sewage treatment plant for Helensville.

These projected population increases and associated infrastructure needs are clearly of consequence for the water resources of the Kaipara catchment.

Rodney District Council (1998a and 1998b) has prepared draft structure plans for Helensville and Kumeu-Huapai-Waimauku which give a more detailed indication of the way in which the potential growth identified in the Growth Strategy can be accommodated. Of particular importance are:

In the Helensville Plan:

- a change in the pattern of land use on the outskirts of the town from extensive to intensive forms of agriculture; and
- the projection that existing water sources will serve municipal supply for the next ten years, with the need to investigate alternative water supplies to cater for anticipated growth beyond this period.

In the Kumeu-Huapai-Waimauku plan;

- the identification of abstractions from the Kumeu River or from a dam in Riverhead Forest as options for future water supply; and

- the introduction of reticulated and sewage treatment and disposal systems.

Subsequently, Rodney District Council have reviewed their water supply strategy (Rodney District Council, 1999). This review has confirmed the need to investigate alternative sources for the future water supply of Helensville. However, the review indicates that bulk water supply from Watercare is the preferred option for supply to the Kumeu-Huapai area, rather than abstractions from the Kumeu River.

Urbanisation not only has the potential to effect demand for water, but also water availability. Typically urbanisation is accompanied by an increase in impervious area. This results in a greater proportion or rainfall contributing to surface runoff and less to groundwater recharge. During dry summer conditions streamflows are generally maintained by groundwater fed baseflows. A reduction in groundwater recharge can therefore result in reduced low flows.

As indicated in section 4.2, the main groundwater recharge areas in the catchment are located in areas of elevated land, away from Kumeu-Huapai and Helensville. As a consequence, urban growth around these existing settlements would not be expected to significantly effect recharge or baseflows at the catchment scale.

However, urbanisation can alter other aspects of the flow regime which are of less importance for water availability, for instance causing an increase in the magnitude and rate of rise of peak flows. Given the flood prone nature of the Kumeu and Kaipara Rivers, control of increased stormwater runoff is likely to be the main flow related issue which urbanisation in the catchment will face.

8.3.3 Project West

Watercare Services Ltd is currently investigating options for the treatment, disposal and reuse of wastewater from urban areas of Waitakere City and adjacent rural towns in southern Rodney District. The options, summarised in an initial public consultation document (Project West, 1997) include:

- disposal of treated wastewater in Woodhill Forest;

- recycling wastewater during the irrigation season; and

- discharging high quality treated effluent to the Kaipara River from offstream storage ponds

The latter two options in particular could influence the availability of surface water resources in the Kaipara River catchment. Reuse of wastewater could reduce demand for freshwater in some parts of the catchment, although this would depend on the water quality requirements of different uses. For instance, market garden crops irrigated with wastewater might not be acceptable to overseas markets.

Treated effluent discharges could augment river low flows whilst simultaneously affecting water quality. Such changes could be beneficial to downstream water users, providing any water quality changes are an improvement on that occurring during existing periods of low flow.

8.3.4 Bush regeneration and Forestry

The results of the land and water use survey indicate that native bush regeneration may be an important way in which private land is developed in the future. This is a continuation of an existing trend. Forestry will also continue to be a significant land use, particularly in the Ararimu Stream and Lower Kaipara sub-catchments where phases of afforestation and harvesting of Riverhead and Woodhill Forests will continue.

Research in New Zealand has demonstrated the effects of afforestation and harvesting on low flows (Rowe et al, 1997). As bush or forest cover becomes established in catchments that were previously under pasture, the increased rates of rainfall interception and evapotranspiration result in reductions in infiltration and groundwater recharge. As a consequence of the reduction in recharge, baseflows also fall. When forested areas are harvested, the reverse happens.

9 Summary

9.1 Key Resource Characteristics and Values

Chapters 4 to 6 of the Resource Statement describe the physical characteristics of the Kaipara River catchment, cultural and natural heritage, and hydrology and quality of the surface water resource. Of the characteristics described, the following are of most importance in guiding water resource management in the catchment:

- The hydrology of the Kaipara River catchment is described as ‘flashy,’ with stream flows rising and falling relatively quickly following rainfall. Summer low flows, or baseflows, vary with the geology of the catchment. Specific discharges (flow per unit of catchment area) are lowest in the south and east of the catchment where relatively low permeability Waitemata Group rocks predominate. Higher specific discharges occur from the dune sand deposits along the western edge of the catchment.

- In general, the water quality of streams in the Kaipara River catchment is typical of a mixed land use catchment. Most streams in the catchment are subject to contamination from rural discharges, whilst the Kumeu River and Lower Kaipara River are also subject to the discharge of urban contaminants. In these parts of the catchment dissolved oxygen levels are likely to be depressed during summer low flow conditions. Water quality and instream habitat is generally better in the Ararimu Stream. Other parts of the catchment in which a relatively significant proportion of the land and riparian margins is forested are also likely to have better water quality. These include the Wharauroa Stream catchment and headwaters of the Kumeu River.

- There are a number of significant wetlands in the catchment which provide habitat and some flood storage, and which may influence stream water quality. These include wetlands at Fordyce Rd, Bradley Rd and the upper Ararimu valley.

Chapters 7 and 8 describe the key values of the resource, firstly in terms of instream ecological, cultural and amenity values, and secondly in terms of demand for consumptive use of the water. Of the values described, the following are of most importance in guiding water resource management in the catchment:

- There are variations in the distribution of native fish and other aquatic biota. Abundance and diversity of species is greater in the Ararimu Stream and headwaters of the Kumeu River than elsewhere in the catchment.

- Maori occupation of the catchment extends back over at least seven centuries. Cultural associations with the water bodies of the catchment, as evidenced by place and stream names and the results of archaeological investigations, are strong.

- Demand for abstractive uses of stream water is greatest in the Lower Kaipara, Upper Kumeu and Waimauku sub-catchments.

- Demand for abstractive uses of water stored in dams is greatest in the Waimauku and Lower Kaipara sub-catchments, although the Kumeu, Upper Kumeu, Tikokopu and Moau sub-catchments have a higher density of dams.

9.2 Knowledge Gaps

The collation of information in this resource statement has not only allowed the identification of key resource characteristics and values guiding water management in the catchment, but also areas in which the current level of information or understanding is poor. An important component of the development of the water allocation strategy for the catchment is to document these knowledge gaps and to determine where to focus further monitoring, investigations and analysis.

There have been various programmes of water quality monitoring in the catchment (described in section 6.2) which have been valuable in identifying spatial variations in water quality, for instance that the Ararimu Stream is generally less compromised by contaminants than the Kumeu and Lower Kaipara Rivers. However, monitoring to date has not given a clear picture of the temporal variation in water quality, and in particular of the relationship between low flows and water quality during mid summer conditions.

Similarly, surveys of aquatic biota (section 7.2) have illustrated variations in the spatial distribution of native fish, but have not identified the ways in which the presence or behaviour of individual species of fish and macroinvertebrates is affected during periods of low flow. Furthermore, there is little information on any linkages between the distribution of aquatic fauna and the presence of physical barriers such as dams.

Another key factor influencing the functioning of aquatic ecosystems is the availability of viable habitat, this reflecting both instream and out of bank conditions. Whilst the vegetation types present in key areas of remnant native bush and wetland have been documented (section 5.2) the quality of instream and riparian environments throughout the majority of the catchment remains to be described. Further to documenting these environments, it is also important to establish the ways in which their ecological functioning relates to instream flow regimes.

Whilst it is the relationship between flow, water quality and ecology that requires most work, a further area in which the current level of knowledge is poor is in the cumulative effect of multiple dams on stream flows. The ARC has commenced a project to quantify how stream flow may be affected, both by a number of onstream dams in series, or by the intensification of small offstream dams in areas of springflow or at the head of streams.

In summary, the key areas in which further monitoring, information gathering and analysis are required to facilitate the development of the water allocation strategy are:

- the spatial and temporal distribution of fish and macroinvertebrates and the relationship between these and:
  - low flows,
  - water quality, especially dissolved oxygen and temperature during summer,
  - instream habitat availability, reflecting both physical channel characteristics and flows,
  - the spatial variability of riparian environments, and
  - the location physical barriers, notably dams;

- the relationship between flow regimes, water levels and ecological functioning of significant wetlands in the catchment;

- the cumulative effects of multiple dams on stream flow regimes.

A program of work which aims to address these knowledge gaps is described in chapter 12 of this report.

It is worth noting that these are all areas of knowledge that require improved understanding not just within the Kaipara River catchment, but at the Regional scale. It may therefore be appropriate to undertake further investigations in the catchment as part of Region wide studies, where such opportunities arise.