Heretaunga Plains

GROUNDWATER STUDY

May 1997

Executive Summary

Hawke's Bay Regional Council

Safeguarding Your Environment

Institute of Geological & Nuclear Sciences Limited

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Frontispiece: Hawke's Bay coast south from Napier to Cape Kidnappers with Scinde Island tied to the mainland and Heretaunga Plains extending south to Havelock Hills and to the west. *(photo: Lloyd Homer, IGNS CN 17339)*

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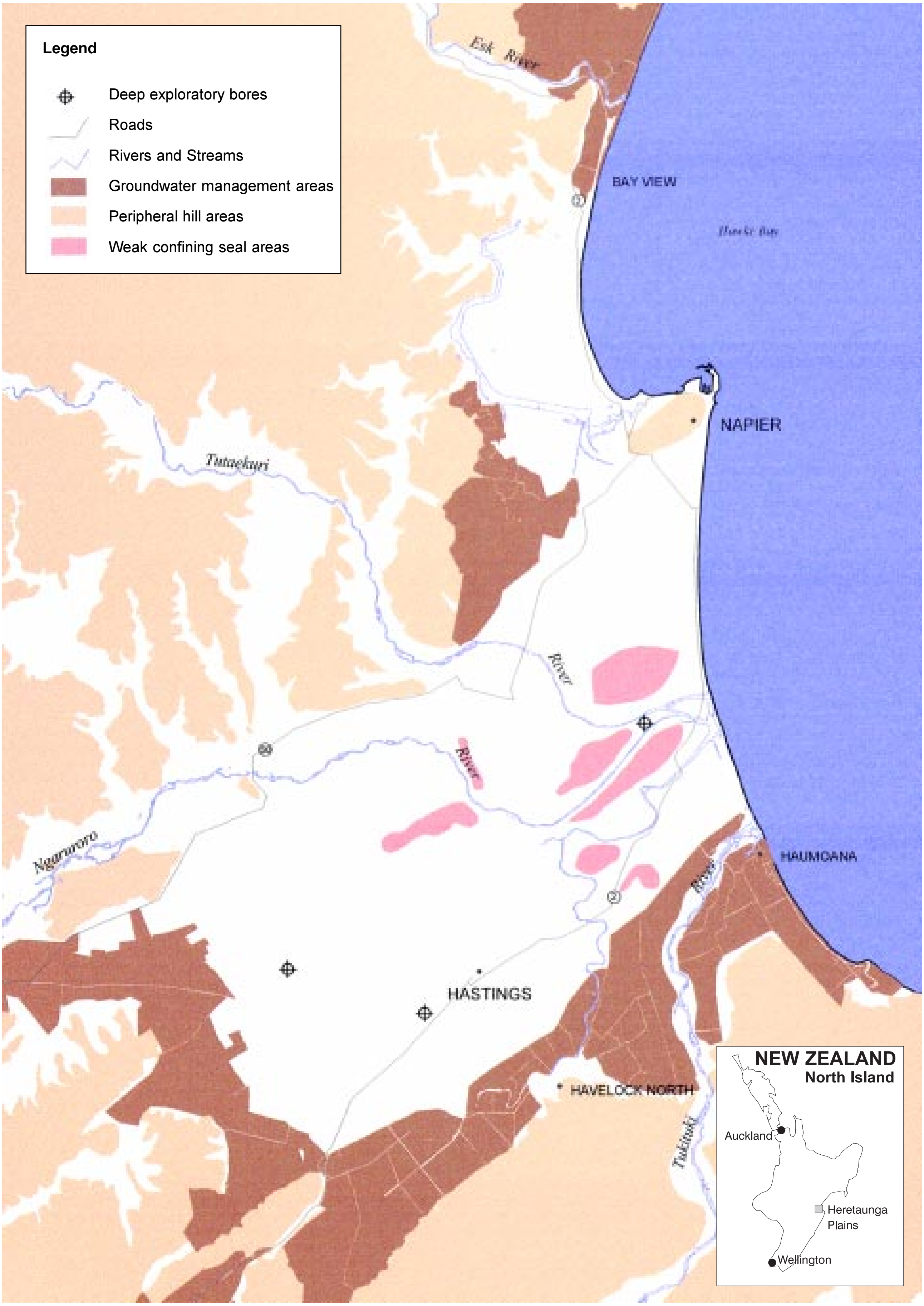


Figure 1: Locality map of the Heretaunga Plains.

CHAPTER 1

INTRODUCTION

The Heretaunga Plains comprise an area of 300 km^2 on the east coast of the North Island of New Zealand (Fig. 1), incorporating the urban areas of Hastings, Havelock North and Napier. The Plains were formed during the last 250 000 years by river sediments deposited by the Tutaekuri, Ngaruroro and Tukituki rivers and coastal lagoon, estuarine and embayment deposits. The Heretaunga Plains are underlain by sequences of fluvial gravel, sand and silt, interbedded with marine gravel, sand and silt channels. There is a general layered structure with coarse permeable gravel beds alternating with fine impermeable beds. The permeable gravel beds form aquifers which in plan reflect their formation as meandering river channels.

The groundwater underlying the Heretaunga Plains is a major natural resource which provides about 85% of the Heretaunga Plains and adjacent areas water requirements. Approximately 63 million cubic metres of groundwater was withdrawn during the year July 1994-June 1995 period for public water supply, irrigation and industrial uses. Figure 2 indicates the water used in three principal sectors.

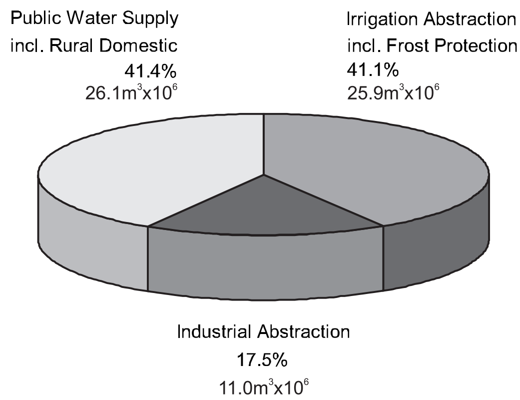


Figure 2: Heretaunga Plains groundwater use during July 1994-June 95

Demand for irrigation from groundwater has expanded considerably in the last twenty years. The combination of temperate climate, fertile soil and groundwater for irrigation, enables the production of about 50% of the total New Zealand harvest of fruit, vegetables and grapes on the Heretaunga Plains. During dry periods, agricultural and horticultural production is heavily reliant on irrigation from groundwater supplies. Currently there are 2500 resource consents for groundwater abstraction on the Heretaunga Plains, of which 2420 are for irrigation.

Since the discovery of artesian groundwater in the Heretaunga Plains in 1867 numerous groundwater investigations have been undertaken to determine how the aquifers were formed, the sources and flow of water in the aquifers and, in particular, susceptibility to contamination. While these investigations extended groundwater knowledge considerably, it was not until 1991 that a co-ordinated and systematic regional investigation began. The impetus for this renewed research and investigation was provided by a significant, new legislation. The Water and Soil Conservation Act (1967) was replaced by the Resource Management Act (RMA) in 1991. The new legislation required a far wider perspective of environmental management, with a specific focus on the *effects* of activities.

STATUTORY CONTEXT

The RMA has as a core requirement, the promotion of sustainable management of physical and natural resources. The RMA places specific emphasis on:

- sustaining the potential of natural and physical resources;
- safeguarding the life-supporting capacity of air, soil, water and ecosystems;
- avoiding, remedying or mitigating any adverse effects of activities on the environment.

The Hawke's Bay Regional Council (HBRC) has identified objectives and priorities for achieving sustainable resource management in the Hawke's Bay Region in the Regional Policy Statement (RPS), which provides direction for a comprehensive Regional Water Resources Plan (RWRP). The Heretaunga Plains groundwater study will provide additional technical input to future reviews of the RWRP.

CHAPTER 2

APPROACH

HERETAUNGA PLAINS GROUNDWATER STUDY

Regional groundwater studies are time consuming and expensive. A multidisciplinary team acquires, collates and assesses hydrogeological information. Effective regional groundwater management planning requires a variety of data and consideration of many issues including public consultation process.

In 1991 the HBRC approached the Institute of Geological and Nuclear Sciences (IGNS), a Crown Research Institute (CRI), as a possible partner in a long-term joint Heretaunga Plains groundwater study programme. Following the agreement with the IGNS for a 5 year (1991/96) joint study, a work programme was formulated to investigate the Heretaunga Plains groundwater resources. The results of these investigations were to be used to identify strategies to enable sustainable management of the Heretaunga Plains groundwater resource.

This plan of work systematically addressed the groundwater study objectives by identifying and carrying out the research and investigations necessary to fill the “gaps in knowledge”. As the joint study proceeded new groundwater management issues were identified and the study objectives were accordingly adjusted.

In 1992 it was decided that land and water use were also an essential component of the groundwater investigation and expertise in these areas was gained by involving the CRI - Landcare Research NZ (Landcare). In 1993, a pesticide leaching study was also initiated by Landcare and Environmental Science and Research (ESR) with the HBRC.

These investigations were funded by the HBRC with specialised research input by CRI's under the public good science fund administrated by the Foundation for Research, Science and Technology.

STUDY OBJECTIVES

The objectives of the Heretaunga Plains groundwater study were:

- to review and collate the existing groundwater information and identify the gaps in knowledge;
- to develop a comprehensive long-term (5 year) regional groundwater investigation strategy and undertake necessary investigations;
- to assess the current state of the environment from the existing water quality data and make appropriate recommendations for future monitoring;
- to provide technical input to facilitate policy development and implementation to enable sustainable development;
- to collate the findings in a study report to HBRC by February 1996.

REPORT STRUCTURE

The Heretaunga Plains groundwater study report is presented in the following format:

- an executive summary (this report), including recommendations;
- volume 1, providing a description of the hydrogeology and geochemistry; identifying groundwater management issues and making specific recommendations;
- volume 2, appending major reports that contributed to the study.

Figure 3 is a schematic representation of the contents of each volume and shows the relationship between different parts of the study report.

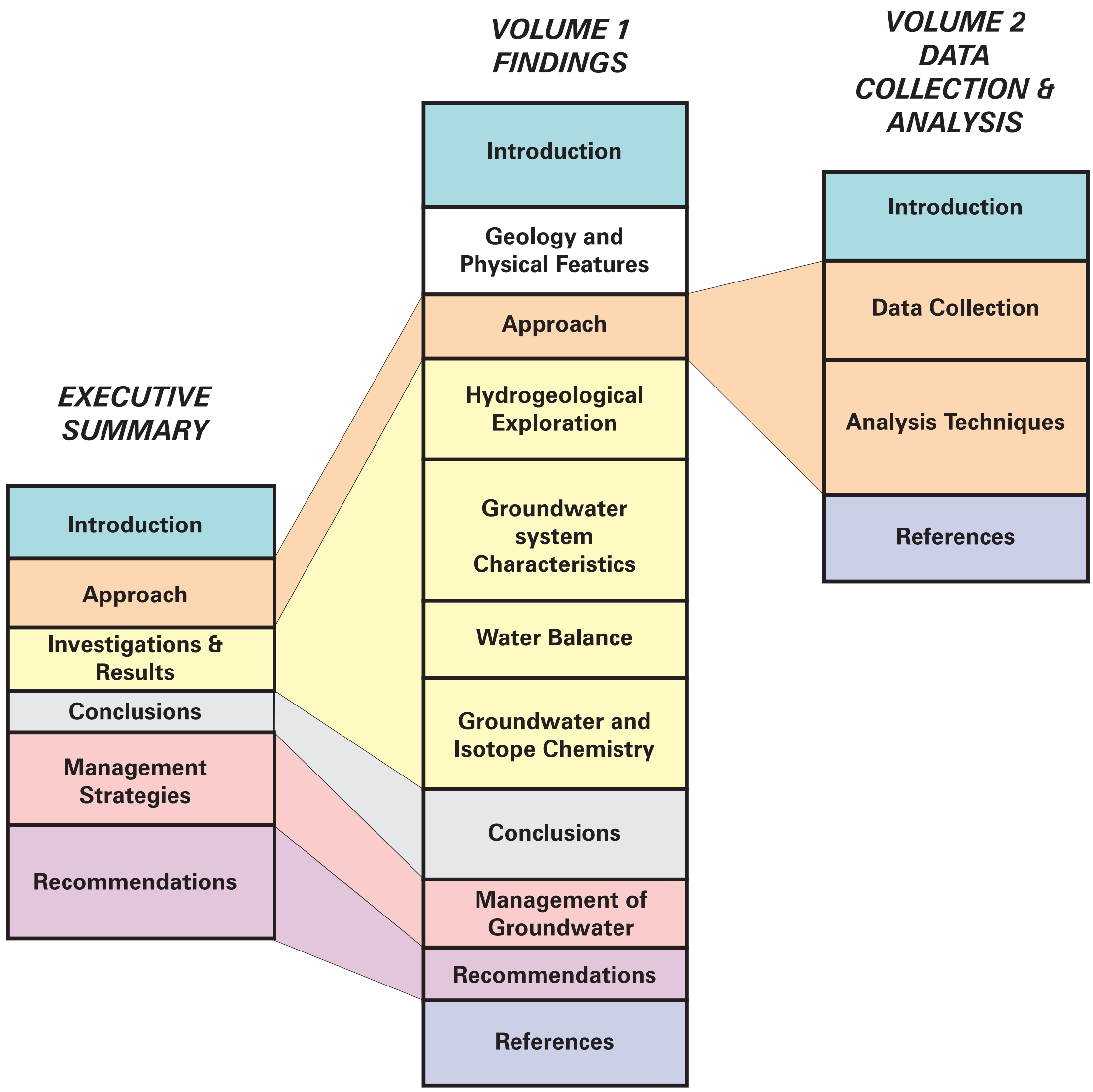


Figure 3: Structure of the Heretaunga Plains Groundwater Study.

CHAPTER 3

INVESTIGATIONS AND RESULTS

Review and collate the existing groundwater information and identify the gaps in knowledge.

Significant "gaps in knowledge" identified were:

- the geological history of deposition and the depth of the aquifer sequence beneath the Heretaunga Plains;
- the groundwater flow direction and flow rates;
- the spatial and time aspects of groundwater chemistry and influence of landuse activities and aquifer lithologies;
- total groundwater recharge, abstractions and outflow;
- the vulnerability to pollution and the continuity of groundwater availability of the aquifers at the fringe of the Heretaunga Plains aquifer system.

GEOLOGICAL HISTORY OF DEPOSITION AND THE DEPTH OF THE AQUIFER SYSTEM.

Three deep exploratory bores were drilled to provide information on the geological history and the depth of the aquifer sequence beneath the Heretaunga Plains.

The drilling, and strata and groundwater sampling and analyses, established that a 250,000 years glacial / interglacial strata sequence was present to a depth of 250 m with interbedded and interconnected gravel aquifers. Deposition had occurred in a depression subsiding at a rate of 1 m per 1000 years.

Figure 4 illustrates a generalised cross section through the three deep exploratory bores and offshore Hawke Bay. The Flaxmere testbore located in the unconfined aquifer area encountered water bearing (saturated) gravels to the final depth of 137 m. The Tollemache Orchard bore located in about the middle of the Heretaunga depression was explored to a final depth of 256 m. Five flowing artesian and one subartesian aquifers were encountered. The coastal Awatoto testbore penetrated six flowing artesian aquifers. The piezometric pressures in Tollemache Orchard testbore show gradual decrease with depth whereas the piezometric pressures increase with depth at the Awatoto testbore. Because of the shallow depositional gradient of the aquifers, only the upper gravel aquifers are likely to outcrop on the sea floor and discharge fresh water into the ocean in Hawke Bay.

The decreasing piezometric pressures observed at the Tollemache Orchard testbore and other deeper bores in the inland Plains, support the concept of a hydraulically interconnected system with a common groundwater recharge source area. Increasing piezometric pressures with depth in the aquifers near the coast suggest a closed or partly closed deeper aquifer system with flow in deeper aquifers maintained by upward leakage through aquitards and aquicludes.

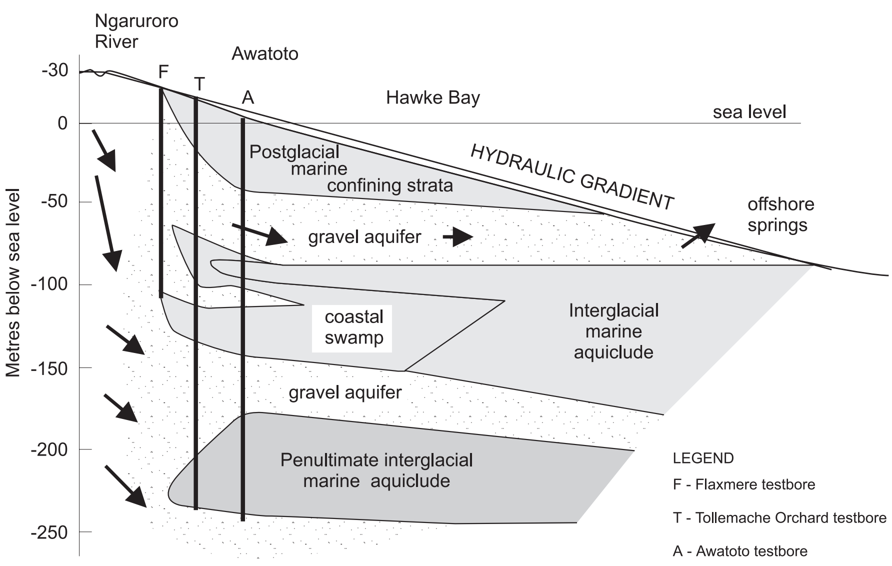


Figure 4: Generalised cross section showing exploratory bores and off-shore Hawke's Bay.

Isotope and chemical analyses of groundwater to 250 m depth suggests a Ngaruroro River recharge.

GROUNDWATER FLOW DIRECTION AND FLOW RATES

A piezometric survey of water levels in 450 wells on and adjacent to the Heretaunga Plains was undertaken on the weekend of 18-19 February 1995. At the time Hawke's Bay was experiencing a drought so the survey provided an excellent opportunity to observe the response of the aquifers to dry conditions. The piezometric contours, gradual decrease in the aquifer pressures with depth, isotope and chemical analyses and river gauging data suggests recharge from the Ngaruroro River between Maraekakaho and Roys Hill. Low flow river gaugings confirm a loss of about 432,000 m^3/day in this reach (Fig. 1). The river water enters the unconfined aquifer through southeasterly trending former river channels that cross and underlie the Plains between the current river course and Flaxmere. The piezometric contours (Fig. 5) show the Ngaruroro River as the major source with groundwater flow eastwards towards Flaxmere and Hastings, then northeastwards toward Taradale and Napier. Isotopic (tritium and oxygen 18) and chemical analyses of groundwater from 32 wells confirm the Ngaruroro River as the recharge source and show that the rate

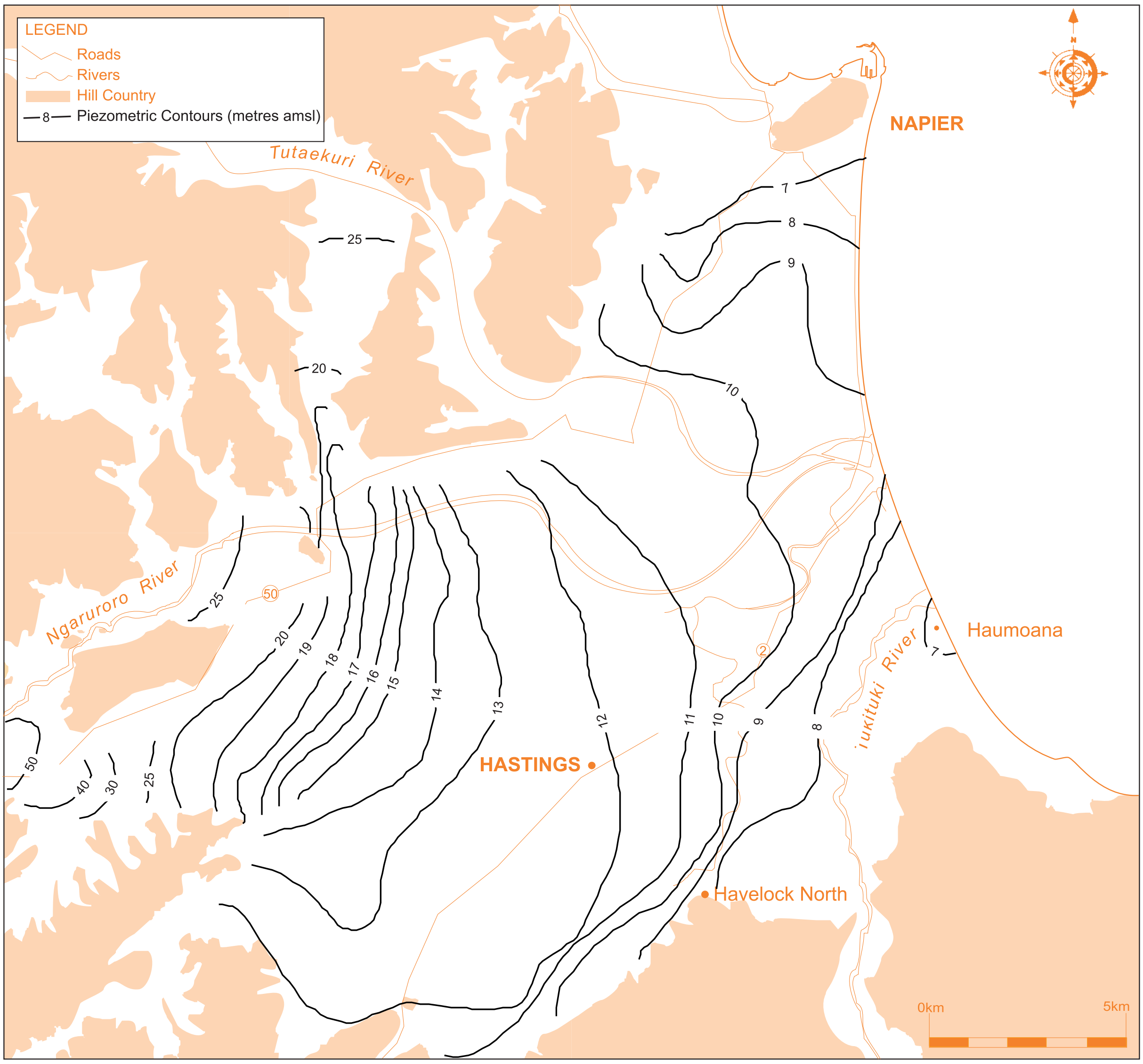


Figure 5: Heretaunga Plains piezometric contour map (18-19 February 1995).

of groundwater flow decreases from unconfined to confined aquifers and also decreases with increasing depth of aquifer.

GROUNDWATER CHEMISTRY

More than 70 wells were sampled over the period March - May 1995 for comprehensive water quality analyses. Results indicated that:

- the quality of groundwater throughout the main confined and unconfined aquifer system (<80 m depth) is high and tends to reflect the quality of the Ngaruroro River as the major recharge and the high flow rate source;
- the quality of water in the deeper (>100 m depth) aquifers of the main system is relatively impaired, with elevated concentration of iron and manganese; it is also considerably harder;
- on the western margin of the Heretaunga Plains (Ngatarawa-Bridge Pa area), the groundwater quality is impaired with relatively elevated nitrate concentrations and hardness;
- in general, the quality of groundwater around the entire fringe of the Heretaunga Plains is inferior to the rest of the aquifer system due to groundwater contribution from the peripheral limestone hills, with mineral enrichment and elevated hardness.

Parts of the Heretaunga Plains unconfined aquifer area are not fully serviced by a public sewage disposal system and the use of septic tanks is common, which has the potential to contaminate groundwater. Irrigation for horticulture requires extensive use of fertilisers and agrichemicals that can degrade both soil and water quality.

GROUNDWATER BALANCE

Groundwater balance (Fig.6) in a complex groundwater system such as the Heretaunga Plains is difficult to quantify accurately due to diverse recharge sources and many abstractions and outflows. Monitoring of groundwater is required to determine the safe yield of the aquifer system. A safe yield is the amount of groundwater that can be withdrawn from an aquifer on a sustained basis, without impairing groundwater quality and quantity, or producing undesirable environmental effects.

For the Heretaunga Plains aquifers it has been possible to estimate abstractions and outflows by considering:

- the outflow of groundwater sourced springs;
- the quantities of groundwater pumped for drainage and dewatering;
- the irrigation, industrial and public water supply groundwater usage.

There is a considerable quantity of groundwater stored in the Heretaunga Plains main aquifer system. Based on the exploratory well drilling and pump test data, the total quantity of groundwater in the Heretaunga Plains main aquifer system is estimated to be about 1050 million cubic metres. This volume is about 18% of the volume of water stored in Lake Waikaremoana (5836 million cubic metres). The total volume of groundwater abstracted from the Heretaunga Plains during July 1994-June 1995 period (66 million cubic metres) is about 6.3% of the total groundwater storage.

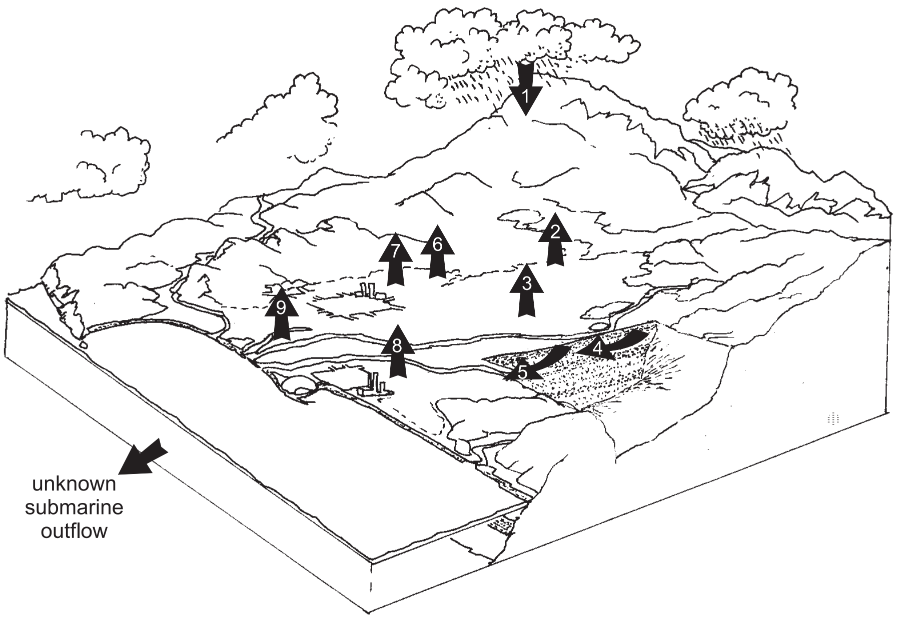
On the margin of the Heretaunga Plains the quantity of readily available groundwater is limited by a combination of a relatively shallow groundwater basement depth (c.40 m) and the less permeable nature of the formation. There is also a limited quantity of groundwater available within the peripheral limestone of the western hills adjacent to the Plains. The quantity of groundwater appears adequate for domestic and stock water supply but cannot support irrigation.

CONTAMINATION VULNERABILITY

The objective of this study was to determine the processes involved in the leaching of pesticides to groundwater (Fig. 7) by monitoring the vertical trans-

INPUT (m^3/year x 1000000)		OUTPUT (m^3/year x 1000000)	
SOURCE	INPUT	SOURCE	INPUT
Ngaruroro River	157.7	Public Water Supply	24.1
Tutaekuri River	25.2	Rural Domestic	2
Rainfall	5	Industries	11
		Irrigation	23.9
		Frost Protection	2
		Drainage Dewatering	3
		Total Pumped	***66.00***
		Spring Leakage	119.8
		Submarine Outflow	unknown
		Total natural	***119.8***
TOTAL	**187.9**	**TOTAL**	**185.8**

Table 1: Heretaunga Plains quifer input / output estimates during July '94 - June '95 period.



LEGEND

1. Rainfall recharge 5 Mm^3 ***2.*** Rural domestic 2 Mm^3 ***3.*** Leakages 123Mm^3 ***4.*** Ngaruroro River recharge 157Mm^3

5. Tutaekuri River recharge 25Mm^3 ***6.*** Irrigation abstraction 11Mm^3 ***7.*** Frost protection abstraction 2Mm^3 ***8.*** Industrial abstraction 11Mm^3

9. Drainage dewatering 3Mm^3

1 Recharge (Input) 2 Abstraction (Output)

Figure 6: Heretaunga Plains July 1994 - June 1995 groundwater balance. *(drawing: Bruce Chuchhouse, HBRC).*

port and attenuation of two pesticides and three tracer compounds through the soil profile and unsaturated zone at two sites (Twyford and Ngatarawa) in the Heretaunga Plains.

As at June 1995, the pesticides have reached a 2.5m depth at the Ngatarawa site. This leaching was probably affected by preferential flow through superficial cracks. At the Twyford site chemical pesticide penetration in the soil has reached 1.3 m depth 500 to 600 days after application and continues to increase. This indicates that pesticide movement is more rapid at the Ngatarawa site in the unconfined aquifer area than at the Twyford site and highlights the potential vulnerability of the unconfined aquifer to pesticide contamination.

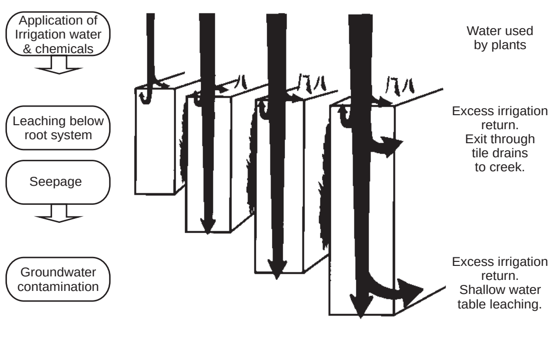


Figure 7: Modern intensive agricultural and horticultural activities discharge contaminants into the soils through interaction of water.

LANDUSE AND WATER USE

The first comprehensive landuse survey on the Heretaunga Plains was undertaken during 1994/95. The landuse data was grouped into six crop types:

- pip fruit (including apples, pears and citrus),
- kiwifruit,
- cropping (tomatoes, squash and market garden),
- stone fruit,
- nursery (including young horticultural trees, hardwood plantations and flowers);
- viticulture.

Figure 8 shows the Heretaunga Plains landuse during 1994/95

In addition, during 1994/95, a study was undertaken to estimate the Heretaunga Plains irrigation water use by correlating irrigation pump power consumption with pump flow rates. To account for soil variability, the Heretaunga Plains area was divided into 8 broad units based on characteristic soil types. The field data collection comprised pump power consumption and flow data from 50 representative paddocks. The Heretaunga Plains landuse-water use study indicated that during the 1994/95 irrigation season:

- irrigation water use was about 23.9 million m^3;
- the actual quantity of irrigation water used during the 1994/95 season was well below the allocated volume for most crop types;
- exceptions were stone fruit and nurseries, where near allocated volumes were used.

Over the last decade, irrigation has become an increasingly important component of the Heretaunga Plains horticulture and agriculture. Ninety two percent of total water use consents in the Heretaunga Plains are for irrigation purposes and about 85% of the total allocated quantity of groundwater on the Plains is used for irrigation. The Hawke's Bay irrigation water allocations are currently made on the basis of 65 mm/ha/fortnight or 650 cubic metres/ha/fortnight. Extrapolating the volume of 650 cubic metres/ha/fortnight over 10,000 ha (one third of the Heretaunga Plains area) during a 4 month summer period, the total volume of irrigation water allocated is 56.8 million cubic metres. This volume is more than double the estimated irrigation water use during July 1994-June 1995 period (23.9 million cubic metres).

Groundwater allocation based on perceived non-specific crop water requirements is a wasteful use of soil and water resources and has the potential to create adverse effects. Efficient use of water and soil are essential requirements for the sustainable management of natural resources. Excess irrigation water applied to any agricultural land is potentially detrimental to:

- soil productivity (leaching of soil nutrients, development of macropores),
- crop productivity (over watering of soil),
- downstream receiving environment (leaching of nutrients and agrichemicals into aquifers, streams and drains).

Typical summer yield pattern based on a series of flow measurements undertaken along the Karamu Stream suggest seepage in the order of 0.5-0.7 cubic metres/second into the stream from the adjacent Plains areas. This seepage during the dry period has come from the western part of the Plains as excess irrigation waters (drainage). Nutrient enrichment and the associated weed growth in recent years within the Heretaunga Plains streams and drains suggest nutrient and fertiliser leaching through the soil by way of excess irrigation.

This suggests that not only is groundwater allocated in excess of use, but actual use may be excessive to irrigation requirements and may be affecting surface waters.

A crop-soil specific irrigation water allocation method is currently under investigation (Watt et al.).

AQUIFERS ON THE MARGINS OF THE HERETAUNGA PLAINS

On the margins of the Heretaunga Plains, groundwater availability is limited by the relatively shallow depth of the aquifer system (c. 40m) and the less permeable nature of the aquifer material.

As a consequence:

- well water levels fluctuate over a wider range, 4-10 m in the margin compared to 2-3 m in the central part of the Heretaunga Plains;
- saltwater intrusion can occur at the coast margin (e.g. Te Awanga);
- groundwater chemistry may change and/or deteriorate as groundwater of inferior quality from peripheral limestone aquifers is drawn into the main aquifer.

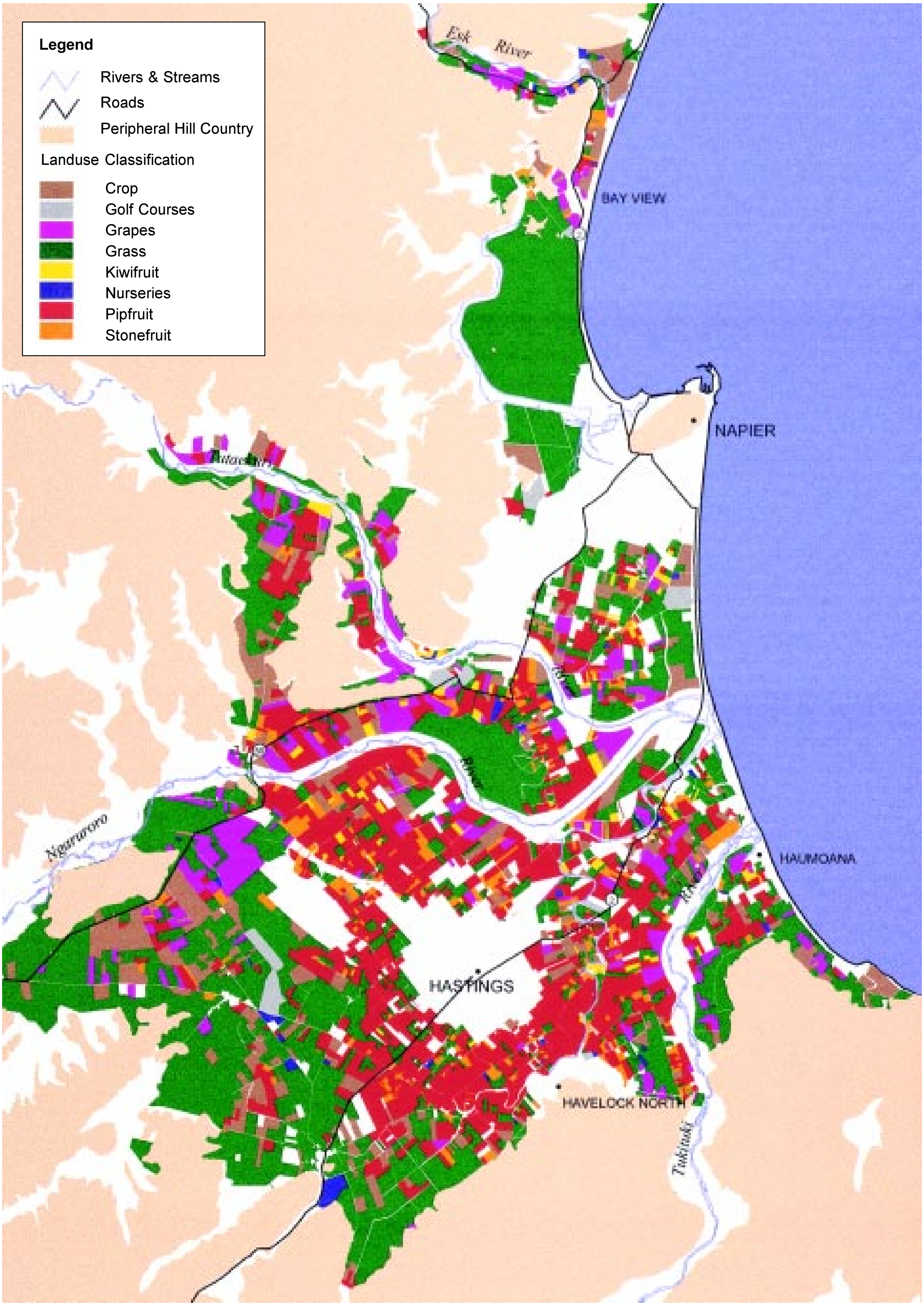


Figure 8: Heretaunga Plains landuse during period 1994 - 1995

CHAPTER 4

CONCLUSIONS

THE GROUNDWATER RESOURCE

CONCLUSION 1

The Heretaunga Plains groundwater is vital to the economy of the Hawke's Bay Region and New Zealand.

It is estimated that groundwater provides about 85% of all the water used for domestic, agricultural and industrial water requirements for the 143,000 people living on and adjacent to the Heretaunga Plains.

Horticultural and farming activities are seasonally dependent on the groundwater supplies.

Approximately 75% of the Heretaunga Plains area supports the production of various crops, fruits and vegetables, constituting about 50% of the total New Zealand harvest.

CONCLUSION 2

Groundwater management planning is required to balance increasing groundwater abstractions with supply to prevent exceedance of the safe yield at the Heretaunga Plains marginal aquifer system.

While the demand for groundwater has increased steadily over the past twenty years, irrigation water use for intensive horticulture has increased several fold. Lowered groundwater levels on the margin of the Plains indicates that the resource is seasonally and locally under stress. Uncontrolled increase of abstraction can create the potential for localised contamination and well interference especially on the margin of the Plains.

CONCLUSION 3

Climate is the dominant influence on the Heretaunga Plains groundwater levels.

The normal seasonal trend in groundwater levels in the Heretaunga Plains is a summer decline followed by a winter recovery. Generally summer static water levels are 2-3 m lower than the winter levels. Groundwater requirements are highest during the summer period (reflecting increased groundwater usage during this period). Increased demand coincides with low summer river flows when recharge to the aquifer system may be at a minimum.

CONCLUSION 4

Changing landuse practices significantly affect groundwater levels and has the potential to alter groundwater quality.

Urban, horticultural and industrial development involves the increased use of, and discharge to, the groundwater aquifers. This creates the potential to affect both the quantity and quality of groundwater:

Landuse policy and planning should consider the impact of developments on groundwater quantity and quality.

GROUNDWATER FLOW AND SOURCES OF RECHARGE

CONCLUSION 5

There is a main aquifer system underlying most of the Heretaunga Plains, which is recharged by the Ngaruroro River, while the Tutaekuri and Tukituki rivers recharge localised and relatively shallow aquifer systems in the northern and eastern margins of the Plains.

CONCLUSION 6

Deep exploratory well drilling suggests a hydraulically interconnected multilayered leaky main aquifer system extending to at least 250 m depth.

At least five flowing artesian aquifers and one subartesian aquifer have been explored within a depth of 250 m.

WATER QUANTITY

CONCLUSION 7

Groundwater quantity is not a limiting factor for the main aquifer system except for the areas on the margins of the Heretaunga Plains.

GROUNDWATER QUALITY

CONCLUSION 8
The quality of water of the Heretaunga Plains main aquifer is generally very high. The quality of water on the margin of the Plains may be affected due to increased hardness and elevated nitrate concentrations.

IRRIGATION WATER ALLOCATION

CONCLUSION 9
Current groundwater allocation is in excess of actual use and actual use may be greater than actually required.

The current method of allocations of surface and groundwater for irrigation, based on bulk assumed non-specific crop water, requires refinement to include soil variability and crop factors.

RESOURCE PROTECTION

CONCLUSION 10
The unconfined aquifer area of the Heretaunga Plains requires strict protection.

Parts of the Heretaunga Plains unconfined aquifer area lack a soil capping layer and has a shallow water table. The potential for pollution through leaching of contaminants into the permeable, unconfined aquifer is very high.

CONCLUSION 11
The *weak seal areas* of the Heretaunga Plains require protection.

The weak seal areas refer to the area between the Ngaruroro and Tutaekuri river channels downstream of State Highway 50 where the strata overlying the main confined aquifer contain a perched sandy pumice aquifer. This shallow aquifer also contains water under pressure and provides a weak seal to the underlying main confined aquifer. It requires specific protection to prevent uncontrolled leakage.

CONCLUSION 12
Sea water intrusion is not a threat for the main aquifer system. Specific coastal areas however, are susceptible to sea water intrusion.

Comparatively minor quantities of groundwater occurs in coastal beach gravel deposits in two areas: Whirinaki to Bay View in the north and Haumoana to Te Awanga in the south. Groundwater in these areas has been affected by salt water intrusion. During periods of high groundwater abstraction (particularly in summer) there is a potential for contamination due to the localised upconing of the salt water wedge into the fresh water in these aquifers.

RESEARCH AND INVESTIGATION

CONCLUSION 13
Regional and site specific resource management issues still remain requiring additional investigation.

Despite the completion of a number of groundwater investigations in the Heretaunga Plains, there are aspects which are not yet fully understood or are currently still being investigated. Current and future research requires monitoring to:

- identify variation in recharge on groundwater quality (initiated);
- establish sustainable irrigation water allocation (initiated);
- refine water balance estimates (initiated);
- assess the risk of seismic structural damage to aquifers (initiated);
- rank the susceptibility of aquifers to contamination vulnerability;
- identify the significance and process of direct rainfall recharge (initiated).

CHAPTER 5

MANAGEMENT STRATEGIES

Twenty years ago, groundwater management was directed towards the exploitation of resources without considerations of possible environmental consequences. Today, with increasing competition for a limited groundwater resource, the management emphasis is on sustainable development, protection and conservation.

The strategic importance of the Heretaunga Plains groundwater resources to the Hawke's Bay region and New Zealand makes the establishment of a groundwater management programme, a top priority.

The goals for the sustainable management of the Heretaunga Plains groundwater should be:

- to achieve a balance between availability and demand for groundwater;
- to match as far as possible, landuse with the local availability of groundwater;
- to use the natural resources efficiently with minimum impact on the environment;
- to recognise the importance of promoting a "prevention from contamination" ethos.

The management strategies do not contain solutions to every soil and groundwater issue on the Heretaunga Plains; they provide a framework in which such issues may be addressed and a mechanism for on-going planning and review of policies.

CONCLUSION 1

A comprehensive groundwater quality and quantity monitoring programme is required to ensure successful groundwater management.

Comprehensive monitoring data and information is necessary to measure the effectiveness of management strategies. This includes surface and groundwater quality, water supply, irrigation and industrial abstractions, spring fed streamflow discharges, dewatering pump abstractions and river and groundwater level data. This information is used to identify new or emerging issues, allowing new policy to be formulated. It is also required to ensure that existing/proposed policy is appropriate.

CONCLUSION 2

Specific groundwater management strategies are required for immediate implementation in designated areas on the margins of the Heretaunga Plains.

A limited quantity of groundwater is available on the margins of the Heretaunga Plains. A number of bores on the southern margin of the Plains barely penetrate the aquifer. These require deepening. Summer water use in these areas requires monitoring. Spatial and temporal variation in groundwater quality requires better understanding.

CONCLUSION 3

Aquifer specific policies are required to prevent contamination.

- Unconfined aquifers require protection due to very high susceptibility to contamination. Specific policies are required regarding: on-site sewage disposal, surface and sub surface storage facilities, stormwater discharges and landuse planning.
- All hazardous chemicals and agrichemical storage areas on the unconfined and confined aquifer require adequate containment to prevent infiltration and site runoff.
- There is also a need for specific construction standards around well heads. This is required specifically to prevent accidental spillage of agrichemicals.
- Industrial, irrigation and public water supply bores require backflow protection devices to prevent accidental contamination of the aquifer by agrichemicals and hazardous substances during use.

CONCLUSION 4

Specific policies are required to prevent irrigation drainage.

An increase in weed growth in surface drains and streams on the Heretaunga Plains in recent years relates to irrigation drainage. Water wastage from inefficient irrigation results in degradation of both soil and water environment by loss of soil fertility and nutrient enrichment in drains and streams. A combination of policy and regulatory measures are required to address these issues.

CONCLUSION 5

Effective public awareness programmes on resource degradation issues are vital to sustainable management of soil and groundwater.

Only a small proportion of the community affected by water resources policies are aware of their purpose and provisions. Community knowledge and understanding of the soil and water degradation issues is generally poor. The issues concerning conservation and preservation of natural resources can be only achieved through effective community participation.

Community awareness and participation in resource management issues is an essential requirement for sustainable management. This could be achieved through:

- on-going community awareness building programmes;
- continued dialogue with the interest groups;
- field workshop and training sessions on specialist soil and water management issues viz. irrigation scheduling, soil compaction, conservation of resources, etc.

CHAPTER 6

RECOMMENDATIONS

The recommendations of the Heretaunga Plains groundwater study have been divided into five pertinent management sectors:

- long-term resource monitoring priorities;
- organisation and integration of groundwater databases;
- research and investigation;
- groundwater management issues;
- community education.

LONG-TERM MONITORING PRIORITIES

It is recommended that the HBRC continue or undertake the following comprehensive long-term monitoring as detailed in volume 1:

- continuous river and groundwater level;
- comprehensive groundwater quality monitoring;
- water supply, industrial and dewatering bore abstractions;
- concurrent river and spring-fed stream gaugings;
- surface water quality;
- landuse with revisions at 5 yearly intervals;
- annual (summer) water use surveys.

ORGANISATION AND INTEGRATION OF DATABASES

It is recommended that the HBRC establish an integrated management system for various natural resource data. This data needs to be accessible for spatial and temporal analysis, such as GIS. The data will include:

- water well and foundation testbore log data;
- water quality data;
- consent related data;
- water use survey data;
- river, dewatering pump, stream and spring gauging data;
- periodic and continuous groundwater level monitoring data.

RESEARCH AND INVESTIGATION

It is recommended that HBRC:

- refine the current groundwater balance estimate;
- continue soil-crop specific water allocation investigation;
- identify aquifer vulnerability to contamination on and adjacent to the Heretaunga Plains;
- undertake further investigations to more accurately define the demand and availability of groundwater for the designated areas on the margin of the Heretaunga Plains main aquifer system.

GROUNDWATER MANAGEMENT ISSUES

It is recommended that the HBRC:

- delineate a Groundwater Management Area (GMA) (Fig. 8) where resource consents to take and use groundwater be granted for a limited duration only. This would include large public water supply bores within the GMA;
- establish a minimum distance criteria for bores for each area included in the GMA;
- make installation of water meters compulsory for all bores in the GMA with the exception of domestic water supply bores;
- encourage use of water from deeper aquifers at suitable locations in the GMA;
- require irrigators in the GMA to present adequate evidence of their actual needs together with an Irrigation Management Plan, which describes in detail the method of irrigation application;
- establish guidelines for appropriate landuse planning and controls over unconfined aquifer areas;
- establish criteria for adequate well head protection zones;
- make installation of a non-return valve at the well head compulsory on all industrial, public water supply and irrigation wells.

COMMUNITY EDUCATION

The HBRC should actively encourage community participation in resource management issues. Raising public awareness on the resource management issues and promoting efficient use of resources are essential for sustainable groundwater management. Groundwater quantity and quality problems directly involve a large number of land owners, and the management solutions will involve questions of values and community needs.

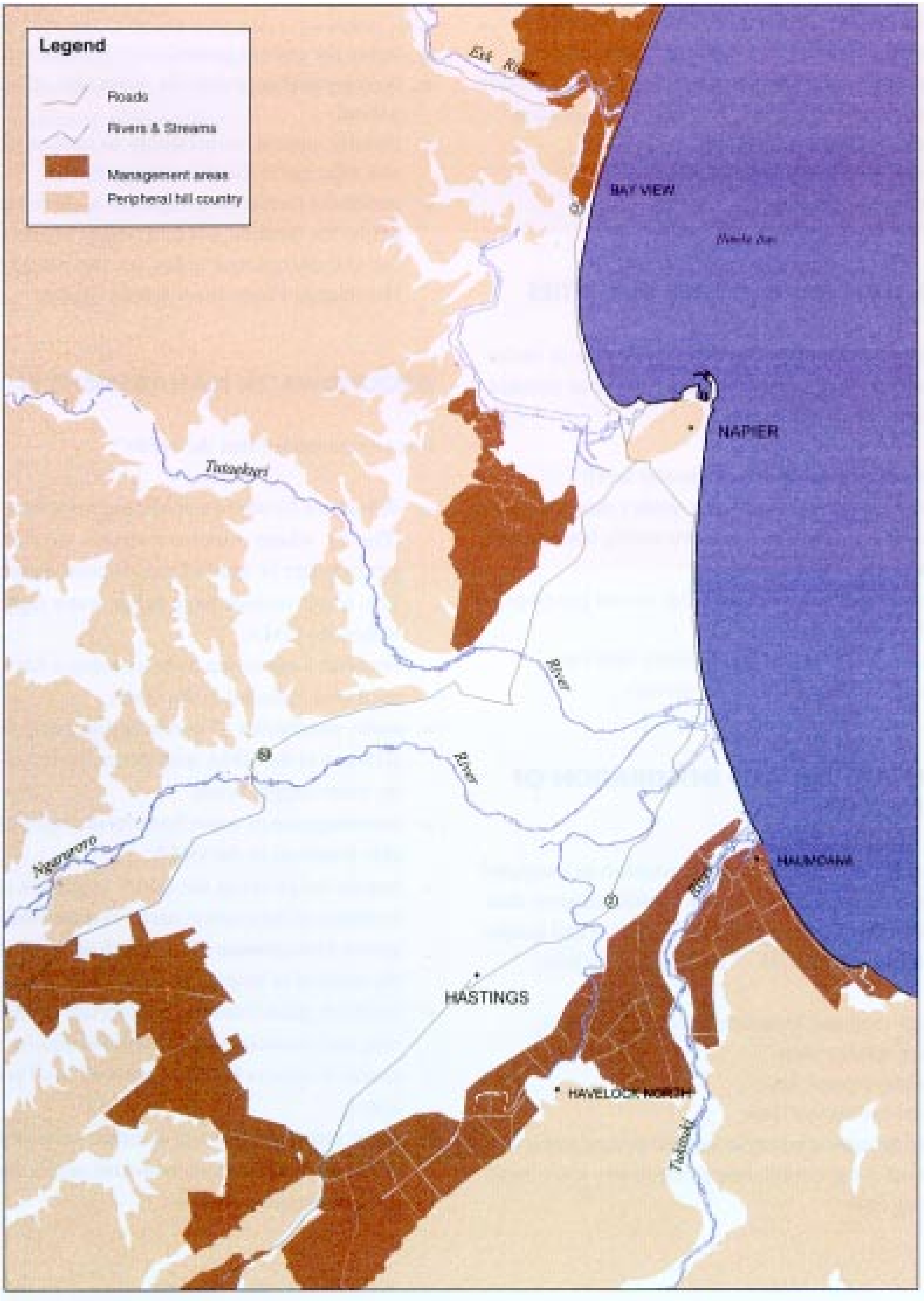


Figure 9: Heretaunga Plains groundwater management area (GMA).

CHAPTER 7

GLOSSARY

Abstraction
Pumping from an aquifer.

Agrichemicals
Natural and synthetic chemicals used in modern agricultural and horticultural practices.

Aquifer
A geologic formation or a group of formations that is capable of yielding a significant amount of water to a well.

Aquifer (Confined)
An aquifer that is overlain by a confining bed.

Aquifer (Unconfined)
An aquifer in which there are no confining beds between the zone of saturation (water table) and the ground surface.

Aquifer (artesian)
A confined aquifer with groundwater under sufficient pressure to rise up the bore above the top of the aquifer. If water rises above the ground surface it is termed a flowing artesian aquifer.

Aquiclude
A saturated formation which yields insignificant quantities of water and also prevents flow between adjacent aquifers.

Aquitard
A semi-pervious geological formation that stores and transmits groundwater but does not realise enough for water supply. Aquitard retards but does not prevent flow of water to or from an adjacent aquifer.

Backflow Protection
A one way non-return valve fitted at the wellhead to prevent accidental entry of foreign substances into the groundwater.

Contamination
The introduction into air, soil or water of any chemical material, organic material, live organism that will adversely affect the quality of the medium.

Dewatering
The removal of groundwater to reduce flow-rate or reduce pressure.

Direct Rainfall Recharge
The volume of rain-water added to the total amount of groundwater in storage in a given period of time.

Discharge
A measure of the water flow at a particular point, e.g. gauging site, or groundwater abstraction well.

Drilling
The process of making a hole into the Earth. Two common methods are cable drilling and rotary drilling.

Ecosystem
Ecological system - a term used to describe the interdependence of species in the living world.

Estuarine
Sediments deposited in an estuary.

Fluvial Deposits
Material laid down by physical processes in the river channels or flood plains.

Fringe (groundwater area)
Used in this report to denote *minor* aquifer areas on the margin of the *main* aquifer system.

Hardness
A measure of the ability of water to form a carbonate scale when boiled.

Hectare (ha)
10,000 square meters or 2.47 acres.

Hydraulic Conductivity
A unit describing quantitatively the ability of a porous material to transmit water under pressure.

Hydrochemistry
The branch of chemistry which deals with the chemical composition of natural groundwaters.

Hydrogeology
The science of groundwater.

Impermeable/Impervious
Rock which will not permit water to flow through it.

Infiltration
Downward entry of water into soil.

Irrigation
The process of artificially augmenting the amount of water available to crops. Usually water is sprayed on to the plant or made available to the root system.

Isotope hydrology
The use of naturally occurring and introduced isotopes to date and identify the water bodies. Most commonly used isotopes are tritium, oxygen 18 and deuterium.

Lagoon
Coastal body of shallow water, characterised by a restricted connection with the sea.

Limestone
Sedimentary type of rock composed mainly of calcite and/or dolomite.

Lithological Log
Descriptive log of sediments penetrated by a well.

Perched aquifer
A shallow localised aquifer.

Percolation
Downward movement of percolate under gravity.

Permeability
A measure of the capacity of aquifer material to transmit water which is amount of flow per unit cross sectional area under the influence of a unit gradient.

Piezometer
An observation well designed to measure the elevation of water table or hydraulic head of groundwater at a particular level.

Piezometric Contour
Lines of equal piezometric pressure. Piezometric surface represents the static water level. It is defined by the levels to which water will rise in a well.

Porosity
Porosity is the ratio of the volume of voids to the total volume of material, expressed as a percentage

Pumping Test
During the pump test water is pumped from a *pumped* well in the aquifer at a measured rate while observing the drawdown in the other nearby *observation* wells.

Recharge
The addition of water to the groundwater by natural or artificial processes.

River gauging
A point at which river flow is measured.

Saltwater Intrusion
The migration of sea water into fresh water aquifers as a result of groundwater abstraction.

Safe Yield
The amount of groundwater that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the natural environment.

Sediment
Material derived from pre-existing rock, from biogenic sources, or precipitated by chemical processes.

Static water level
Natural water level in a bore.

Subartesian
A non-flowing confined aquifer with groundwater pressure below ground level.

Subsidence
A progressive depression of the Earth's crust, which allows sediment to accumulate and be preserved.

Transmissivity
The rate at which the water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.