ENVIRONMENTAL MANAGEMENT GROUP

Technical report

INTERNAL

HAWKE'S BAY
REGIONAL COUNCIL

SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Heretaunga Steady-State Ground-Water Model

April 2006
EMI 0408
HBRC plan No. 3765

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Environmental Management Group Technical Report

Internal

Environmental Monitoring Section

Heretaunga Steady-State Ground-Water Model

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Definitions

Terms

Term	Definition
Council	Hawke's Bay Regional Council
Daisy	Council consent database
Hilltop	water-level and surface-water database
MODFLOW	Modular three-dimensional finite-difference ground-water flow model
MODFLOW 2000	Updated MODFLOW model
NIWA	National Institute of Water and Atmospheric Research, Limited
WellStor	Council well information database

Symbols

Term	Definition	Units
A	cross-sectional area	metre
b	thickness	metre
I	Gradient	unitless
K	hydraulic conductivity	metre/day
Q	Discharge	metre^3/day
T	Transmissivity	metre^2/day

Abstract

This report documents the development of a steady-state model for the Heretaunga ground-water basin. The main objectives were to predict pumping effects on basin water levels, predict effects of pumping wells on surface water, and determine basin water balance. Data in this report is from Council databases WellStor (well information), Daisy (consent allocations), Hilltop (surface- and ground-water data), and various compliance pumping records.

The Heretaunga basin consists of about 5 to 7 primary aquifers that supply water to Hastings, Napier, Havelock North, Flaxmere, coastal, and inland communities. The main rivers in decreasing discharge are the Tukituki, Ngaruroro, Tutaekuri, and the Clive

Water entering the ground-water basin is river losses (73 percent, nearly all from the upper Ngaruroro) and rain infiltration (27 percent). Water leaving the basin is river gains (69 percent) and pumping (31 percent). Public and industrial users each take 38 percent of basin ground water and irrigation takes about 24 percent.

The model is constructed as one layer with maximum depth about 400 metres. It is bounded on all sides by no-flow boundaries representing the bedrock hills and the predominantly silt and clay seabed along the seashore. The model grid is every 500 metres, evenly spaced throughout the model area in a north-south, east-west orientation.

Three rain recharge zones, based on rainfall and permeability, assume that 30 to 40 percent of rain infiltrates. Hydraulic conductivity decreases in three zones from west to east, 400 m/d to 100 m/d. River conductances range from 100 m/d for the Tutaekuri, lower Ngaruroro, and Clive to 90,000 m/d for the upper Ngaruroro.

The model was calibrated to the average 2004 water levels for Council state-of-environment wells to match model simulation with actual measurement. All simulated water levels are within three metres of measured levels and 60 percent are within one metre. River simulations differ as much as 40 percent for the Tukituki River but within 10 percent for the upper Ngaruroro River. Model simulations are most sensitive to changes in basin permeability (hydraulic conductivity) and less affected by changes in river conductance and rainfall recharge.

The calibrated steady-state model can be used to predict the effects for different pumping scenarios. Simulation suggests that water levels have declined about 2 metres across the Heretaunga ground-water basin since ground-water pumping began in the early 1900s.

1 Introduction

The Heretaunga Plains consists of about 5 to 7 primary aquifers that supply water to Hastings, Napier, Havelock North, Flaxmere, coastal, and inland communities. Ground water is used for public supply, agricultural, industrial, and domestic use. As surface waters have become nearly fully allocated, ground water has become an important supply, especially for drinking because it is relatively safe to drink without treatment.

Ground water management requires hydrogeologic information and ground-water use to determine optimal benefits from ground-water development. Information needs include hydrogeologic and water use data.

This report documents development of a steady-state ground-water model for the Heretaunga Plains. A steady-state model describes the ground-water basin at equilibrium; meaning that the pumping rates are constant and water levels are also constant--that this condition remains constant. Physical characteristics are as realistic as possible, and then matched against measured values, such as water level, to confirm the model is realistic.

A computer model does not reproduce or replace the physical basin. It is instead, a mathematical model that generalises basin information to simulate real measured data, such as water levels. Therefore, simulations and predictions are most reliable for basin areas and least reliable at a specific point in the basin.

Following steady-state model, transient models may be developed to show how changing pumping rates and other variables will change water levels and affect rivers.

In this report, Council refers to Hawke's Bay Regional Council unless otherwise noted. Terms used in this report are defined on page vi.

1.1 Purpose

The purpose of the Heretaunga steady-state ground-water model is to establish the Heretaunga basin water balance in preparation for a subsequent transient model to predict different ground-water management options.

Council staff that will use the model, rated what they want the model to do. Results are categorised into three groups, from “most useful” to “some interest.” These top-rated priority items directed model development to ensure efficiency and usefulness.

Most useful	• *Predict effects of pumping wells on basin water levels* • *Predict effects of pumping wells on surface water* • *Determine basin water balance*
Useful	• *Determine potential for seawater intrusion* • *Predict effects of different annual rains on ground-water levels* • *Improve hydrogeology understanding*
Some interest	• *Determine reasonableness of aquifer test data* • *Determine reasonableness of existing ground-water contour maps* • *Determine ground-water flow direction* • *Determine rain/recharge ratio* • *Identify and quantify surface water gains and losses*

Bredehoeft and Hall (1995) suggest that the primary purpose of a ground-water model is to educate the hydrogeologist on how aquifers function.

> *He/she should use the computer to test conceptual models of the system, design the investigation, and collect data on those parameters the model indicates are most critical in affecting systems behaviour. In other words, one uses the computer model to test parameter sensitivity. As data are collected and one’s conceptual model changes, the computer model is revised.*

Bredehoeft and Hall (1995) also warn the hydrogeologist to not refine parameters, such as transmissivity or rain recharge, to a greater accuracy than warranted by the other limited parts of the conceptual and mathematical model.

1.2 Model steps

The greatest effort in developing a ground-water model is the initial steps to develop the conceptual model and collate information and data to enter into the model. The ground-water model was developed using steps identified in Anderson and Woessner (1992), as shown in Figure 1. Step "verify" was excluded in this steady-state model because there is not a separate time data set to verify results with. Pattle Delamore Partners, Ltd. (2002) gives guidelines for developing a ground-water model.

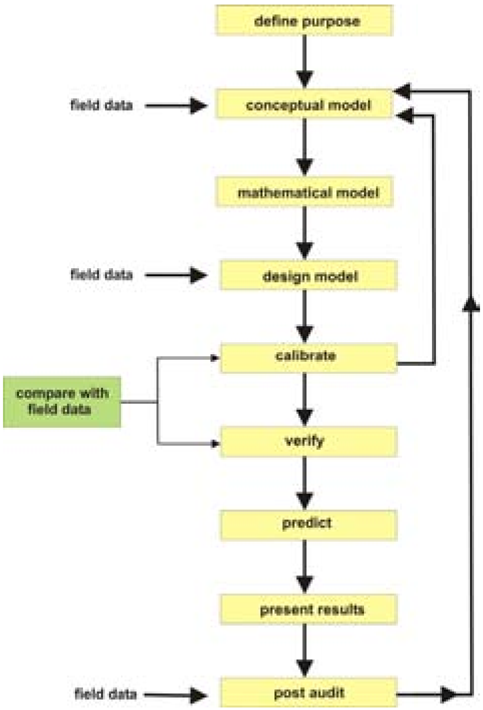

Figure 1. Modelling steps.

1.3 Data sources

Data in this report is from Council's databases: WellStor (well information), Daisy (consent allocations), Hilltop (surface- and ground-water data), and various compliance pumping records. The data is taken as stored, some with no quality-assurance review.

1.4 Acknowledgements

Thom Krom, Aqualinc, assisted with model development. Council staff that contributed includes Kim Coulson (water-level), Darrel Hall (graphical-information system), Simon Harper (well information), Jenna Hewetson (compliance pumping), Leeanne Hooper (ground-water consent allocations), and Carol Robertson (surface water). Council staff Terry Jamieson (compliance), Liz Lambert (planning), Colin McLellan (consents), and Geoff Wood (surface water) contributed guidance for model use.

2 Conceptual model of Heretaunga hydrogeologic basin

The conceptual model is a hydrogeologic description of the Heretaunga basin, consisting of field-, data-, and information-based maps, stratigraphic sections, aquifer test review, etc.

2.1 Relevant reports

Several reports describe Heretaunga Plains hydrogeology, though only Unknown (1997) describes a ground-water model of western Heretaunga Plains. Dravid and Brown (1997) is a comprehensive hydrogeology investigation, McLellan (1988) describes the basin configuration in western Heretaunga Plains, and Grant (1972) is an early report describing Heretaunga ground waters in relation to streamflow.

2.2 Base map

The Heretaunga ground-water model boundary shown in Figure 2 encloses the main Heretaunga Plains, including the Heretaunga ground-water basin. It is bounded by limestone rock, river inlets, and the sea. Maps shown in this chapter are 1:200,000 scale.

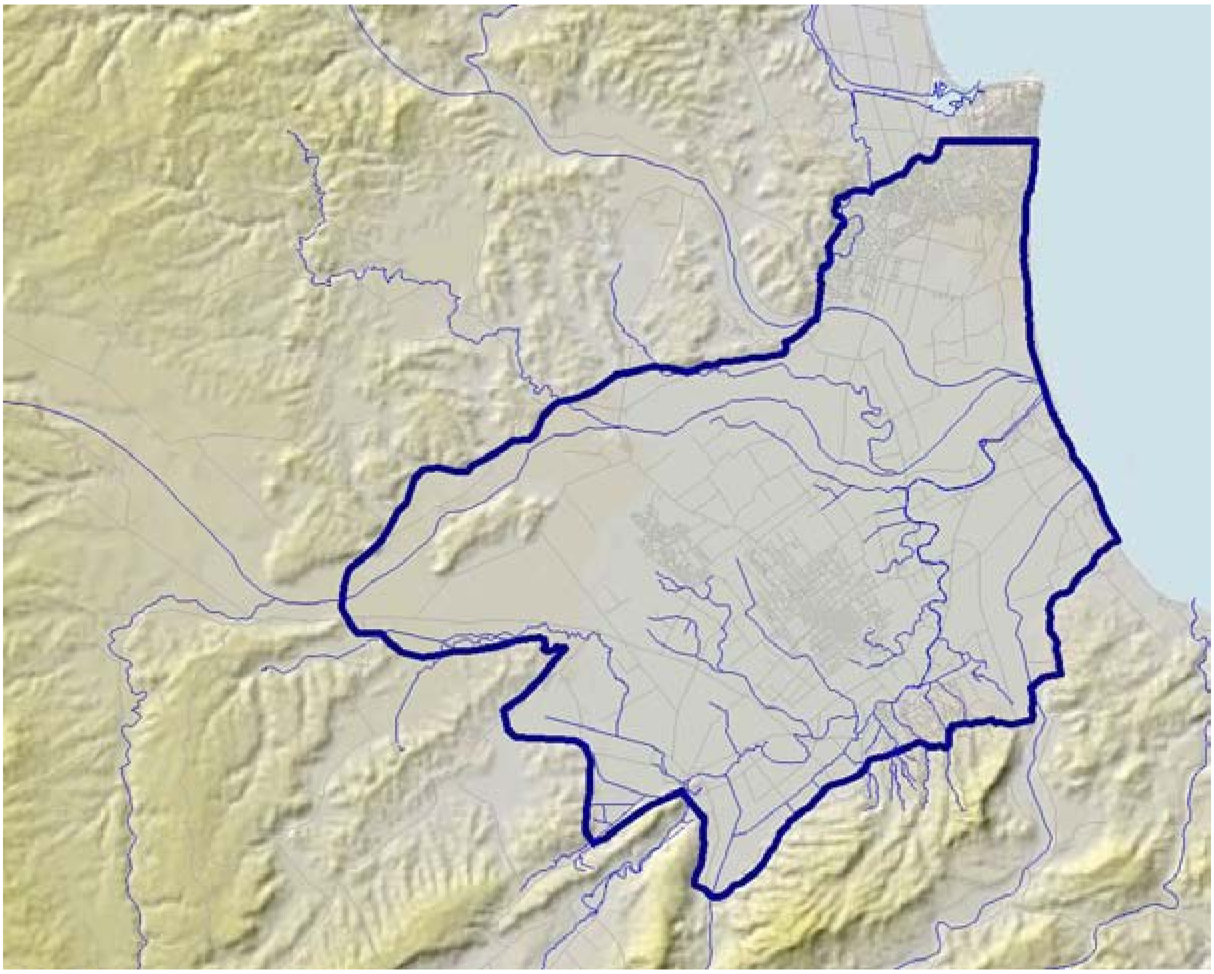

Figure 2. Heretaunga model basemap.

2.3 Basin dimensions

The Heretaunga model area is about 330 km^2. The basin has a maximum thickness of about 400 metres, extending from land surface to basin bottom. The model land surface is shown in Figure 3 as 5-metre intervals and has a gradient of about 0.002 from Roys Hill to the sea (Grant, 1972, p. 17). The model area is bound by about 14 km of shoreline to the east.

Basin thickness is greatly approximated because only 26 basin wells intercepted basin bottom. Of the 26, only the Whakatu oil and gas exploration well (Darley and Kirby, 1969) intercept the basin depth near the basin centre. Taradale oil and gas well (Ozolins and Francis, 2000) penetrates the base outside the model boundary. Dravid and Brown (1997, fig. 2.5) estimates the peak basin depth of about 400 m near Flaxmere but the value is not based on drilling. The basin bottom in western Heretaunga, Roys Hill, is interpreted from seismic described by McLellan (1988).

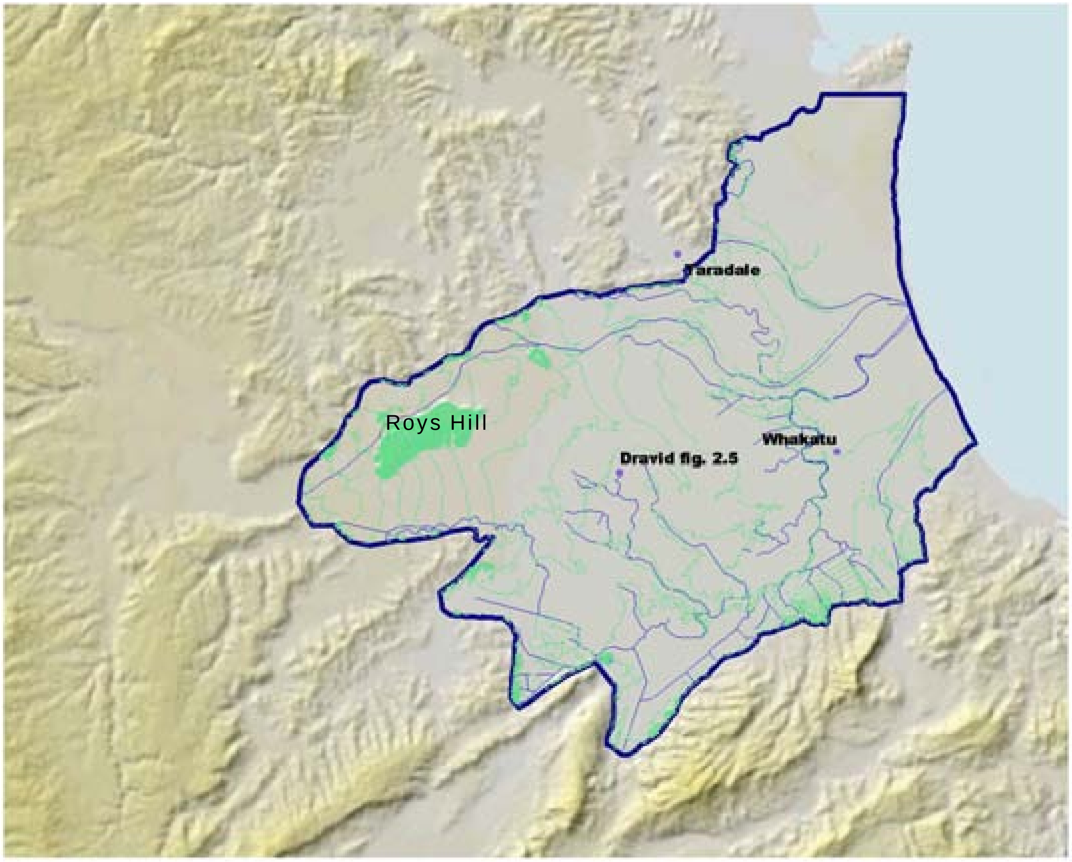

Figure 3. Surface 5-m contour intervals and basin depth control points.

2.4 Basin hydrogeology

The median Heretaunga aquifer transmissivity is 4,000 m^2/day (WellStor database, 2005). This value is typical for Heretaunga gravels but does not represent the full basin thickness. Distinguishing aquifers, similar to geologic formations, is scale dependent. A small clay lens within a sandstone is too insignificant to warrant a separate formation name for the clay. So too in hydrogeology, a small-scale perspective would regard a clay lens within a gravel as a confined layer, but viewed in a larger context, it is incorporated as part of the greater gravel aquifer. For this reason, a basin transmissivity is required rather than the anomalous gravel transmissivity for determining a basin balance.

2.4.1 Hydraulic conductivity

Figure 4 shows the Whakatu 1 (Ozolins and Francis, 2000, appendix 1) and Awatoto well 3699 well logs simplified to "more permeable" and "less permeable." Because drillers did not log the upper 70 metres of Whakatu 1, well 4402's log is applied. This representation suggests there are about 6 main aquifers in the Heretaunga Basin. Whakatu 1 reached the sediment/bedrock contact at about 380 metres. About 140 metres of the total column have "more permeability," consisting mostly of gravels and sands with some clay. About 240 metres have "less permeability," consisting of clays, silts, sands, and some gravel.

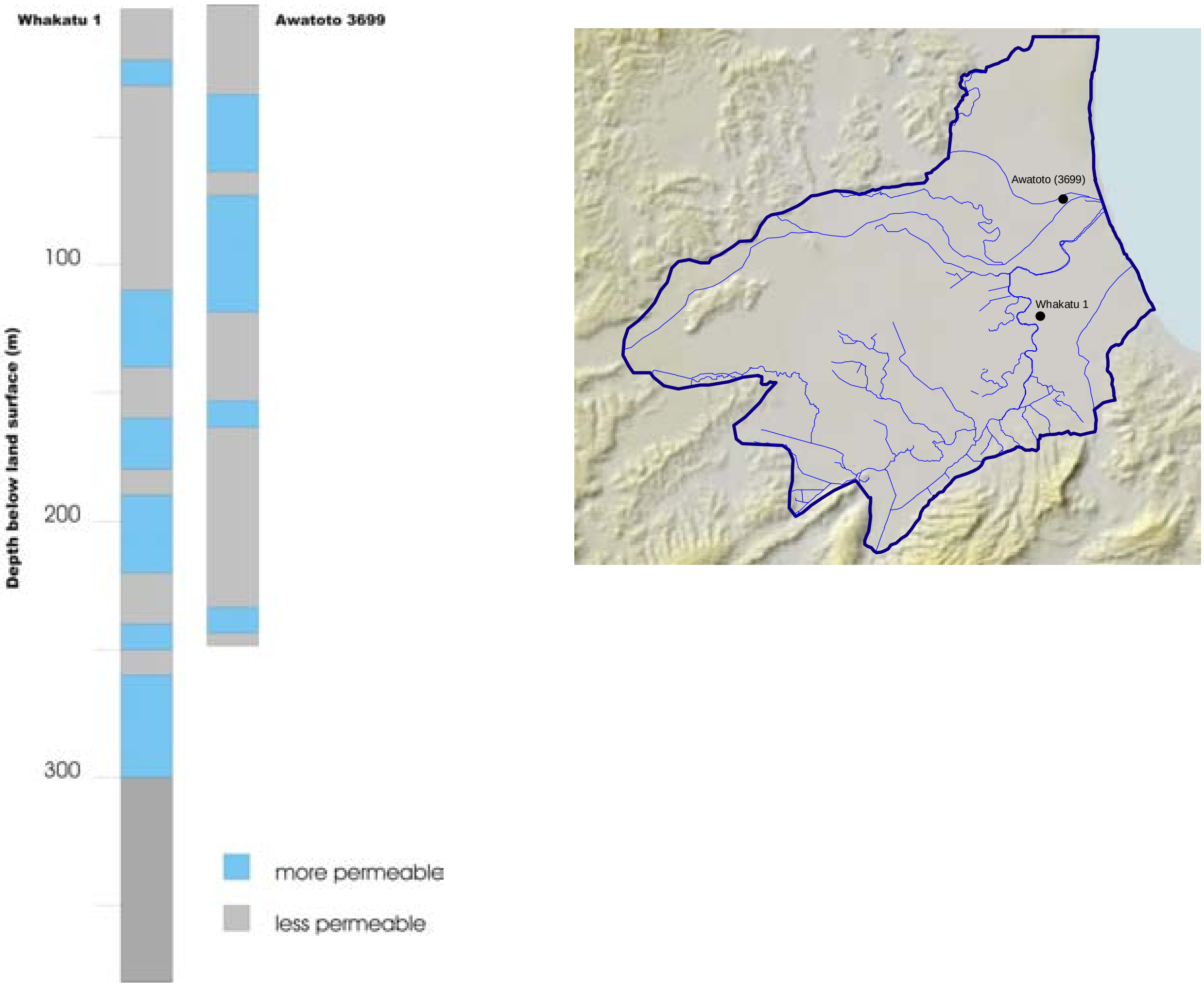

Figure 4. Whakatu 1 and Awatoto general well logs.

Median Heretaunga transmissivity is about 4,000 m^2/day. Median thickness of more permeable lithology (Figure 4) in the upper 100 metres (where aquifer tests have been done) is about 10 metres. Therefore approximate hydraulic conductivity for the more permeable basin lithology is:

$$K = \frac{T}{b}\frac{\frac{4000m^2}{day}}{10m} \approx \frac{400m}{day}$$

This value is within the range given by Domenico and Schwartz (1990, table 3.2) for sand to gravel lithologies. The same reference gives values for lower permeability materials, such as silt, sand, gravel as about 100m/day and this value is used for the less permeable lithologies.

To estimate the basin composite hydraulic conductivity (permeability), values for more and less permeabilities are proportionally determined.

$$\overline{K} = \sum_{m=1}^{n} \frac{K_m b_m}{b}$$ Fetter (1994, equation 4-40)

where:

K_m = hydraulic conductivity of the mth layer
b_m = thickness of the mth layer

Therefore, average basin composite hydraulic conductivity is:

$$\overline{K} = \frac{\left(\frac{400m}{day} \bullet 140m\right)}{380m} + \frac{\left(\frac{100m}{day} \bullet 240m\right)}{380m} = 210m/day \approx 200m/day$$

The calculated estimate is about three times greater than Grant's (1972, p. 16) 76 m/d for a Hastings City supply well, assumed to be in a 45-m deep aquifer.

The Heretaunga Plains is often divided into "unconfined area" in western Heretaunga (Figure 12) and "confined area" in the rest of the Heretaunga. Though this division simplifies the hydrogeology for the layperson, it is not technically accurate. The "unconfined area" is mostly gravel but does contain semi-confining layers. The "confined area" contains unconfined aquifers near land surface and confined below confining layers. This report uses these terms for the recognised areas, without quotation marks, to differentiate lithology zones used in the model.

Luba (1999) reports a maximum aquifer thickness of about 200-m in the unconfined area. The median transmissivity is 3000 m^2/day (appendix A), but all but two tests are rated as "unreliable." Only one of those, well 4909 (Figure 5), was pumped a standard 24 hours to result in a transmissivity of about 8,000 m^2/day and this value is assumed to represent aquifer transmissivity for the unconfined area. Because the unconfined transmissivity is about twice the average Heretaunga basin transmissivity, it follows that hydraulic conductivity in the unconfined area is greater than the basin average value--greater than 200 m/day. The unconfined area, being all aquifer and gravel, is assumed to be 400 m/d.

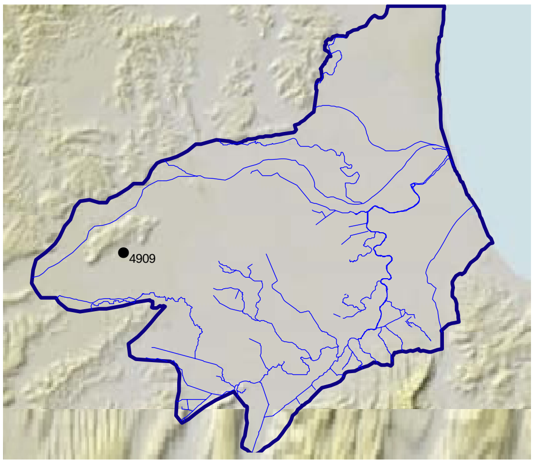

Figure 5. Well 4909 well location.

Lithology typically grades from more coarse to more fine from mountain to sea as shown in Dravid and Brown's Heretaunga cross sections (1997 figures 4.19 and 4.21). This is because more coarse and heavy materials (boulders and gravel) drop out stream suspension before fines (silt and clay), which are transported further from the sediment source (mountains). With this, the more coarse materials such as gravel make up more permeable lithology. Therefore, hydraulic conductivity can range from greater to lesser hydraulic conductivity. Approximate hydraulic conductivity values are given in Table 1.

Table 1. Approximate hydraulic conductivity.

Area	Hydraulic conductivity (m^2/day)
unconfined	400
middle basin	300
eastern basin	100
seashore	10

2.4.2 Ground-water velocity

Ground-water velocity may range from 0.5 to 20 m/d in the Heretaunga basin, with values between 0.5 and 2 m/d more typical. This would result in travel time of 30 to 200 years from Roys Hill to the sea (about 20 kilometres). This range is reasonable because some water will travel faster by way of preferential flow paths, such as through shallow gravels. Other ground water will travel deep or through clay and requires much greater time.

Average linear velocity is calculated from approximate Heretaunga values, given in section 2.4.1.

$$V_x = \frac{K \bullet I}{n_e} = \frac{200m \bullet 0.0008}{d(0.3)} \approx 0.5m/d$$

where:

K = average basin hydraulic conductivity ≈ 200 m/d
n_e = effective porosity ranges from about 0.2 to 0.4 (Fetter, 1994, table 4.3), here assumed ≈ 0.3
I = ground-water gradient ≈ 0.0008 (from Figure 7)

Dravid and Brown (1997, p.215) used tritium data to determine a 2 m/d velocity. Samples taken from wells 37- to 125-m deep near the coast have "substantial components" of 1964 -

1974 recharge water. The time difference between recharge dates (1964 - 1974) and well sample date (1994) is about 25 years. Assuming the flow path from Roys Hill to the coast is about 20 kilometres, this results in about 2 m/d velocity. In Table 2, the distance from Roys Hill/Fernhill to the sea is about 20 kilometres.

Table 2. Ground-water velocity.

Ground water velocity (m/d)	Area	Reference	Comments
0.5	Roys Hill to coast	This report	*Subjective calculation from review of driller's logs*
2	Roys Hill to coast	Cameron and Morgenstern (2002, table 3.1)	*Age dating of Napier City wells from 15 - 60 years old.*
2	Roys Hill to coast	Dravid and Brown, 1997, p. 215	*25 years from Roys Hill to coast (1994 sample date - 1969 tritium water)*
8	Fernhill to coast	• Grant-Taylor and Taylor (1967) • Grant (1972, figure 9)	• *Tritium samples taken from shallow wells (Dravid and Brown, 1997, p. 215)* • *7 years from Fernhill to coast.*
10	central Heretaunga	Dravid and Brown, 1997, p. 105	
20	Flaxmere	Dravid and Brown, 1997, p. 105	

The calculated average linear velocity of 0.5 m/d using values from Table 1 is much less than published values of 2 - 20 m/d shown in Table 2. Published values, often based on tritium analysis, are maximum velocities of ground water following preferential paths, such as gravel aquifers and old buried river channels. Rather, the basin average includes longer travel times through clays and silts, as well as faster times through gravels. Therefore, ground-water velocity may range from 0.5 to 2 m/d.

If basin ground-water velocity ranges between 0.5 and 2 m/d, then Table 1 values may underestimate basin hydraulic conductivity. Using 2 m/d velocity instead of 0.5 m/d, then average basin hydraulic conductivity would be about 750 m/d. This value is more typical of gravels, whereas the basin sediment consists of a mix of clays, silts, sands, and gravels.

2.5 Water levels

Ground-water scientists measure water level to know what direction ground water flows. In the same way that energy differences drives mass from greater to lesser energy, water moves from greater to lesser water levels. A measured water level is the total energy at a 3-dimensional point in a lithology, whether sediment, rock, aquifer, or confining layer. For this reason, water levels show the direction that ground water moves, horizontal and vertical.

In Figure 6, the basin water-level surface is superimposed on land surface to show horizontal and vertical ground-water flow direction. The water level line is dashed to represent a potentiometric (pressure) surface, rather than water table. Ground water typically flows downward in the upper basin (Roys Hill) and upward in the lower basin (seashore). Water levels between Hastings and the seashore are above land surface, so a well that penetrates the confined aquifer would flow to land surface.

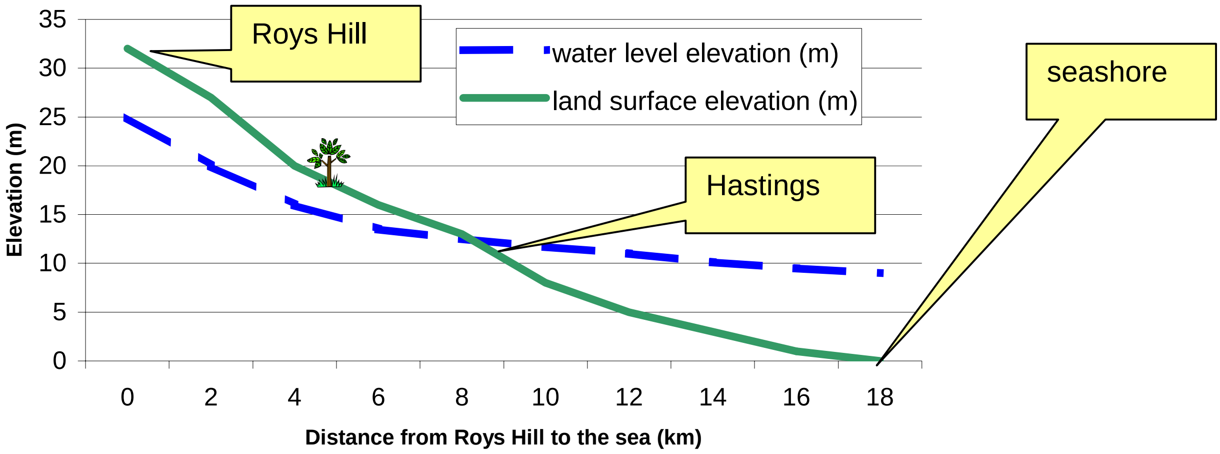

Figure 6. Water and land surfaces, Roys Hill to the sea.

2.5.1 Horizontal gradient

Ground water flows from western Heretaunga Plains to the sea with a gradient of about 0.0008, based on Figure 7. The gradient from Roys Hill to Hastings is about 0.001 and the gradient from Hastings to the sea is about 0.0005. Greatest ground-water discharge is to the Tutaekuri, Ngaruroro, and Clive Rivers in eastern Heretaunga. Ground water contours in eastern Heretaunga (Figure 7) show the apex of the "V" pointing downriver along the confluence of the three rivers, characteristic of ground-water discharge to rivers and indicating a discharge area. Conversely, the 20-m contour shows the opposite "V" direction that indicates a recharge area, where river water moves to ground water.

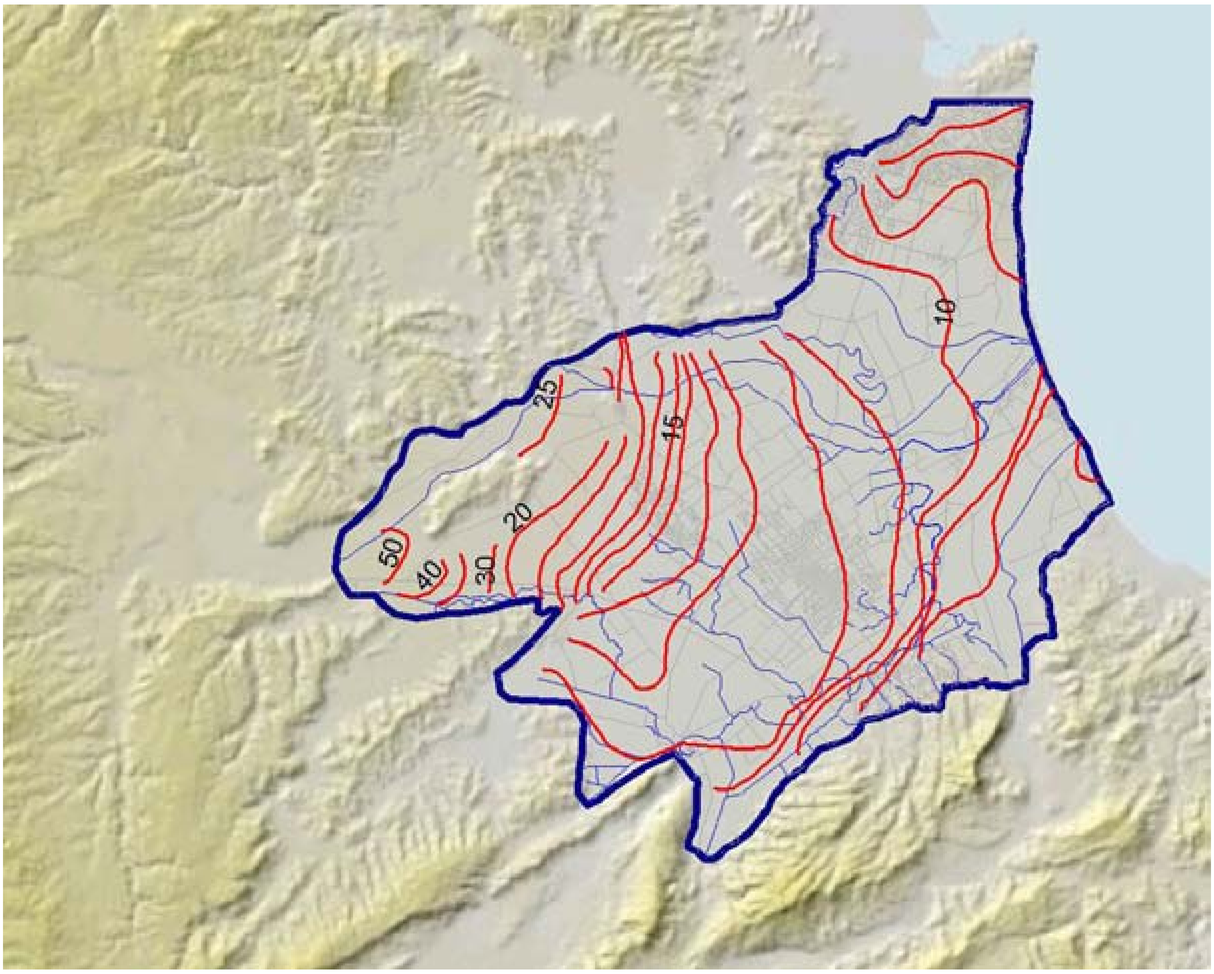

Figure 7. Ground water contours (metres above sea level, summer 1995).

These contours are based on composite water-level measurements. All water level measurements were used to create this contour map without regard to each aquifer having it's own water level. Therefore, these contours may be valid in a regional scale but not local. The contours show that ground water moves to the sea, but there are local anomalies that are inaccurate.

2.5.2 Vertical gradient

Many of the basin wells flow to land surface, indicating confined conditions and different water level at different depths. Even so, Figure 8 shows three multiple piezometer sites (each site has different-depth piezometers) for which two of the three sites, water levels don't vary with depth. Flaxmere varies by about 1 metre, Tollemache has insignificant variation, and Awatoto has the greatest difference with about 2 meters (Table 3). Water level datum is land surface.

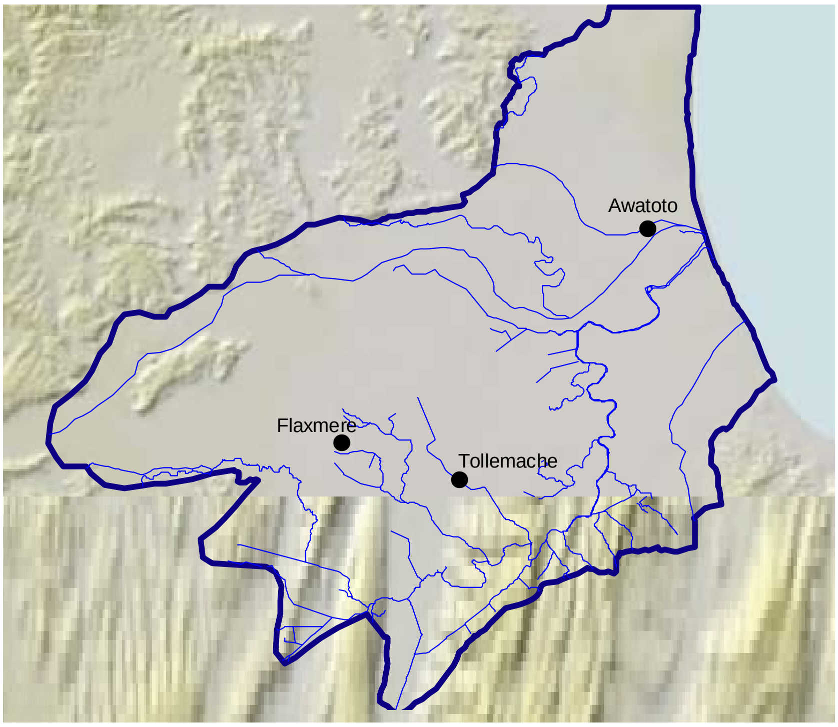

Figure 8. Multiple-depth piezometers.

Table 3. Water levels at multi-depth sites.

Area (date)	**Piezometer**	**Depth (m)**	**Water level (m)**	**Comments**
Flaxmere (28/05/2003)	15011	114	-3.1	*Inconsistent with downward water-level trend at this site.*
	15009	75	-3.8	
	15010	49	-3.0	
	3698	14	-2.6	
	Maximum difference		1.2	***Downward ground-water gradient***
Tollemache 19/08/2005	15018	153	+3.3	
	15019	132	+0.4	
	15012	115	+3.9	
	3697	89	+4.0	
	3336	48	+3.5	
	Maximum difference		0.2	***Uncertain ground-water gradient***
Awatoto 19/08/2005	3699	251	-0.2	*Approximate--unable to convert the measured 0.355 below measuring point to land-surface datum.*
	15001	162	+5.7	
	15002	90	+3.9	
	15003	58	+3.8	
	15022	38	+3.8	
	Maximum difference		1.9	***Upward ground-water gradient***

2.6 Rivers

The main Heretaunga Rivers, in decreasing discharge to the sea, are the Tukituki, Ngaruroro, Tutaekuri, and the Clive (Table 4 and Figure 9).

The Tukituki and Ngaruroro Rivers discharge the most and similar rates to the sea. The Clive discharges the least. Values in Table 4 are based on means for the full record except for the Clive, which is estimated from flow regression and specific yield. Clive tributaries include the Irongate (upper Clive) and Karamu (middle Clive).

Figure 9 shows the representative river gauging sites are greater than 6 kilometres from the sea; the Tukituki and Ngaruroro representative sites are 15 kilometres. River loss to the sea is expected to be greater than the amounts in Table 4 because rivers gain more ground water near the eastern basin.

Table 4. River discharges.

River	Drainage area (km^2)	Mean discharge (m^3/sec)	Annual discharge (km^3/year)	Gauging site (Figure 9)	Distance to sea (km)	Comments
Tukituki	2,500	43.8	1.4	Red Bridge	15	*Contributes the least to Heretaunga ground water and gains the least from ground water.*
Ngaruroro	2,500	41.2	1.3	Chesterhope	6	*Contributes the most to ground water.*
Tutaekuri	900	14.6	0.5	Puketapu	15	*Contributes second most to ground water.*
Clive	500	3.8	0.1	see comments		*Estimated. Difficult to measure because of weeds and changing stream cross section.*

Though the Tukituki discharges more water to sea than any other river, the Ngaruroro adds more to ground water (Dravid and Brown, 1997, p. 220). The river discharges shown in Figure 9. Tides affect the lower river discharges and any data measured would include tidal effects. The Ngaruroro, the main contributor to ground water, loses water most of the year (Table 5). The Tutaekuri-Waimate and Clive rivers gain water throughout the year.

Table 5. Seasonal river gains and losses.

River	Spring	Summer	Autumn	Winter	Comments
Tutaekuri	+/-	+	+/-	+	*gains*
Ngaruroro	no data	-	-	-	*loses*
Tutaekuri-Waimate	+	+	+	no data	*gains*
Clive	+	+	+	+	*gains*
Tukituki	+	-	no data	no data	*not enough data*

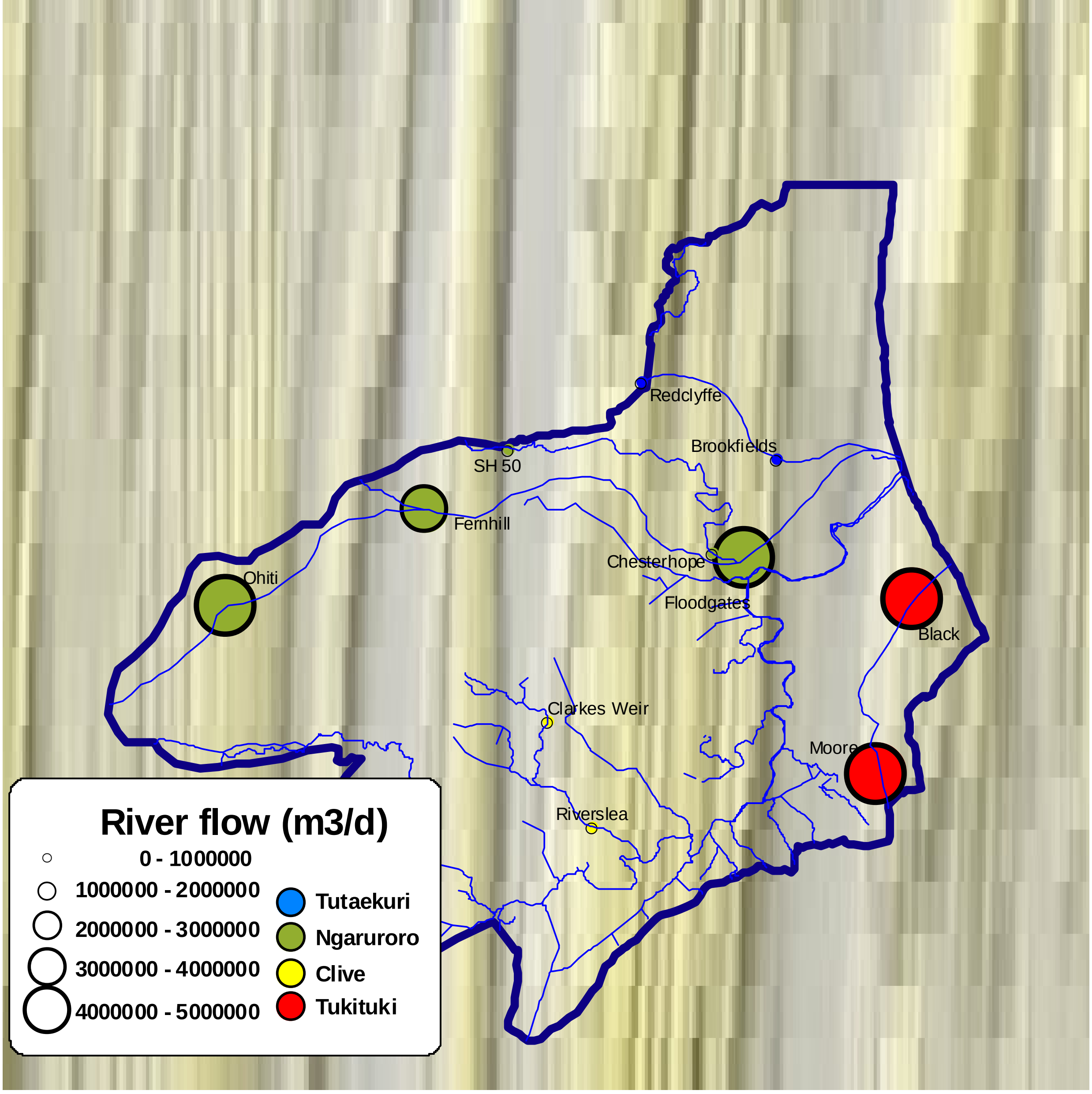

Figure 9. Heretaunga river flows.

Figure 9 is based on Table 6 same-day streamflow values (see table column "Dates with same-day measurements"). This data was selected because they are near annual typical river flows

Table 6. River gains and losses.

River	Upper (m^3/d)	Lower (m^3/d)	Change (m^3/d)	Date	Dates with same-day measure-ments
Tutaekuri	848,000 (Redclyffe)	833,000 (Brookfields)	-15,000	24/09/1996	13
Ngaruroro	4,246,000 (Ohiti)	4,033,000 (Chesterhope)	-213,000	05/08/1996	16
Tutaekuri-Waimate	126,000 (SH 50)	213,000 (Chesterhope flow)	+91,000	06/09/1972	11
Clive	25,000 (Clarke's Weir)	175,000 (Floodgates)	+150,000	09/04/1981	9
Tukituki	1,477,000 (Tennant)	1,590,000 (Black)	+112,000	16/11/2005	2

3 Water balance

Water enters the Heretaunga Basin by river losses and rain infiltration. Water leaves the ground-water basin as river gains, pumping wells, and discharge to sea.

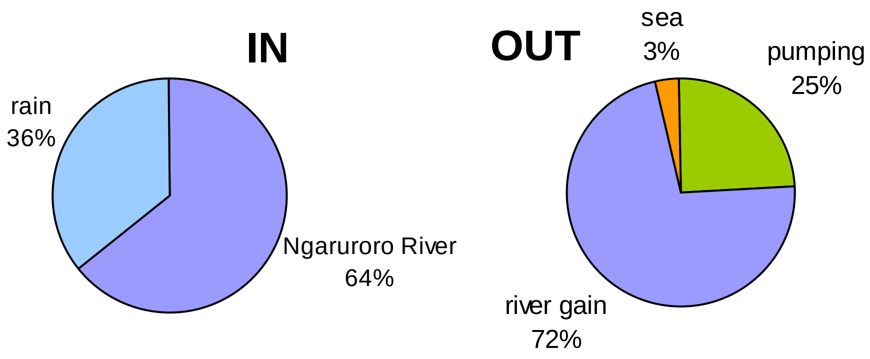

Figure 10. Heretaunga water balance (2004).

The balance shown in Figure 10 and Table 7 are for 2004 and supported in the following sections.

Table 7. Heretaunga ground-water basin water balance (2004).

IN ($m^{3/}year$)		OUT ($m^3/year$)	
		177,000,000	rivers[3]
158,000,000	Ngaruroro River[1]	61,000,000	pumping[4]
88,000,000	rain[2]	8,000,000	sea discharge[5]
246,000,000		**246,000,000**	

[1] section 3.1.1, [2] Table 8, [3] calculated as remainder, [4] Table 9, [5] section 3.2.3

3.1 In

The two ways that water enters the Heretaunga ground-water basin is by the Ngaruroro River losing water through its riverbed in the western basin and rain over the entire basin.

3.1.1 River recharge

Dravid and Brown (1997) report that the upper Ngaruroro contributes the most to ground water, 158,000,000 m^3/year (432,000 m3/d). The same publication reports the Tutaekuri contributes 25,200,000 m^3/year (69,000 m^3/d), though this is before the river enters the basin model area and therefore not included in this model. The Tukituki may contribute to ground water but there is only two sets of same-day measurements (Table 6). Though the Clive River drains much of the Heretaunga basin, the river is relatively insignificant compared to other basin river flows.

Figure 9 shows that the Ngaruroro River loses water to ground water in the western basin, but other basin river flows are somewhat constant across the basin while gaining ground water nearer the seashore.

3.1.2 Rain recharge

Figure 11 shows annual rain for much of the Heretaunga Plains is 0.8 m, with greater totals associated with mountains in the northern area and near Havelock North. Data is from NIWA records.

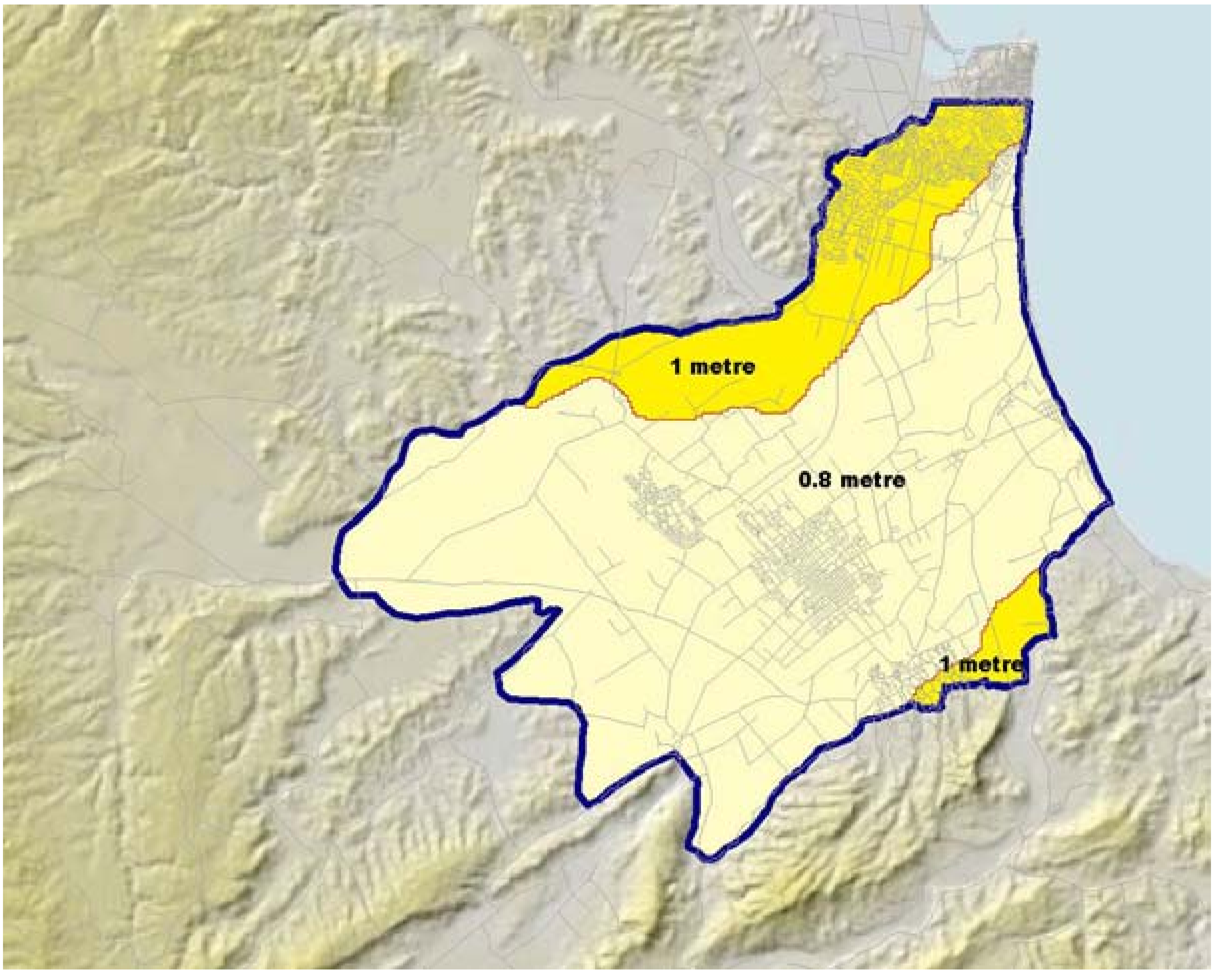

Figure 11. Annual rain.

Rain recharge typically ranges from 1 to 50 percent of rain (Appendix B). About 40-50 percent of rain recharges ground water in sand or gravel; 5 to 20 percent in less porous material (Raymond, 1992). Recharge data from the U.S. includes 1% for high-country arid areas, 15% for central grasslands, and 50% for sandy coastal areas (Fetter, 1994, p. 192).

Dravid and Brown's water balance (1997, p. 221, table 8.1) reported rain recharge only for the unconfined area (Figure 12). White and others (2003, table 2, p. 42) reports that about 35% of Canterbury Plains rain recharges ground water.

Heretaunga ground-water recharge is divided into three zones, shown in Figure 12, based on rainfall and aquifer condition (confined or confined/unconfined). Recharge is assumed to be 30% of rain for the confined area and 40% for the unconfined area.

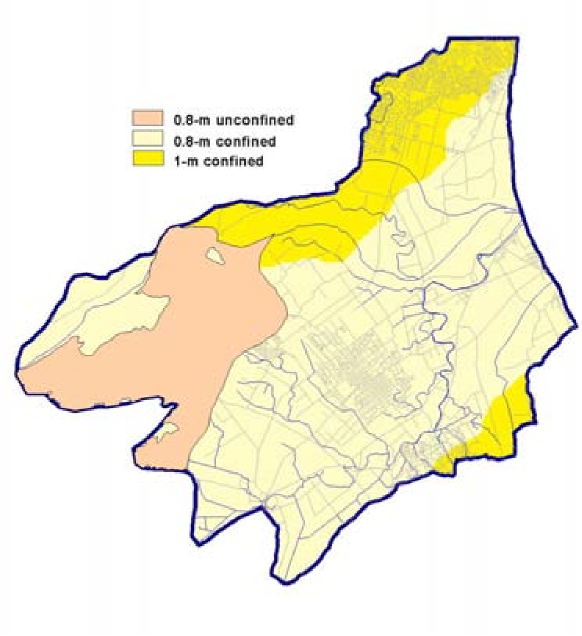

Figure 12. Rain recharge zones.

Rain recharge =
(1-m confined area x 1m x 0.3) + (0.8-m confined area x 0.8m x 0.3)+(0.8-m unconfined area x 0.8m x 0.4)

Table 8. Annual rain recharge estimates.

	0.8-m rain unconfined zone	**0.8-m confined zone**	**1-m rain zone**	**Totals**
area (m^2)	60,000,000	208,000,000	62,000,000	274,000,000
rain (m)	0.8	0.8	1	
% of rain recharge	40	30	30	
recharge (m^3/year)	19,000,000	50,000,000	19,000,000	88,000,000

Rain recharge of 88,000,000 m^3 is much greater than Dravid and Brown's (1997, table 8.1) value of 5,000,000 m^3 and is more typical of rain's contribution to a basin's ground-water recharge.

3.2 Out

There is less certainty about how much water leaves the ground-water basin than water entering the basin because of lack of supporting data. The greatest basin discharge is ground water rising upward to enter rivers before discharging to sea. But there are few river gaugings near the sea to establish annual volume. The most reliable basin discharge is pumping. The least reliable data is for ground water discharges to the seabed because it cannot be directly measured.

3.2.1 Ground water discharge to rivers

The Clive River gains ground water throughout the year (Table 5), about 54,000,000 m^3/year (149,000 m^3/d) from Table 6. The Tutaekuri River can gain ground water in all seasons, especially in summer and winter.

Because there is no river discharge data for the lower river reaches, river gains from ground water in the lower reaches, near the sea, are solved for using other water-balance values, as shown in Figure 10. To determine how much ground water moves to rivers near the sea, first establish the ground-water balance.

water entering ground-water basin = water exiting ground-water basin

river recharge to ground water+ rain recharge = ground-water discharge to river + pumping + sea discharge

Then, solving for annual ground-water discharge to rivers:

ground-water discharge to river = river recharge to ground water + rain recharge - pumping - sea discharge

$$= (158{,}000{,}000 + 88{,}000{,}000 - 61{,}000{,}000 - 8{,}000{,}000)\ m^3/yr = 1787000{,}000\ m^3/yr$$

and this number is used in Table 7.

Though ground water can also enter the basin within river channel “underflow” from up-river tributaries, such flows are insignificant compared to river and rain recharge.

3.2.2 Ground water pumping

Ground-water allocation is the basis for the maximum water that may be pumped. In addition, Council holds metered records for actual pumping for public supply and industrial use. There are too few irrigation wells with metered data so this use is estimated. Frost protection pumping represents less than 1% of ground-water discharge (Harper, 2006) and is included within general irrigation pumping.

3.2.2.1 Ground-water allocation

Figure 13 shows that ground-water allocation tripled from 1984 to 2004, with a significant increase from 2002 to 2003. This increase may be explained by the Resource Management Act sunset clause that required that all consents prior to 1991 be applied for after 2001 (oral communication, Colin McLellan, Council consent team leader, 6/10/2005). The median allocation rate is about 1800 m^3/week; the least is 25 m^3/week and the greatest is 62,900 m^3/week (well 1722, Awatoto).

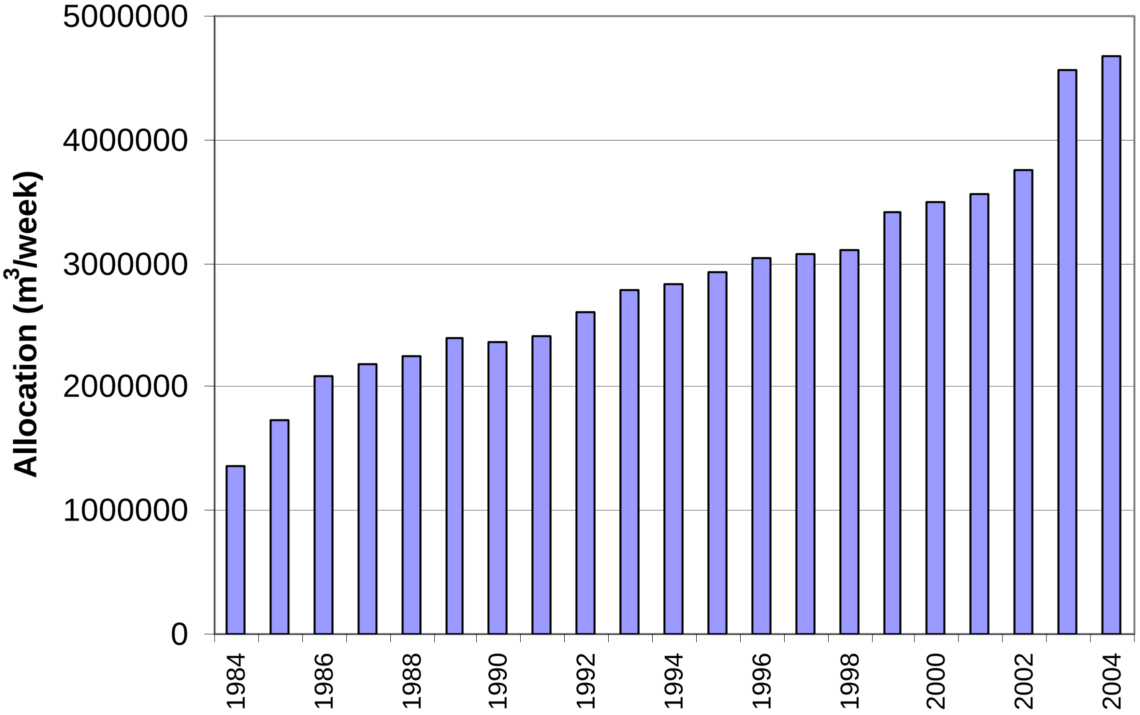

Figure 13. Ground-water allocation, 1984 - 2004.

But less water is used than the allocated. For irrigation use, McLellan (1985) reports that 5% of allocated ground water was pumped over an irrigation season. Other regional councils use values from 27% to 55% (15 July 2005 ground-water forum; Waikato 27%, Wairarapa 20%, Auckland 55%, Canterbury 30%). About 30% of allocated ground water was actually pumped in the Ruataniwha Basin from 1994 to 2000 (Appendix C).

Irrigation pumping is effectively allowed only in the summer based on the following consent condition.

> *The volume taken shall not exceed that required to replace soil moisture depleted by evapotranspiration over the irrigated area, up to a maximum of __ cubic metres in any 7-day period (i.e. at the maximum rate authorised in Condition __, taking should normally be less than, and never exceed (0.27777 X (weekly volume/take rate)) hours per week).*

3.2.2.2 Historical pumping estimates

In previous investigations, public supply, irrigation, and industry use the most Heretaunga ground water, as shown in Figure 14. Dravid and Brown (1997, table 8.1) shows a different data proportionality for ground-water use than Scott and Thorpe (unknown date).

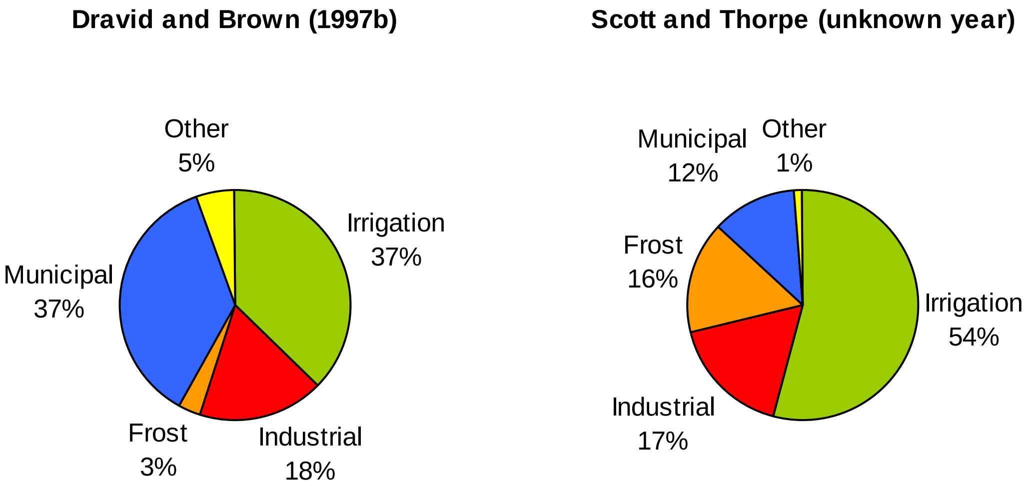

Figure 14. Comparison of ground-water use data.

The difference may be caused by the different dates. Dravid and Brown (1997) uses data up to 1995 and Scott and Thorpe (unknown date) uses data up to 1988. The total water used is more important than the proportion, though the differences may indicate data errors caused by no direct well metering.

Scott and Thorpe (unknown date) shows ground-water allocations as early as 1966 but Council consent database (Daisy) has records to only 1984.

3.2.2.3 Current pumping estimate

Figure 15 shows that ground-water pumping has increased about 15% in the ten years from 1996 to 2005. The slow pumping increase suggests the basin is approaching maximum development and more efficient use. The greatest increase has been in industrial use.

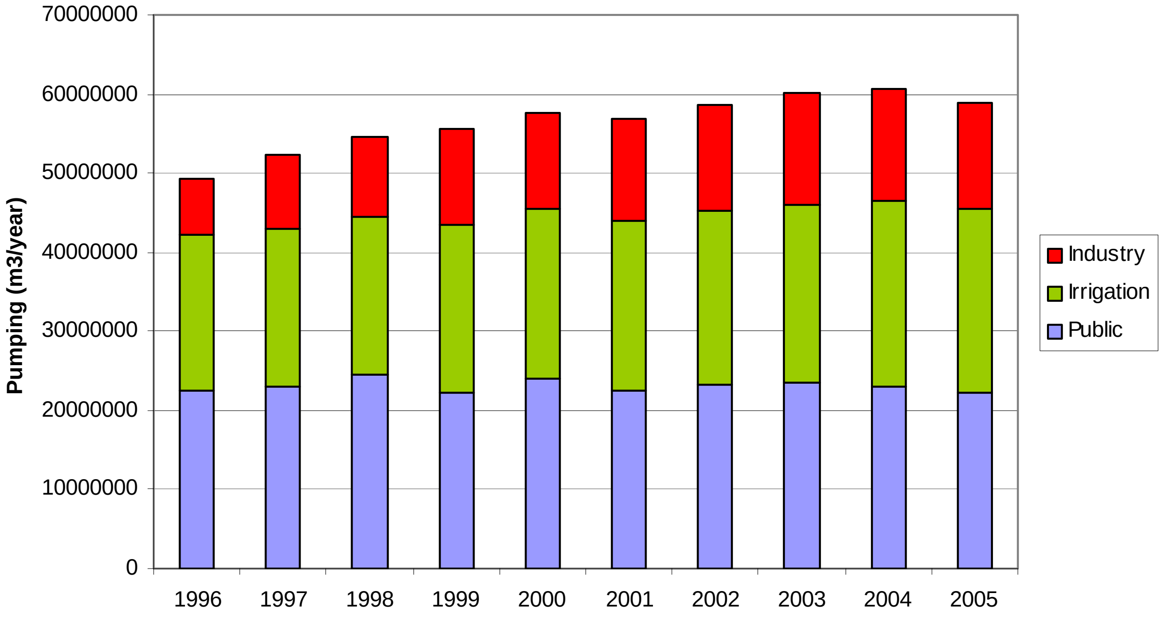

Figure 15. Ground water use, 1996 - 2005.

Public and industry values are from water meter records. This report uses the Ruataniwha 30% coefficient (section 3.2.2.1) to estimate actual irrigation pumping because it is more recent data and consent allocations have become more realistic since 1985. Actual irrigation is estimated over an irrigation season (26 weeks), corrected for actual rather than allocated.

irrigation year estimate = maximum allocation weekly rate x 26 weeks x 0.3

Less than half the ground water allocated is actually used. Table 9 summaries consent allocations and actual use estimates for Heretaunga ground water in 2004. Irrigation allocation given in Table 9 is given per week but this rate may not be pumped year round, as described in section 3.2.2.1. For this reason, the maximum weeks is assumed to be 26.

Table 9. 2004 ground water use.

Use	Wells	Total weekly allocation (m^3)	Total yearly allocation (m^3/year)	Use (m^3/year)	Percent allocation used (%)	Comments
Public supply	39	950,000	49,400,000	23,100,000	46%	Metered.
Industrial	89	640,000	33,300,000	14,300,000	43%	Metered.
Irrigation	1171	2,907,000	75,600,000[1]	23,300,000	30%	Assumes 26 weeks pumping, 30% used.
Other	7	8,000	400,000	400,000	unknown	Assumes all allocated water is used.
Total				**61,100,000**		

Figure 16 shows estimated annual ground-water use for 2004 is proportionally similar to Dravid and Brown (1997, table 8.1) shown in Figure 14. Though irrigation pumping is the same as public use on an annual basis, irrigation is the greatest use in summer. In winter, with no irrigation pumping, public use would be about 60% and industry about 40%.

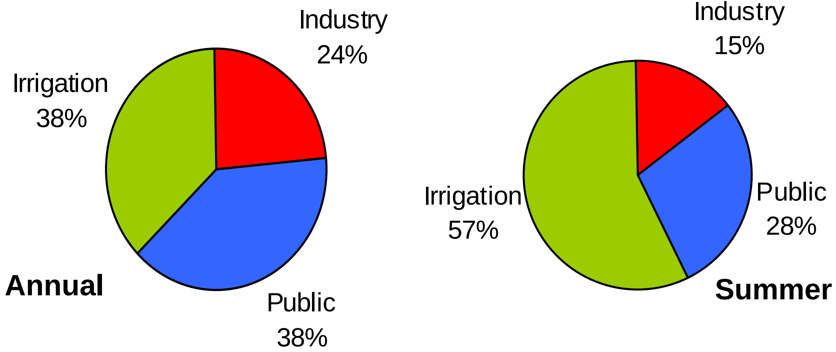

Figure 16. Estimated annual and summer pumping.

Napier City well 1998, near Taradale, pumps the most water (2.799,752 m^3/year) in the Heretaunga basin. The average Heretaunga well pumps about 50,000 m^3/year, which is well below maximum pumping value shown in Figure 17. Though public supply and irrigation use the most total ground water, public and industrial wells have the greatest individual ground-water pumping rates. Irrigation pumping is more evenly distributed over the basin.

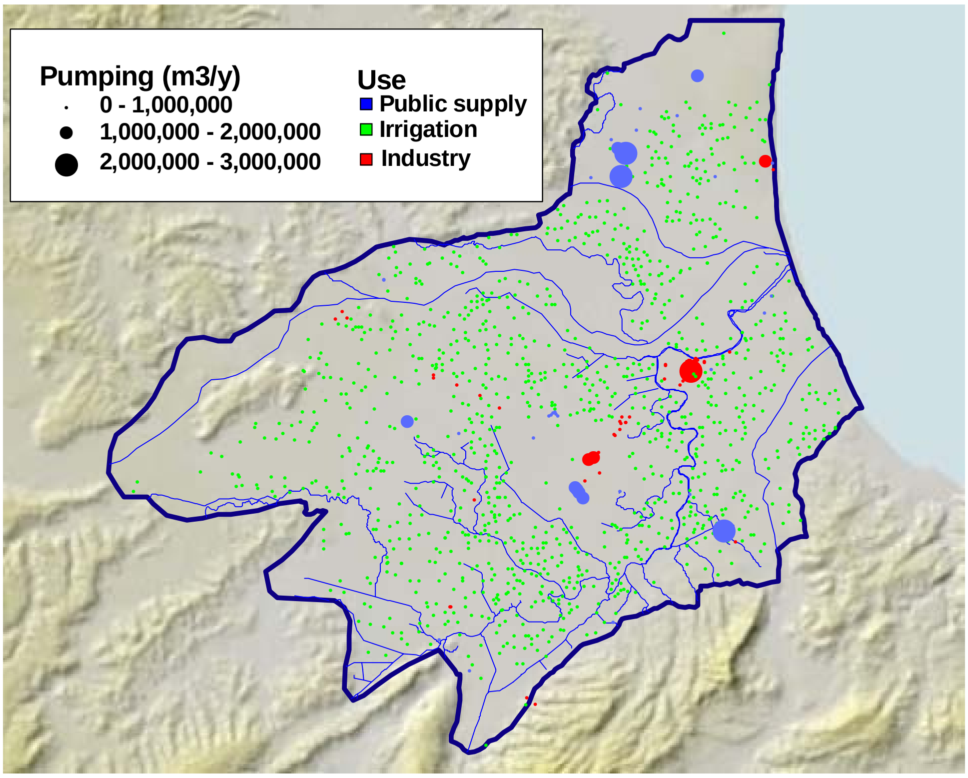

Figure 17. 2004 ground-water use estimate.

A steady state model, as described in this report, is limited to a year's water balance and cannot show seasonal effects. But a transient model could show seasonal variation such as summer pumping as expressed in Figure 16, with irrigation using more than half the summer ground water pumped.

3.2.3 Ground water discharge to sea

Ground water discharge to sea cannot be directly measured. Dravid and Brown (1997) reports it as unknown. Though there are certain to be ground-water discharges to sea, it would be difficult to verify because the small discharge would be greatly diffused in the much greater sea. But one of the effects of ground-water pumping would be diminished or depleted springs, including seabed springs.

Nautical Chart NZ 56 (Royal New Zealand Navy Hydrographer, 1989) shows 13 seabed springs about 20 – 40 kilometres east of Napier (Figure 18), but Land Information New Zealand has no data supporting the springs. Ridgway and Stanton (1969) were unable to verify the mapped springs. The New Zealand Navy, on request of Thorpe and Scott (about 1985 – 1990) could not confirm the plotted springs (oral communication, D. Scott, Canterbury Regional Council hydrogeologist, 2/3/2006). It is unlikely that ground water would travel an additional 20,000 – 40,000 metres through increasingly dense clays rather than rising 200 metres upward near shore to discharge to rivers.

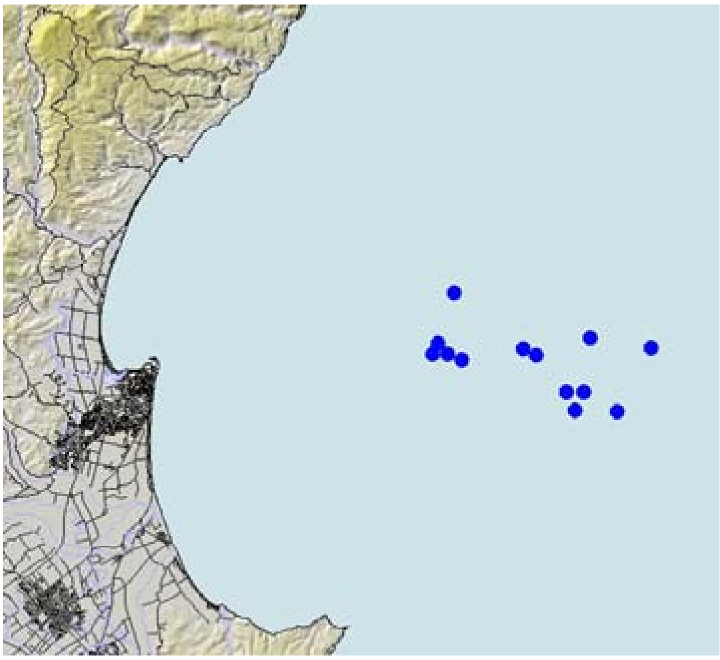

Figure 18. Unconfirmed seabed spring sites.

3.2.3.1 Calculated ground-water discharge to sea

Dravid and Brown's (1997, p. 221, table 8.1) notes that ground-water discharge to the sea is "unknown." Ground-water discharge to sea can estimated using Darcy's equation, $Q = KIA$, where Q is discharge, K is hydraulic conductivity (permeability), and A is cross-sectional area.

$$Q_{seashore} = KIA = \frac{3{,}000m}{year} \bullet 0.0007 \bullet 4{,}000{,}000m^2 \approx 8{,}000{,}000m^3 / year$$

which is about 3% of the ground-water balance. Equation values are derived as follows.

<u>Seashore hydraulic conductivity (K)</u> is developed from the Awatoto and Whakatu well cross sections shown in Figure 4. The calculation establishes representative hydraulic conductivity as a proportion of aquifer (gravel, sand) thickness (about 100 metres) and confining layers (silt, clay) thickness (about 300 metres) to total basin thickness (about 400 metres), based on the Whakatu well. There are no significant aquifers greater than 300 metres, in part because of the greater compaction with depth. The method given in section 2.4.1 for the Whakatu 1 well may be used to establish hydraulic conductivity at the seashore, using well 3699 (Awatoto) cross section (Figure 4).

$$K_{seashore} = \frac{\frac{30m}{d} \bullet 100m}{400m} + \frac{\frac{0.00002m}{d} \bullet 300}{400} \approx 7m/d \approx 3{,}000m/year$$

- clay geometric mean ≈ 0.00002 m/d (Domenico and Schwartz, 1990, table 3.2, p. 65)
- unsorted gravel ≈ 30 m/d (Domenico and Schwartz, 1990, table 3.2, p. 65)

<u>Ground-water gradient (I)</u> is about 0.0007 and is the most reliable equation parameter, based on measurement (Dravid and Brown, 1997, p. 103, fig. 5.5).

where:

I = 0.0007 (Dravid and Brown (1997, p. 103, figure 5.5)

$$I = \frac{\Delta_{head}}{length} \frac{23m - 9m}{19000m} = 0.0007$$

<u>Seashore cross-sectional area (A)</u>

Assuming the basin is half of an ellipse:

$$A = 0.5(\pi \bullet 6{,}500m \bullet 400m) \approx 4{,}000{,}000m^2$$

- 6,500 m = half the greatest axis length = 0.5(average basin width) = 0.5•13,000 m
- 400 m = half the shortest axis length = basin depth

To understand this volume, annual ground water discharge to sea is a rugby field covered with about 1 kilometre of water in one year or 2 city wells pumping non-stop at 125 l/s each.

This small discharge suggests that nearly all ground water enters rivers before final discharge to sea, as shown in Figure 19. It has little significance in the water balance.

The U.S. Geological Survey qualitative ground-water flow model TopoDrive (Hsieh, 2001) shows that topography greatly controls ground-water flow. Figure 19 shows that most ground water moves up and enters basin rivers where the topography flattens, at and above Hastings. Little ground water moves along the more resistive path, further out under the sea. Seabed springs plotted in Figure 18 would plot 20 to 40 centimetres to the right of "seashore" labelled in Figure 19.

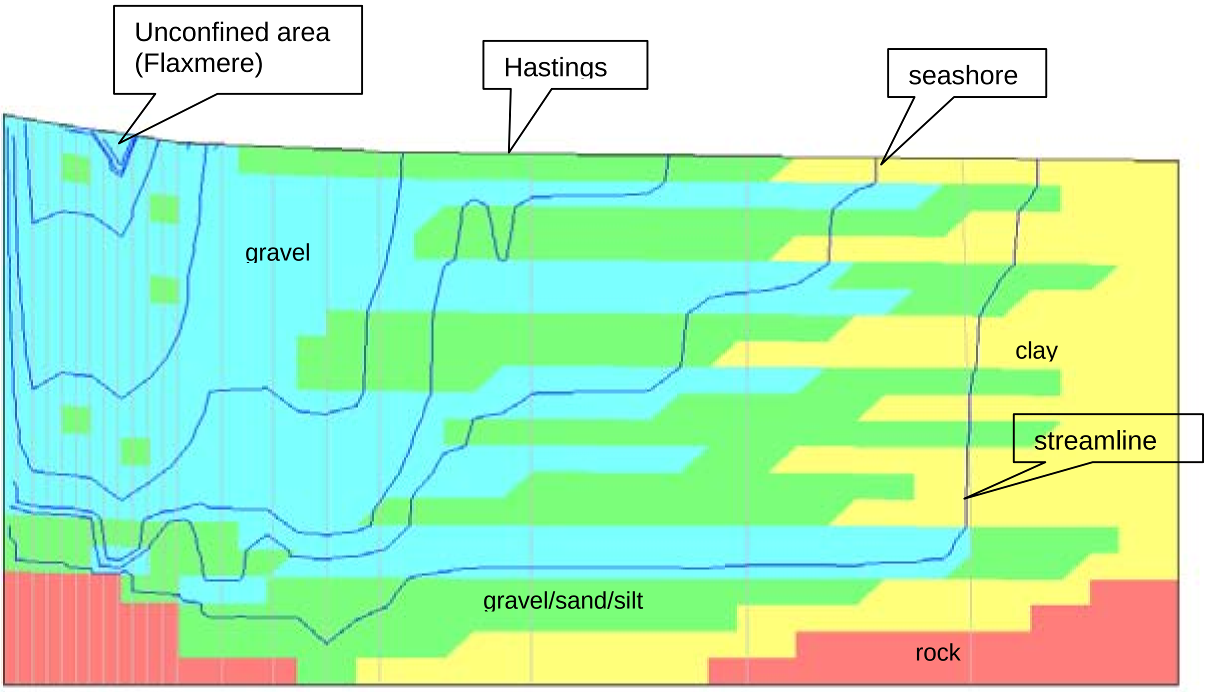

Figure 19. TopoDrive model example (scale about 1:1,00,000)**.**

4 Model design

The ground-water model was developed using MODFLOW 2000 within a Groundwater Vistas[1] software. The final model design follows several model runs to best match field data with model results, also called model calibration (chapter 5).

The conceptual model information in inserted into the mathematical model and model choices are made to suit the data entered and output required. Groundwater Vistas requires model data to be entered as consistent units. Selected units are metres and day. Model needs include:

Structure information

- layers
- elevation limits
- grid
- No-flow (inactive) boundaries

Data

- rain recharge
- surface elevation
- bottom elevation
- ground-water pumping
- aquifer characteristics
- river conductance
- river bottom and stage
- initial water levels

In this section, values highlighted are used in the ground-water model.

4.1 Structure information

The model framework, given in Table 10, includes grid configuration and area extent.

Table 10. Model framework.

Characteristic	Value
Maximum model elevation	60 metres above sea level
Minimum model elevation	400 m below sea level
Layers	1
Grid size	500 m x 500 m
Rows	52
Columns	54

4.1.1 Layers

There is one model layer. Though there are several aquifers in local detail, ground-water level data suggests one basin aquifer in basin-wide estimation. Wells with different depths at the same site have approximately the same water level (section 2.5.2).

4.1.2 Elevation limits

The maximum model elevation is 60 metres above sea level, which is the Upper Ngaruroro River area, west of Roys Hill (Figure 3). The greatest model depth is 400 metres below sea level, which is assumed to be the lowest sediment depth in Heretaunga basin.

4.1.3 No-flow boundaries

No-flow boundaries represent the full model perimeter, where little or no ground water crosses the model boundary. This includes bedrock bounds and the seashore, where little ground water extends beyond the seashore boundary (section 3.2.3).

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[1] Use of brand names in this report is for identification purposes only and does not consititute endorsement by Hawke's Bay Regional Council.

4.1.4 Grid

The model grid is every half kilometre, evenly spaced throughout the model area in a north-south, east-west orientation. This grid concentration is adequate to establish basin water balance and represent ground- and surface-water connections. The grid size allows the model to run quickly and there is not enough detailed data, such as well locations or river discharge, to warrant a smaller grid size.

The model grid includes 52 rows and 54 columns. Model extent is shown in Figure 20.

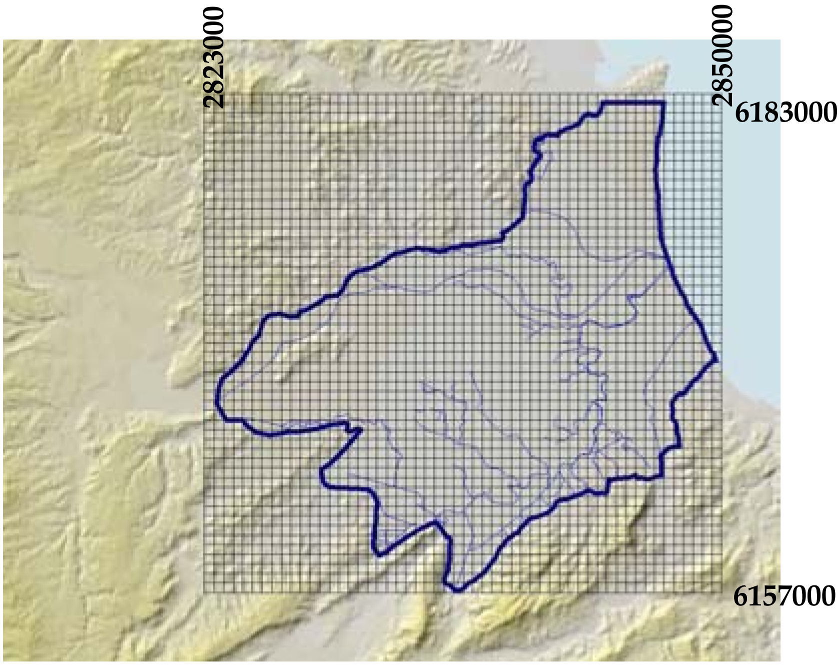


Figure 20. Model grid.

Active model cells are shown in Figure 21, with only full cells active.

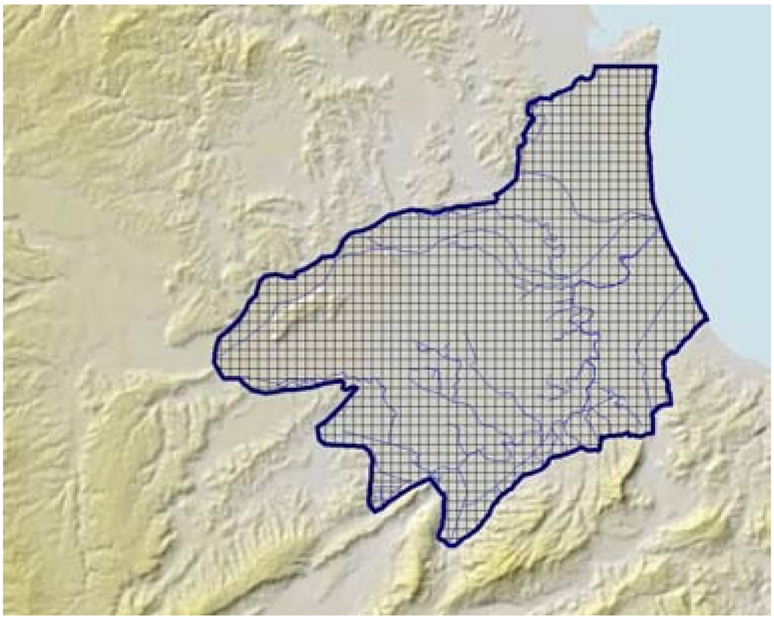


Figure 21. Active model cells.

4.2 Rain recharge data

There are three rain recharge zones that add water to ground water.

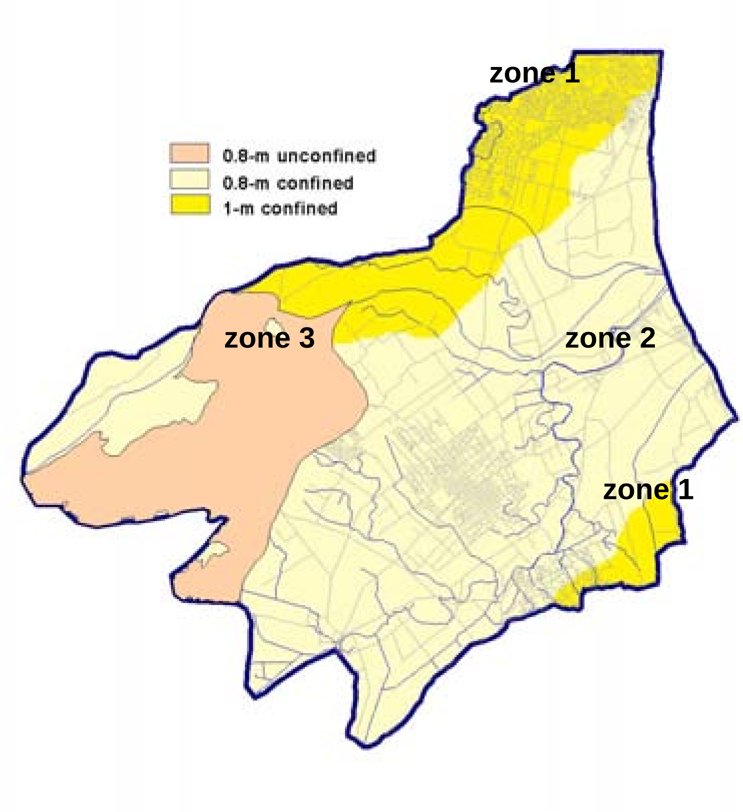


Figure 22. Rainfall recharge zones.

Table 11. Model rain recharge values.

Zone	Recharge rate[1] (m^3/year)	Recharge area[2] (m^2)	Recharge zone rate (m/d)
1	19,000,000	62,000,000	0.0008
2	50,000,000	208,000,000	0.0007
3	19,000,000	60,000,000	0.0009

[1] Table 8, [2] GIS determination

The ground-water model requires recharge to represent a recharge rate for a zone area--length/time. To report in these units, recharge rate is divided by recharge area, and then further divided by 365 days to report as m/d.

4.3 Elevation data

Surface and bottom elevations are entered to give model volume within the model perimeter. Surface elevation data was exported from ArcView into Surfer. Surfer contoured the data and the resulting file was exported to Groundwater Vistas. Groundwater Vistas will only read cell values where a contour line crosses it.

4.3.1 Surface elevation

Model surface elevations shown in Figure 23 were entered into the model as a data file, sourced from a GIS elevation database grid spaced 10-m apart.

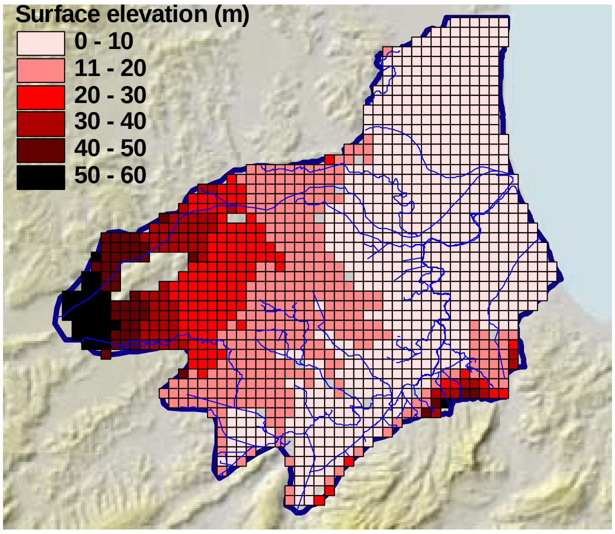


Figure 23. Model surface elevation.

4.3.2 Bottom elevation

Model bottom elevation shown in Figure 24 was established from three sources.

- Geophysical data in the Roys Hill area, western Heretaunga
- 26 wells that intercepted the basin bottom
- 3 400-m depth estimated control points to reduce middle basin anomalies

Data is given in Appendix D.

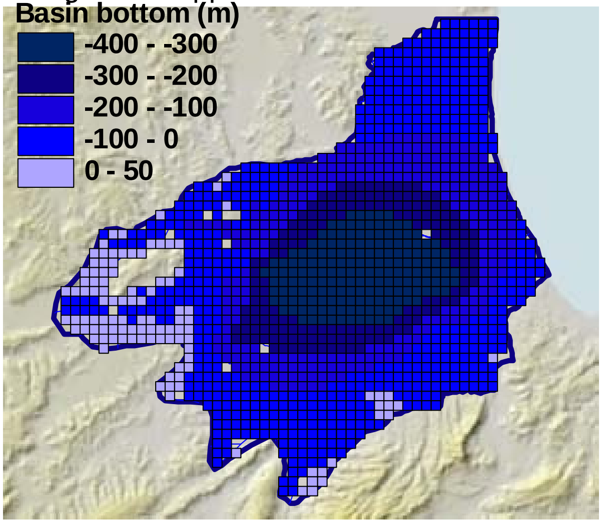


Figure 24. Model basin bottom.

4.4 Ground-water pumping data

The steady-state model uses 2004 pumping volumes for 1279 wells (Figure 17 and Appendix E). Of the 1279 pumping wells, 1152 were irrigation (estimated), 89 were industry (metered), and 38 were public supply (metered).

Pumping data was created in Excel with column headings:
- well number
- easting
- northing
- pumping volume for a year
- layer top (1 for this model)
- layer bottom (1 for this model)

The ground-water model accumulates all pumping wells within a cell and sums the pumping rate for that same model cell.

4.5 Aquifer characteristics data

Though the Heretaunga Plains consist of several hydrogeologic layers, ranging from clay to gravel, the model summarises these as one layer to simplify the result for a first step in model validation. This can be justified where the model is considered on a macroscopic scale where the one clear distinction is between basin sediment underlain and bounded by bedrock. Model layers may be added in the future as data warrants it.

4.5.1 Hydraulic conductivity

Figure 25 shows how hydraulic conductivity zones are assigned from where the Ngaruroro River recharges the ground water to the sea, where most ground water rises to the rivers rather than continue into reduced hydraulic conductivity lithology.

The maximum value underlying the upper Ngaruroro River near Roys Hill is 750 m/d and taken from tritium travel time data described in section 2.4.2. The minimum value at the seashore is 1 m/d (estimate) and represents the much-reduced hydraulic conductivity that is typical of lithology grading from greater to lesser permeability from mountains to sea--gravel to clay.

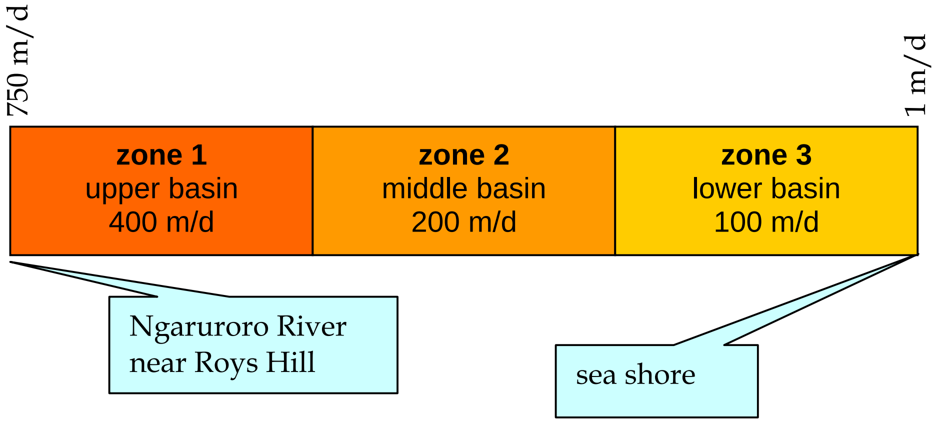


Figure 25. Hydraulic conductivity zones.

The values in Figure 25 agree, relatively, with those of the Ruataniwha ground-water basin. Phreatos (2003) assigns hydraulic conductivity values from 10 to 35 m/d in the Ruataniwha ground-water model. Because Heretaunga transmissivity values are about 13 times greater than those of Ruataniwha (WellStor database, 2004), all else being equal, relative

Heretaunga hydraulic conductivities would be about 130 to 455 m/d. The greater upper value represents the unusually permeable gravels in the unconfined area (zone 1).

Values in Table 12 are for hydraulic conductivities in all directions (homogenous, isotropic).

Table 12. Hydraulic conductivity zone values.

Zone	Hydraulic conductivity (m/day)	Comments
1	400	Unconfined
2	200	Middle basin
3	100	Lower basin

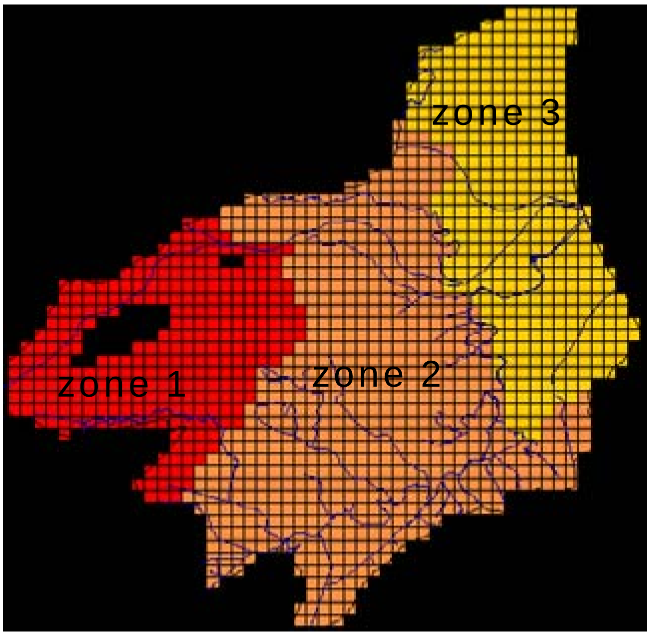


Figure 26. Hydraulic conductivity zones.

4.5.2 Storativity

Storativity is not used in a steady-state model but the values entered are for future model development. Entered values are given in Table 13. Zone 1 is the confined area (same as rain recharge zones 1 and 2 in Figure 22) and uses a typical confined storativity of 0.0001. Zone 2 is the rest of the unconfined area (rain recharge zones 3 in Figure 22) and uses a typical unconfined storativity (specific yield) of 0.1.

Table 13. Storativity and porosity.

Zone	Storativity	Specific yield	Porosity[1]	Comments
1	0.0001	0.01	0.3	Confined
2	0.01	0.1	0.3	Unconfined

[1] section 2.4.2

4.6 River data

River data entry includes riverbed conductance, riverbed bottom elevation, and river-water surface elevation.

4.6.1 River conductance

The Tutaekuri, Ngaruroro, Clive, and Tukituki Rivers are assigned river cells and river conductances. The Ngaruroro and Clive Rivers, because of their lengths, are further divided into reaches, as shown in Figure 27 where river cells approximate actual rivers.

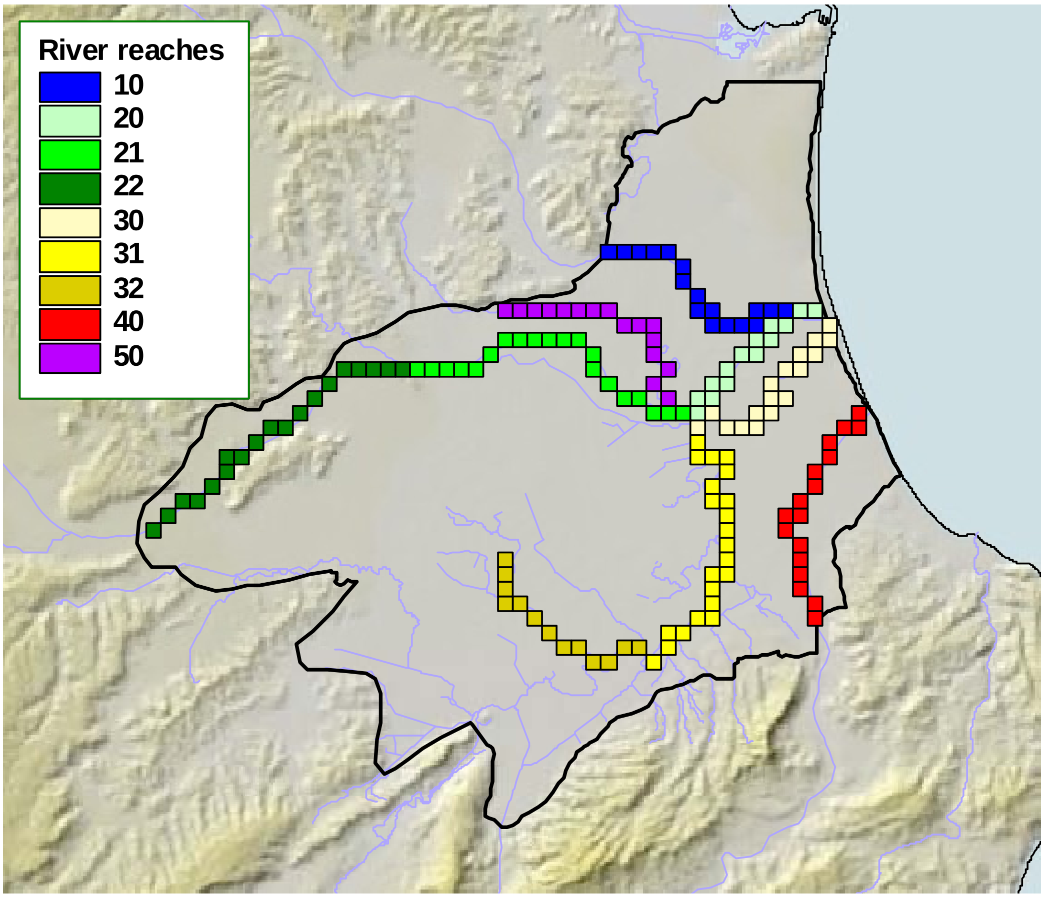


Figure 27. River reaches.

Ground water model's "conductance" is river conductance and defined as follows.

$$river\ conductance = \frac{water\ width \bullet bed\ conductance \bullet cell\ length}{bed\ thickness}$$

Individual conductance parameters may be specified, but insufficient data does not warrant it. For this reason, conductance values were estimated based on the modeller's experience and then adjusted by trial-and-error to match reality.

Riverbed conductance values shown in Figure 13.

Table 14. River conductances.

River	Reach	Conductance (m/d)	Comments
Tutaekuri	10	100	Some river water enters ground water
Lower Ngaruroro	20	100	Ground water enters river
Middle Ngaruroro	21	2,000	Some river water enters ground water
Upper Ngaruroro	22	90,000	Much river water enters ground water
Tutaekuri-Waimate	50	2,000	Ground water enters river
Clive	30	100	Ground water enters river
Karamu	31	250	Little or no ground-water exchange
Irongate	32	500	Little or no ground-water exchange
Tukituki	40	6,000	Little or no ground-water exchange

4.6.2 River bottom and stage

River losses to ground water and river grains from ground water are managed with a model river package. The package uses lowest elevation in the river cross section, estimated stream stage, and streambed conductance to determine streambed losses and gains.

River stage is assumed to be 1 metre above the streambed bottom, except for the upper Clive (reaches 21 and 22) that is assumed to be 0.5 metres above streambed bottom. Streambed bottom was determined from 309 river cross-section data for the four main rivers. Riverbed elevations was assumed to be the lowest point in each river cross section.

4.6.3 River data entry

There are three ways to enter river data--river module, stream module, or streamflow routing. The river module is used in this model because it is simple and adequate for steady-state models.

Data tables were created in ArcView and exported to Groundwater Vistas. Table headings include:

- reach (integer)
- stage (floating or double precision)
- streambed hydraulic conductivity (floating or double precision)
- stream width (floating or double precision)
- stream length (floating or double precision)
- streambed thickness (floating or double precision)
- invert, which is river bottom elevation (floating or double precision)

4.7 Water level data

Water level data is entered for initial conditions, before the model is run, and to calibrate simulated results with measured.

4.7.1 Initial water level data

Dravid and Brown’s (1997, figure 5.6) summer 1995 water level contours were entered as initial heads. Summer and winter water-level contours (Dravid and Brown, 1997, figures 5.5 and 5.6) were available but summer contours were used because the model uses average irrigation pumping. The winter contours are associated with no irrigation pumping.

4.7.2 Target well data

Average 2004 water levels (Appendix F) for Council state-of-environment wells were entered for use as target wells—water levels to match model result with actual measurement.

4.8 Ground water discharge to sea

The steady-state model assumes the seashore is a “no-flow” boundary so that there is no ground-water discharge to the sea. This assumption is based on:

1. Sea discharge is estimated to be less than 3% of basin outflow, without the ability to measure or calibrate sea discharge.
2. There is no river gain data near the seashore to refine ground-water discharge to sea.
3. There are no observation wells at sea for calibration.
4. Subsequent model sensitivity analysis (section 5.2.4) shows that removing the “no-flow” boundary would have little affect on the model.

5 Calibration

Model calibration determines how well the model results simulate field measurements, such as water level in wells and river gains and losses. Model values for such things as rain recharge and hydraulic conductivity are changed by trial-and-error to best and reasonably match measured data.

The most useful parameters for model calibrations are river conductance, rain recharge, and hydraulic conductivity. Table 15 ranks model parameters that are most affect model calibration and, therefore, warrant the most scrutiny. Though important, some parameters such as riverbed conductance are difficult to measure and are, instead, estimated by relativity.

Table 15. Model parameters prioritised.

Model parameters	Confidence	Sensitivity	Edit priority	Comments
Riverbed conductance	least	greatest	**1**	9 reaches; trial and error
rain recharge	some	greatest	**2**	3 zones
hydraulic conductivity	some	greatest	**3**	3 zones
pumping wells	some	some	4	Public and industrial metered, irrigation estimated.
bottom elevation surface	some	least	5	Little data; 3 points added to expand basin centre depth to about 400 m below sea level.
initial heads	greatest	some	6	Reliable, based on summer water levels (Dravid and Brown, fig. 5.6, p. 104)
target (monitor) wells	greatest	greatest	7	Reliable, based on 29 wells.
top elevation surface	greatest	greatest	8	Reliable, based on data, 10-m apart.

Model extremes (Table 16) represent minimum and maximum values possible for the conceptual model. These values should not be exceeded in calibrating the ground-water model.

Table 16. Extreme model variables.

Parameter	Minimum	Maximum	Comments
K (m/d)	10	1,000	silty sand to clean gravel
River conductance	50	500,000	silty drain to Rakaia River (Canterbury) type
Rainfall recharge (%)	10	50	silt to gravel land cover

5.1 Calibration values

Highlighted values in this section are those that the model results were calibrated to.

5.1.1 Rivers losses to and gained from ground water

The upper Ngaruroro River contributes about 432,000 m^3/d (Table 17) in the Roys Hill area (Figure 3)—river reach 22 (Figure 27).

Because the steady-state model is based on average annual conditions, rivers calibrations are best with October and May data, when average flow typically occurs. Summer low flows and winter high flows do not express annual average flow. Therefore, highlighted field measurements in Table 17 are the most reliable field measurements to calibrate with model simulation. Though there are only four annual river flow estimates for model calibration, other river gain and loss values given in Table 17 may be considered, qualitatively.

Table 17. Heretaunga rivers gains and losses for calibration.

River	**Model reach**[1]	**Loss (m^3/d)**	**Gain (m^3/d)**	**Comments**
Tutaekuri	10	no data	15,000	Redclyffe to Brookfields (24/09/1996)
Lower Ngaruroro	20	no data	no data	
Middle Ngaruroro	21	20,000	no data	Roys Hill to Chesterhope measurements (March, 1998)
Tutaekuri-Waimate	50	No data	87,000	SH 50 to Chesterhope flow (06/09/1972)
Upper Ngaruroro	22	432,000	none	Dravid and Brown (1997, p. 220)
Lower Clive	30	no data	no data	
Middle Clive	31	none	63,000	Karamu @ Hastings/Havelock Rd to Karamu @ Floodgates measurements (March 1998)
Upper Clive	32	none	18,000	Irongate @ Clarke's Weir to Karamu @ Hastings/Havelock Rd measurements (March 1998)
Tukituki	40	none	112,000	Tennant to Black Bridge measurement (16/11/2005)

[1] Figure 27

There is little other same-day river data to calibrate against and, where there is data, it is biased to summer or winter anomalies. Additionally, there is no river flow data in the lower river reaches because it would be tide affected.

5.1.2 Ground-water levels

Model results are calibrated with average 2004 water levels in 25 wells. (Figure 28 and Table 18).

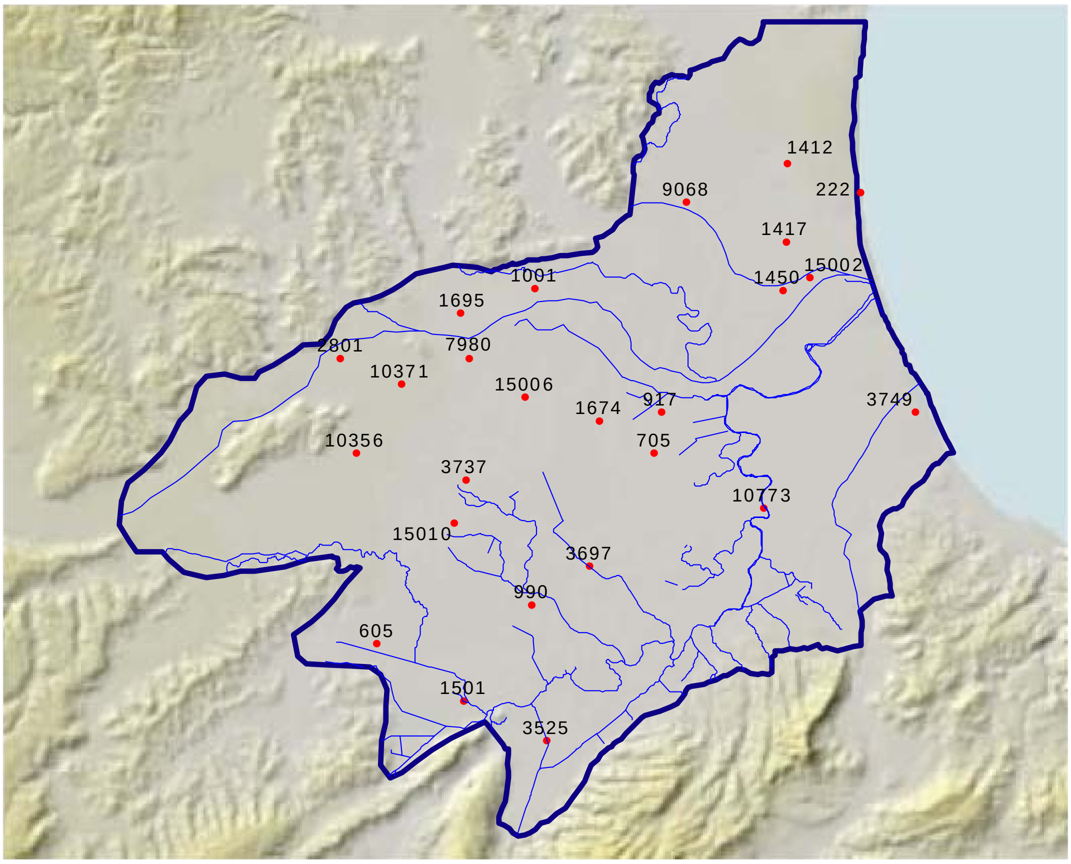


Figure 28. 2004 water-level target wells.

Wells near model boundaries are affected (constrained) by that boundary and can result in a dry model cell (calculation failure). Wells were “weighted” for model calibration, as shown in Table 18.

Model water levels are considered calibrated where they are within 3 metres of the average 2004 water levels.

Table 18. Average 2004 water levels.

Well	Weight[1]			Water level (m)
	little reliability	some reliability	reliable	
222[2]	✓			7.8
605	✓			11.5
705			✓	11.0
917			✓	11.0
990			✓	12.2
1001			✓	12.4
1412		✓		6.6
1417			✓	8.6
1450			✓	9.0
1501	✓			12.2
1674			✓	11.9
1695			✓	17.2
2801			✓	27.3
3525	✓			10.8
3697			✓	11.4
3737			✓	14.1
3749		✓		5.0
7980			✓	17.0
9068		✓		9.0
10356		✓		18.7
10371		✓		19.8
10773			✓	7.9
15002			✓	8.7
15006			✓	13.1
15010			✓	13.0

[1] Groundwater Vistas software weight values as 1 = reliable, 10 = some reliability, 100 = little reliability

[2] Well 222's actual location is outside the model boundary, because of boundary approximation. To include the well in model calibration, the model easting for well 222 (New Zealand map grid easting - model easting origin = 2846786 - 2823000 = 23786) was reduced from 23786 to 23400.

5.2 Calibration results

The steady state model simulates water levels very well and reasonably correlates with river gains and losses.

5.2.1 Model water balance

The model water balance shown in Figure 29 in is similar to the conceptual water balance developed in section 3. Table 19 summarises the differences.

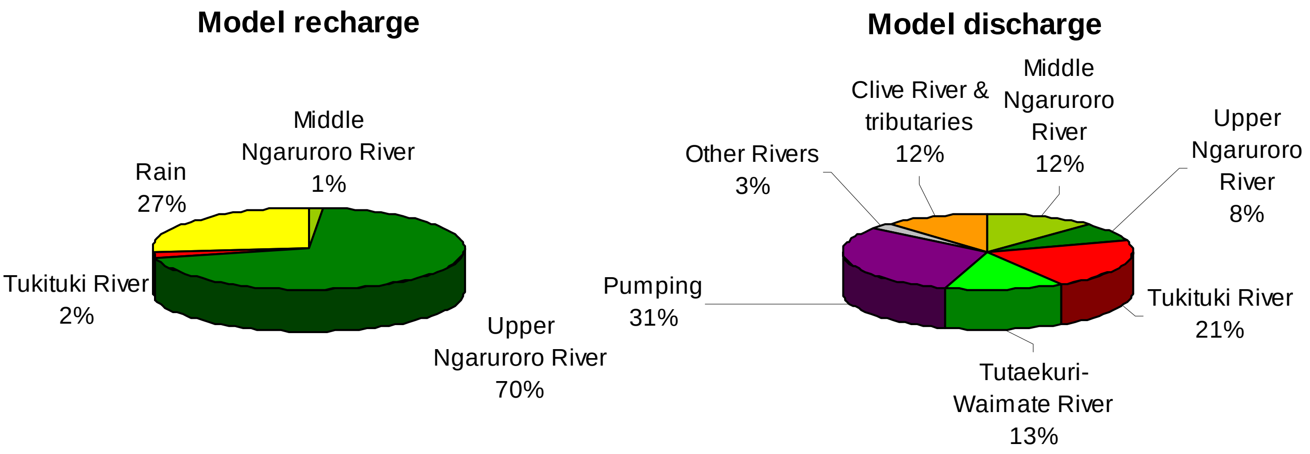


Figure 29. Model water balance.

The greatest difference for the two models is the conceptual model projected more rain input than the mathematical model. The greatest agreement of the two models is for river outputs. Though ground-water losses to the sea is projected to be 3% of the out water balance, the “no-flow” basin boundary along the sea shore causes all ground water to rise to rivers before exiting the basin.

Table 19. Model balance compared to conceptual balance.

	IN (%)		**OUT** (%)	
	concept	model	concept	model
Ngaruroro River	64	70		
Tukituki River		2		
All rivers			72	69
Rain	36	27		
Pumping			25	31
Sea			3	

5.2.2 Water levels

Model water levels and measured water levels are similar. Each red dot in Figure 30 plots a monitor well's (Figure 28) simulated water level with field-measured water level. A perfect match would plot along the blue line.

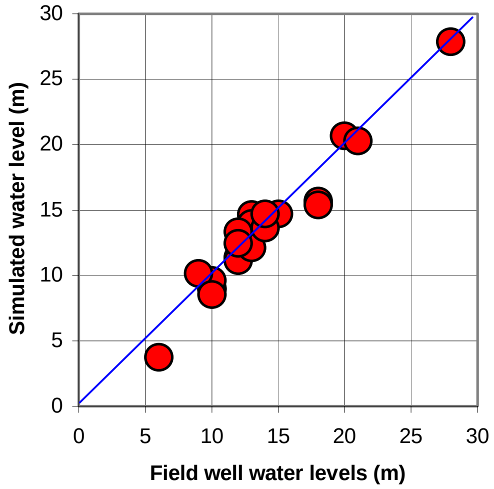


Figure 30. Model simulated compared to field measured water levels.

All simulated water levels are within three metres of measured levels and 60% are within one metre (Figure 31). Residual water level is the difference between simulated and measured. Figure 31 shows that the residual distribution is evenly distributed for values over the full range of water levels, higher to lower. This indicates that there is no bias in model simulation for the model area, Heretaunga basin.

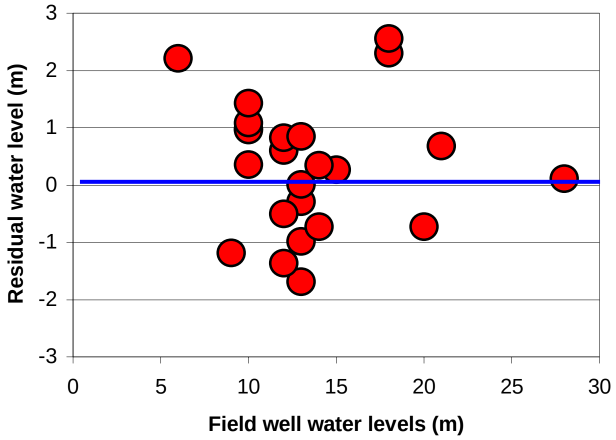


Figure 31. Model residual compared to field measured water levels.

The model has little simulation bias. The straight line in Figure 32 indicates that the data is normally distributed—a good thing. Unbiased results would show that the residual 0 residual value would correlate with 0.5 (50%) cumulative probability. Instead, the 0 residual correlates with about 0.3 cumulative probability, indicating that the model under predicts water levels by about 0.3-m bias.

A cumulative probability graph shows increasing probability to the right, as the data accumulates probability increments along the summation of all residuals. The graph data and line would extend from 0 to 1 (100%) probability except that there aren't an infinite number of well sites across the model area to provide full data correlation.

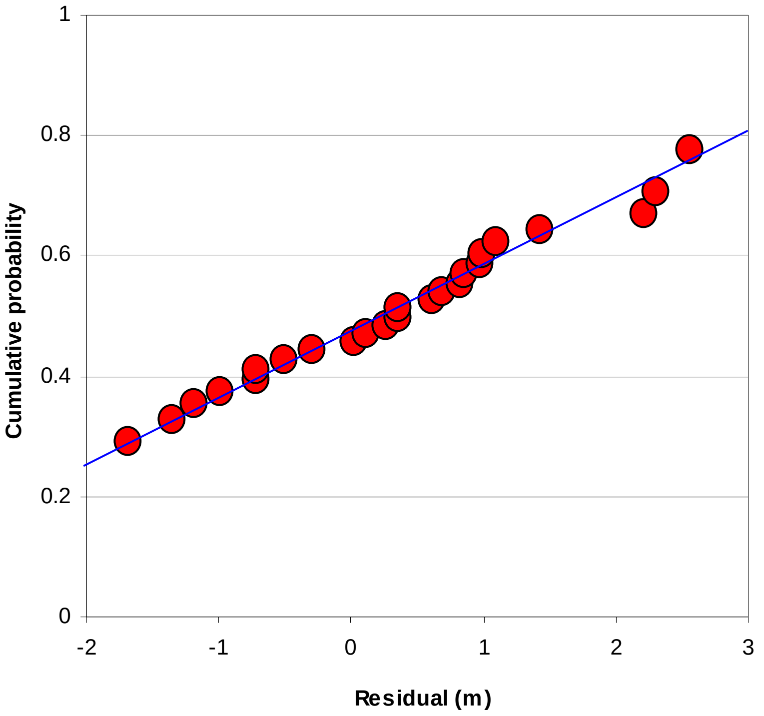


Figure 32. Normal residual probability.

Calibrated water levels show ground water moving from the left (Roys Hill) to the sea on the right. The simulated contours broadly resemble those in 1995, the last year a field survey was done (Figure 7). Figure 7 data was used as initial model water levels, to speed model solution to the final contours. Figure 33 simulated contours show greater movement toward the Tukituki River in the southeast, than the 1995 contours.

The simulated model is calibrated to 2004 annual average measurements. Whereas the 1995 contour map (Dravid and Brown, 1997) does show some ground moving northward to Napier, the 2004 simulated model shows a depression centred on the Taradale area (9-m contour) where Napier City wells have the greatest pumping rate in the Heretaunga basin.

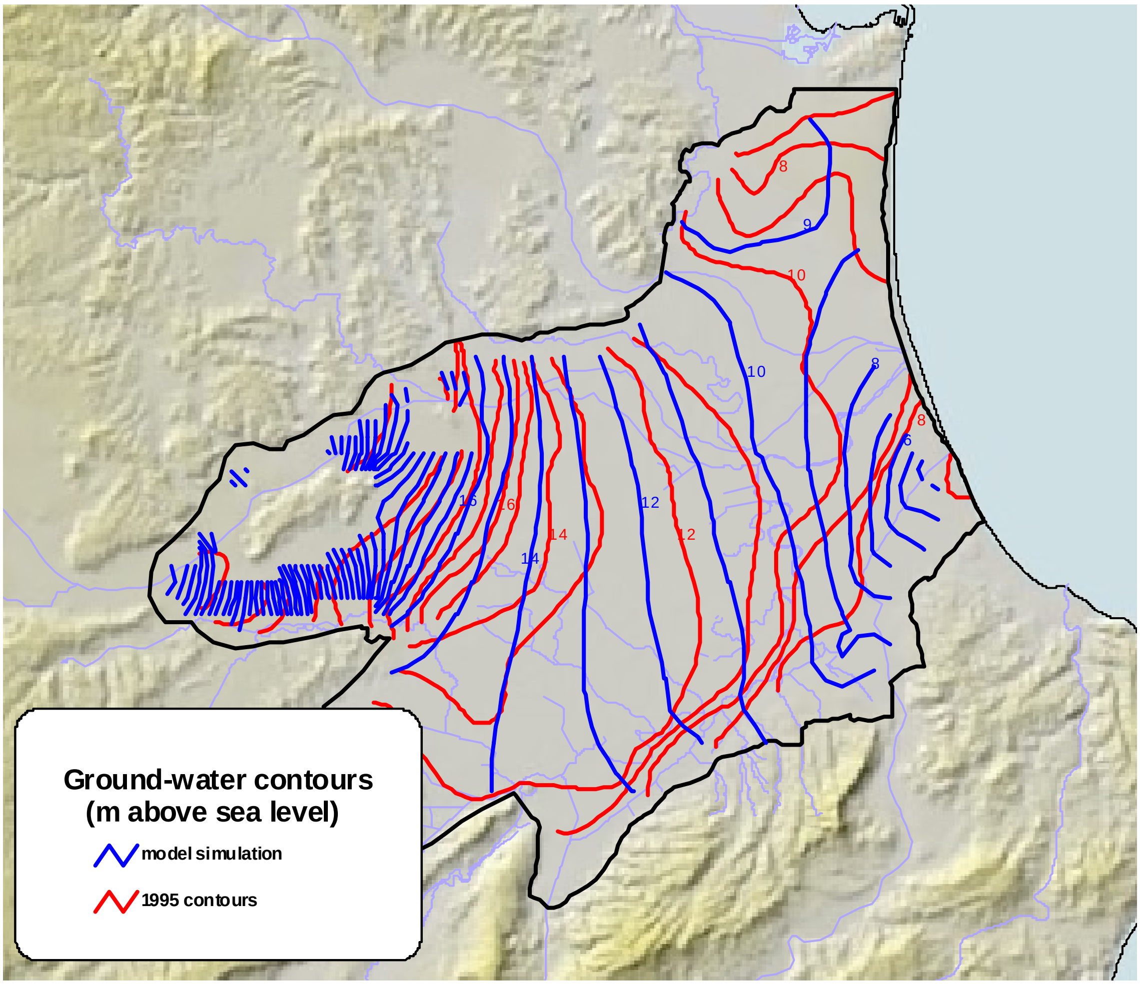


Figure 33. Simulated (2004) and measured (1995) water-level contours.

5.2.3 River gains and losses

The steady-state model overestimates most river gain and loss values but provides acceptable simulation (Table 20 and Figure 34). Measured and simulated gains and loss values are as much as about 40% different, such as for the Tukituki River. But more importantly, they are only about 10% different for the upper Ngaruroro River—the most important model and basin recharge.

River gain and loss calibration values are not as reliable as water level data and, therefore, river calibrations are secondary to water levels for calibrating the steady-state model.

Table 20. Heretaunga rivers gains and losses for calibration.

River	Model reach[1]	Measured (m^3/d)	Simulated (m^3/d)
Tutaekuri	10	15,000	12,000
Tutaekuri-Waimate	50	87,000	118,000
Upper Ngaruroro	22	-432,000	-478,000
Tukituki	40	112,000	177,000

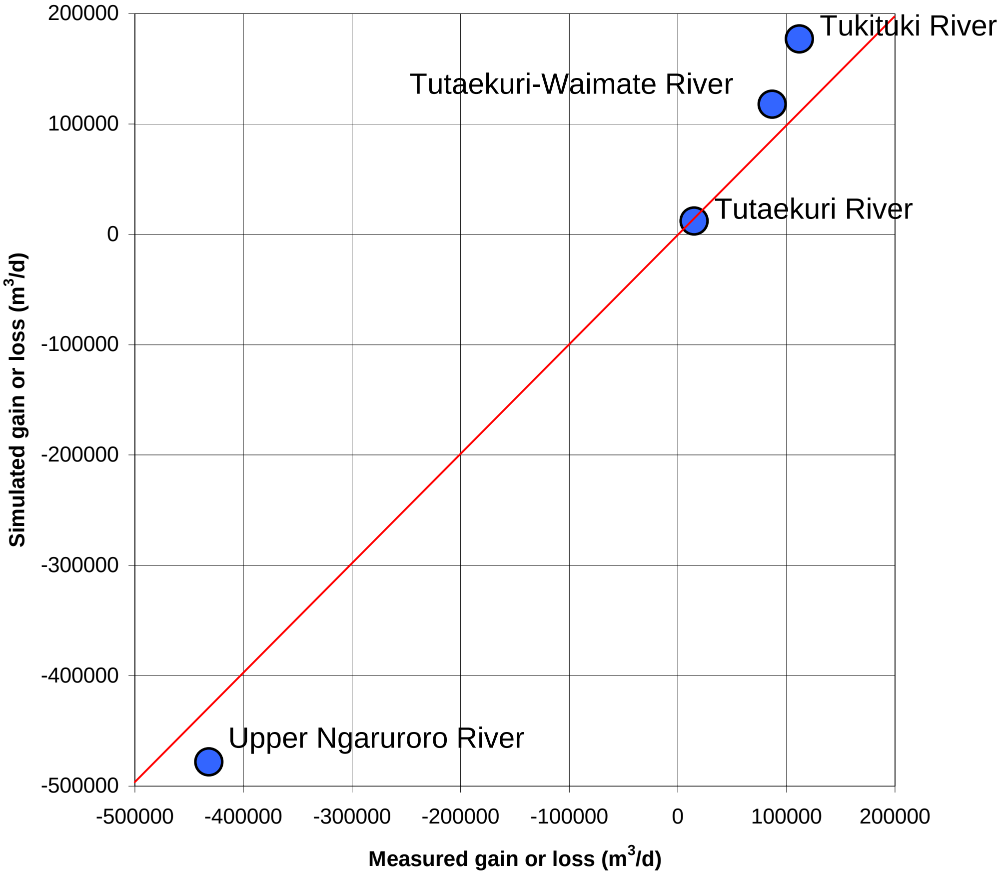


Figure 34. Simulated and measured river gains and losses.

5.2.4 Sensitivity analysis

Figure 35 shows that the steady-state model simulation is most sensitive to changes in basin permeability (hydraulic conductivity) and less affected by changes in riverbed conductance and rainfall recharge. Making the eastern model boundary a no-flow boundary has little affect on model simulation and resulting predictions.

Figure 35 compares how each model parameters relates to all simulated water levels, on average. For example, the value chosen for the model's zone 1 permeability has the greatest control over resulting basin water levels. And changing zone 1's permeability would cause the greatest water-level change. Consequently, the greatest improvement to model prediction would be to refine basin permeability, especially for zone 1 (Figure 26).

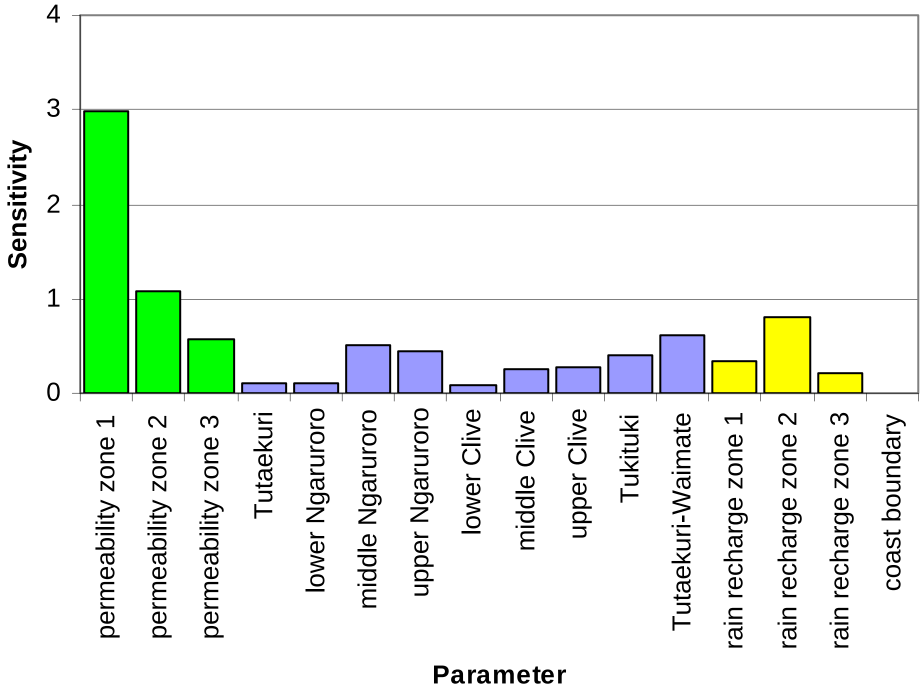
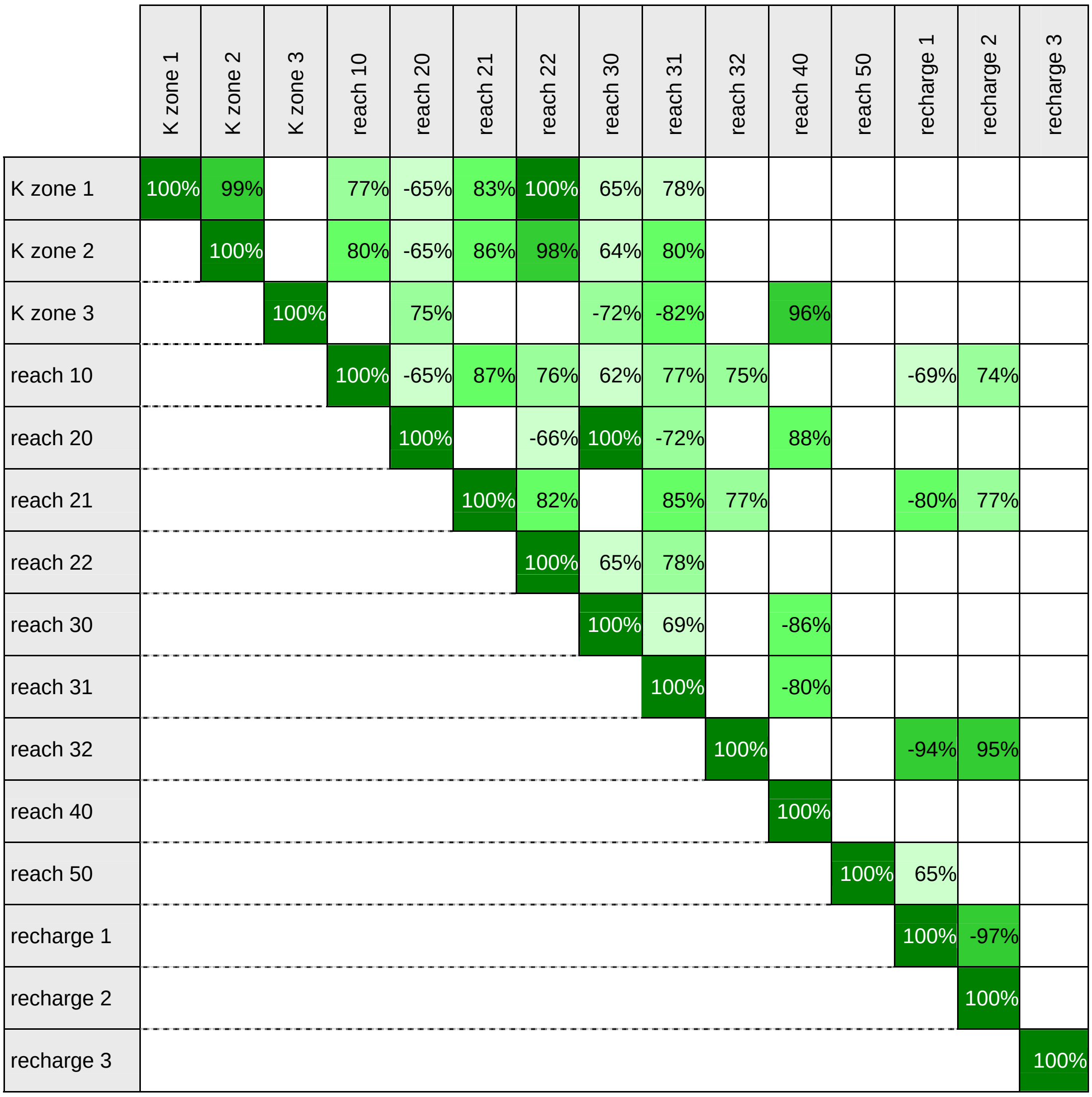


Figure 35. Model sensitivity.

Figure 36 shows how different model parameters correlate with other model parameters. For example, zone 1 permeability (K zone 1) shows 100% correlation with itself, as it should. In addition, zone 1 permeability shows a strong correlation (99%) with zone 2 permeability. This indicates that permeability zones 1 and 2 are closely related in affecting the model results. Cells lacking percent values have less than 60% correlation.



	K zone 1	K zone 2	K zone 3	reach 10	reach 20	reach 21	reach 22	reach 30	reach 31	reach 32	reach 40	reach 50	recharge 1	recharge 2	recharge 3
K zone 1	100%	99%		77%	-65%	83%	100%	65%	78%						
K zone 2		100%		80%	-65%	86%	98%	64%	80%						
K zone 3			100%		75%			-72%	-82%		96%				
reach 10				100%	-65%	87%	76%	62%	77%	75%			-69%	74%	
reach 20					100%		-66%	100%	-72%		88%				
reach 21						100%	82%		85%	77%			-80%	77%	
reach 22							100%	65%	78%						
reach 30								100%	69%		-86%				
reach 31									100%		-80%				
reach 32										100%			-94%	95%	
reach 40											100%				
reach 50												100%	65%		
recharge 1													100%	-97%	
recharge 2														100%	
recharge 3															100%

Figure 36. Model parameter correlations.

The upper row and left column in Figure 36 refer to:

- K zones 1 – 3 shown in Figure 26.
- Reaches 10 (Tutaekuri), 20, 21, 22, 50 (Ngaruroro), 30, 31, 32 (Clive), and (40) Tukituki shown in Figure 27.
- Recharge zones 1 – 3 shown in Figure 22.

Parameter sensitivity can be done for any well, as required. For example, Figure 37 shows that the greatest factor affecting well 2801's water level is the upper Ngaruroro River streambed conductance (river reach 22). This is reasonable because well 2801 is located near the upper Ngaruroro River, near Roys Hill (Figure 28).

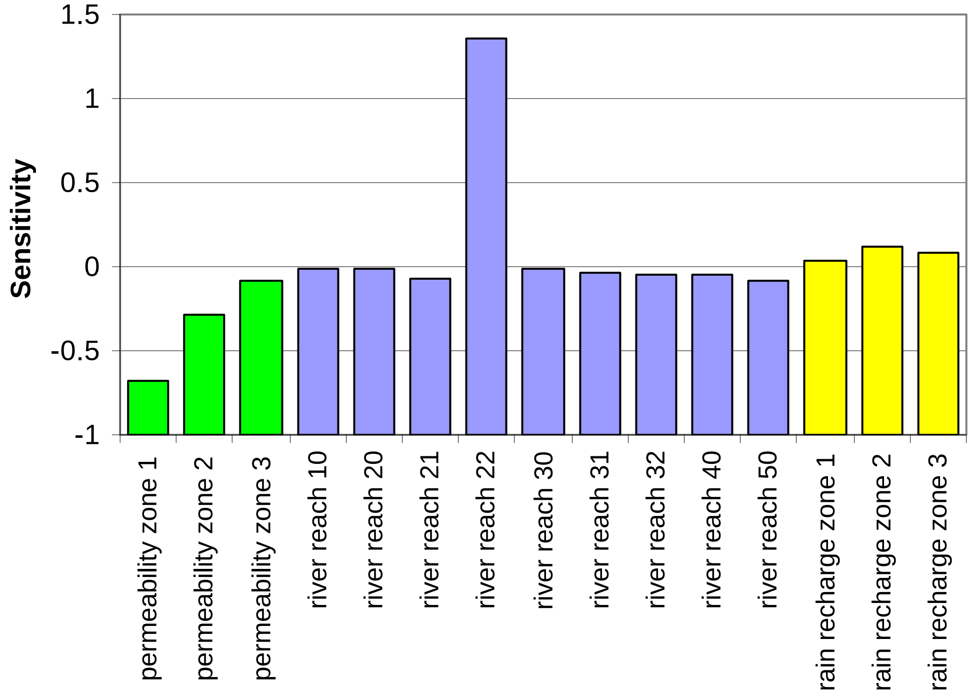


Figure 37. Relational sensitivity for well 2801 and model parameters.

Conversely, changing zone 1 permeability would least affect the simulated water level in well 2801, even though the well is located in permeability zone 1. This is because zones 2 and 3 control the ability of the model to drain zone 1 and, indirectly, control well 2801's resulting water level.

Sensitivity values in Figure 37 are scaled and non dimensional.

6 Predictions

The calibrated steady-state model can be used to predict the effects for different pumping scenarios. Two examples are given for no-pumping and double-pumping, are reviewed.

6.1 No pumping

Model simulation suggests that water levels have declined about 2 metres across the Heretaunga ground-water basin, since ground-water pumping began in the early 1900s.

In 2004, there was a ground-water depression in the Taradale area, caused by Napier City pumping (Figure 17). Water levels declined about 3 metres in the Taradale area since pumping began. There is a ground-water divide a few kilometres south of Taradale—between the two “no-pumping” 12-m contour lines.

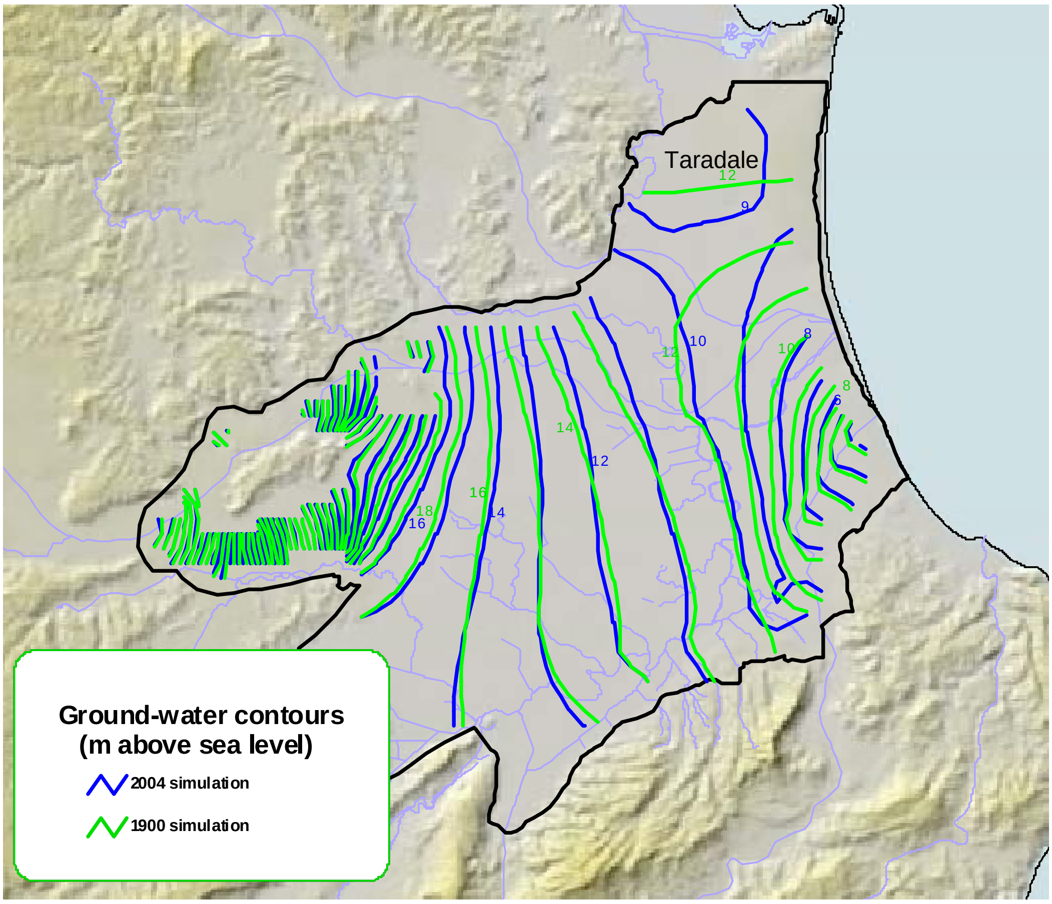


Figure 38. 2004 simulated and pre-pumping water levels.

6.2 Double 2004 pumping rate

Figure 15 shows that pumping has increased by about 15% from 1996 to 2005. If this trend continued, then pumping would again double by about 2070. This may overestimate the effects because pumping decreased from 2004 to 2005.

Doubling all 2004 pumping rates for the exiting wells suggests that water level would decrease 2 metres below 2004 levels—4 metres since pumping began in the early 1900s. There would be an increased gradient toward Taradale pumping wells and a second pumping depression area near Havelock North caused by Hastings City pumping.

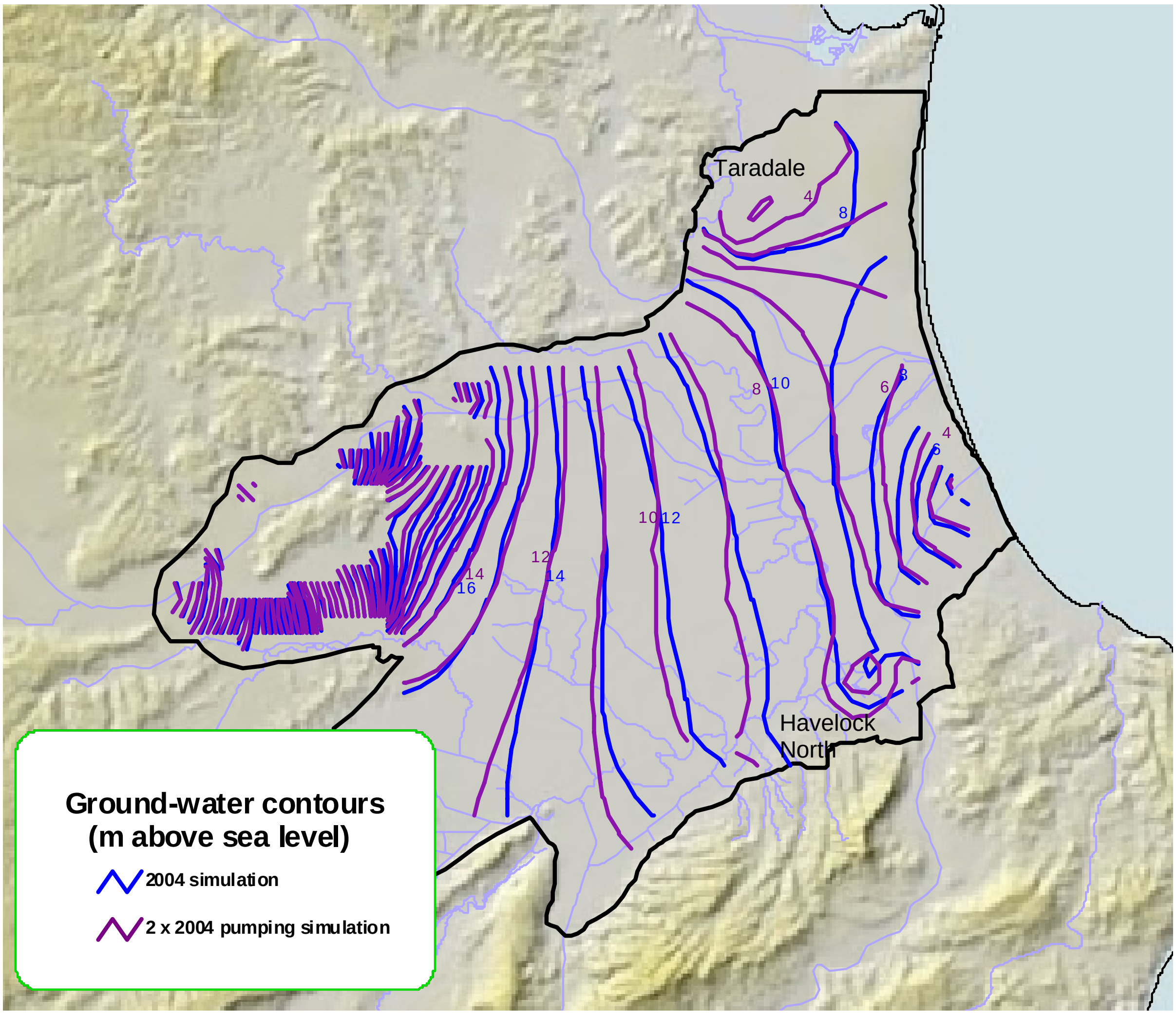


Figure 39. 2004 and double 2004 pumping-rate water-level contours.

Doubling the 2004 pumping rates would cause greatest decreased flow in the upper Ngaruroro and Tukituki Rivers (Table 21). Perhaps more importantly, rivers losing the greatest percentage of base flow would be the Tutaekuri-Waimate and Clive Rivers, both losing about 25%. The greater sensitivity is caused by less river base discharge and greatest losses from conductive streambed or proximity to pumping.

Table 21. Predicted river losses with doubled pumping rate.

River	Model reach[1]	2004 simulated gain/loss (m^3/d)	Double 2004 simulated gain/loss (m^3/d)	Decrease[2] (m^3/d)	Baseflow[3] (m^3/d)	Baseflow decrease[4] (%)
Tutaekuri	10	12,000	8,000	4,000	833,000	0.005
Lower Ngaruroro	20	13,000	10,000	3,000	4,033,000	0.03
Middle Ngaruroro	21	96,000	50,000	46,000		
Tutaekuri-Waimate	50	118,000	62,000	56,000	213,000	26
Upper Ngaruroro	22	-558,000	-624,000	76,000		
Lower Clive	30	15,000	11,000	4,000	175,000	23
Middle Clive	31	47,000	35,000	12,000		
Upper Clive	32	44,000	30,000	14,000		
Tukituki	40	177,000	102,000	75,000	1,590,000	0.5

[1] Figure 27
[2] Difference from 2004 and double-2004 simulations.
[3] Table 6
[4] Total for same-river sections divided by baseflow.

7 Recommendations for model improvement

The Heretaunga ground-water steady-state model may be improved with additional data collation and data collection.

7.1 Model updates and audits

The model should be updated every year and audited every 5 years to determine if model predictions occurred in field data, such as water levels. If in that audit, the predictions were reasonably valid, the model is determined to be valid. If the post audit determines that field measurements do not match predictions, the model should be redesigned.

7.2 Estimate river discharge to the sea.

River discharge to sea is useful to establish the basin water balance and identify where, and how much, the rivers gain from and lose to ground water.

Estimate sea discharge by correlating the main river gauging sites with the furthest site downriver. Initially, review historical records to determine if such a correlation can be established. If not, then begin discharge measurements near the sea and correlate these to the main gauging sites.

7.3 Additional same-day river gaugings

Additional river gaugings in the middle and eastern basin would help calibrate the steady-state model. River gaugings should be made when river flow is most typical, such as in October. Sites include, from greatest to least priority.

Tukituki River
Upstream: Moore Road or Tennant Road
Downstream: Black Bridge

Tutaekuri-Waimate
Upstream: State highway 50
Downstream: Chesterhope flow

Ngaruroro River
Upstream: Chesterhope
Downstream: State highway 2

Tutaekuri
Upstream: Napier-Hastings Motorway Bridge or Brookfields Bridge
Downstream: State highway 2 (Waitangi)

Clive River
Upstream: just below the Ruapare confluence with the Ruahapia
Downstream: State highway 2

7.4 Refine data

Though the model calibrates well, improvements may be made by refining values for permeability, streambed permeability, river stage, and rain recharge.

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Appendices

Appendix A
Aquifer tests in unconfined area (WellStor 2005)

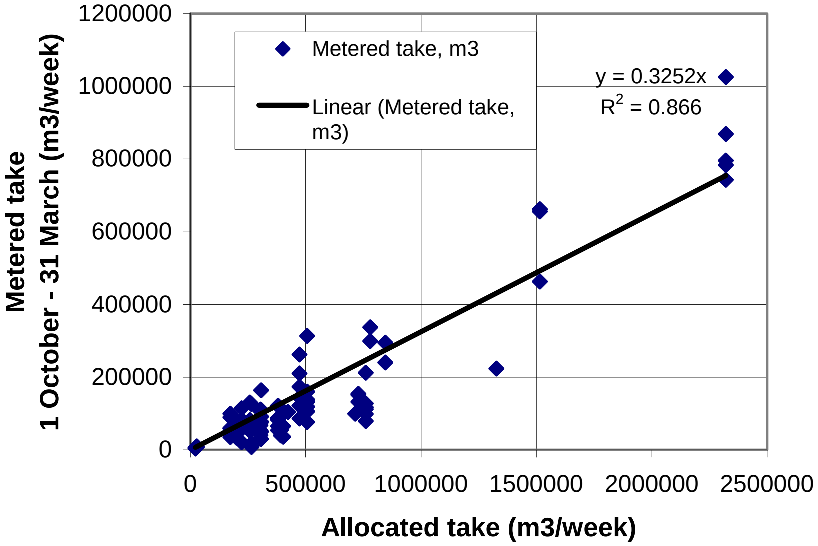
Well	Report	Maximum pumping rate (l/s)	Maximum drawdown (m)	Duration (hours)	Pumping steps	Transmissivity (m2/d)	Storativity	Test reliability
1225	30	12	1	3	4	2700		Unreliable
1247	31	12	5	3	2	860		Unreliable
1348	33			4	1	3000	0.002	Unreliable
1942	102	37	12	21	3	1440		Unreliable
2101	112	14		4	6	1900		Unreliable
2150	139	33	9	6	1	1300		Unreliable
2417	146	15	0	4	4	16000		Unreliable
3144	157	39	2	2	3	250		Unreliable
3148	156					350		Unreliable
3148	174	15		36	2	19000	0.008	Unreliable
4618	184	34	10	22	2	3160	0.0004	Unreliable
4676	194	112	10	24	2	22000	0.00032	Unreliable
4909	219	35	1	24	1	7782	0.027	Some reliability
10372	13	28		96	2	32000	0.00046	Unreliable
10372	13	28		144	2	39000	0.00091	Unreliable
15125	163	32	31	7	1	62		Some reliability

Appendix B
Rain recharge to ground water

Rain recharge to ground water (%)*	Surface lithology
1	clay
30	sand
50	gravel

*from oral communication (N. Merrick, University of Technology, Sydney, 9/12/2004)

Appendix C
Allocated compared to actual pumping in Ruataniwha (1994 - 2000)



Appendix D
Basin bottom elevations

Easting	Northing	Elevation (m above sea level))	Geophysical data	Well	Invented
2829630	6171170	-108	☆		
2829903	6171700	-75	☆		
2830240	6171870	-86	☆		
2830050	6171450	-93	☆		
2830610	6171904	-135	☆		
2830480	6171232	-85	☆		
2830900	6171520	-96	☆		
2831110	6171690	-129	☆		
2831410	6171905	-91	☆		
2832160	6172100	-105	☆		
2832744	6172170	-110	☆		
2830490	6172160	-67	☆		
2830580	6172350	-52	☆		
2830250	6168960	-32	☆		
2829820	6168651	-1	☆		
2830840	6169963	-50	☆		
2830946	6170220	-95	☆		
2831170	6170460	-52	☆		
2832160	6171280	-62	☆		
2831510	6170740	-52	☆		
2831850	6171120	-66	☆		
2830520	6169350	-14	☆		
2831020	6168690	-28	☆		
2831560	6169070	-49	☆		
2831210	6169270	-68	☆		
2831430	6169598	-35	☆		
2831930	6170010	-70	☆		
2832310	6170320	-94	☆		
2832650	6170580	-89	☆		
2832950	6170810	-113	☆		
2833200	6171150	-129	☆		
2833550	6171250	-120	☆		
2833730	6171430	-102	☆		
2831970	6169280	-65	☆		
2832990	6170040	-71	☆		
2833330	6170360	-64	☆		
2833550	6170560	-96	☆		
2832010	6168350	-38	☆		
2832210	6168680	-56	☆		
2832490	6168940	-85	☆		
2833250	6169450	-53	☆		
2833590	6169770	-60	☆		
2834000	6170030	-139	☆		
2834730	6170440	-154	☆		
2832710	6168193	-128	☆		
2834590	6169550	-310	☆		
2835080	6169890	-310	☆		
2833930	6168770	-157	☆		
2833240	6168520	-153	☆		
2832250	6167720	-20	☆		
2830690	6168370	-37	☆		
2831040	6167950	-10	☆		
2831600	6167190	-21	☆		
2832240	6166590	-56	☆		
2832890	6166065	-210	☆		
2830080	6168160	-34	☆		
2830330	6167720	5	☆		
2831410	6166540	-15	☆		
2829290	6168370	-27	☆		
2829500	6167860	-11	☆		
2829700	6167320	-3	☆		
2829810	6166820	-15	☆		
2828740	6168240	4	☆		
2829050	6167590	-6	☆		
2829060	6167080	-11	☆		
2829080	6166240	5	☆		
2828140	6167920	8	☆		
2828270	6167350	-1	☆		
2828231	6166880	5	☆		
2828350	6166216	16	☆		
2827560	6167800	10	☆		
2827600	6167210	-6	☆		
2827620	6166670	-4	☆		
2827100	6167480	7	☆		
2827146	6167180	-4	☆		
2827120	6166680	18	☆		
2826990	6166090	15	☆		
2826810	6167170	2	☆		
2826640	6166740	23	☆		
2826810	6167670	11	☆		
2826510	6167370	-2	☆		
2826210	6167070	4	☆		
2825850	6166720	20	☆		
2825550	6166275	27	☆		
2826340	6168030	20	☆		
2825760	6167790	-10	☆		
2825210	6167400	-13	☆		
2824480	6167000	7	☆		
2824010	6166710	6	☆		
2828150	6168570	24	☆		
2828680	6168840	22	☆		
2829180	6169000	21	☆		
2828210	6168270	-28	☆		
2826360	6165250	29	☆		
2831010	6166890	0	☆		
2827650	6165970	23	☆		
2834960	6173050	-80	☆		
2834580	6173280	-100	☆		
2833920	6172410	-100	☆		
2833480	6173180	-91	☆		
2833025	6173250	-75	☆		
2832410	6172960	-29	☆		
2832580	6173330	-61	☆		
2831730	6172560	-96	☆		
2831430	6173230	-82	☆		
2831490	6173550	-88	☆		
2830690	6173630	46	☆		
2830260	6173100	-22	☆		
2829050	6171930	-90	☆		
2828360	6171320	-77	☆		
2828050	6171680	-45	☆		
2827800	6170750	-40	☆		
2827550	6171040	-20	☆		
2827170	6170090	28	☆		
2827020	6170680	-12	☆		
2826170	6171360	-21	☆		
2826030	6171520	44	☆		
2826625	6169225	30	☆		
2826036	6169741	39	☆		
2825690	6170120	-16	☆		
2825330	6169190	26	☆		
2823869	6168130	-10	☆		
2823100	6167480	-9	☆		
2822850	6167880	48	☆		
2822420	6166260	27	☆		

2822260	6166960	7	☆
2822340	6167550	40	☆
2823870	6166300	80	☆
2823580	6165700	80	☆
2823873	6166300	80	☆
2825240	6166070	60	☆
2824330	6165330	60	☆
2825590	6165160	60	☆
2827690	6165370	60	☆
2828330	6165100	60	☆
2828930	6165630	60	☆
2830230	6165680	60	☆
2823400	6168250	80	☆
2824800	6168630	60	☆
2825120	6169270	60	☆
2825120	6169640	60	☆
2824560	6170160	60	☆
2824720	6170370	60	☆
2825400	6170160	60	☆
2825710	6170480	60	☆
2825760	6171500	60	☆
2826400	6172150	60	☆
2827030	6171630	60	☆
2828090	6172740	60	☆
2828580	6173100	60	☆
2828300	6172090	85	☆
2827700	6171890	100	☆
2825360	6170961	100	☆
2824760	6169511	100	☆
2824020	6168640	100	☆
2829810	6173000	125	☆
2829640	6172590	60	☆
2830260	6173430	60	☆
2831050	6174080	60	☆
2831690	6174180	60	☆
2832640	6172880	40	☆
2832860	6172590	78	☆
2832620	6172530	40	☆
2833150	6172310	40	☆
2830630	6170590	40	☆
2829640	6170550	40	☆
2830020	6170470	100	☆
2830210	6170090	100	☆
2829210	6170580	110	☆
2828950	6170530	100	☆
2828830	6170560	40	☆
2828870	6170040	130	☆
2828390	6170200	100	☆
2828020	6170190	60	☆
2827190	6169990	60	☆
2827110	6169410	100	☆
2827260	6169430	145	☆
2826810	6169160	60	☆

2826941	6168650	100	☆		
2826700	6168290	60	☆		
2826825	6168000	100	☆		
2827490	6168350	60	☆		
2827730	6168830	100	☆		
2828060	6168810	60	☆		
2829260	6169350	60	☆		
2829790	6169890	134	☆		
2829850	6169325	110	☆		
2829910	6169221	40	☆		
2830370	6169990	40	☆		
2822390	6165982	80	☆		
2822940	6168150	80	☆		
2823150	6165800	150	☆		
2826850	6168110	145	☆		
2829150	6172375	60	☆		
2828325	6172775	60	☆		
2828575	6172075	60	☆		
2832160	6171800	-132	☆		
2825880	6169200	-7	☆		
2824400	6167825	-25	☆		
2828500	6172900	25	☆		
2845000	6164400	-2		258	
2843925	6181791	-80		777	
2848181	6168562	-38		929	
2836149	6157354	-19		2147	
2846618	6165770	-21		2221	
2846762	6164875	9		2313	
2829539	6163002	10		2445	
2838100	6159700	-25		2542	
2838200	6159300	9		2557	
2835000	6160700	-11		2813	
2836679	6157407	8		2835	
2840478	6162944	14		2889	
2828332	6166400	46		3337	
2843880	6165690	-20		3482	
2829759	6166565	16		3511	
2829919	6166163	26		4191	
2846212	6163036	-45		4213	
2838796	6160492	-51		4921	
2844100	6181800	-27		10054	
2844100	6181800	-27		7638	
2843700	6181800	-50		10011	
2839800	6177900	-20		10079	
2833500	6160200	3		10311	
2832500	6173700	28		10331	
2835000	6160900	-1		10548	
2844312	6168777	-365		Whakatu 1	
2835941	6168795	-400			☆
2839910	6171388	-400			☆
2840703	6167154	-400			☆

Appendix E
2004 pumping volumes
(Ir = irrigation, P = public supply, In = industry)

Well	Easting	Northing	m^3/d	Use
4	2848100	6168000	16473.6	Ir
7	2842744	6169405	16614	Ir
21	2836200	6167700	3666	Ir
22	2846370	6164369	10569	Ir
23	2846900	6171500	7605	Ir
37	2842198	6168223	44928	Ir
38	2840400	6169900	10140	Ir
39	2837200	6168400	2925	Ir
47	2838800	6166500	25935	Ir
48	2844600	6168600	31395	Ir
49	2840900	6169800	19266	Ir
53	2844794	6177523	6591	Ir
55	2844400	6169800	7098	Ir
62	2835000	6167200	19367.4	Ir
63	2832800	6166900	8463	Ir
74	2843561	6165058	2730	Ir
75	2844100	6175200	7605	Ir
80	2832600	6166900	5452.2	Ir
82	2837123	6166010	14632.8	Ir
101	2837100	6167500	9469.2	Ir
102	2832700	6166300	7800	Ir
107	2845983	6168722	15210	Ir
112	2844800	6168200	15210	Ir
115	2832900	6167000	4680	Ir
129	2838100	6171200	6138.6	Ir
132	2843798	6177995	12675	Ir
133	2846600	6171000	25350	Ir
134	2842600	6168000	17979	Ir
136	2845600	6168000	36387	Ir
137	2843998	6167662	12519	Ir
138	2833400	6165000	5070	Ir
140	2846400	6167300	10140	Ir
142	2841336	6174342	7605	Ir
149	2845700	6165300	10140	Ir
150	2843000	6177600	4305.6	Ir
152	2840000	6170200	9239.1	Ir
153	2837500	6163000	17214.6	Ir
155	2840439	6169041	5187	Ir
157	2846300	6171600	20280	Ir
160	2836900	6168800	12480	Ir
166	2838300	6164200	998.4	Ir
179	2846300	6169000	22050.6	Ir
218	2842918	6177757	4056	Ir
221	2837419	6162634	15210	Ir
224	2844800	6175300	10140	Ir
231	2836300	6162700	62244	Ir
234	2843300	6167600	40302.6	Ir
239	2837800	6163100	8611.2	Ir
241	2843503	6168246	10561.2	Ir
242	2837000	6165300	6992.7	Ir
247	2840000	6169400	16473.6	Ir
255	2844500	6170100	2355.6	Ir
256	2848900	6169400	17472	Ir
264	2833400	6164500	11988.6	Ir
276	2841628	6162740	25350	Ir
283	2831800	6162700	50934	Ir
285	2835300	6162000	20280	Ir
288	2833000	6165600	12675	Ir
297	2840200	6170100	11403.6	Ir
301	2828700	6168400	54600	Ir
303	2843700	6177900	12675	Ir
309	2845000	6169600	50700	Ir
310	2847684	6169379	1267.5	Ir
313	2844300	6178800	10140	Ir
314	2844200	6168100	7332	Ir
317	2836600	6162700	19367.4	Ir
322	2844100	6178800	10140	Ir
325	2833000	6167200	9126	Ir
326	2832800	6167600	6357	Ir
328	2845400	6176600	10140	Ir
333	2847000	6171000	12168	Ir
347	2843075	6167982	8587.8	Ir
355	2842600	6178600	10140	Ir
366	2843500	6168800	5070	Ir
367	2841379	6162757	4547.4	Ir
368	2844600	6166100	18589.97	Ir
370	2841223	6161964	12870	Ir
373	2843893	6170251	23064.6	Ir
374	2837100	6168400	1689.948	Ir
378	2839100	6175300	20280	Ir
379	2847277	6167974	15210	Ir
381	2838000	6169600	13938.6	Ir
382	2839169	6164543	5382	Ir
385	2839500	6170200	19008.6	Ir
388	2844500	6169200	17745	Ir
389	2845800	6165492	12246	Ir
392	2833400	6161800	39292.5	Ir
397	2832700	6163000	107866.2	Ir
400	2836100	6164200	16598.4	Ir
407	2844900	6170800	11407.5	Ir
420	2839921	6164090	17955.6	Ir
421	2834300	6162700	21969.95	Ir
426	2844300	6167200	13923	Ir
427	2839800	6164200	11310	Ir
433	2844800	6164100	1482	Ir
435	2848600	6168200	33150	Ir
442	2837500	6162700	17745	Ir
452	2845500	6169800	13689	Ir
457	2837704	6162840	12675	Ir
460	2841400	6179600	8463	Ir
463	2838632	6162640	7480.2	Ir
467	2840400	6175200	12675	Ir
476	2831876	6171934	6942	Ir
495	2839900	6170400	32955	Ir
500	2845700	6171500	2535	Ir
507	2836600	6172000	10140	Ir
509	2832700	6172300	6364.8	Ir
512	2844800	6178900	8868.6	Ir
513	2832800	6164900	8112	Ir
518	2845314	6178836	2535	Ir
519	2831600	6172000	11661	Ir
522	2844200	6170000	15210	Ir
523	2843500	6173000	30420	Ir
525	2843300	6175900	7605	Ir
527	2840500	6175700	10140	Ir
529	2845900	6164700	17979	Ir
532	2841518	6163896	780	Ir
540	2839800	6175500	5070	Ir
551	2841500	6174800	25584	Ir
560	2844700	6166300	18589.97	Ir
561	2839333	6163747	10561.2	Ir
563	2834000	6172900	12729.6	Ir
565	2839878	6162190	16902.6	Ir
566	2839087	6169041	5070	Ir
568	2846900	6171100	12675	Ir
571	2838200	6170400	10140	Ir
574	2832300	6171900	7433.4	Ir
575	2841977	6168543	24570	Ir
576	2837500	6172600	20280	Ir
577	2836100	6164400	29959.8	Ir
579	2833722	6165775	58305	Ir
582	2836000	6162500	9555	Ir
600	2835400	6172400	15210	Ir
605	2831677	6163103	105019.2	Ir
615	2845000	6176200	12417.6	Ir
616	2846400	6179100	1794	Ir
617	2832200	6171900	4095	Ir
620	2836748	6172811	10140	Ir
622	2843600	6168800	7605	Ir
626	2840046	6163311	8455.2	Ir
627	2846404	6169791	10140	Ir
628	2838640	6169106	2535	Ir
630	2843900	6164800	702	Ir
633	2841804	6174255	8112	Ir

634	2848800	6168400	7542.6	Ir
640	2846209	6164119	8229	Ir
642	2834100	6164200	17491.5	Ir
643	2833800	6163700	10374	Ir
646	2843300	6169300	25818	Ir
648	2844920	6167099	14781	Ir
649	2836800	6170800	30295.2	Ir
650	2847200	6165500	2028	Ir
651	2841700	6174500	10140	Ir
653	2835400	6168100	2574	Ir
655	2842558	6172877	26613.6	Ir
659	2836000	6171700	12675	Ir
668	2835100	6163100	19110	Ir
671	2838172	6169280	8868.6	Ir
675	2837200	6173500	30420	Ir
678	2843800	6168900	25350	Ir
680	2841396	6164883	4524	Ir
681	2839591	6174906	19773	Ir
683	2844500	6169500	10140	Ir
685	2843400	6175600	15600	Ir
688	2837800	6160200	35958	Ir
694	2839100	6172700	24078.6	Ir
695	2839000	6172700	25350	Ir
698	2839511	6162857	13182	Ir
702	2834302	6168735	33345	Ir
705	2840351	6169047	3237	Ir
708	2843455	6173876	15210	Ir
710	2843600	6177500	2028	Ir
713	2848825	6168396	10140	Ir
715	2838200	6168800	2535	Ir
716	2842500	6170600	14488.5	Ir
718	2838600	6162700	2496	Ir
720	2843700	6176500	10140	Ir
724	2841806	6170642	16965	Ir
727	2836100	6169200	8463	Ir
730	2843000	6175700	22542	Ir
734	2843680	6167383	249.6	Ir
736	2831000	6171000	5577	Ir
741	2839200	6163600	19016.4	Ir
753	2847048	6170554	17745	Ir
755	2839600	6162000	4641	Ir
756	2835800	6163700	48165	Ir
757	2844000	6175600	7605	Ir
758	2844253	6177700	9633	Ir
762	2838612	6163325	10124.4	Ir
763	2845000	6174900	23969.4	Ir
764	2840915	6176290	38025	Ir
765	2836585	6168570	3369.6	Ir
771	2839800	6175000	10140	Ir
774	2844300	6177300	10140	Ir
775	2842300	6172100	5070	Ir
778	2840300	6169700	10140	Ir
782	2836800	6164700	10140	Ir
785	2837600	6164600	19016.4	Ir
786	2833000	6165200	6684.6	Ir
787	2837400	6170100	29733.6	Ir
788	2843624	6179716	5070	Ir
789	2844400	6170100	16477.5	Ir
790	2839400	6164900	1560	Ir
792	2837921	6163828	5148	Ir
793	2843772	6173934	32955	Ir
794	2844100	6176900	5701.8	Ir
795	2836400	6172800	12675	Ir
797	2837184	6167048	11099.4	Ir
798	2844700	6166100	18589.97	Ir
801	2838500	6164200	17214.6	Ir
803	2834400	6163100	93600	Ir
807	2835500	6169000	2340	Ir
812	2835300	6161600	5070	Ir
815	2841500	6170200	17487.6	Ir
816	2842783	6179204	11505	Ir
817	2842300	6165800	14781	Ir
819	2841618	6175338	27885	Ir
820	2840800	6161670	35490	Ir
824	2843427	6173791	29148.6	Ir
825	2848600	6168200	20280	Ir
827	2846840	6170705	5070	Ir
828	2843640	6168559	20295.6	Ir
829	2834674	6162333	21969.95	Ir
830	2844077	6166692	15951	Ir
831	2843470	6166518	8158.8	Ir
836	2847900	6167730	27885	Ir
837	2839600	6162300	873.6	Ir
843	2845193	6179274	3798.6	Ir
844	2835600	6174500	20280	Ir
845	2846200	6179100	8112	Ir
846	2843772	6179508	11661	Ir
849	2844900	6165400	10140	Ir
856	2838000	6171500	15210	Ir
857	2836716	6166711	10003.5	Ir
858	2841900	6169800	12246	Ir
859	2836863	6168335	1689.948	Ir
862	2837480	6169458	22815	Ir
867	2837400	6166000	15178.8	Ir
869	2845500	6167200	16497	Ir
870	2835600	6171800	32955	Ir
871	2834403	6172028	35490	Ir
874	2836200	6166500	14788.8	Ir
878	2843733	6177479	8872.5	Ir
879	2842905	6179126	12675	Ir
881	2838866	6175356	17238	Ir
883	2843061	6168959	31200	Ir
884	2836042	6166650	8611.2	Ir
885	2848600	6169600	31687.5	Ir
889	2837500	6172600	20280	Ir
891	2838900	6162500	33072	Ir
894	2833024	6167324	8970	Ir
896	2830854	6168551	16364.4	Ir
898	2843212	6166130	10420.8	Ir
899	2836700	6169800	7605	Ir
900	2839500	6164800	7277.4	Ir
903	2847579	6167483	15210	Ir
905	2841290	6162645	6419.4	Ir
906	2844014	6177393	3042	Ir
909	2841000	6178100	9126	Ir
911	2834100	6165100	7605	Ir
912	2847400	6171800	14952.6	Ir
914	2836800	6165800	8455.2	Ir
917	2840569	6170336	20022.6	Ir
924	2842523	6163048	912.6	Ir
929	2848400	6168500	10140	Ir
931	2836800	6175000	5070	Ir
932	2848800	6169700	7542.6	Ir
936	2846708	6171712	16473.6	Ir
938	2848144	6169638	5070	Ir
940	2837100	6166500	9484.8	Ir
946	2835500	6171300	17238	Ir
947	2843017	6171351	5070	Ir
949	2845300	6170300	20280	Ir
950	2838100	6158800	12058.8	Ir
951	2835700	6171400	45630	Ir
952	2832500	6171700	6341.4	Ir
953	2842200	6173400	2535	Ir
954	2839862	6168933	15210	Ir
955	2841262	6164962	2535	Ir
958	2833200	6161500	19094.4	Ir
959	2846700	6169900	760.5	Ir
962	2838717	6163517	3377.4	Ir
963	2838800	6164400	4227.6	Ir
965	2846200	6169600	10140	Ir
968	2838519	6164053	12675	Ir
970	2837000	6168300	1689.948	Ir
971	2834855	6170561	7605	Ir
972	2835998	6172579	101400	Ir
973	2847700	6168000	25350	Ir
976	2834500	6165400	8112	Ir
982	2839000	6162700	19164.6	Ir
983	2839000	6169300	4563	Ir
984	2844000	6177700	7605	Ir
992	2843425	6176230	11700	Ir
994	2836673	6165007	10530	Ir
995	2839254	6164350	4563	Ir
996	2834600	6167200	21520.2	Ir
999	2836500	6174300	8112	Ir
1000	2836700	6174100	5701.8	Ir
1001	2836630	6174183	5701.8	Ir
1003	2831800	6166000	8580	Ir
1006	2839700	6170600	13938.6	Ir
1007	2832100	6171800	6435	Ir
1008	2836700	6172100	25350	Ir
1009	2841193	6162561	1817.4	Ir
1011	2843800	6177600	6084	Ir
1013	2835500	6164100	10779.6	Ir
1017	2844300	6165700	21138	Ir

1019	2836100	6164700	8158.8	Ir
1020	2844200	6175600	15210	Ir
1021	2838299	6163326	7277.4	Ir
1023	2841000	6163700	4485	Ir
1024	2841998	6163945	1310.4	Ir
1025	2841610	6164534	1021.8	Ir
1026	2829694	6168220	32760	Ir
1027	2846526	6180308	32955	Ir
1030	2845900	6171500	23322	Ir
1031	2832500	6162300	55036.8	Ir
1033	2832051	6172167	13650	Ir
1034	2841626	6170480	17487.6	Ir
1036	2838200	6170200	6333.6	Ir
1038	2837724	6173004	55770	Ir
1040	2838270	6163710	15600	Ir
1044	2838690	6164237	8611.2	Ir
1045	2838400	6171400	15966.6	Ir
1048	2843800	6175500	3822	Ir
1051	2844300	6171100	32955	Ir
1052	2841900	6173900	2535	Ir
1053	2842113	6172056	9882.6	Ir
1058	2842684	6177748	12675	Ir
1059	2842592	6173067	12675	Ir
1062	2841900	6169600	37245	Ir
1063	2837700	6161200	19008.6	Ir
1064	2840816	6164274	34437	Ir
1065	2839654	6164422	17214.6	Ir
1066	2840200	6164000	24687	Ir
1067	2843100	6173500	10140	Ir
1068	2832700	6171800	5460	Ir
1073	2844889	6166913	10725	Ir
1074	2837600	6171500	16473.6	Ir
1075	2836900	6163500	17745	Ir
1076	2836920	6163143	15061.8	Ir
1081	2836400	6168900	3120	Ir
1082	2840600	6162300	8580	Ir
1083	2836993	6162425	21075.6	Ir
1085	2840646	6174781	12675	Ir
1088	2844760	6167269	14781	Ir
1089	2845900	6165700	13533	Ir
1090	2840526	6168651	6084	Ir
1093	2838000	6172600	32955	Ir
1094	2842116	6165015	2535	Ir
1097	2836100	6172300	13813.8	Ir
1099	2845700	6169200	5070	Ir
1100	2838100	6170000	22815	Ir
1101	2842463	6177763	9126	Ir
1102	2847100	6172100	10140	Ir
1104	2841500	6162800	10140	Ir
1105	2843200	6178900	11154	Ir
1106	2837400	6164400	10218	Ir
1108	2844700	6170600	5070	Ir
1110	2828800	6166300	21840	Ir
1111	2840222	6161212	14788.8	Ir
1114	2842068	6173479	7098	Ir
1121	2843406	6166147	10561.2	Ir
1122	2846053	6171963	7605	Ir
1123	2837100	6164400	2808	Ir
1129	2845086	6164471	22815	Ir
1130	2841879	6164188	5070	Ir
1131	2831049	6172013	25740	Ir
1133	2839700	6167300	975	Ir
1134	2837054	6165154	6992.7	Ir
1135	2843200	6173600	10140	Ir
1136	2838700	6161400	21450	Ir
1137	2835300	6164600	64545	Ir
1138	2841900	6162700	3783	Ir
1141	2842100	6170400	14488.5	Ir
1143	2840534	6169527	50700	Ir
1144	2846233	6172118	35490	Ir
1145	2844052	6165091	6747	Ir
1149	2835744	6171005	35490	Ir
1154	2846800	6167600	31200	Ir
1155	2834068	6164545	17071.08	Ir
1156	2834900	6161900	5070	Ir
1159	2836700	6167000	20280	Ir
1165	2841700	6167400	24960	Ir
1166	2845912	6178740	2535	Ir
1167	2837100	6171300	55005.6	Ir
1170	2845500	6168800	38851.8	Ir
1172	2845200	6171500	14859	Ir
1177	2841000	6169200	11661	Ir
1178	2832500	6167400	19110	Ir
1179	2840500	6161300	10140	Ir
1180	2831300	6166200	20280	Ir
1181	2834500	6170800	8268	Ir
1189	2837045	6162294	20638.8	Ir
1190	2832200	6166800	1560	Ir
1191	2829552	6168539	83811	Ir
1192	2842300	6174400	12675	Ir
1193	2842400	6174200	13182	Ir
1195	2838770	6163776	20490.6	Ir
1196	2837200	6171600	8743.8	Ir
1201	2835400	6161700	14289.6	Ir
1209	2833300	6163900	15327	Ir
1221	2838300	6162200	93600	Ir
1222	2841800	6167500	27105	Ir
1223	2836200	6172800	9633	Ir
1224	2836400	6173000	12675	Ir
1225	2828200	6167900	117000	Ir
1235	2839425	6171113	18501.6	Ir
1246	2844700	6178400	17745	Ir
1249	2845600	6171700	4102.8	Ir
1253	2839000	6163900	4227.6	Ir
1257	2835000	6170600	4056	Ir
1261	2843400	6171700	20280	Ir
1264	2848100	6168300	20280	Ir
1266	2835815	6161219	101400	Ir
1267	2841369	6162999	11817	Ir
1268	2848400	6168300	15210	Ir
1269	2834200	6170900	10530	Ir
1271	2843857	6167013	12675	Ir
1272	2841600	6174600	10140	Ir
1273	2839204	6175980	5070	Ir
1276	2839400	6163101	10561.2	Ir
1279	2844200	6171400	36246.6	Ir
1280	2844829	6164660	14196	Ir
1281	2832700	6162200	53870.7	Ir
1292	2842077	6171831	13938.6	Ir
1294	2834975	6170478	3549	Ir
1296	2837200	6166000	10756.2	Ir
1297	2836536	6159723	69708.6	Ir
1300	2841900	6167000	8931	Ir
1301	2845300	6166000	9730.5	Ir
1304	2836300	6171200	7605	Ir
1305	2844907	6178441	20280	Ir
1306	2837314	6166584	7277.4	Ir
1308	2834100	6163100	21969.95	Ir
1319	2844200	6168400	16887	Ir
1320	2842894	6164277	17261.4	Ir
1321	2847200	6173500	13938.6	Ir
1330	2841211	6163137	12043.2	Ir
1335	2839550	6175590	24570	Ir
1338	2839000	6165000	5070	Ir
1345	2844400	6169300	20280	Ir
1346	2836500	6168000	30123.6	Ir
1347	2844600	6170300	1138.8	Ir
1348	2835900	6170300	35490	Ir
1349	2832320	6167132	20670	Ir
1356	2833300	6163400	14028.3	Ir
1359	2837800	6175100	12675	Ir
1363	2842800	6178300	40560	Ir
1365	2835600	6162000	17745	Ir
1391	2842866	6176803	13306.8	Ir
1403	2840200	6176200	38025	Ir
1404	2840900	6175900	38025	Ir
1412	2844516	6178079	38025	Ir
1417	2844469	6175650	15210	Ir
1448	2832000	6169100	12967.5	Ir
1449	2830000	6168500	18330	Ir
1450	2844366	6174136	45708	Ir
1451	2837600	6171300	30420	Ir
1453	2844456	6165223	13455	Ir
1454	2836200	6161900	19476.6	Ir
1457	2843100	6168200	8619	Ir
1459	2842199	6165582	31090.8	Ir
1469	2847000	6170400	10896.6	Ir
1470	2838426	6164964	18213	Ir
1471	2843777	6165365	7800	Ir
1472	2846500	6167000	12675	Ir
1479	2842500	6166800	25350	Ir
1486	2830700	6168300	18174	Ir
1488	2829306	6166201	5850	Ir
1489	2844366	6174135	27300	Ir

1490	2838836	6173217	27495	Ir
1495	2840900	6180700	10140	Ir
1498	2846003	6164671	10140	Ir
1501	2834408	6161309	35100	Ir
1502	2847500	6167700	20280	Ir
1504	2840556	6161982	15210	Ir
1508	2839862	6164569	8408.4	Ir
1513	2842683	6165915	7394.4	Ir
1514	2840119	6162916	4563	Ir
1515	2842991	6167748	1755	Ir
1516	2840300	6175700	23322	Ir
1517	2836800	6163700	37791	Ir
1519	2835300	6164600	6454.5	Ir
1521	2836400	6172600	12675	Ir
1525	2841200	6170800	15210	Ir
1535	2835800	6172300	20280	Ir
1539	2841578	6164679	7176	Ir
1540	2846700	6172300	5896.8	Ir
1541	2842000	6173700	27885	Ir
1543	2833500	6172100	22815	Ir
1544	2833726	6164545	27885	Ir
1548	2838000	6163700	10561.2	Ir
1550	2844000	6171100	17994.6	Ir
1551	2843300	6171200	12675	Ir
1552	2832700	6161600	53870.7	Ir
1556	2833767	6173810	7488	Ir
1559	2845384	6167275	15405	Ir
1562	2844924	6170918	7098	Ir
1563	2844562	6164760	2535	Ir
1564	2846641	6172985	8275.8	Ir
1566	2842300	6170100	23673	Ir
1567	2837600	6167200	9360	Ir
1570	2836600	6163100	8611.2	Ir
1571	2842337	6168448	9126	Ir
1573	2841969	6174940	60840	Ir
1574	2840690	6170064	20280	Ir
1575	2837200	6160600	8455.2	Ir
1578	2842414	6167061	31691.4	Ir
1579	2835100	6170800	32955	Ir
1580	2842100	6174000	38025	Ir
1584	2841600	6173800	20280	Ir
1588	2841196	6163542	5678.4	Ir
1590	2842308	6164182	2418	Ir
1592	2838675	6162909	54935.4	Ir
1597	2844509	6178968	20280	Ir
1598	2841300	6170600	17745	Ir
1600	2840116	6174802	18759	Ir
1601	2838800	6172700	20280	Ir
1605	2841100	6169500	7761	Ir
1607	2836600	6173100	25350	Ir
1608	2838000	6163000	26102.7	Ir
1611	2837470	6160933	10140	Ir
1613	2837200	6166500	6809.4	Ir
1614	2842437	6165379	9516	Ir
1616	2842553	6165806	12675	Ir
1619	2842675	6176769	5070	Ir
1621	2845400	6171000	2535	Ir
1623	2842900	6172200	13942.5	Ir
1626	2835900	6173800	8236.8	Ir
1629	2843818	6165645	10140	Ir
1631	2839300	6175800	24570	Ir
1633	2844500	6178800	11910.6	Ir
1634	2843600	6167300	2808	Ir
1635	2835000	6170500	8868.6	Ir
1636	2839200	6168500	9375.6	Ir
1642	2842512	6178660	8213.4	Ir
1643	2840008	6175797	7605	Ir
1646	2845400	6169100	5850	Ir
1659	2831193	6166325	14352	Ir
1667	2839200	6174900	17745	Ir
1668	2837100	6164800	13759.2	Ir
1670	2842939	6165830	11817	Ir
1674	2838641	6170055	20280	Ir
1679	2845649	6169526	12675	Ir
1688	2842700	6173700	8619	Ir
1690	2843127	6165194	29382.6	Ir
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1693	2836800	6164500	8502	Ir
1694	2846100	6179700	11403.6	Ir
1695	2834301	6173428	5914.974	Ir
1696	2835100	6167000	18564	Ir
1698	2841850	6165450	17745	Ir
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1701	2834431	6173494	5914.974	Ir
1702	2842207	6175243	20280	Ir
1703	2833368	6174281	30420	Ir
1704	2834600	6174600	28392	Ir
1707	2840101	6169007	12675	Ir
1708	2837100	6162500	9508.2	Ir
1710	2841284	6163351	6318	Ir
1711	2838155	6173406	45630	Ir
1712	2837500	6171000	17745	Ir
1713	2840160	6175137	10140	Ir
1714	2843406	6166147	10561.2	Ir
1718	2836400	6174700	11793.6	Ir
1724	2833600	6174500	44865.6	Ir
1727	2847070	6172387	6333.6	Ir
1728	2846238	6170359	22815	Ir
1730	2844300	6164600	6357	Ir
1732	2837700	6163300	22596.6	Ir
1733	2837196	6174672	38025	Ir
1734	2842740	6174186	60333	Ir
1736	2842079	6165323	16692	Ir
1738	2836900	6173073	45123	Ir
1740	2841310	6163742	6411.6	Ir
1741	2833074	6171807	7020	Ir
1744	2833600	6163300	33384	Ir
1746	2836700	6170300	21902.4	Ir
1749	2839345	6163973	9586.2	Ir
1751	2842792	6170042	19012.5	Ir
1752	2840700	6168700	24297	Ir
1753	2842995	6164568	12675	Ir
1755	2841600	6177500	10140	Ir
1756	2845254	6166964	16458	Ir
1761	2842358	6164987	17082	Ir
1766	2844700	6171200	30420	Ir
1772	2832300	6172600	15600	Ir
1777	2836700	6171800	30420	Ir
1778	2836213	6172469	13813.8	Ir
1780	2842079	6163831	7534.8	Ir
1781	2837100	6166700	7394.4	Ir
1783	2839923	6163278	8642.4	Ir
1784	2839545	6171767	10140	Ir
1785	2838913	6171268	6084	Ir
1789	2834100	6174100	25350	Ir
1790	2836274	6168248	33540	Ir
1794	2835900	6163100	25825.8	Ir
1795	2835745	6161670	10062	Ir
1796	2844204	6164909	4212	Ir
1798	2835252	6171013	16473.6	Ir
1799	2845885	6170137	22815	Ir
1802	2833406	6171918	3042	Ir
1805	2838000	6161600	17323.8	Ir
1814	2837000	6165400	6992.7	Ir
1816	2840300	6169000	429	Ir
1819	2839936	6163465	8455.2	Ir
1823	2839295	6161908	40450.8	Ir
1824	2836123	6171448	5070	Ir
1835	2837800	6170600	20787	Ir
1843	2832639	6167782	10920	Ir
1862	2840215	6163447	21520.2	Ir
1863	2835270	6172250	22308	Ir
1865	2844690	6175052	16902.6	Ir
1870	2839100	6169200	18252	Ir
1875	2839800	6166400	15210	Ir
1884	2842016	6170593	18213	Ir
1888	2834900	6167100	16458	Ir
1890	2845097	6164922	31668	Ir
1892	2842800	6168100	6474	Ir
1893	2844200	6178900	8853	Ir
1895	2840900	6174400	27627.6	Ir
1897	2844014	6164417	10218	Ir
1899	2838762	6170125	15210	Ir
1907	2842558	6172877	10140	Ir
1908	2836800	6161800	12753	Ir
1910	2845232	6163726	17277	Ir
1916	2835805	6174354	20280	Ir
1917	2843800	6165500	14001	Ir
1919	2847700	6168200	18501.6	Ir
1926	2845595	6165902	25350	Ir
1927	2836600	6165400	10530	Ir
1928	2841200	6175800	73515	Ir
1929	2834300	6170400	10920	Ir
1933	2842796	6169137	5265	Ir

1937	2837000	6171900	18353.4	Ir
1938	2841401	6175425	10140	Ir
1942	2830828	6166567	14352	Ir
1943	2830600	6167900	107835	Ir
1950	2841600	6174300	2535	Ir
1956	2842558	6172877	16575	Ir
1964	2845700	6168200	32955	Ir
1965	2844690	6169193	8463	Ir
1967	2843035	6179161	10140	Ir
1969	2844929	6178949	20280	Ir
1970	2831800	6166300	10140	Ir
1976	2833629	6173978	20280	Ir
1983	2845600	6177800	15210	Ir
1985	2838600	6170300	2925	Ir
1988	2840200	6170500	15210	Ir
1990	2836900	6170100	30420	Ir
1993	2847600	6165200	8229	Ir
1994	2842585	6178009	12285	Ir
1995	2838000	6164200	4305.6	Ir
1996	2837600	6175100	38937.6	Ir
2000	2837626	6163516	10327.2	Ir
2001	2843746	6165825	6903	Ir
2008	2838523	6169570	17745	Ir
2011	2843685	6163672	5577	Ir
2012	2842200	6169100	3432	Ir
2016	2841938	6174616	10140	Ir
2022	2839915	6163591	11840.4	Ir
2026	2835600	6169500	20038.2	Ir
2040	2833660	6165107	11793.6	Ir
2049	2847257	6168544	25350	Ir
2057	2837540	6165258	28407.6	Ir
2058	2845626	6168586	20280	Ir
2059	2830476	6169758	12558	Ir
2065	2845349	6179612	24585.6	Ir
2092	2838112	6163966	8361.6	Ir
2093	2835900	6166700	12386.4	Ir
2097	2846987	6165076	17745	Ir
2098	2845013	6170070	14149.2	Ir
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2108	2841804	6173406	7605	Ir
2112	2841076	6165052	7605	Ir
2116	2830368	6168957	54600	Ir
2119	2843103	6177132	27885	Ir
2122	2833800	6163700	10140	Ir
2124	2847845	6171481	15600	Ir
2133	2843858	6177073	5070	Ir
2139	2842451	6172721	8619	Ir
2140	2845700	6170800	2535	Ir
2141	2835981	6172176	26613.6	Ir
2142	2834421	6171632	10140	Ir
2144	2836339	6164616	23376.6	Ir
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2150	2831109	6164883	28641.6	Ir
2152	2841126	6174936	21645	Ir
2161	2840998	6168823	2691	Ir
2164	2836759	6166151	19016.4	Ir
2165	2841169	6165005	1950	Ir
2167	2844300	6163500	12246	Ir
2178	2846800	6174100	10140	Ir
2187	2839633	6168842	20280	Ir
2188	2838465	6163290	8314.8	Ir
2201	2844426	6176989	8872.5	Ir
2202	2842188	6166630	4024.8	Ir
2203	2844100	6168400	2535	Ir
2221	2846618	6165770	20280	Ir
2229	2837500	6165200	16138.2	Ir
2237	2834500	6173400	23659.97	Ir
2240	2836600	6172700	10140	Ir
2250	2843200	6178700	7605	Ir
2253	2845700	6172800	17745	Ir
2254	2845500	6164900	121680	Ir
2260	2832643	6160615	144300	Ir
2266	2833800	6170000	3510	Ir
2267	2843900	6174600	29148.6	Ir
2273	2842660	6168316	8158.8	Ir
2275	2834902	6167629	36722.4	Ir
2282	2838074	6163433	10272.6	Ir
2285	2841600	6170200	17238	Ir
2286	2845200	6172800	20280	Ir
2287	2845700	6173400	40560	Ir
2294	2845700	6177600	14196	Ir
2300	2840579	6175255	10140	Ir
2314	2833511	6174706	20280	Ir
2315	2845600	6172600	18252	Ir
2316	2840800	6175500	10140	Ir
2328	2838935	6172989	25350	Ir
2331	2842792	6168664	2574	Ir
2332	2847900	6169900	10140	Ir
2336	2847800	6168400	10140	Ir
2346	2830400	6170400	2535	Ir
2360	2841600	6164400	2262	Ir
2362	2844800	6168600	10140	Ir
2366	2838300	6169800	22815	Ir
2371	2836100	6160500	21450	Ir
2376	2847000	6171500	10140	Ir
2385	2840300	6169300	4056	Ir
2389	2833324	6163751	5850	Ir
2391	2841600	6163900	5265	Ir
2403	2845000	6168300	20280	Ir
2405	2833252	6160504	144300	Ir
2407	2844300	6174700	55770	Ir
2416	2848443	6169245	20280	Ir
2417	2831963	6164754	21840	Ir
2420	2844300	6169900	21543.6	Ir
2425	2836400	6163600	48227.4	Ir
2430	2837700	6172200	94348.8	Ir
2432	2842340	6178150	1271.4	Ir
2433	2844200	6178600	32955	Ir
2434	2841799	6177130	9718.8	Ir
2438	2836700	6171300	20280	Ir
2444	2838500	6173000	30420	Ir
2449	2839348	6175327	5070	Ir
2457	2834400	6164700	17071.08	Ir
2459	2843000	6176200	76050	Ir
2461	2834947	6171945	40560	Ir
2468	2840200	6170700	3120	Ir
2470	2837000	6166300	12909	Ir
2473	2846000	6177600	107640	Ir
2474	2839300	6161400	9504.3	Ir
2476	2840617	6169275	1872	Ir
2479	2833500	6161300	39292.5	Ir
2512	2839357	6162580	5109	Ir
2519	2842783	6173752	20280	Ir
2525	2839769	6162848	8392.8	Ir
2538	2831700	6170100	38937.6	Ir
2540	2829300	6166700	65520	Ir
2550	2838000	6170800	9126	Ir
2552	2845600	6164500	81861	Ir
2561	2842900	6172700	7605	Ir
2562	2830767	6168418	16380	Ir
2563	2837416	6166827	15490.8	Ir
2564	2832600	6163200	35100	Ir
2569	2844400	6168800	116235.6	Ir
2572	2839000	6169200	3042	Ir
2574	2836257	6163520	36422.1	Ir
2580	2845652	6166057	11778	Ir
2582	2840800	6170000	17745	Ir
2586	2837149	6162450	11388	Ir
2588	2832876	6163916	50700	Ir
2591	2843900	6175800	20280	Ir
2594	2834100	6165400	1794	Ir
2595	2834757	6171994	10140	Ir
2599	2830700	6166500	12870	Ir
2600	2846600	6169700	9633	Ir
2602	2833300	6169600	61308	Ir
2616	2836000	6164700	10140	Ir
2628	2832400	6169700	64935	Ir
2705	2838200	6161200	21543.6	Ir
2708	2832300	6161700	35490	Ir
2710	2834700	6162200	10218	Ir
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2723	2842800	6172400	15210	Ir
2731	2836000	6168300	20865	Ir
2735	2838100	6161200	7605	Ir
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2764	2847900	6171500	15210	Ir
2777	2833800	6161300	29148.6	Ir
2787	2831985	6167718	21840	Ir
2790	2835000	6162300	15210	Ir
2795	2847900	6169600	32955	Ir

2796	2844708	6165074	12675	Ir
2797	2843000	6174000	17745	Ir
2798	2832000	6167600	15210	Ir
2799	2837800	6161900	9508.2	Ir
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2807	2846000	6173800	50700	Ir
2808	2846100	6174000	50700	Ir
2817	2838700	6162400	10140	Ir
2819	2830400	6166300	6942	Ir
2820	2832400	6171900	7410	Ir
2821	2844200	6167800	6318	Ir
2824	2839242	6162447	3603.6	Ir
2825	2842200	6174500	23571.6	Ir
2831	2833800	6172300	30420	Ir
2832	2846000	6169200	10140	Ir
2833	2844200	6172000	25350	Ir
2834	2843100	6169500	30420	Ir
2835	2836700	6157400	35490	Ir
2841	2838513	6163682	12909	Ir
2845	2847261	6170983	16473.6	Ir
2847	2841100	6163000	4960.8	Ir
2862	2844942	6170595	10140	Ir
2867	2844000	6172200	50700	Ir
2872	2834772	6163787	17071.08	Ir
2874	2830754	6168957	98280	Ir
2877	2848200	6169400	19016.4	Ir
2880	2845281	6176088	80340	Ir
2882	2839400	6176100	5779.8	Ir
2883	2835700	6174000	8236.8	Ir
2888	2837181	6161556	9820.2	Ir
2892	2844000	6177000	5701.8	Ir
2894	2835300	6163330	18720	Ir
2895	2847871	6171117	17745	Ir
2899	2840450	6162916	33337.2	Ir
2908	2845102	6179708	7605	Ir
2922	2843100	6176600	20506.2	Ir
2925	2848600	6168200	15210	Ir
2928	2839800	6171500	33711.6	Ir
2937	2844131	6177050	3042	Ir
2941	2831752	6166578	20475	Ir
2944	2841050	6162820	4547.4	Ir
2950	2831869	6164710	30638.4	Ir
2951	2831710	6165051	31691.4	Ir
2954	2845522	6166211	16887	Ir
2955	2838434	6162363	93600	Ir
2958	2842800	6173400	40560	Ir
2961	2836000	6171500	6333.6	Ir
2971	2837400	6161700	12675	Ir
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2980	2838207	6172383	7605	Ir
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2987	2846833	6167373	3404.7	Ir
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2994	2842813	6166724	27151.8	Ir
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3000	2842445	6177528	10140	Ir
3002	2836800	6166000	5389.8	Ir
3004	2845800	6171100	18501.6	Ir
3005	2841200	6169600	21840	Ir
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3027	2845917	6172833	7605	Ir
3029	2837200	6165400	5226	Ir
3030	2833600	6173700	25350	Ir
3042	2845400	6171000	7605	Ir
3043	2835800	6165200	15490.8	Ir
3050	2838380	6169988	21543.6	Ir
3054	2839224	6162311	4789.2	Ir
3055	2839400	6161800	32065.8	Ir
3056	2838354	6164630	10611.9	Ir
3065	2847900	6168200	11407.5	Ir
3068	2844933	6177588	4812.6	Ir
3069	2844950	6182110	22815	Ir
3070	2838000	6160200	13182	Ir
3095	2842229	6177246	8868.6	Ir
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3126	2836530	6169430	7605	Ir
3127	2836812	6172862	25350	Ir
3131	2830295	6168633	8970	Ir
3135	2842290	6173200	7605	Ir
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3148	2829462	6168019	50700	Ir
3153	2838830	6175140	20280	Ir
3158	2842390	6178710	17940	Ir
3160	2843170	6164920	21130.2	Ir
3162	2837890	6162620	13377	Ir
3165	2848930	6168910	16473.6	Ir
3167	2836112	6166582	6084	Ir
3184	2831645	6168136	19094.4	Ir
3185	2836680	6167790	33298.2	Ir
3193	2844290	6179250	20280	Ir
3196	2828170	6166710	5460	Ir
3197	2828139	6166761	5460	Ir
3200	2837130	6162600	15061.8	Ir
3201	2834426	6165705	8876.4	Ir
3202	2845327	6177360	91260	Ir
3205	2836780	6171110	22815	Ir
3210	2837439	6172958	13938.6	Ir
3211	2834890	6166520	15327	Ir
3214	2831342	6170154	26364	Ir
3278	2834280	6166290	16692	Ir
3302	2837890	6165410	8611.2	Ir
3317	2835590	6167480	35880	Ir
3318	2847820	6169010	20280	Ir
3319	2834890	6167420	37986	Ir
3323	2831180	6169370	253500	Ir
3325	2842800	6177030	11403.6	Ir
3327	2845191	6167808	31668	Ir
3328	2842800	6176880	13306.8	Ir
3337	2828280	6166400	151320	Ir
3339	2841082	6168787	12987	Ir
3341	2829420	6166020	39585	Ir
3356	2843772	6166244	2113.8	Ir
3362	2834750	6174130	10140	Ir
3381	2837137	6170204	7550.4	Ir
3393	2840320	6171160	19008.6	Ir
3414	2845355	6166136	9730.5	Ir
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3438	2838191	6170016	15210	Ir
3442	2844064	6169845	29655.6	Ir
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3529	2841781	6170220	8619	Ir
3530	2832281	6168034	48445.8	Ir
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3540	2843389	6178546	1326	Ir
3547	2844390	6165498	11700	Ir
3549	2837187	6172925	25350	Ir
3552	2843148	6178158	50700	Ir
3553	2840652	6176293	53235	Ir
3556	2842292	6176908	4368	Ir
3566	2842971	6175572	35490	Ir
3572	2842377	6170455	12909	Ir
3580	2842802	6165274	36582	Ir
3601	2834414	6161612	21060	Ir
3604	2830415	6170362	3634.8	Ir
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3616	2839869	6163034	8424	Ir
3624	2842978	6179370	15210	Ir
3646	2835856	6165637	70761.6	Ir
3654	2826820	6166879	64974	Ir
3655	2847185	6165729	58141.2	Ir
3691	2833003	6173721	10771.8	Ir
3696	2836328	6170476	10140	Ir
3703	2844550	6177910	11403.6	Ir
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3705	2844505	6165303	15834	Ir
3712	2843883	6166654	5460	Ir
3713	2836710	6167229	18213	Ir
3716	2839262	6165593	3042	Ir
3735	2836327	6167545	31200	Ir
3756	2834361	6168111	66315.6	Ir
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3759	2833321	6173161	10140	Ir
3760	2833551	6168370	24055.2	Ir
3769	2835903	6169242	19500	Ir
3842	2829745	6166679	27300	Ir

3851	2835130	6164072	17071.08	Ir
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3897	2846356	6178340	48165	Ir
3898	2836238	6160187	20280	Ir
4029	2845710	6171426	9882.6	Ir
4034	2833579	6171744	9976.2	Ir
4044	2835492	6165541	120120	Ir
4051	2843183	6175583	10140	Ir
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4075	2843682	6164306	702	Ir
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4088	2824639	6166538	81900	Ir
4092	2830103	6167982	16715.4	Ir
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4139	2830573	6171469	71073.6	Ir
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4169	2836716	6166706	10003.5	Ir
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4178	2831753	6167393	40170	Ir
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4191	2829919	6166163	7020	Ir
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4202	2834964	6163744	17071.08	Ir
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4217	2841777	6169099	8560.5	Ir
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4303	2832885	6170193	25818	Ir
4327	2834567	6172078	49436.4	Ir
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4347	2844752	6163314	1965.6	Ir
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4371	2838993	6161172	25248.6	Ir
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4423	2831874	6169608	873.6	Ir
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4638	2836680	6164868	5460	Ir
4640	2836143	6170024	21715.2	Ir
4676	2833401	6168438	93600	Ir
4690	2830946	6170811	33430.8	Ir
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4739	2830616	6170849	29936.4	Ir
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4898	2836525	6171788	14983.8	Ir
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4921	2838796	6160492	39000	Ir
4927	2837247	6162080	19016.4	Ir
4947	2845855	6179515	19476.6	Ir
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4986	2844025	6176403	41067	Ir
5015	2846913	6166291	26223.6	Ir
5045	2840269	6175054	16481.4	Ir
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5067	2839037	6162399	3034.2	Ir
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6449	2836600	6169900	23571.6	Ir
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6511	2843949	6164883	10530	Ir
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7034	2833500	6171500	4547.4	Ir
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7655	2836800	6169200	24180	Ir
8102	2834700	6174100	17745	Ir
8148	2835531	6170767	10140	Ir
8194	2835680	6166918	33384	Ir
8243	2834700	6167500	23002.2	Ir
8265	2835100	6166700	17994.6	Ir
8351	2842086	6164456	8455.2	Ir
8355	2838500	6161200	22183.2	Ir
8358	2836585	6161860	62244	Ir
8360	2834394	6169934	18174	Ir
8364	2845600	6169000	22050.6	Ir
8365	2844286	6166802	14781	Ir
8366	2834600	6167400	7277.4	Ir
8367	2836200	6167900	11840.4	Ir
8368	2838300	6161100	7605	Ir
8370	2833300	6163700	5850	Ir
8372	2836800	6165100	10530	Ir
8373	2835900	6164800	25100.4	Ir
8374	2835900	6163200	36422.1	Ir
8375	2833542	6170174	13689	Ir
8378	2842003	6174255	10140	Ir
8379	2841700	6174700	15210	Ir
8382	2837900	6163100	26102.7	Ir
8384	2834300	6173600	16224	Ir
8385	2842800	6168200	7371	Ir
8388	2843662	6164557	14488.5	Ir
8389	2841839	6174030	16458	Ir
8390	2839400	6161400	9504.3	Ir
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8396	2840800	6164800	25357.8	Ir
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8407	2837000	6163300	4422.6	Ir
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8416	2839400	6170600	7605	Ir
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8422	2845700	6168400	22815	Ir
8424	2842200	6169500	8560.5	Ir
8425	2837100	6169600	3042	Ir
8427	2844871	6165568	11388	Ir
8432	2837900	6171600	5070	Ir
8447	2838900	6161000	17347.2	Ir
8448	2841500	6174100	7605	Ir
8456	2833100	6166900	6240	Ir
8457	2843500	6171500	21294	Ir
8459	2831100	6164200	105019.2	Ir
8460	2841200	6175300	10140	Ir
8462	2843965	6165379	7800	Ir
8464	2842100	6173400	1770.6	Ir
8470	2835200	6170600	8619	Ir
8474	2838216	6169167	12675	Ir
8478	2835100	6171100	16465.8	Ir
8506	2833300	6167200	8611.2	Ir
8514	2831700	6169600	22035	Ir
8528	2834100	6171300	43095	Ir
8534	2843300	6171300	12675	Ir
8535	2837900	6173500	13938.6	Ir
8540	2836200	6168600	15795	Ir
9005	2844000	6167400	7878	Ir
9006	2842021	6165014	5070	Ir
9007	2844137	6166218	8241.948	Ir
9008	2833800	6161100	29148.6	Ir
9014	2835400	6164800	14562.6	Ir
9018	2834000	6160900	40435.2	Ir
9019	2841800	6172100	10140	Ir
9020	2846800	6170900	13938.6	Ir
9022	2834800	6160900	18447	Ir
9024	2838200	6170600	20280	Ir
9027	2835000	6164200	10140	Ir
9030	2843960	6167500	7995	Ir
9037	2843587	6165298	12558	Ir
9043	2838870	6163339	9898.2	Ir
9055	2839600	6163200	4438.2	Ir
9056	2838300	6170300	15210	Ir
9058	2840144	6169925	31687.5	Ir
9059	2838100	6170600	17745	Ir

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9061	2839668	6162098	21949.2	Ir
9063	2837300	6162100	12675	Ir
9065	2848400	6168000	11762.4	Ir
9067	2835962	6166237	49171.2	Ir
9072	2842400	6167900	6084	Ir
9086	2833200	6166900	3276	Ir
9100	2846300	6178400	10140	Ir
10057	2846100	6177000	17940	Ir
10298	2831100	6164500	105019.2	Ir
10469	2837500	6163500	10272.6	Ir
10513	2837800	6164100	8611.2	Ir
10518	2837700	6160800	10140	Ir
10519	2838500	6160700	62875.8	Ir
10574	2836900	6165500	22772.1	Ir
10591	2838000	6164400	27970.8	Ir
10592	2837700	6164500	19016.4	Ir
10595	2837000	6165700	22772.1	Ir
10597	2836500	6164500	10561.2	Ir
10625	2838800	6164800	8190	Ir
10627	2836000	6162200	9555	Ir
10849	2848000	6171200	3166.8	Ir
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-68	2839985	6166060	1255295	P
-67	2839145	6168875	279955.6	P
-66	2839086	6168946	279955.6	P
-65	2839040	6168906	279955.6	P
130	2839194	6168813	279955.6	P
439	2843776	6166107	65159	P
469	2840076	6165932	1255295	P
472	2841921	6178720	734201	P
473	2844511	6170447	41762	P
480	2841040	6178391	201006	P
542	2846363	6172370	49809	P
766	2839926	6166147	1255295	P
872	2840344	6177098	58044	P
897	2835766	6168199	21249	P
1151	2846620	6177580	4608	P
1171	2839871	6166224	1255295	P
1302	2839818	6166295	1255295	P
1329	2845145	6164998	815518	P
1389	2842048	6179482	808754	P
1572	2838361	6168060	81861	P
1658	2846610	6172990	37497	P
1765	2838912	6168806	279955.6	P
1905	2835103	6161066	4428	P
1998	2841570	6177913	2799752	P
2106	2845117	6164977	242323	P
2390	2843324	6179241	201811	P
2577	2844634	6177134	55456	P
3253	2834004	6168595	1509499	P
3506	2841125	6161660	2986	P
3619	2836134	6159988	13694	P
4144	2841390	6177111	2456312	P
4151	2844946	6164825	2114847	P
4219	2841364	6166183	263826	P
4595	2841297	6178066	1131532	P
4671	2844053	6180574	1305594	P
6152	2838979	6168864	279955.6	P
8531	2833183	6173539	8084.5	P
10334	2833190	6173547	8084.5	P
119	2831514	6172178	133376	In
195	2835468	6162194	3638	In
235	2842942	6170565	876533	In
517	2840133	6166565	16759	In
594	2831896	6172198	2622	In
665	2841391	6168534	13240	In
709	2843954	6170649	439	In
709	2843954	6170649	219396	In
848	2841363	6168631	131537	In
866	2835690	6169899	47683	In
886	2841555	6168582	203666	In
886	2841555	6168582	233457	In
943	2840292	6167262	1038250	In
997	2831756	6172434	62436	In
1022	2843630	6170420	380604	In
1098	2845346	6164441	4667	In
1109	2841702	6168799	4138	In
1164	2834891	6170231	188643	In
1254	2840447	6167338	1685090	In
1258	2843424	6169900	7658	In
1259	2843549	6170042	7378	In
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1641	2841135	6168173	206883	In
1722	2846410	6177620	1538096	In
1751	2842900	6170100	36796	In
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2159	2836300	6165900	54992	In
2418	2840307	6167182	210960	In
2451	2840347	6167361	281720	In
2453	2836496	6169511	110395	In
2544	2837193	6169096	251647	In
2811	2844262	6170682	56015	In
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3797	2843855	6170578	439	In
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3798	2843837	6170565	439	In
3798	2843837	6170565	219396	In
3799	2843818	6170551	439	In
3799	2843818	6170551	219396	In
3800	2843804	6170541	439	In
3800	2843804	6170541	219396	In
3801	2843862	6170614	439	In
3801	2843862	6170614	219396	In
3802	2843926	6170737	2623	In
3802	2843926	6170737	439	In
3802	2843926	6170737	1543	In
3802	2843926	6170737	92982	In
3803	2843788	6170720	2623	In
3803	2843788	6170720	439	In
3803	2843788	6170720	1543	In
3803	2843788	6170720	92982	In
3804	2843765	6170693	2623	In
3804	2843765	6170693	439	In
3804	2843765	6170693	1543	In
3804	2843765	6170693	92982	In
3805	2843754	6170728	2623	In
3805	2843754	6170728	439	In
3805	2843754	6170728	1543	In
3805	2843754	6170728	92982	In
3806	2843779	6170729	2623	In
3806	2843779	6170729	439	In
3806	2843779	6170729	1543	In
3806	2843779	6170729	92982	In
3807	2843686	6170713	439	In
3807	2843686	6170713	1543	In
3807	2843686	6170713	92982	In
3810	2843990	6170800	439	In
3810	2843990	6170800	1543	In
3811	2844030	6170752	439	In
3811	2844030	6170752	1543	In
3812	2843962	6170796	3617	In
3816	2843820	6170380	2029220	In
3878	2834912	6170138	41116	In
4274	2835498	6162213	4247	In
4376	2841345	6168348	179802	In
4596	2842929	6170610	876533	In
4767	2844266	6170686	56015	In
4906	2843860	6170496	137000	In
4906	2843860	6170496	100936	In
9040	2845160	6171050	24533	In
9071	2838122	6159024	4174	In
15155	2841423	6168785	135	In
15156	2840469	6167348	6200	In
15157	2840347	6167405	52966	In
15241	2840361	6167359	69678	In

Appendix F
2004 average water level

Well	Easting	Northing	water level (m above sea level)
222	2846786	6177188	9.2
605	2831677	6163103	12.6
705	2840351	6169047	12.1
917	2840569	6170336	11.7
990	2836519	6164318	13.4
1001	2836630	6174183	12.8
1412	2844516	6178079	9.7
1417	2844469	6175650	9.7
1450	2844366	6174136	9.9
1501	2834408	6161309	13.4
1674	2838641	6170055	12.9
1695	2834301	6173428	17.7
1703	2833368	6174281	19.0
2801	2830517	6172020	27.8
3525	2836995	6160097	12.5
3697	2838342	6165518	12.4
3737	2834452	6168216	14.9
3749	2848524	6170326	6.5
7980	2834578	6172026	17.6
9068	2841366	6176871	10.0
10356	2831027	6169052	19.5
10371	2832439	6171204	20.5
10496	2845092	6164640	8.0
10773	2843756	6167354	9.0
15002	2845228	6174527	9.9
15004	2829801	6166372	23.3
15005	2830250	6170833	26.5
15006	2836313	6170794	14.1
15010	2834092	6166866	14.1