Development of a groundwater monitoring network in the East Coast Holocene alluvial areas

C. Tschritter
P. Murphy

P.A. White
M. Moreau

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BIBLIOGRAPHIC REFERENCE

Tschritter, C.[1]; White, P.A.[1]; Murphy, P.[2]; Moreau, M.[1] 2016. Development of a groundwater monitoring network in the East Coast Holocene alluvial areas, *GNS Science Report* 2016/39. 36 p.

[1] GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo 3352, New Zealand
[2] Gisborne District Council, PO Box 747, Gisborne 4010, New Zealand

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ABSTRACT

Gisborne District Council (GDC) and GNS Science jointly undertook a review and update of information available for the Holocene East Coast alluvial areas (ECAs), excluding Poverty Bay Flats, for the Gisborne region. The aim of this review was to: identify data gaps and provide recommendations regarding further data collection and groundwater monitoring to inform GDC's sustainable management of these areas, in the context of the National Policy Statement for Freshwater Management and increased interest from the community. This work was funded through an Envirolink medium advice grant, and built on previous collaborative work between GDC and GNS Science, which identified twelve ECAs that potentially host aquifers. To date, no groundwater monitoring activities have been undertaken within any of the ECAs.

Geological (GDC bore records, QMAP), hydrological (river gaugings, wetland and spring locations), soil, and land use datasets were collated and reviewed to consider the aquifers' potential. The geological data review resulted in an update of the 2012 ECA boundaries; and for five of the ECAs (Pakarae, Wharekahika, Muriwai, Uawa and Waiapu), sub-divisions of up to three zones were developed as proposition for management purposes. To improve the conceptual understanding of the ECAs, recharge mechanisms and connections between the ECA and potential adjacent aquifers were also investigated. ECA boundaries, land use and soil data were used to investigate hazards that may have a negative impact on groundwater quantity and quality within the ECAs, e.g., sea water intrusion, or contamination from land use activities. Water budgets were calculated for all ECAs to estimate the amount of groundwater that is potentially available for allocation. Using the estimated groundwater available for allocation (GAA), the possible allocation rate (PAR) for groundwater was calculated for each area. Due to the lack of data (e.g., synoptic gaugings), the water budgets had to be simplified, which also had uncertainty implications for the calculated PAR.

Identified data gaps include: systematic recording of well depth and lithological information; borehole information deeper than 5 m; groundwater level information; groundwater quality information; hydraulic properties of individual ECAs; adequate mapping of springs and wetlands within each ECA; and synoptic gaugings and low flow river / stream water chemistry sampling.

Based on the findings of this review, the following recommendations have been made:

- Establish a monitoring programme to characterise both groundwater quality and quantity. This essential information will, on the mid to long-term (> 5 years) inform freshwater management policies within the ECAs, to manage or mitigate identified risks to potential aquifers.
- Establish a drilling programme to investigate vertical lithological variations in the ECA and the occurrence of Pleistocene deposits, which may locally act as an additional groundwater source.
- Acquire data pertaining to groundwater-surface interaction (e.g., synoptic gaugings, radon surveys) to understand freshwater dependencies and refine the water budget, which in turn will inform GAA calculations.
- Communicate with local iwi, hapu and other land holders to determine locations of springs and wetlands as well as to identify values and threats to the groundwater resources.

KEYWORDS

Gisborne groundwater, Gisborne aquifers, East Coast groundwater

1.0 INTRODUCTION

Gisborne District Council (GDC) developed their regional freshwater plan in response to the National Policy Statement for Freshwater Management 2014 (NPS-FM: Ministry for the Environment, 2014), which is a national framework that directs all regional and unitary authorities in New Zealand to set objectives, limits and methods for freshwater management in regional plans. GDC holds responsibility for providing water for municipal and economic uses, whilst preserving ‘the mauri and natural character values of freshwater’ and protecting ‘lakes, rivers and wetlands and their margins from inappropriate use and development’ (Ministry for the Environment, 2014).

The Gisborne region is located on the central and northern east coast of the North Island. The region has a land area of 8,265 km^2 and a population of 43,656 (Statistics New Zealand, 2013). The region consists mainly of steep hill country, with small areas of rolling hills and strips of terrace and river flats in the valleys. The dominant topographical features of the region are the Huiarua and Raukumara Ranges, which divide the catchments of the East Cape peninsula from the Bay of Plenty. The Gisborne region is susceptible to meteorological drought because it is sheltered from the prevailing westerly winds by the ranges. Rivers and streams of the region typically have low flows in summer. Therefore, groundwater is important for the economy of the region as it provides vital backup to potable water supplies when other sources are unavailable (Gisborne District Council, 1995). Almost all the known groundwater aquifers in the region are located on the Poverty Bay Flats, which formed within the floodplain of the Waipaoa River. In a concurrent project, groundwater monitoring of the Poverty Bay Flats area will be reviewed by GDC and GNS Science (Moerau *et al.*, 2016).

GDC and GNS Science have previously identified 12 individual Holocene East Coast alluvial areas (ECAs), excluding the Poverty Bay Flats (Murphy and Tschritter, 2012). The ECAs include: Wharekahika; Karakatuwhero; Orutua; Tunanui; Waiapu; Mangahauini; Waipare; Uawa; Pakarae, Waiomoko, Wainui and Muriwai (Figure 1.1). However, the presence and productivity of aquifers within the ECAs is generally unknown at present.

Groundwater in the ECAs is currently only used for permitted use such as stock water and domestic supply. To date, no groundwater monitoring activities have been undertaken within the ECAs. However, the response to the NPS-FM and GDC’s proposed regional plan, in conjunction with a growing interest from the community for potential irrigation takes, and potential land use changes from extensive sheep and beef farming to more intensive land uses, highlights the need for further groundwater investigations and monitoring in the ECA’s. Monitoring in the Poverty Bay Flats groundwater began in the mid-1980s (Gordon, 2001). An East Coast surface water monitoring programme that incorporates 19 surface water monitoring sites is run by GDC. Monitoring was at bi-monthly interval until 2015 when monitoring frequency was increased to a monthly interval for a range of analytes (Murphy, 2016). The surface water monitoring programme has enabled GDC to consider the environmental impact of any potential development in terms of water takes and/or land use changes in these areas (Greenwood and Unwin, 2014).

The objectives of this study were to:

1. Develop a conceptual understanding of the ECAs by:
    a. investigate groundwater available for allocation (GAA), risks to the aquifer and recharge mechanisms;
    b. develop minimum groundwater levels to prevent seawater intrusion;
    c. identify connections with any potential adjacent aquifers;

   d. identify potential recharge areas of spring-fed surface water bodies; and
   e. refine the aquifer boundaries.

2. Design a groundwater quality monitoring programme for the ECAs, including identifying monitoring objectives, risks and recommendations for the following: sampling sites and frequency, analytical suite to be monitored, and field collection methodology.
3. Design a simplified ECA groundwater level monitoring programme to support regional environmental monitoring reporting and monitoring of groundwater quantity and potential sea water intrusion.

The results of this study will be used by GDC to establish the ECAs monitoring programme. This project was funded through an Envirolink medium advice grant (1655-GSDC130), and was completed jointly by GDC and GNS Science, to continue the development of GDC's groundwater capabilities.

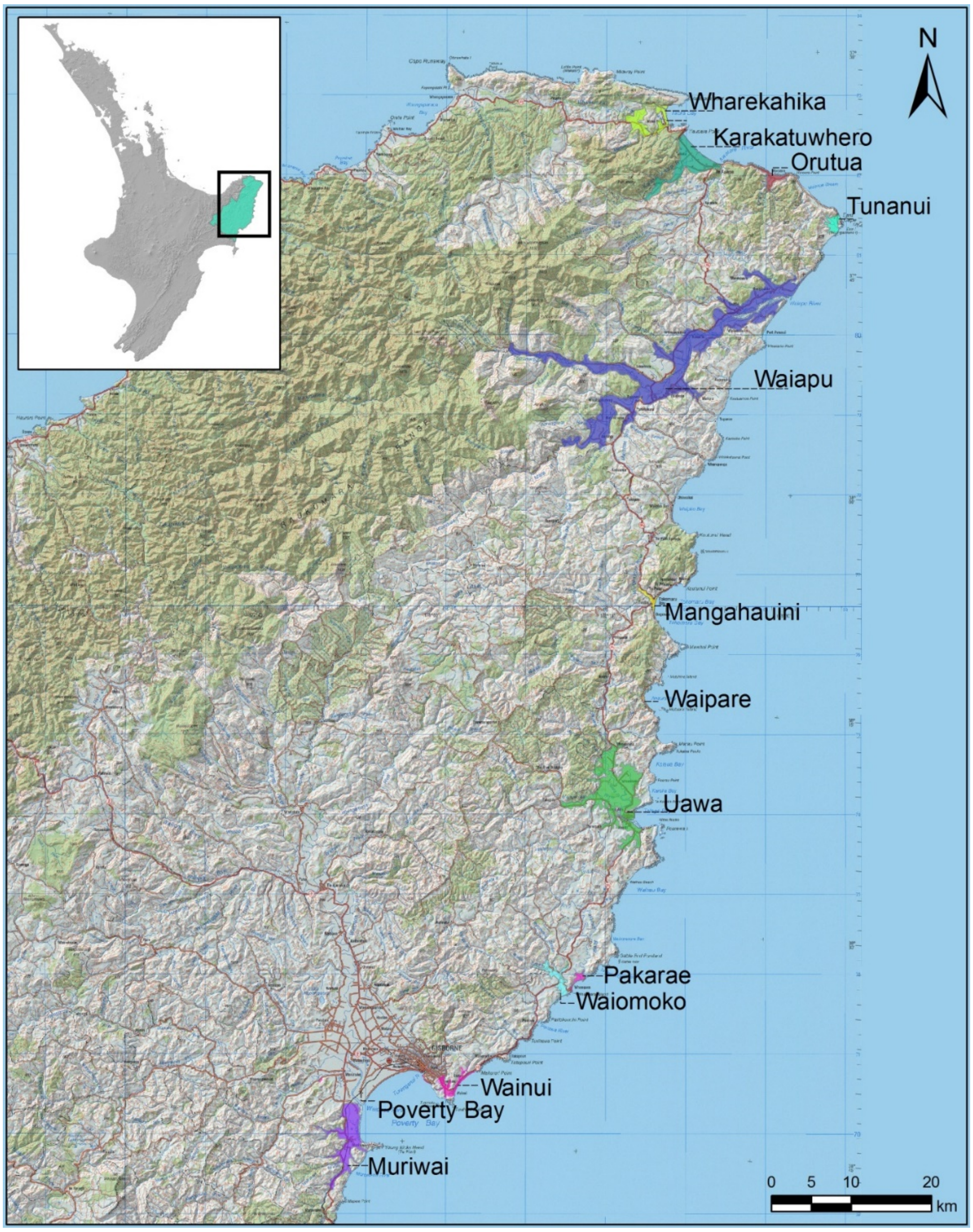

Figure 1.1: ECAs as identified by Murphy and Tschritter (2012), excluding Poverty Bay Flats.

2.0 STOCKTAKE OF HYDROGEOLOGICAL INFORMATION ON THE ECAS

2.1 DATA REVIEW AND UPDATE

2.1.1 GDC Bore Records

Of the 1,833 bores hosted in the GDC database (May, 2016), 595 had a lithological log. The majority of bores with lithology information (456) were located in the Poverty Bay Flats aquifer system, and 73 bores with lithological logs were sited in the identified ECAs. The latter were predominantly located in the Waiapu, Uawa, and Wainui ECAs. In many other ECAs, bores with lithological information were absent, and therefore, little is known beyond the geological information recorded in the 1: 250,000 geological map (QMAP) (Heron, 2014; Mazengarb and Speden, 1996). In addition, of the 24 bores with lithological records sited in the Uawa aquifer, the maximum depth of these bores was 4.7 m (Table 2.1).

Table 2.1: Summary of ECA information including area and lithological log information including total number of bores and maximum depth.

ECA	Area (km^2)	Number of bores with lithological logs	Maximum depth of bores with logs
Wharekahika	9.32	0	-
Karakatuwhero	17.51	0	-
Orutua	3.47	0	-
Tunanui	2.93	0	-
Waiapu	112.8	22	23.6
Mangahauini	1.84	0	-
Waipare	0.75	0	-
Uawa	44.54	24	4.7 m
Pakarae	1.45	1	11.9
Waiomoko	5.58	2	33.5
Wainui	4.37	26	17.4 m
Muriwai	19.81	2	89 m

2.1.2 Aquifer Boundaries

Aquifer boundaries for the ECAs defined by Murphy and Tschritter (2012) were primarily based on the distribution of Holocene sediments in alluvial plains and river flats along the Gisborne region coastline. The Raukumara 1:250,000 geological map (Heron, 2014; Mazengarb and Speden, 1996) was used to identify the extent of sediments and refine the aquifer boundaries using a 20 m digital terrain model, and information about existing groundwater use if available. This methodology was chosen, because lithological records and groundwater information were lacking in these areas. Using the geological map, it was possible to identify Holocene deposits that are primarily composed of sand and gravel, which were inferred to be indicative to be potential aquifers.

In this project, boundaries of the ECAs were re-assessed with regard to their suitability for the management of the aquifers. The boundaries of three ECAs were adjusted as part of this assessment as follows:

- The Waiomoko ECA boundary was extended further up-stream, and two additional polygons were added to the Pakarae aquifer, following the mapped extents of Holocene river deposits in the QMAP (Heron, 2014; Mazengarb and Speden, 1996).
- The boundary between the Poverty Bay aquifer system and the Muriwai ECA was moved up to 2.6 km south of the previous boundary delineated by White *et al.* (2012). There was one bore in the Muriwai aquifer that was close to the previous boundary and exhibited similar lithological units to Poverty Bay aquifer bores in the vicinity of the boundary (Figure 2.1). The new boundary was based on the QMAP geological map and the Poverty Bay soil map (Figure 2.2).

Aquifer boundaries for the other ECAs were also assessed and deemed appropriate for groundwater management in these aquifers.

2.1.3 East Coast Low Flow Gauging Data

Low flow gauging data associated with the ECA was extracted from the GDC gauging database (Table 2.2). The low flow gauging data was used to inform the potential groundwater – surface water interaction when determining the GAA. Numbers of individual low flow gaugings were counted, and a mean low flow was calculated for each gauging site. Where a flow record was available, the mean, median, and 90th and 95th percentile flows were calculated to help inform the low flow gauging data assessment.

2.1.4 Springs and Wetlands

One spring was identified in the Racecourse Spring, Ruatoria (Waiapu ECA), based on local knowledge of the area (Figure 2.3). The locations and boundaries of wetlands were derived from the Land Information New Zealand swamp shapefile (Figures 2.2 to 2.10). Further springs and wetlands exist within the East Coast aquifer areas, however their exact locations were not identified. It is recommended by the authors to contact local iwi, hapu, and other land owners for more information on spring and wetland locations (see Section 5.0).

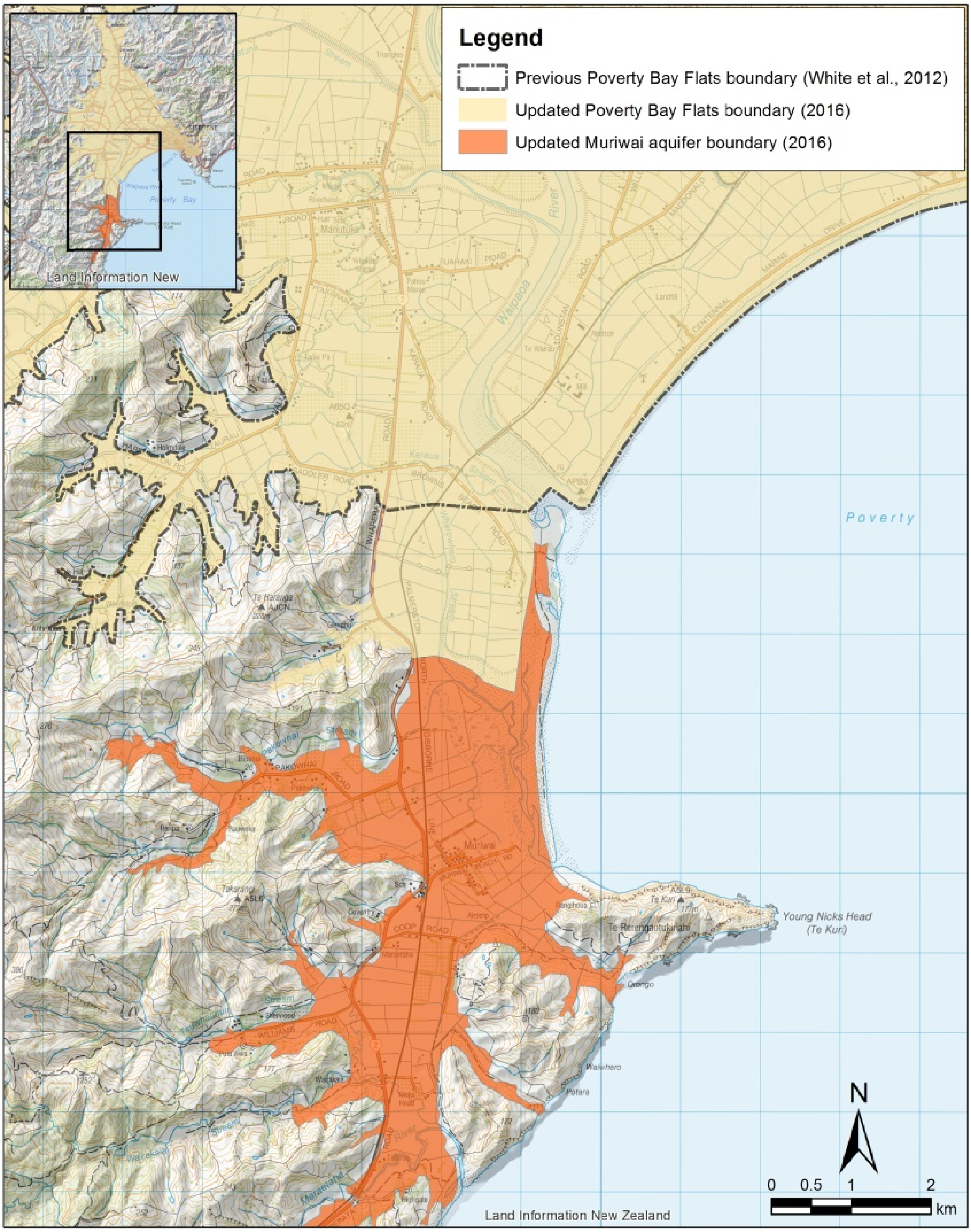

Figure 2.1: Map showing the updated boundary between the Poverty Bay Flats aquifer and the adjacent Muriwai aquifer. The previous boundary from White *et al*. (2012) boundary has been included for comparison.

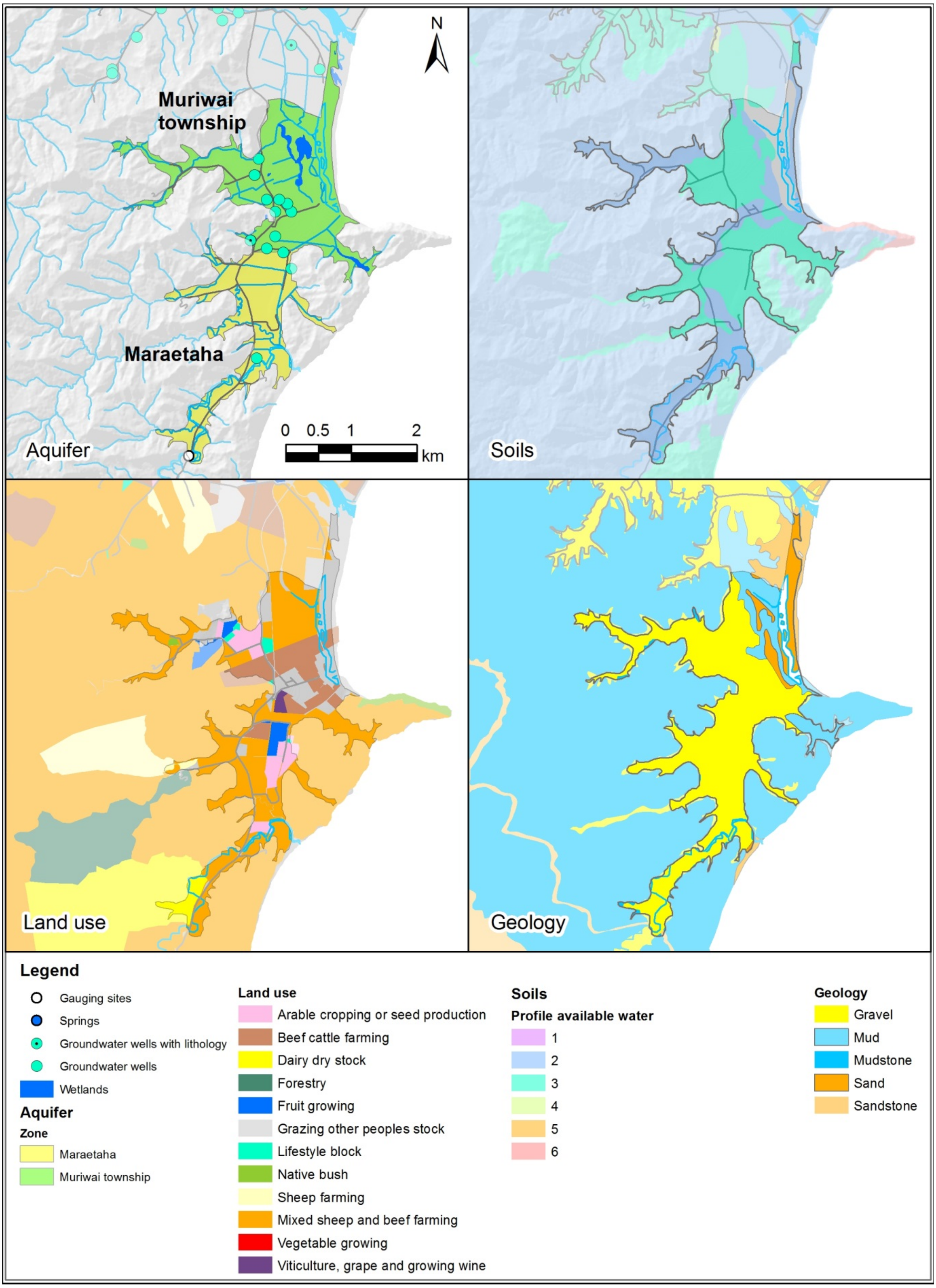

Figure 2.2: Maps of available aquifer, soils, land use and geology data available for the Muriwai ECA (Maraetaha and Muriwai township zones) (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water (PAW) is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

Table 2.2: GDC East Coast low flow gauging (LFG) dataset. Flow statistics from stage recording sites are calculated from rated stage-recorder measurements. NZTM refers to the New Zealand Transverse Mercator 2000 projection.

Site name	NZTM Easting	NZTM Northing	No. of gaugings	Gauging time period	Catchment Area Upstream (km^2)	New Zealand reach number	Elevation (m asl)	LFG mean (m^3/s)	Flow statistics from stage recording sites		
									Period of record	Flow mean (m^3/s)	Flow median (m^3/s)
Wharekahika at Rock Pools	2066003	5828885	25	28/12/06 to 24/02/15	147.4	5000066	3	1.6	30/10/1995 to 19/03/2012	8.6	5.3
Wharekahika River at Bridge	2066644	5828540	6	21/01/09 to 178/05/16	148.7	5000084	0	1.9	20/05/1993 to 6/07/2016	18.4	6.5
Karakatuwhero River at SH35 Bridge	2070933	5822291	16	28/12/06 to 14/01/15	78.77	5000331	82	1.1	14/01/2011 to 19/06/16	3.6	2.5
Poroporo River at SH35 Bridge	2074753	5804228	17	28/12/06 to 11/02/15	n/a	5001833	25	0.1	n/a	n/a	n/a
Mangaoporo River at SH35 Bridge	2065961	5798974	3	28/12/06 to 16/09/15	66.07	5002352	82	0.8	n/a	n/a	n/a
Waiapu River at SH35 Bridge	2065727	5792657	22	31/01/07 to 24/02/15	1376.1	5002964	53.49	4.2	01/01/1975 to 19/01/15	86.9	36.4

Site name	**NZTM Easting**	**NZTM Northing**	**No. of gaugings**	**Gauging time period**	**Catchment Area Upstream (km^2)**	**New Zealand reach number**	**Elevation (m asl)**	**LFG mean (m^3/s)**	**Flow statistics from stage recording sites**		
									Period of record	**Flow mean (m^3/s)**	**Flow median (m^3/s)**
Mata River at Aorangi Bridge	2058031	5787017	6	31/03/09 to 23/11/12	825.7	5003397	97	0.4	n/a	n/a	n/a
Hikuwai River at Willowflat	2061012	5748611	3	14/01/04 to 12/02/09	306.56	5007406	4.5	0.1	n/a	n/a	n/a
Mangaheia River at Paroa Bridge	2058824	5742582	14	20/12/06 to 30/01/14	83.56	5008439	3	0.3	n/a	n/a	n/a
Pakarae River @ Station Bridge	2058268	5723931	17	16/01/07 to 13/01/2015	231.59	5011612	8	0.2	n/a	n/a	n/a
Waiomoko @ Andrew Bridge	2052865	5720854	38	20/12/06 to 13/06/16	60.05	5012109	19	0.1	n/a	n/a	n/a
Maraetaha @ No.3 Bridge	2025703	5693120	26	3/01/03 to 9/02/15	42.81	5013922	20	0.1	n/a	n/a	n/a

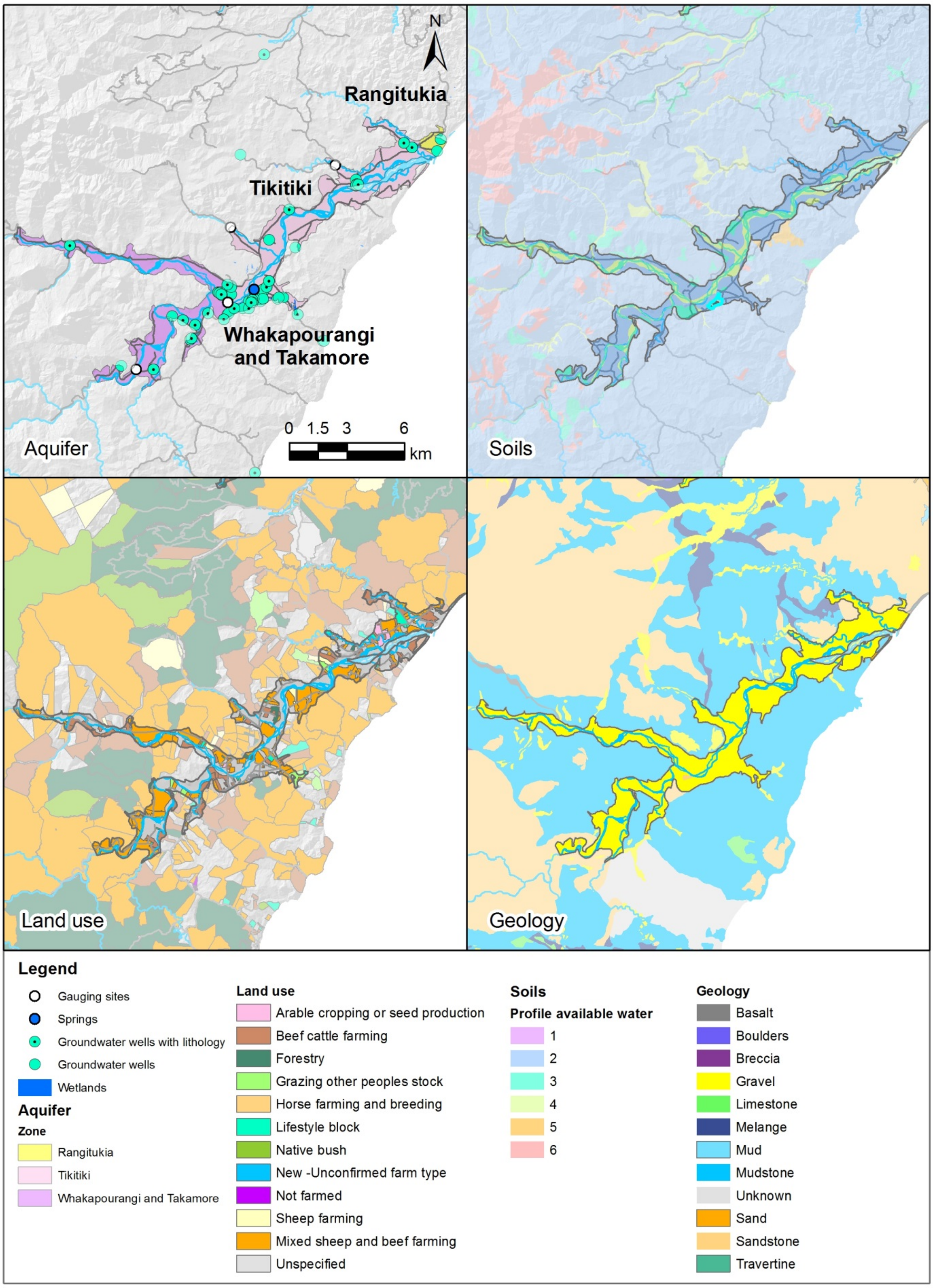

Figure 2.3: Maps of available aquifer, soils, land use and geology data available for the Waiapu ECA (Rangitukia, Tikitiki and Whakapourangi and Takamore zones) (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

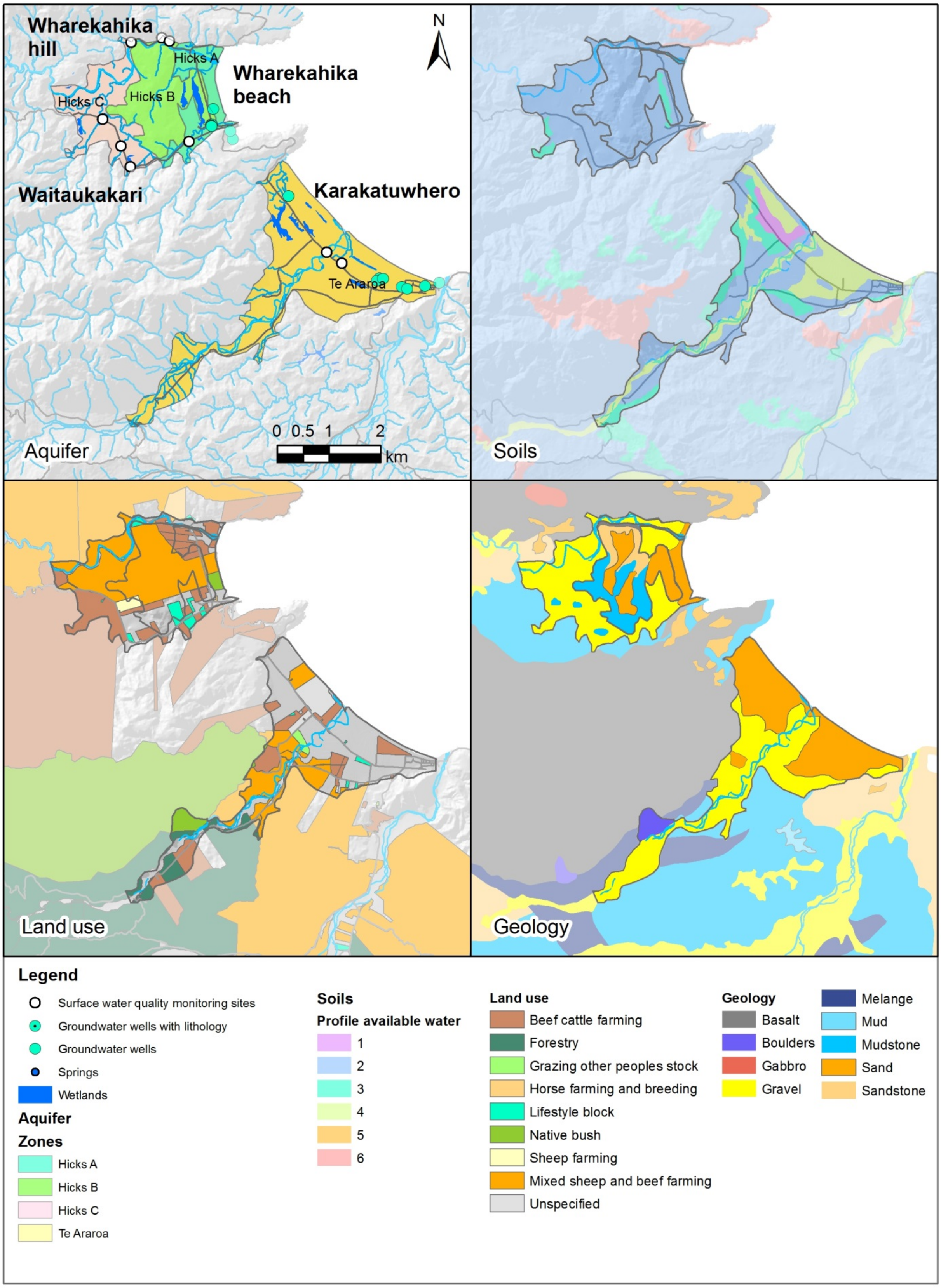

Figure 2.4: Maps of available aquifer, soils, land use and geology data for the Wharekahika (Wharekahika beach, Wharekahika hills and Waitaukakari zones) and Karakatuwhero ECAs (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

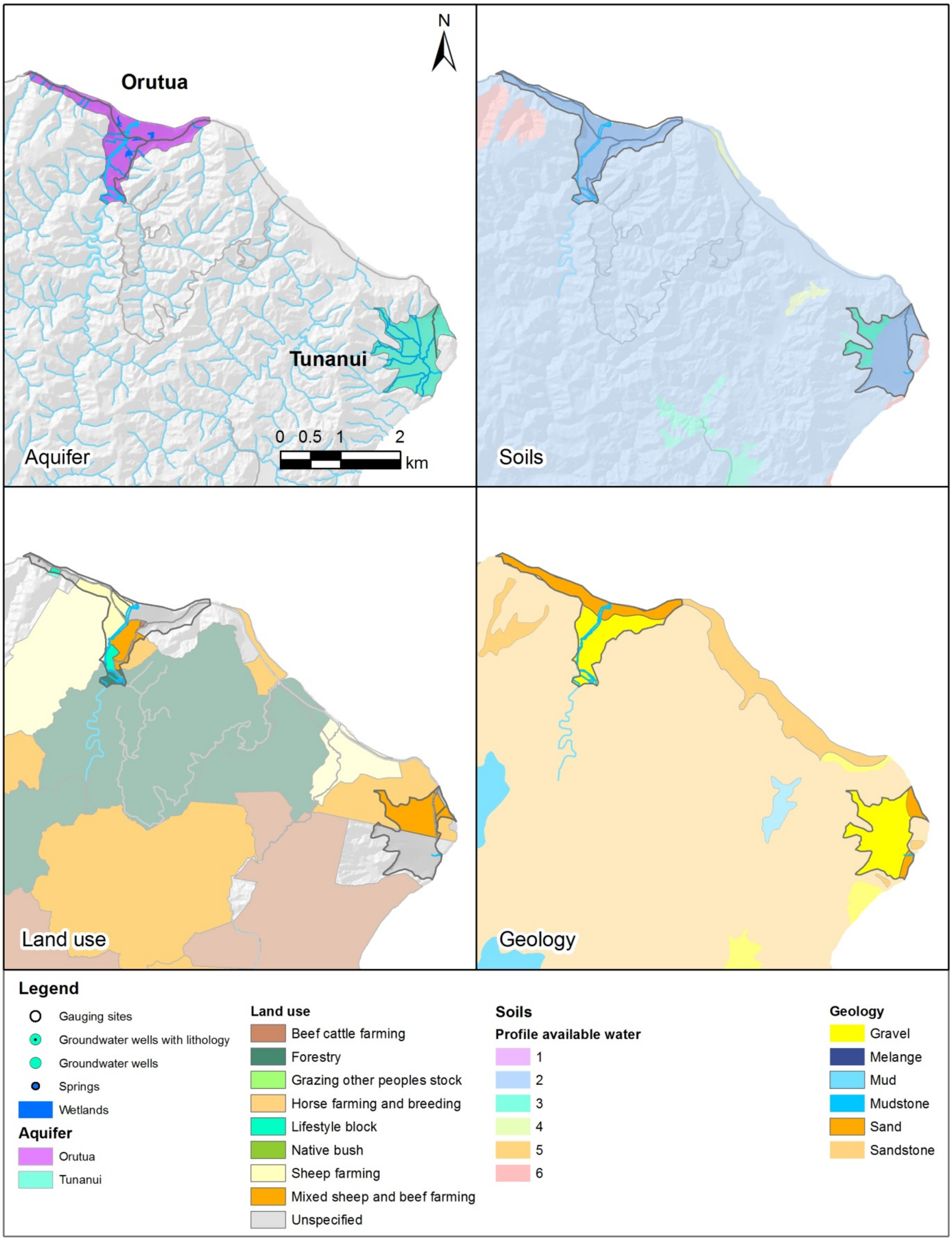

Figure 2.5: Maps of available aquifer, soils, land use and geology data available for the Orutua and Tunanui ECAs (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

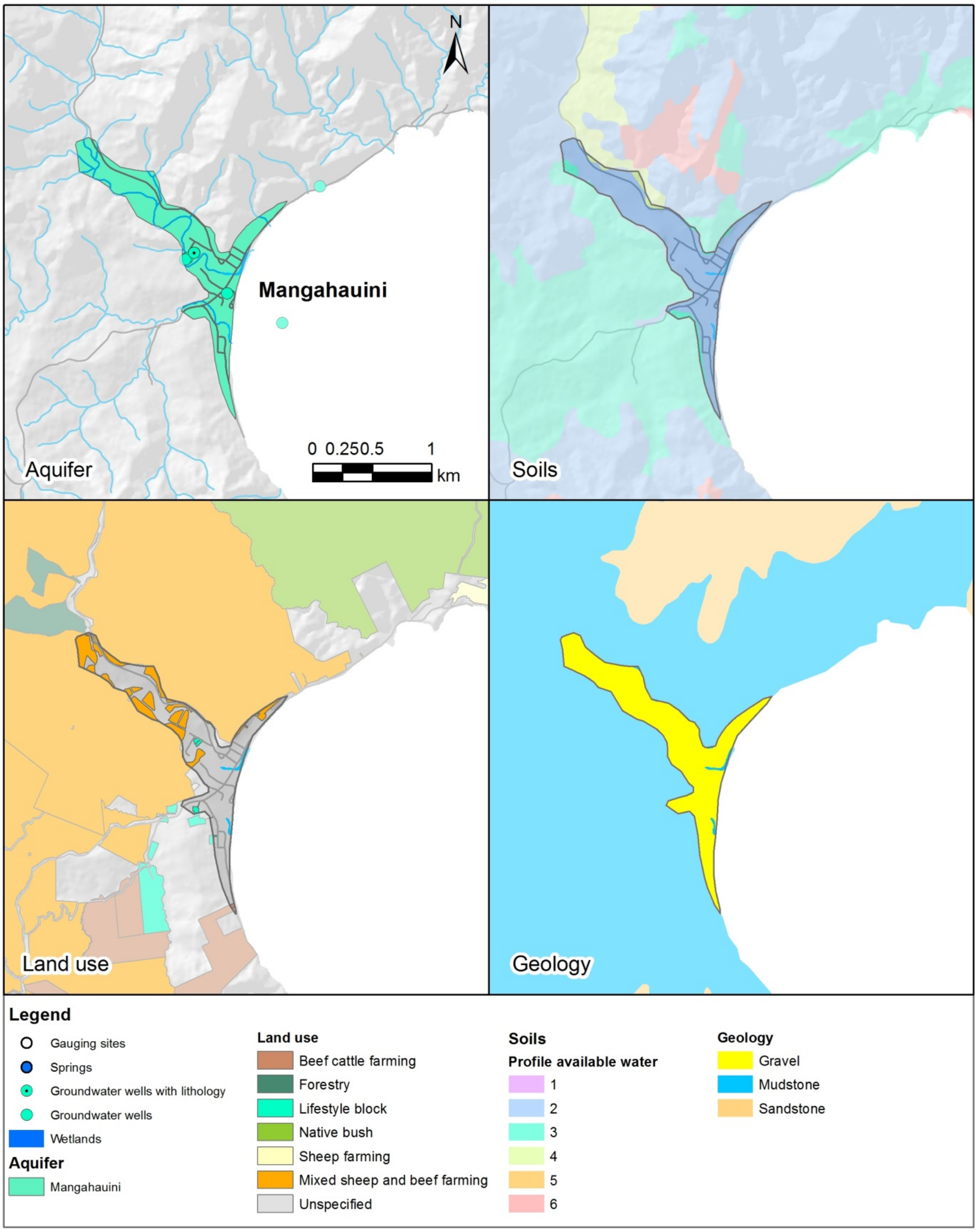

Figure 2.6: Maps of available aquifer, soils, land use and geology data available for the Mangahauini ECA (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

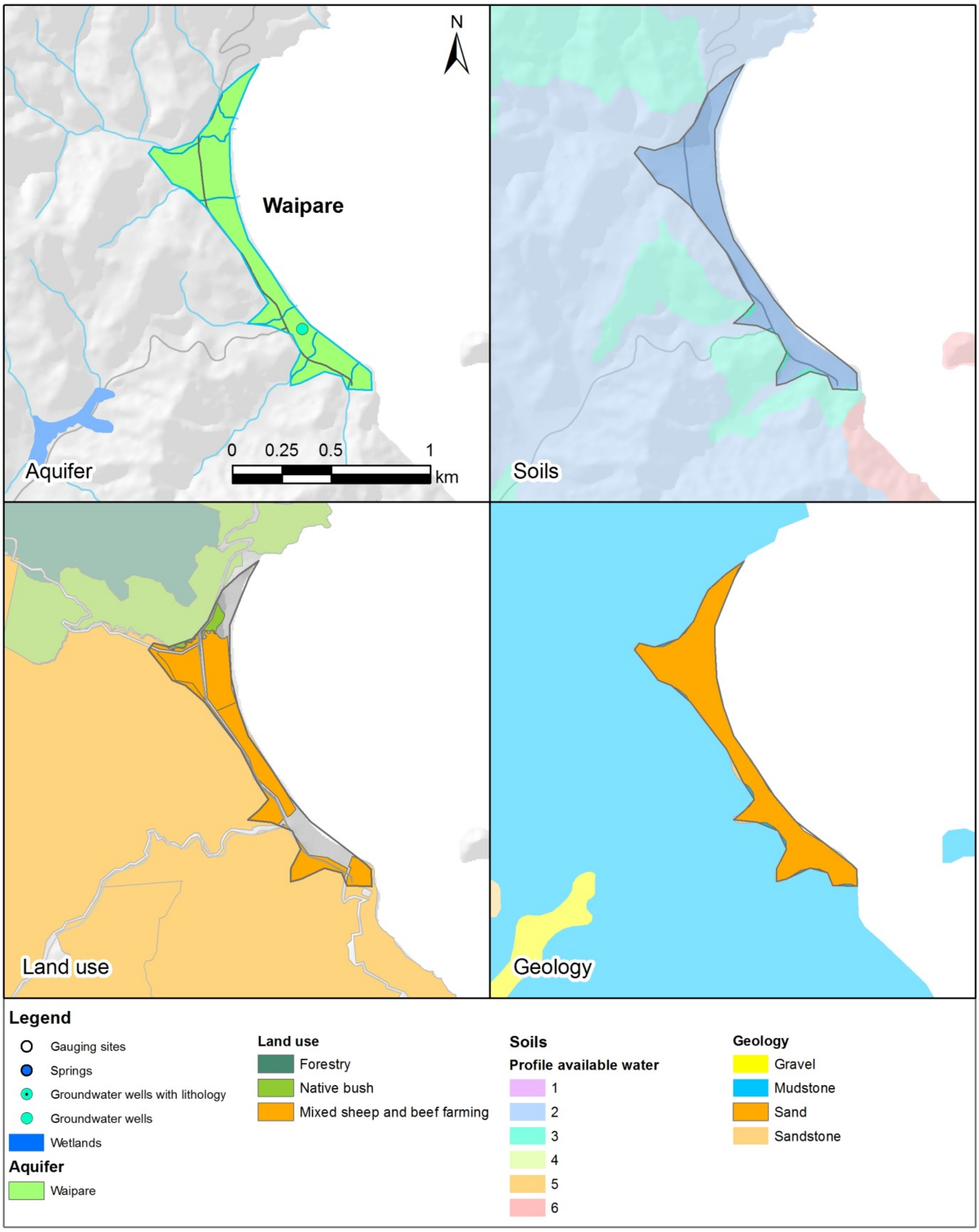

Figure 2.7: Maps of available aquifer, soils, land use and geology data available for the Waipare ECA (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

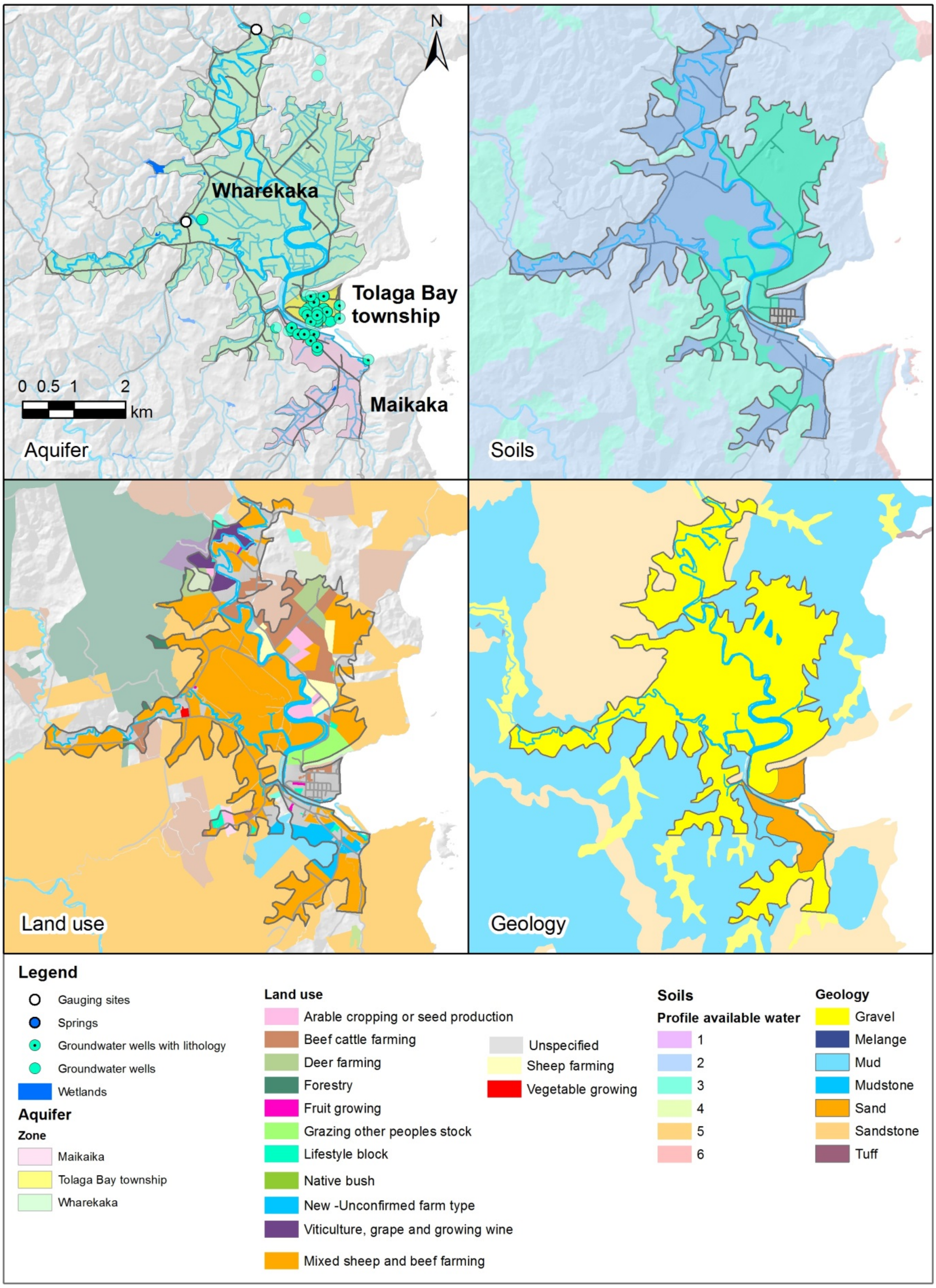

Figure 2.8: Maps of available aquifer, soils, land use and geology data available for the Uawa ECA (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

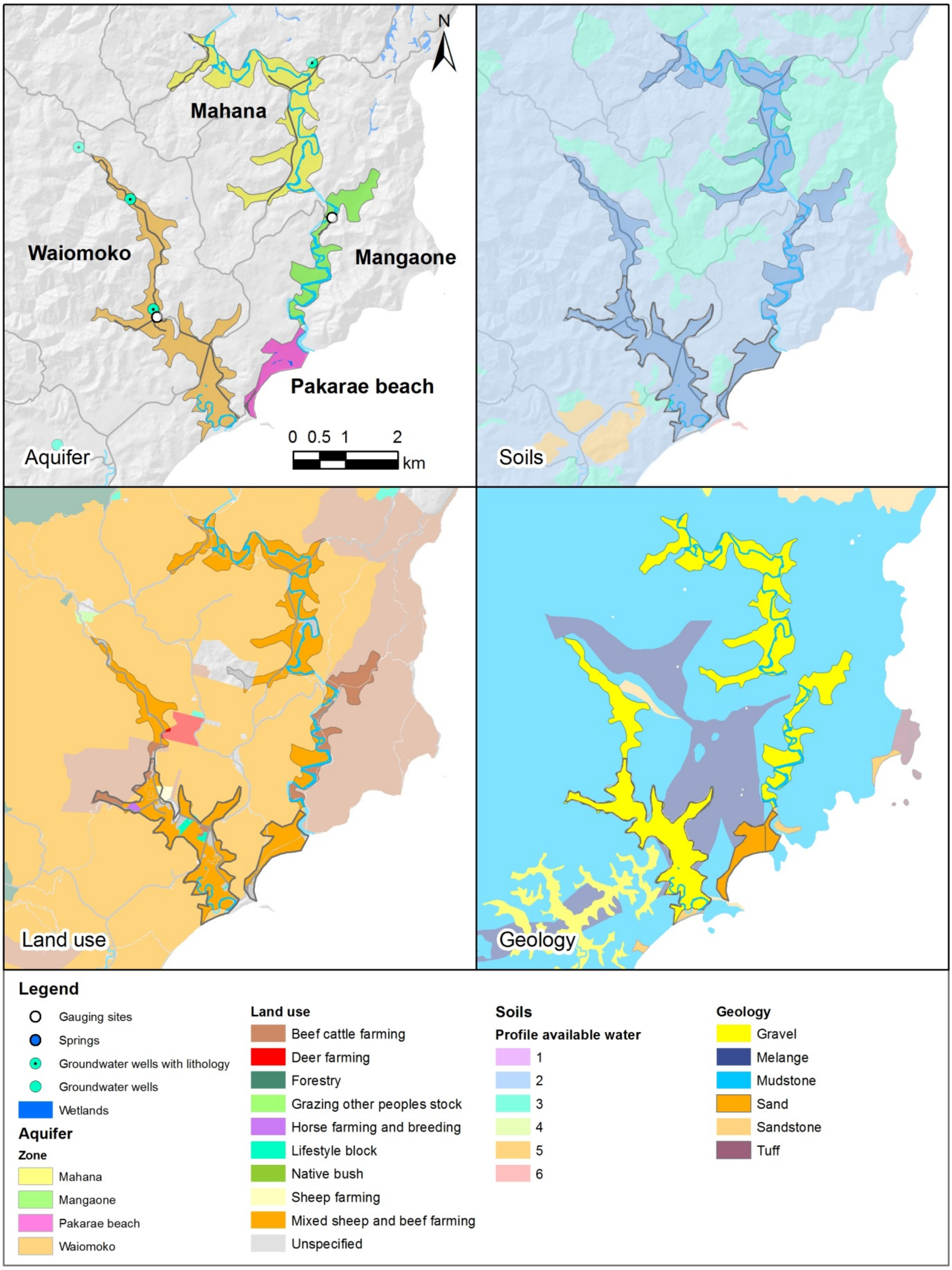

Figure 2.9: Maps of available aquifer, soils, land use and geology data available for the Pakarae (Pakarae beach, Mangaone and Mahana zones) and Waiomoko ECAs (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

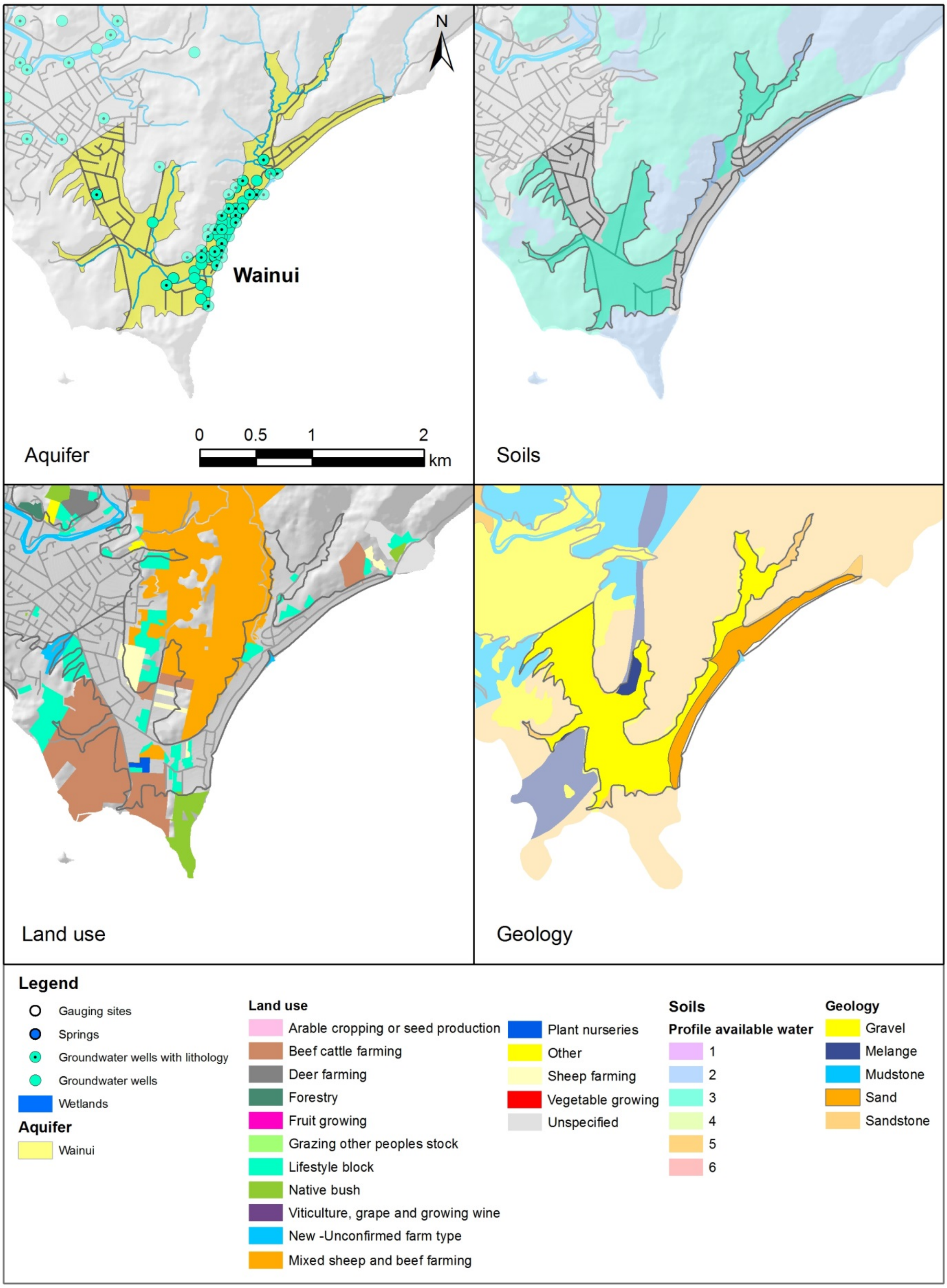

Figure 2.10: Maps of available aquifer, soils, land use and geology data available for the Wainui ECA (Sources: Soil and AgriBase layers: Dennison (2016); Geology: Heron (2014)). Profile available water is the amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. It is usually expressed in mm, however on this map it is shown as categories, which are discussed in detail in Section 2.4.

2.2 ECA BOUNDARIES

As part of this study, the ECA boundaries were revised and in some instances, subdivided into zones for future freshwater management purposes, including water allocation (surface and groundwater), land use planning and community engagement. Existing land use activities were documented for each ECA and zone based on observations of land use at the date of this report (Table 2.3).

The Wharekahika ECA has been split into three zones (Figure 2.4): Wharekahika Beach, Wharekahika Hill and Wharekahika Waitaukakari (inland plateau).

- Wharekahika Beach Zone is the coastal sandy area that extends from the Wharekahika River mouth upstream to approximately the Wharekahika Bridge. Groundwater in the Wharekahika Hill and Waitaukakari zones contributes to base flow in the Wharekahika River during extended dry periods.
- Wharekahika Hill Zone is the mudstone hill that separates the coastal area from the upper Wharekahika River catchment.
- Wharekahika Waitaukakari Zone is an upper catchment plateau.

Groundwater in the Karakatuwhero ECA is likely to be hydraulically connected with the Karakatuwhero River upstream of the State Highway 35 Bridge (Figure 2.4). The Karakatuwhero River has a large gravel bed and potentially recharges groundwater through the bed. A wetland lies downstream of the State Highway 35 Bridge and may be hydraulically connected to groundwater.

The Orutua and Tunanui ECAs are small coastal areas near the East Cape (Figure 2.5). Streams flowing up gradient of these areas have native fish values associated with them.

The Waiapu ECA consists of land areas upstream of Ruatoria including both the Mata and Tapuaeroa river terraces and was split into three zones: Rangitukia, Tikitiki (Rangitukia to Ruatoria), and Whakapourangi and Takamore (Figure 2.3). The Waiapu River is the largest river catchment on the East Coast, and is underlain by a thick gravel bed. It is possible that through that gravel bed, the river recharges a deeper Pleistocene aquifer. The Rangitukia Zone includes the land surrounding Rangitukia township near the coast. Groundwater is likely to occur within river silts, gravels and sands in this zone. A lagoon occurs at the Waiapu River mouth, and the lagoon may be hydraulically connected to groundwater. The Tikitiki Zone is located upstream of Rangitukia to Ruatoria between Rangitukia and the Rotokautuku Bridge. The Waiapu River is likely to be connected with groundwater, as suggested by the occurrence of numerous springs throughout the Tikitiki and the Whakapourangi and Takamore zones.

The Mangahauini and Waipare ECAs are generally coastal strips which follow the coastline and bounded inland by steep hill country (Figures 2.6 and 2.7).

The Uawa ECA has been split into three zones: Tolaga Bay Township; Maikaika (south of Tolaga Bay township) and Wharekaka (inland) (Figure 2.8). Groundwater in the Tolaga Bay Township Zone is likely to occur within river silts and sands and likely discharges through the Uawa River mouth. Groundwater in the Wharekaka Zone is assumed to flow via surface drainage features to the Uawa River

Table 2.3: Summary of the ECA zones and predominant land uses within each zone. Existing land use activities were based on observations of current land use supplemented by AgriBase data (Dennison, 2016).

ECA	Zone	Predominant land use
Wharekahika	Wharekahika beach	Rural residential and extensive sheep and beef farming
	Wharekahika hill	Regenerating scrub
	Waitaukakari	Extensive sheep and beef farming
Karakatuwhero	Karakatuwhero	Extensive sheep and beef, regenerating scrub, native bush and forestry
Orutua	Orutua	Regenerating scrub and extensive sheep and beef
Tunanui	Tunanui	Forestry and extensive sheep and beef farming
Waiapu	Rangitukia	Rural residential, regenerating scrub and extensive sheep and beef farming
	Tikitiki	Cropping, rural residential, residential, regenerating scrub and extensive sheep and beef farming
	Whakapourangi and Takamore	Cropping, rural residential, regenerating scrub, forestry and extensive sheep and beef farming
Mangahauini	Mangahauini	Regenerating scrub and extensive sheep and beef farming
Uawa	Tolaga Bay township	Residential and extensive sheep and beef farming
	Maikaika	Cropping, extensive sheep and beef farming
	Wharekaka	Cropping, extensive sheep and beef farming
Pakarae	Pakarae beach	Extensive sheep and beef
	Mangaone	Cropping and extensive sheep and beef
	Mahana	Cropping and extensive sheep and beef
Waiomoko	Waiomoko	Cropping and extensive sheep and beef
Wainui	Wainui	Residential, lifestyle and extensive sheep and beef farming
Muriwai	Muriwai township	Cropping, residential, lifestyle, horticulture and extensive sheep and beef farming
	Maraetaha	Cropping, horticulture and extensive sheep and beef farming

The Pakarae ECA has been split into three zones: Pakarae Beach, Mangaone, and Mahana (Figure 2.9). Aquifers comprise river terrace deposits (Mangaone and Mahana zones) and sands (Pakarae Beach Zone). It is likely that the Pakarae River is hydraulically connected to groundwater. Note that the Mahana and the Mangaone zones are not connected as the alluvial Holocene sediments pinch out between these zones.

The Waiomoko ECA has similar characteristics to the Pakarae ECA (Figure 2.9), and it is likely that the Waiomoko River is hydraulically connected to groundwater.

The Wainui ECA is a relatively thin coastal strip that follows the coastline. Consequently, Wainui is likely to comprise primarily sand deposits (Figure 2.10). However, the Sponge Bay area was historically an estuary and likely has estuarine silt sediments. Groundwater likely flows to the Wainui or Hamantua streams and across the coastal boundary.

The Muriwai ECA has been split into two zones: Muriwai Township to the north and Maraetaha to the south, the latter includes the Maraetaha River mouth (Figure 2.2). The Wherowhero Lagoon occurs within the Muriwai Township Zone and may be hydraulically connected to groundwater.

2.3 CONNECTIONS TO ADJACENT AQUIFERS

No previous information on the hydraulic connections between the Holocene ECAs and adjacent lithologies was available. This section aims to address this information gap using the digital seamless version of the QMAP geological map at a 1:250,000 scale (Heron, 2014; Mazengarb and Speden, 1996). It is possible that aquifer connectivity may exist vertically if there is a deeper aquifer system beneath a Holocene aquifer, and/or laterally, between the ECAs and adjacent geological units that may form aquifers. Potential deeper aquifers could be older Quaternary deposits, or deposits that are part of the geological formations and units forming the hill country adjacent to the ECAs.

The surface geology surrounding the ECAs is dominated by Cretaceous (basement) to Tertiary deposits (Mazengarb and Speden, 1996). The majority of these rocks are mudstone deposits (Figure 2.11), which is reflected in the high silt and clay content in the unconsolidated sediments. Sandstone deposits may also occur, either as part of the mudstone units (e.g., Tolaga Group around Muriwai) or as the dominating lithology (e.g., Tokomaru Sandstone west and northwest of the Uawa ECA). ECAs adjacent to primarily Tertiary mudstone deposits are Muriwai, Waiomoko, Pakarae, Waipare, Mangahauini and Waiapu. In the case of the Waiapu ECA, Tertiary mudstones are limited to its northern to north-western sides, whereas the mudstones in the south to southeast of the ECA are of Cretaceous to Tertiary age. ECAs that are mostly adjacent to sandstone-dominated deposits are Wainui, Tunanui, and Orutua. The geology in the far north of the Raukumara Peninsula differs from the more southern and eastern parts of the peninsula and the northernmost ECAs, Wharekahika and Karakatuwhero, are surrounded by mudstones, sandstones, and basalts (Matakaoa Volcanic Group).

Tertiary mudstone and sandstone deposits may include low-yielding aquifers, for example the Waitemata Group sandstone and mudstone deposits that are utilised aquifers in the Auckland area (Crowcroft and Smaill, 2001).

Basement rocks are generally not regarded as aquifers in New Zealand, although a limited groundwater resource may be available in fractured zones, as demonstrated by geothermal fields in the Taupo Volcanic Zone. For example, basement drilled at Ohaaki geothermal field is generally not permeable enough for geothermal production (Yang *et al*., 2001; Wood *et al*., 2001). The basement at the Kawerau geothermal field is mostly impervious, but productive zones have been encountered along faults (Bignall and Milicich, 2012). Basement rocks in Southland host a limited groundwater resource that is utilised in hill regions (Hughes, 2011; Durie, 2001). However, based on their predominantly low aquifer potential across New Zealand, Cretaceous basement rocks in the Gisborne region are assumed to be largely impermeable for the purpose of this project.

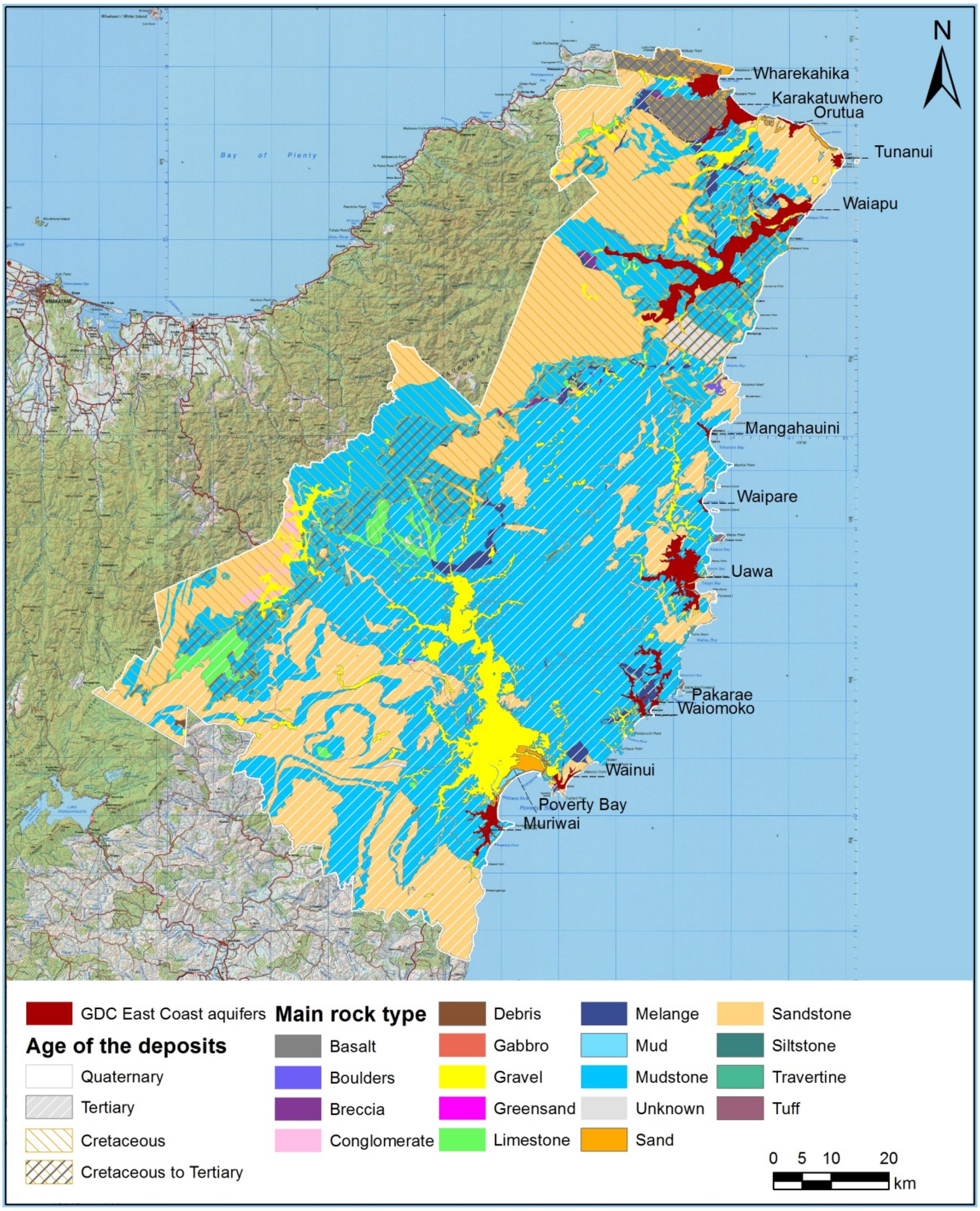

Figure 2.11: Map showing the location of the ECAs and the main rock type of the geological formations in the Gisborne region, categorised by age (Heron, 2014).

2.4 GROUNDWATER RECHARGE MECHANISMS

Sources of groundwater recharge to the ECAs include rainfall, and potentially surface water recharge (e.g., rivers) and recharge from underlying or adjacent aquifers comprising basement rocks and other deposits (Section 2.3). Rainfall recharge is the most important source of recharge to groundwater in the ECAs, and was estimated as the difference between long-term average rainfall and the long-term average actual evapotranspiration (Section 3).

The total amount of rainfall recharge is dependent on environmental variables and also soil properties, e.g., profile available water (PAW), which are ordered from high (Class 1) to low (Class 6) (Figures 2.3 to 2.10; Newsome *et al*., 2008). Typically, soil water balance models also use PAW as the soil property parameter that controls the rate of soil drainage, or groundwater recharge (e.g., White *et al*., 2003). Where PAW is large, less water will be held in the soil profile, and more rainfall recharge will occur. For example, rainfall recharge on the river flats of the Waiapu River will be greater than rainfall recharge on the terraces surrounding the river (Figure 2.3). This is because the PAW of the soils on the river bed is less (i.e., PAW class 4) than PAW on the terraces (PAW class 2).

Rivers are an important source of groundwater recharge throughout New Zealand (White *et al*., 2001). They are particularly important where gravel-bed braided rivers flow across gravel aquifers, e.g., the Ngaruroro River, Hawke's Bay and the Waimakariri River, Christchurch. Two gravel-bed rivers are located in the ECA areas, i.e., the Karakatuwhero River and the Waiapu River. Gravel aquifers are potentially located in the sediments below these rivers. However, the geology below the river bed is unknown because no drill holes have investigated these sediments. Rainfall recharge can potentially flow from basement rocks in the hinterland into coastal aquifer systems. However, the likelihood of recharge from basement is low because it is typically composed of low-permeability rocks with low infiltration rates (Section 2.3). In addition, most rainfall on the hinterland probably runs off directly to rivers. For these reasons, recharge from the basement was discounted as a source of groundwater for the Poverty Bay Flats aquifers (White *et al*., 2012).

2.5 RISKS TO THE AQUIFERS

The ECAs are shallow coastal aquifers, which are vulnerable to threats that may affect groundwater quantity and quality (e.g., anthropogenic activities or environmental hazards). If not mitigated or managed, these threats could have a negative impact on: groundwater-dependent ecosystems; current and future uses of the aquifers (economic value); and social and cultural values associated with the aquifers. Risks to groundwater quantity are due to potential over-abstraction and climate-change (e.g., where declining rainfall over time may result in reduction of groundwater recharge). Risks to groundwater quality are considered to be mainly due to contamination from land use impacts (e.g., nutrients). Shallow, unconfined aquifers are susceptible to contamination as they are generally unprotected by a hydrogeological barrier (i.e., a confining layer). Additionally, the flow pathways into shallow aquifers are short, which results in only limited attenuation of potential contaminants. This section provides a high-level overview about potential risks to the ECAs (Table 2.4). An individual, more detailed risk assessment for the ECAs has been recommended (Section 5.2).

Table 2.4: Summary of the threats to groundwater in the ECAs as a result of human and environmental risks, and planned mitigation measures.

	Risk	**GDC management and mitigation options**
Threats to groundwater quantity	Over-use or over-allocation	Setting groundwater allocation limits, monitoring use and establishing appropriate policies
	Seawater intrusion	Setting groundwater allocation limits, monitoring use and establishing appropriate policies
	Climate change (e.g., less recharge through changes in precipitation and evaporation)	Setting groundwater allocation limits, monitoring use and policies
	Volcanoes (e.g., ash can pollute surface water sources and shallow, unconfined aquifers, which increases pressure on groundwater)	Civil defence preparedness plans
Threats to groundwater quality	Pollution from land use activities (e.g., nitrate, phosphorous, *E. coli*,) from residential, industrial, agriculture, horticulture etc.	Monitoring land use and groundwater quality, implementing land use controls through GDC Freshwater Plan
	Deforestation (e.g., risk to groundwater recharge and groundwater quality)	Monitoring land use and groundwater quality, implementing land use controls through GDC Freshwater Plan
	Leaching from landfills	Best practise landfill management, monitoring network around landfills (e.g., background monitoring wells, impact monitoring wells, surface water monitoring)
	Land treatment risks (e.g., municipal and domestic wastewater, commercial waste)	Monitoring and policies
	Seawater intrusion due to over-abstraction	Setting allocation limits, monitoring programme and policies
	Leakage from enhanced oil recovery (e.g., from fracking operations etc.)	Policies associated with enhanced oil recovery, including monitoring of effects on soils, surface water and groundwater
	Climate change (e.g., increased rate of weathering, change in biological/microbiological processes, sea level rise)	Setting allocation limits, monitoring programme and policies
	Earthquakes	Civil defence preparedness plans
	Tsunami	Dunes, sea barriers

3.0 WATER BUDGETS AND GROUNDWATER FLOWS

A general water budget equation was used to describe water inflows and water outflows from the ECAs, and was based on a water balance equation a defined area of a catchment (Scanlon *et al.*, 2002; Scanlon, 2012), Figure 3.1.

$$\text{water inflow} = \text{water outflow} \tag{1}$$

i.e., $$P + Q_{IN} = AET + Q_{OUT} + \Delta S \tag{2}$$

Water inflows include:

P = precipitation,

$$Q_{IN} = Q^{SW}_{IN} + Q^{GW}_{IN} \tag{3}$$

Q^{SW}_{IN} i.e., quick flow (Q^{SW}_{INBF}) + base flow (Q^{SW}_{INQF})

Q^{GW}_{IN} groundwater inflow

Water outflows include:

AET actual evapotranspiration

Q_{OUT} water flow out from the area

ΔS change in water storage.

With:

$$Q_{OUT} = Q^{SW}_{OBF} + Q^{SW}_{OQF} + U^{SW} + Q^{GW}_{OUT} \tag{4}$$

$$Q^{GW}_{OUT} = U^{GW} + Q^{GW}_{AOUT} \tag{5}$$

Q^{SW}_{OBF} surface water base flow outflow, i.e., base flow inflow plus base flow generated in the area (i.e., discharge to surface water from the saturated portion of the groundwater system)

Q^{SW}_{OQF} surface water quick flow outflow, i.e., quick flow inflow plus quick flow generated in the area (i.e., interflow and runoff)

U^{SW} consumptive use of surface water

Q^{GW}_{OUT} groundwater outflow, including consumptive groundwater use (U^{GW}) and groundwater discharge across the area boundary (Q^{GW}_{AOUT})

Expanding Equation 2 for surface water and groundwater terms, with the assumption that ΔS is zero, meaning that all flows are the same over time, has:

$$P + Q^{SW}_{INBF} + Q^{SW}_{INQF} + Q^{GW}_{IN} = AET + Q^{SW}_{OBF} + Q^{SW}_{OQF} + U^{SW} + U^{GW} + Q^{GW}_{AOUT} \tag{6}$$

.

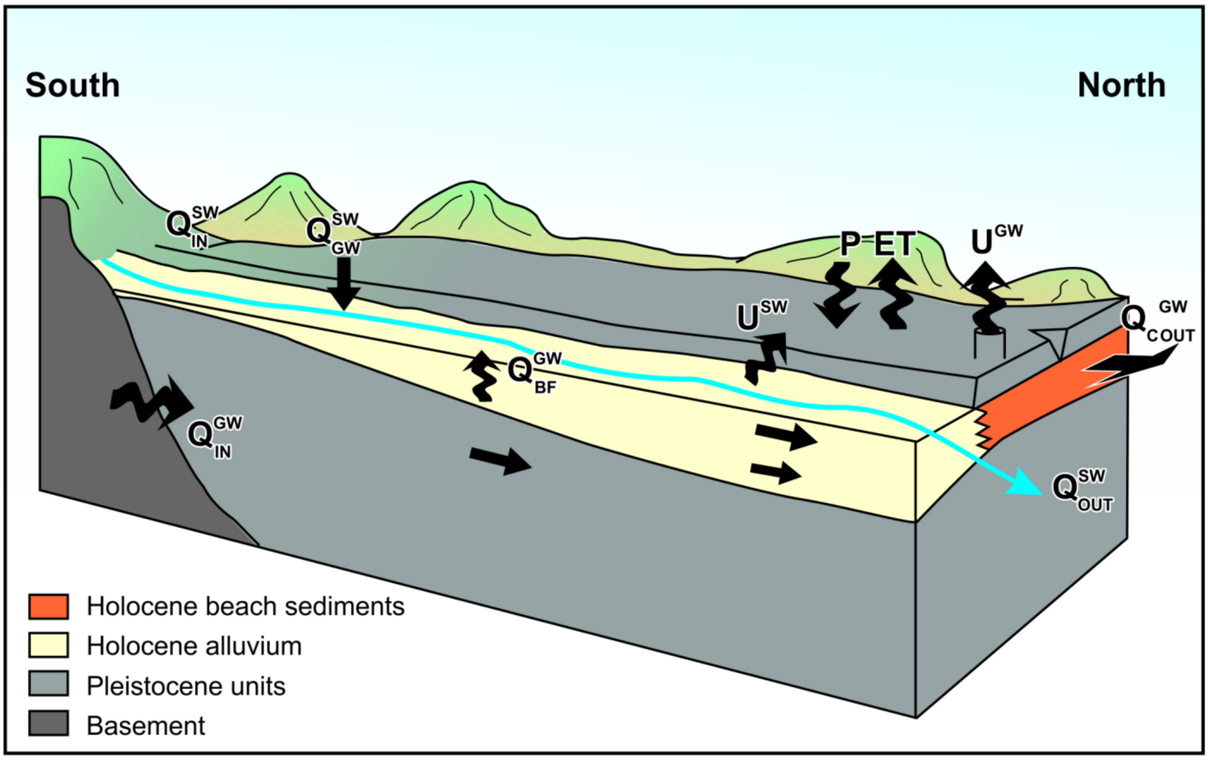

Figure 3.1: Conceptual model of groundwater flow in the ECAs and water budget components.

The following text discusses each of the components, and simplifying assumptions, that have been used for the ECA water budgets

3.1 RAINFALL AND EVAPOTRANSPIRATION

Mean annual rainfall (P) was estimated, using GIS, from the nationwide National Institute of Water and Atmospheric Research (NIWA) dataset based on the rainfall measurements at individual climate stations, interpolated throughout New Zealand by NIWA and averaged for the period 1960-2006 (Tait *et al.*, 2006). Mean annual evapotranspiration (ET) was estimated by GIS as actual evapotranspiration from the land surface derived from a national-scale map developed by NIWA for the period 1960-2006 without specific consideration of land use, land cover, soil type, or groundwater recharge (Woods *et al.*, 2006).

3.2 SURFACE WATER FLOW

Surface water flow was measured at flow recorder sites and gauging sites in the areas of the ECAs (Figures 2.2 to 2.10). These measurements were not used in the water budgets as they were generally not suitable for use in the water budgets for the following reasons: surface flow was not measured in many of the aquifer zones; flow measurements did not include zone inflows and zone outflows; and surface flow at the coast was not measured. In addition, the gauged flow measurements were not suitable for the calculation of baseflow and quick flow. However, flow measurements were very relevant to the calculation of GAA (Section 4.0).

3.3 GROUNDWATER-SURFACE WATER INTERACTION

Groundwater-surface water interaction, i.e., $Q^{SW}{}_{GW}$ (surface water discharge to groundwater) and $Q^{GW}{}_{BF}$ (groundwater discharge to surface water) probably occur in the ECAs. However, this interaction is not assessed in this report because GDC's gauging data does not include synoptic gaugings. However, several characteristics of groundwater-surface water interaction in these systems are proposed because the systems appear to share common features with other coastal aquifer systems in New Zealand. These features include:

- Wetlands and impeded drainage near the coast. This is caused by groundwater coming to the surface near the coast because horizontal groundwater drainage is impeded by low-permeability sediments that were deposited in the Holocene marine incursion as in other New Zealand coastal aquifers, e.g., Wairau Plains (White *et al*., 2016) and Poverty Bay (White *et al.,* 2012).
- Surface water discharge to groundwater where gravel-bed rivers flow from the hinterland onto the coastal plain, e.g., the Wairau River on the Wairau Plain (White *et al*., 2016).

3.4 GROUNDWATER INFLOW

Groundwater inflow to ECAs is possible. However, this inflow is assumed as zero because: the lithology in the hinterland is generally relatively impermeable and steep so runoff will be high; no data was available to estimate groundwater recharge in the hinterland; this is a conservative assumption in regards of GAA.

3.5 GROUNDWATER OUTFLOW

Groundwater outflow can generally be calculated from the water budget. However, key flow information (i.e., surface flows) were generally unavailable. Therefore, the water budgets were not used to calculate groundwater outflow from the ECAs.

3.6 WATER USE

Groundwater allocation from the ECAs is zero, or very low. The only water allocation recorded by GDC is from groundwater near Ruatoria township, where a combined allocation to two groundwater users totals 2.8 L/s, and an allocation near the Karakatuwhero River to one user totals 5.0 L/s. Groundwater is also used by ‘permitted’ users, i.e., to provide drinking water for houses or stock. However, GDC has no information on these uses of groundwater in the ECAs.

3.7 GROUNDWATER RECHARGE CALCULATIONS

The water budget was simplified to calculate groundwater recharge, because of the general lack of data on surface water flows and on groundwater-surface water interaction. Groundwater use was not relevant to this calculation.

$$RR = P - AET \tag{8}$$

Generally, rainfall recharge is low (i.e., less than 100 L/s, Table 3.1) in the ECAs. Rainfall recharge is largest in the Waiapu aquifer zones.

Table 3.1: Rainfall recharge to groundwater in the ECAs and aquifer zones. Flows are rounded to the nearest L/s.

ECA – zone	Area (km^2)	Rainfall mean (mm/yr)	AET mean (mm/yr)	Rainfall mean (L/s)	AET mean (L/s)	Rainfall recharge mean (L/s)
Uawa – Tolaga Bay township	1.6	1,347	962	68	49	19
Uawa – Maikaika	5.8	1,429	972	263	179	84
Uawa – Wharekaka	37.2	1,442	974	1,701	1,149	550
Waiapu – Rangitukia	3	1,612	1,067	153	102	51
Waiapu – Tikitiki	62.2	1,839	1,069	3,627	2,108	1,500
Waiapu – Whakapourangi and Takamore	47.2	2,146	1,040	3,212	1,557	1,700
Wharekahika – Beach	3.27	1,984	1,110	206	115	91
Wharekahika – Hill	6.17	2,031	1,111	397	217	180
Wharekahika – Waitaukakari	5.84	2,157	1,114	399	206	190
Karakatuwhero	17.5	2,150	1,117	1,193	620	570
Orutua	3.5	1,561	1,078	173	120	53
Tunanui	2.9	1,399	1,036	129	95	34
Mangahauini	1.8	1,575	1,005	90	57	33
Waipare	0.8	1,426	981	36	25	11
Pakarae – Beach	1.5	1,239	934	59	44	15
Pakarae – Mangaone	3	1,225	922	117	88	29
Pakarae – Mahana	6.6	1,433	964	300	202	98
Waiomoko	7.1	1,386	954	312	215	97
Wainui	4.1	1,098	881	143	115	28
Muriwai – township	9.7	1,113	881	342	271	71
Muriwai – Maraetaha	6	1,240	918	236	175	61

4.0 GROUNDWATER AVAILABLE FOR ALLOCATION AND SUGGESTED ALLOCATION LIMIT

GAA is defined as an estimate of the maximum flow that could be allocated to groundwater users. The GAA should be calculated from the water budget (Section 3), i.e., the rainfall recharge estimate equals GAA (Tables 3.1 and 4.1), respectively. For the ECAs, an estimate of rainfall recharge is the sole component of groundwater inflow that was considered because many other water budget components were unknown, particularly surface water inflows and outflows from the zones. GAA is generally low in the ECAs, with the exception of two Ruatoria zones (Table 4.1).

Allocation limits are recommended to be a fraction of GAA, and are set by the regional authority. For example, Canterbury Regional Council set a groundwater allocation limit in Canterbury groundwater zones as '50% of average annual land-surface recharge including the recharge component contributed by intermittent streams' as part of a policy that aimed to protect environmental values (Scott, 2004). In addition, The Ministry for the Environment (2008) provided guidelines on groundwater allocation limits in the National Environmental Standard (NES), including:

'For shallow, coastal aquifers (predominantly sand)', an allocation limit of, whichever is the greater of:

- 15% of the average annual recharge as calculated by the regional council; or
- the total allocation from the groundwater resource on the date that the standard comes into force less any resource consents surrendered, lapsed, cancelled or not replaced.

For all other aquifers: an allocation limit of, whichever is the greater of:

- 35% of the average annual recharge as calculated by the regional council;
- the total allocation from the groundwater resource on the date that the standard comes into force less any resource consents surrendered, lapsed, cancelled or not replaced.

For groundwater that is shown to be connected to adjacent surface water, the environmental flow or water level set for the surface water body will also apply to the management of groundwater takes.'

These guidelines were used to suggest possible allocation rate (PAR) for groundwater within ECAs (Table 4.1). The PAR values were developed to protect against sea water intrusion into aquifers with a coastal boundary and preserve low flow in rivers in groundwater and surface water systems that are possibly hydraulically linked. Therefore, PAR estimates consider available surface flow data, particularly summer low-flow gaugings. PAR is set to zero in some aquifer zones, i.e., where GAA is very low in coastal aquifer zones or where the measured summer stream flow is extremely low.

Table 4.1: Estimates of possible allocation limits for zones within the 12 ECAs.

ECA – zone	**GAA (L/s)**	**Surface flow measurements**				**Allocation options**		**PAR (L/s)**	**Comment**
		Surface flow (L/s, 90th percentile)	**Surface flow (L/s, 95th percentile)**	**Mean flow, low flow gaugings (L/s)**	**Minimum flow, low flow gaugings (L/s)**	**15% annual recharge (L/s)**	**35% annual recharge (L/s)**		
Uawa – Tolaga Bay township	20	n/a	n/a	n/a	n/a	3	7	0	Zero PAR to protect against salt water intrusion
Uawa – Maikaika	80	n/a	n/a	n/a	n/a	12	28	0	Zero PAR to protect against salt water intrusion
Uawa – Wharekaka	600	141	112	142	138	90	210	210	NES 35% default for inland aquifer
Waiapu – Rangitukia	50	n/a	n/a	n/a	n/a	8	18	8	NES 15% default for coastal aquifer
Waiapu – Tikitiki	1500	9803	7518	4231	232	225	525	525	NES 35% default for inland aquifer
Waiapu – Whakapourangi and Takamore	1700	9803	7518	4231	232	255	595	595	NES 35% default for inland aquifer
Wharekahika – Wharekahika beach	90	n/a	n/a	n/a	n/a	14	32	14	NES 15% default for coastal aquifer
Wharekahika – Wharekahika hill	200	2290	1695	1600	22	30	70	30	NES 15% default to preserve summer low flows in Wharekahika River

ECA – zone	GAA (L/s)	Surface flow measurements				Allocation options		PAR (L/s)	Comment
		Surface flow (L/s, 90th percentile)	Surface flow (L/s, 95th percentile)	Mean flow, low flow gaugings (L/s)	Minimum flow, low flow gaugings (L/s)	15% annual recharge (L/s)	35% annual recharge (L/s)		
Wharekahika – Waitaukakari	200	2290	1695	1600	22	30	70	30	NES 15% default to preserve summer low flows in Wharekahika River
Karakatuwhero	600	1948	1607	1119	145	90	210	90	NES 15% default for coastal aquifer
Waiomoko	100	n/a	n/a	79	1	15	35	0	Zero PAR to protect against salt water intrusion and preserve summer low flows
Tunanui	30	n/a	n/a	n/a	n/a	5	11	5	NES 15% default for coastal aquifer
Mangahauini	30	n/a	n/a	n/a	n/a	5	11	0	Zero PAR to protect against salt water intrusion
Waipare	10	n/a	n/a	n/a	n/a	2	4	0	Zero PAR to protect against salt water intrusion
Pakarae – Pakarae beach	20	n/a	n/a	166	4	3	7	0	Zero PAR to preserve summer low flows
Pakarae – Mangaone	30	n/a	n/a	166	4	5	11	0	Zero PAR to preserve summer low flows

ECA – zone	GAA (L/s)	Surface flow measurements				Allocation options		PAR (L/s)	Comment
		Surface flow (L/s, 90th percentile)	Surface flow (L/s, 95th percentile)	Mean flow, low flow gaugings (L/s)	Minimum flow, low flow gaugings (L/s)	15% annual recharge (L/s)	35% annual recharge (L/s)		
Pakarae – Mahana	100	n/a	n/a	166	4	15	35	15	NES 15% default for coastal aquifer
Muriwai – township	70	n/a	n/a	n/a	n/a	11	25	11	NES 15% default for coastal aquifer
Muriwai Maraetaha	60	47	10	88	6	9	21	21	NES 35% default for inland aquifer
Wainui	30	n/a	n/a	n/a	n/a	5	11	5	NES 15% default for coastal aquifer
Orutua	50	n/a	n/a	n/a	n/a	8	18	8	NES 15% default for coastal aquifer

5.0 RECOMMENDATIONS

In the following sections, recommendations for further work are provided, in no particular order.

5.1 PROPOSED MONITORING PROGRAMME

A long-term monitoring programme on groundwater quantity and quality should be implemented to characterise the state and trends in each of the ECAs currently in use. This programme should be extended, should the investigation identify new groundwater sources.

Suitable sites for groundwater monitoring (quantity and quality) include non-pumping wells for which lithological information, depth and screen interval is available, and protective measures have been taken to prevent run-off from entering the well (e.g., casing is established above the ground and sealed using a concrete pad). Springs may also be considered as groundwater quality monitoring sites, provided the flow is continuous throughout the year, and that both the flow and access to the spring outlet are suitable to allow sampling in flowing conditions without contamination of the sample. At minimum, there should be one well sited within each of the ECA zones, near the coast. It is recommended, where possible, to select sites along the flow path from the hills to the sea.

In order to characterise the system, groundwater quality monitoring sites should be initially selected away from potential contaminant sources. The recommended initial sampling frequency is quarterly in order to capture seasonal variations in both quality and quantity. Groundwater samples should be collected according to the New Zealand sampling protocol for State of the Environment monitoring (Daughney *et al*., 2006), which includes purging operations and the collection of field measurements. Occasional sampling for age tracers will provide information of transit time in the groundwater system, which will be relevant to environmental reporting. To characterise the aquifer, it is recommended to analyse groundwater samples for: the full suite of major cations and anions (calcium, sodium, potassium, magnesium, chloride, bicarbonate, and sulphate); nutrients (nitrate-nitrogen, ammoniacal-nitrogen, and dissolved reactive phosphorous); and selected metals (iron, manganese and silica). The analysis of these parameters will enable routine quality assurance procedures to be performed, ensuring the integrity of the analytical results (e.g., charge balance error calculations); thus building a strong dataset to support management policies.

The minimum time period recommended to report on the state of groundwater quality varies between two and six years (European Commission, 2009). The longer period applies to time series with seasonal variations. Analysis of the Poverty Bay Flats dataset (74 sites, 34 parameters) in a concurrent study (Moreau *et al*., 2016; Envirolink contract 1654-GSDC129, 1656-GSDC131) indicated that seasonality affects up to 8% of parameter-specific data. State of the Environment reporting should include concentrations of: nutrients (nitrate-nitrogen, ammoniacal-nitrogen, and dissolved reactive phosphorous); salinity (e.g., total dissolved solids content or electrical conductivity, sodium and chloride); redox indicators (iron, manganese, and dissolved oxygen); microbial indicators (*E. coli*, and faecal coliform) to be consistent with national reporting. However, should freshwater values and pressures identify a need for specific parameters, these should be included. Trend analysis undertaken to inform State of the Environment reporting should use a consistent time period for both groundwater levels and quality.

Following this period, a review of the network, sampling frequency and analytical suite should be undertaken to ensure cost-effectiveness.

For the long-term monitoring network, a survey of well depth and water levels for each aquifer should be undertaken to assess depth range (e.g., possible multiple gravel lenses), to assess the groundwater gradient, and review the number of aquifers to be monitored (e.g., in multi layered systems). Along with the collection of regular groundwater quality samples, a one-off survey for pesticides will be useful to assess anthropogenic impact of the ECAs.

5.2 MINIMUM GROUNDWATER LEVELS

A policy on allocation from the ECAs could be implemented to maintain groundwater outflow to the sea and protect water quality from seawater intrusion. Until monitoring data is collected for a reasonable time period (e.g., > four years), it is recommended to use sea water intrusion monitoring in the Te Hapara Sand aquifer of the Poverty Bay Flats as a proxy for the ECAs. The Poverty Bay Flats area receives the least amount of rainfall within the region (Murphy and Tschritter, 2012), which combined with the low groundwater elevation gradients in the Te Hapara Sand (White *et al*., 2012), should provide a conservative approach for managing seawater intrusion in the ECAs.

5.3 REFINEMENT OF WATER BUDGET ESTIMATES

Gauging at the upper and lower surface water reaches are recommended, associated with chemistry sampling, to inform on baseflow quantity and chemistry. Synoptic gaugings could be undertaken to investigate groundwater surface-water interaction. These surveys do not require chemistry sampling and may be followed by more detailed investigations (e.g., radon survey, temperature sensing).

The drilling and hydrogeological logging of boreholes near the coast, in key aquifer systems, will allow for geological characterisation. In the Waiapu and Karakatuwhero aquifers, the drilling programme could be used to investigate the occurrence of Pleistocene aquifers at depth.

Further work is recommended to estimate groundwater discharge at the coast (also relevant to drilling at the coast), and groundwater use by domestic supplies to refine the water budgets.

Aquifer tests at bores, where good lithological logs are available, should be undertaken in conjunction with groundwater sampling and water level recording, near the coast. Piezometric surveys could be undertaken in key wetlands (e.g., Karakatuwhero and Muriwai) to assess water fluxes between surface- and groundwater.

5.4 ADDITIONAL INFORMATION

It is recommended that GDC contact local iwi, hapu and other land owners for the identification, location and history of springs and wetlands in the area.

It is also recommended that GDC contact local iwi, hapu and other land owners to simultaneously map values and identify hazards to each aquifer. GDC may also consider monitoring land use within the ECAs.

6.0 CONCLUSIONS

GNS Science and GDC jointly undertook a data review of the twelve ECAs within the Gisborne region (excluding Poverty Bay Flats) to: identify hydrogeological data gaps; and provide recommendations regarding further data collection and groundwater monitoring to inform GDC's sustainable management of these areas. This project was developed in the context of the NPS-FM and arose from growing interest from the community.

There was limited information available to characterise the twelve alluvial areas: there were no bores with lithological records in many of the aquifers, including the four northernmost East Coast aquifers; other aquifers only had one or two bores. Therefore, little information about the hydrostratigraphic character of these aquifers existed, beyond QMAP information. Information about possible hydraulic connections between the Holocene alluvial deposits and potential adjacent aquifers was, therefore, also limited. The alluvial deposits are surrounded and underlain by Tertiary and basement deposits that are unlikely to provide much recharge to them. In other areas of New Zealand, Holocene deposits are underlain by Pleistocene sediments that can host aquifers. Drilling and lithological logging of bores are required to investigate the occurrence of Pleistocene deposits beneath the ECA. If groundwater-bearing Pleistocene deposits are encountered, it would be worthwhile to investigate a potential hydraulic connection with the ECA.

Bore depth and water level information is not routinely recorded in wells. Therefore, it is recommended to undertake a bore depth and water level survey at all recorded wells. In addition, no aquifer test data currently exists at any bores within the Holocene alluvial areas. Aquifer testing is recommended for current and future bores at strategic locations and depths in order to characterise hydraulic properties of the deposits.

Additionally, little information was available on the existence and exact locations of springs. The extents and locations of wetlands were sourced from a nationwide, small scale (1: 250,000) dataset that is not suited for investigations at the scale of most of the ECAs. Therefore, it is recommended that both the spring and wetland datasets are updated, ideally with the help from local land holders. Spring data may include spring flow and an indication of the perennial or seasonal status of the springs. While surveys involving communities are undertaken, information about the temporal changes to the wetlands should be obtained.

The aquifer boundaries for two of ECAs (Pakarae and Waiomoko) were modified based on the geological map to include additional areas of potential interest for groundwater management. The boundary between Muriwai and the Poverty Bay Flats alluvial areas was moved further south based on well logs and soil data. The boundaries of some of the ECAs (e.g., Wharekahika, Waiapu, Uawa, Pakarae and Muriwai) were subdivided to allow for better hydrogeological characterisation of these areas.

A high-level risk assessment was completed for the ECAs. Multiple anthropogenic and environmental risks were identified within the ECAs that may have a negative impact on groundwater quantity and quality. For example, over allocation of available groundwater resources could lead to decreasing water levels throughout an aquifer, which could result in seawater intrusion occurring at the coast. Therefore, groundwater allocation limits should be set to prevent overuse of an aquifer and the aquifers should be monitored regularly. In addition, minimum groundwater level at indicator wells in the Te Hapara Sand aquifer, as a proxy for the ECAs, could be set to monitor seawater intrusion. To date no groundwater quality and quantity monitoring occurs in the ECAs. A monitoring programme to characterise both groundwater quality and quantity should be set up with the aim to manage and mitigate risks.

A more specific risk assessment addressing values, risks, and mitigation strategies is also recommended.

GAA was derived from water budgets that estimate the inflow and outflow to, and from, the aquifers. Therefore, water budgets were calculated for all ECAs. However, there was only limited information available for these calculations. Surface water flow measurements were not suitable for the water budgets and, therefore, not used. Also, there were no synoptic gaugings that would allow estimations of groundwater –surface water interaction. As a result of these data gaps, the water budgets had to be simplified, and some outputs, like groundwater outflow, could not be calculated. GAA was generally low in the ECAs, with the exception of two Waiapu zones. GAA estimates may be further refined, e.g., through a systematic gauging programme that includes synoptic gaugings.

Possible allocation limits are recommended to protect against seawater intrusion into aquifers with coastal boundaries and to preserve low flow in rivers in groundwater and surface water systems that are potentially hydraulically linked. These limits were set to zero in some of the ECA zones, where GAA is very low in coastal aquifer zones or where measured summer stream flow was extremely low.

In conclusion, the boundaries of the twelve ECAs were refined, and GAA was derived based on preliminary water budgets. A large number of possible investigations were identified in these areas, without a particular order. However, due to the current lack of any monitoring within the ECA, it is recommended that a groundwater monitoring network be established to characterise the groundwater currently in use and assess their current state.

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www.gns.cri.nz

Principal Location

1 Fairway Drive
Avalon
PO Box 30368
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Private Bag 1930
Dunedin
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road
Wairakei
Private Bag 2000, Taupo
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road
PO Box 31312
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4657