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Water Management REPORT

GISBORNE REGIONAL WATER ASSESSMENT

PREPARED FOR
Gisborne District Council

RD23011

21 September 2023

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EXECUTIVE SUMMARY

Key question

The purpose of the regional-scale water assessment is to provide Gisborne District Council (GDC) with information on quantifying risks to water supply security, including where and how this will be experienced most acutely and how it may be amplified or accelerated in the future (considering a mid-century timeframe). This report aims to provide information to support GDC's strategic freshwater management and planning and comes amid major 3 Waters Reform and the need to implement new freshwater policy under the National Policy Statement for Freshwater Management (NPS-FM, 2020).

This work has been carried out at time when Tairāwhiti has been dealing with the emergency response to flood events. Climate change is likely to increase the incidence of extreme weather events: both droughts and floods. This assessment considers the projected impacts of future climates and population growth on water supply security.

A similar study was completed in 2013 (Aqualinc, 2013). Estimates of water availability and demands have been updated based on the current state of the resource, and improvements in the temporal resolution of the analysis have been made. In this assessment we have also removed a significant assumption from the 2013 study by calculating the water balance using a daily time-step model where possible, rather than representative statistics, thereby increasing the accuracy of reporting compared to the 2013 study.

Study area

The assessment has focussed on seven catchments within Tairāwhiti:

- Waipaoa
- Waimata
- Hangaroa – Ruakituri (Southern)
- Motu
- Uawa
- Waiapu
- Wharekahika – Waikura (Northern).

Because the Waipaoa catchment represents a significant proportion of the total resource and the total water demand, this catchment has been divided into nine sub-catchments, consistent with the approach taken in Aqualinc (2013).

While individual catchments / sub-catchments have been considered, the analysis has been completed at a regional scale to give a regional overview of the balance of water availability and demands. The level of detail reflects this: details of individual water takes, for example, are not necessarily represented.

Approach taken

The approach that has been taken to quantify water security risks is to:

- Estimate the current state of water demands from all sectors: irrigation, municipal supply, stockwater, private domestic use.
- Estimate the current availability of surface water and groundwater in each catchment (or sub-catchment as appropriate) within the study area
- Estimate the current balance of water availability and demand for both groundwater and surface water.
- Investigate potential changes to the balance of water availability and demands for future periods (2035, 2045, 2055), considering both future climate projections and population growth.

GDC has made significant progress in recent years with removing or reducing “paper allocation” on irrigation consents. This means that consented rates and volumes will be a reasonable approximation of the actual water demands.

Key findings and implications

How much water does Tairawhiti have?

Under the Tairāwhiti Resource Management Plan (TRMP), up to 4,170 l/s is able to be allocated for abstractive use from surface water resources in the Waipaoa and Te Aria catchments. In this assessment we have estimated that a further 3,668 l/s can be allocated from surface water resources in other catchments where specific allocation limits have not yet been set.

The actual availability of the allocated water depends on river flows. Over winter and spring (June – October), surface water is typically at or close to 100% availability, although during high flow periods it may not be possible / desirable to take sediment-laden water. Surface water availability is typically lowest in January – February. Average supply security over this period is around 70% for the Waipaoa River and 45% for the Te Arai River. Supply security at this level during key parts of the growing season is a potential challenge for high-value land uses that rely on highly reliable water supplies.

Groundwater is three-dimensional, and does not follow the same catchment boundaries as surface water. Allocation limits have been set for the TRMP for aquifers within the Waipaoa Catchment. For aquifers in the remaining catchments, groundwater availability can be estimated from rainfall recharge, but these estimates will change if the estimated aquifer extent changes (for example as a result of SkyTEM surveys).

Consented groundwater allocations exceed the estimated availability for the Te Hapara Sands and Makauri aquifer units. GDC is targeting reductions in existing allocations to address over-allocation The Matokitoki aquifer has some available allocation. Outside of the Waipaoa catchment, it is estimated that there is groundwater available, but there is no guarantee that it is economically accessible.

On an average annual basis, the volumes available from surface water are substantially larger than those available from groundwater.

How much water does Tairawhiti use?

Based on resource consent data provided by GDC in November 2022, an annual volume of approximately **33 million cubic metres** is consented for abstraction. Approximately **90% of this is from surface water.**

On an instantaneous rate basis, 3,134 l/s is consented for abstraction from surface water, and 700 l/s is consented for abstraction from groundwater.

Uses of water that do not require resource consents are estimated to be very small in comparison to the consented volume.

What is the water being used for?

The majority of water use is estimated to be for irrigation, within the Waipaoa catchment.

Water demands in all other catchments are relatively small at present, with the exception of the demand for Gisborne City's municipal supply (from impounding dams in the Mangapoike catchment).

Where are the greatest pressures on water resources at present?

In key areas surface water and groundwater resources are under pressure at present. While Tairawhiti has been focussed on flood damage recovery in 2023, water shortages during drought conditions are equally possible and should not be ignored.

For the Waipaoa and Te Arai catchments the supply-demand balance calculated from a daily time-step model shows that while on average supply might exceed demand, deficits may still exist in a month due to demand exceeding available supply on a daily basis. Water supply surpluses (i.e., available water exceeds demand) on an annual or monthly basis may mask shorter-term supply shortfalls.

Using January as a "sentinel month", demand exceeds supply in the Waipaoa A block, the Te Arai A and B blocks, and is close to the supply in the Waipaoa B block.

Overall, in this assessment we have estimated that Tairāwhiti has a 52.3 Mm3/year groundwater surplus. However, groundwater resources in the Waipaoa catchment is calculated to be 3.7 Mm3/year in deficit. Five Waipaoa sub-catchments have groundwater use at present, and three of these are in deficit.

At a regional scale, the overall surplus is due to large calculated groundwater availabilities in the remaining catchments. This is driven by large mapped aquifer extents. Results from further investigations, economic and technical feasibility of groundwater abstraction, and values considerations may mean this calculated surplus is not available for use in reality.

The following figures illustrate, for surface water and groundwater respectively, the current state of the water balance, and how this is projected to change over the next 30 years under the assumptions used in this assessment. In the figures, blue / green shading represents a surplus, and orange / red shading represents a deficit.

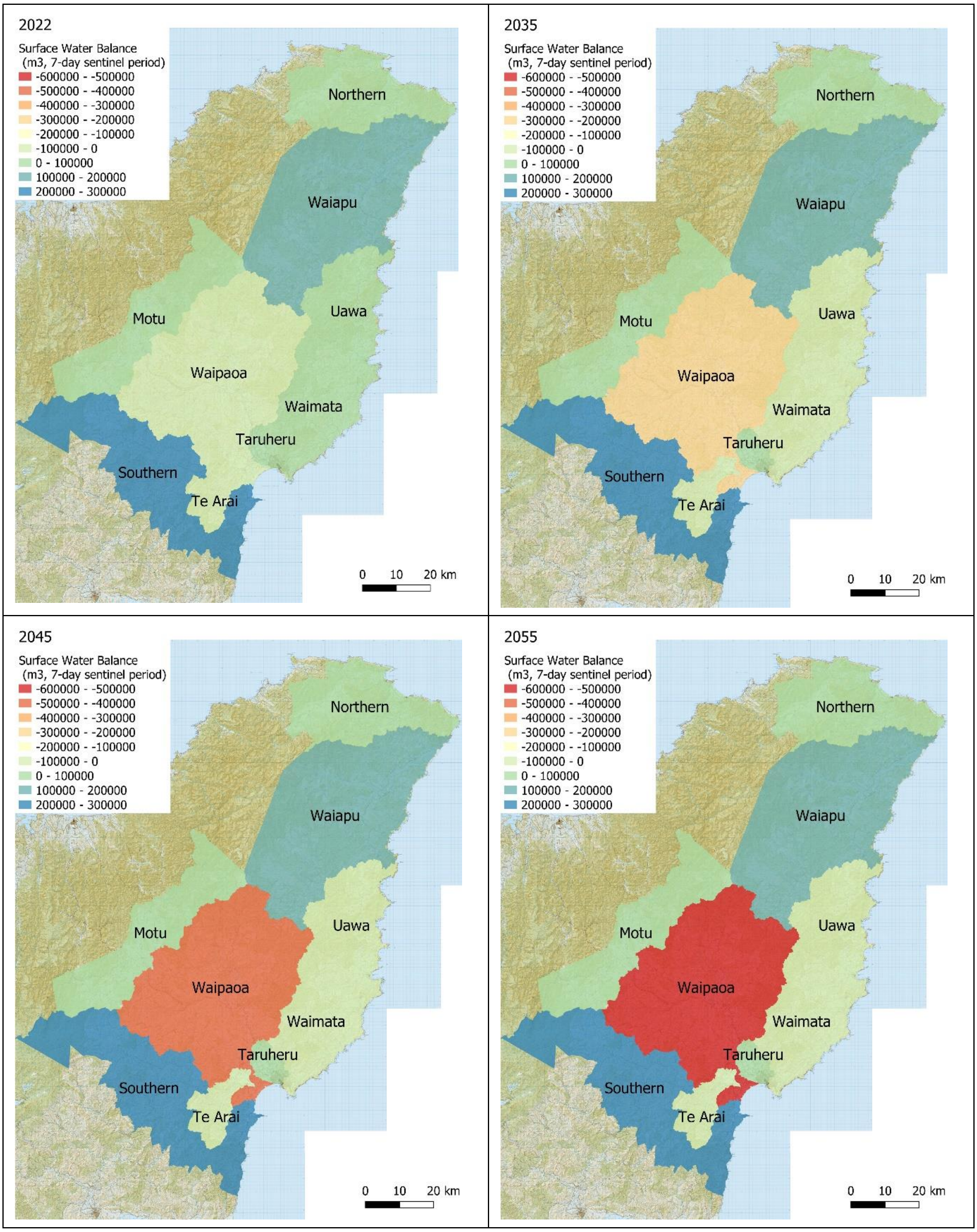

Figure 1-1 - Surface water balance over the next 30 years, based on a 7-day sentinel period.

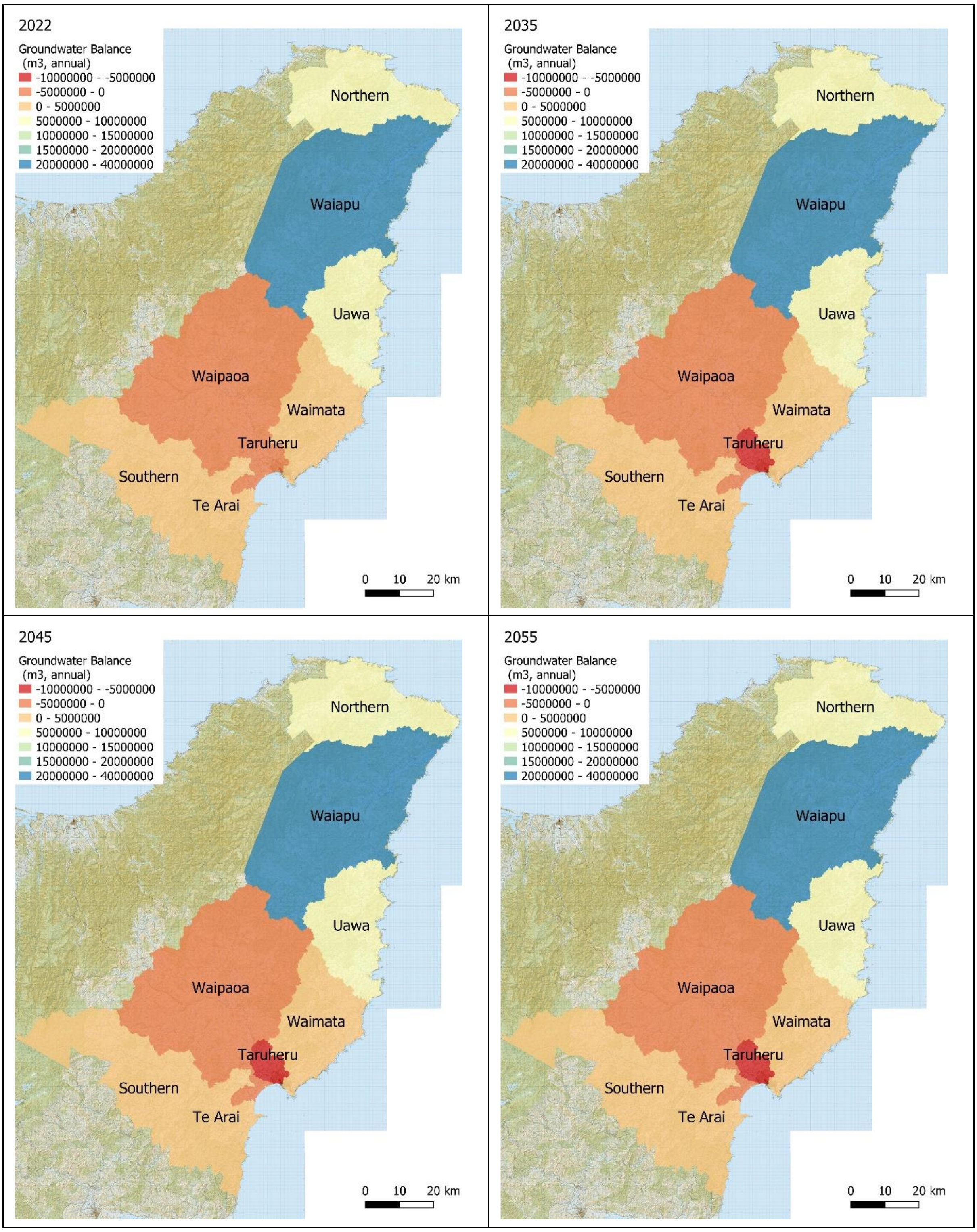

Figure 1-2 Groundwater balance over the next 30 years, based on annual volumes.

What is this assessment telling us about the future?

Based on 2018 census data, population growth is expected to drive increased demand for municipal water and private domestic supplies.

Irrigation demand for existing irrigated areas, which represents the highest proportion of total water demands in most catchments, is projected to increase under future climates. The annual volumes required for irrigation may increase by up to 15% by mid-century. In addition, new irrigation may increase the total demand for irrigation water - there is land within Tairawhiti that is topographically suited to irrigation but is not currently irrigated.

The groundwater resource is currently in a state of decline in the areas where it is used most intensively. This situation is likely to continue without specific interventions. Groundwater availability is likely to reduce under future climate projections.

Daily time-series analysis in the Waipaoa catchment (which has sufficient data for this type of analysis to be feasible) shows that the supply deficit in the Waipaoa catchment is projected to worsen over time. This potentially impacts high-value horticulture and vegetable production that requires a high level of supply reliability.

The water balance in the main municipal water supply catchment (Southern-Mangapoike) shows a surplus overall under current and future conditions. Projected changes to the seasonality of rainfall may create challenges for the impounded reservoirs, however. Inadequate or poorly-timed rainfall can reduce supply reliability and availability. In terms of water supply resilience, the backup municipal supply from the Waipaoa River is likely to come under increased pressure in the future as the climate changes. A changing climate is highly likely to result in more frequent extreme weather, both droughts and floods. Flood damage to infrastructure in 2023 has highlighted the risk of relying on surface water for municipal supply.

Te Mana o te Wai

Allocating more water to maintaining or improving the health of rivers results in less available for abstractive use. It should be noted that if allocation rules are revised to give effect to Te Mana o te Wai as part of implementing the NPS-FM 2020, the rates and volumes of water available in the future could be less than modelled in this assessment.

1 INTRODUCTION

1.1 Background

Gisborne District Council (GDC) has engaged Aqualinc Research Limited (Aqualinc) to carry out a regional water assessment to increase understanding of the water supply-demand balance for their seven Tairāwhiti freshwater catchments.

Aqualinc completed a similar assessment in 2013 (Aqualinc, 2013). In this report we have updated our estimates of water demands and availability based on the current state. We have also removed a significant assumption from the 2013 project by calculating the water balance using a daily time-step model rather than representative statistics, increasing the accuracy of reporting compared to the 2013 study.

Most surface water and groundwater use in the region occurs in the Waipaoa catchment, with water takes in this catchment accounting for around 90% of the region’s consented water allocation. This includes all reticulated municipal drinking water supply. While the wider catchment is used for sheep and beef farming, the Poverty Bay Flats are used for intensive arable farming, market gardening, horticulture, and viticulture, with irrigation playing a key role in productivity.

Most waterbodies used for abstraction on the Poverty Bay Flats remain fully allocated or over-allocated, largely due to a move towards higher value and more water-demanding crops such as kiwifruit and apples since the 2013 report was published. Demand for water is likely to remain high going forward, with potential increases due to continued horticultural development, population growth, urban expansion, and climate change. As well as abstractive use (from all sectors), freshwater on the Poverty Bay Flats also has important social, cultural, and ecological values.

The Poverty Bay Flats is generally considered by GDC to be fully- to overallocated. The exception is the Waipaoa B Block, which is currently around 50% allocated. There is also allocation available in the Te Hapara Sands aquifer on paper. However, during the development of the Freshwater Plan, information on the actual use of water showed that large amounts of allocated water are unused. This is partly due to the variation in water use from year to year depending on weather conditions, soil moisture, and crop growing cycles, i.e., a consent holder may only use their full allocation once every 10 years. GDC have made good progress in recent years in reducing “paper allocation”. Despite the actual use being below consented allocation, there is still a general decline in water quantity, especially in deep groundwater. Interventions in the form of either increased supply or reduced demand are deemed necessary. GDC have in recent years trailed Managed Aquifer Recharge (MAR) to test the viability of these tools to support increasing available supply to the deeper groundwater system and options like this may be considered..

Key water bodies for productive use are the Waipaoa and Te Arai rivers as well as the five main aquifers under the Poverty Bay Flats. These aquifers are the deep Matokitoki and Makauri aquifers, and the shallow Te Hapara Sands, and other shallow Waipaoa gravel aquifers. The Waipaoa River is also the major recharge source for most aquifers.

The Waipaoa Catchment Plan sets allocation limits and minimum flows that provide for instream values such as ecosystem health. There is a two-tier system for issuing permits, with the higher-reliability A Block permits allowing water to be taken until the river reaches the minimum flow requirement. B Block permits allow the taking of water during higher flows so are less reliable. A Block and B Block allocation limits have been set for the Waipaoa and Te Arai Rivers. Note that current allocation rules may be revised as part of the process to implement the requirements of the National Policy Statement for Freshwater Management (NPS-FM) and give effect to Te Mana o te Wai.

1.2 Purpose

The purpose of the analysis described in this report is to:

- Estimate water demands in each (sub-)catchment[1] from all main sectors (irrigation, municipal supply, stockwater, private domestic use, other consented demand), now and into the next 30 years.
    - The water demands were estimated on a daily basis using consent details, irrigation mapping, and municipal water use data provided by GDC, irrigation demand modelling, and population estimates from StatsNZ.
    - We estimated future water demands using StatsNZ population projections, crop area mapping data from GDC, and estimated changes in per-hectare irrigation demand due to climate change.
- Estimate the surface water and groundwater availability in each (sub-)catchment.
    - The allocated surface water and groundwater in each (sub-)catchment were obtained from planning documents. In the case of surface water, where the allowed abstraction is also limited minimum flow restrictions set on the river, we calculated the available water on each day by comparing either daily recorded flow data, or representative flow statistics where recorded flows were poor quality or unavailable, to the allocation rules.
    - We used estimate changes in mean annual low flow (MALF) made by Collins et al. (2018) and NIWA (2020) to estimate future surface water availability, and projected changes in land-surface recharge (Collins et al., 2022) to estimate future groundwater availability.
- Estimate a present-day surface water balance. In its simplest form, the water balance is calculated by subtracting demand from availability over a unit of time, e.g., a day or a year.
    - We have presented the results of a daily water balance for the Waipaoa and Te Arai surface water units, as these units have the most reliable surface water flow records and most intensive water use. We used the water balance for these catchments to select a “sentinel month”, during which demand puts the most pressure on supply.
    - For the remaining (sub-)catchments, we estimated the demand and supply during the sentinel month. For all catchments we compared the 7-day minimum supply to the 7-day maximum demand during the sentinel month to estimate a sentinel water balance.
- Estimate a present-day groundwater balance. Groundwater is allocated on an annual basis, so we calculated the total annual demand for each sector in each (sub-)catchment and compared the demand to the allocated supply.
- Investigate potential changes in the surface water and groundwater balance in future years (2035, 2045, and 2055). For the surface water balance, we calculated the sentinel water balance for future scenarios and compared it to the present.

The analysis is based on data provided by Gisborne District Council as of November/December 2022. It is supplemented by StatsNZ data and projections from the last 5 years. The daily water balance is based on a 30-year modelling period (1993 – 2022).

1.3 Key assumptions

A number of assumptions were required to carry out the estimates of demand, supply, and the water balance. Some of the key assumptions are listed below:

1. We have treated groundwater abstractions which are hydraulically connected to surface water (assigned to surface water allocation units) as demands on surface water.
    a. These abstractions are generally from the Waipaoa Gravel Aquifer or Shallow Fluvial Deposits and are allocated within the Waipaoa A and B Blocks.
2. We have relied on measured data where it is reliable, adequate, and fit for purpose. Where measured data is not deemed to meet this threshold, modelled data has been used.
3. We have partitioned demands between surface water and groundwater, and between individual allocation blocks using the consent database provided by GDC.

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[1] ‘(sub-)catchment' is used extensively throughout this report as both the catchment and sub-catchment scale is used for reporting. (sub-)catchment is a catchall for both unit scales

4. The supply-demand balance was carried out on the allocation unit scale; we compared the total allocation in each allocation unit (e.g. Uawa) to the total demand assigned to that same unit.
5. The consents database indicated that in some cases water is not supplied by the (sub-)catchment where it is used, e.g., a proportion of the surface water demand in the Taruheru and Te Arai surface water units was supplied by the Waipaoa surface water unit.
    a. In the demand assessment, we have apportioned demand based on the (sub-)catchment where the demand is located. Using the above example, this means demand is assigned to the Taruheru and Te Arai units.
    b. In the supply-demand modelling, we have apportioned surface water demand based on the allocation unit the water is taken from. Using the above example, this means demand is assigned to the Waipaoa unit.
6. We modelled irrigation demand using climate data from 1991 – 2022 using Aqualinc's irrigation simulation model, IrriCalc. The irrigation demand was estimated using irrigated area and land use estimated from consent data, Gisborne Aero climate data, and S-Map profile available water (PAW) data. We used modelled irrigation demand rather than measured water use data as measured use data (i.e. from water meters) covers limited time periods, with records of varying length and completeness. Measured use data may also vary in response to non-climate-related factors, e.g., other farm activities and development works, or irrigation management that does not reflect good practice. In our experience, where the total number of meter records in a catchment is relatively low, relying on this data without sufficient contextual information (knowledge of the irrigation system and farm management; soil moisture records as a means of demonstrating good management practice) is likely to bias the results. Using a soil-moisture balance model provides consistency across catchments and time-scales, which is important in a regional-scale analysis.
7. We have not considered the effects of land use change in the assessment of future scenarios. We have assumed that irrigated land areas will continue under the same land uses provided by GDC in the consents database and crop surveys. We have assumed that all areas which are currently cropped will convert to irrigation by 2055, except for areas in the Motu catchment, which is under a Water Conservation Order. This assumption has been made due to the uncertainties surrounding the multiple drivers of future land uses. This approach is consistent with the national-scale analysis of water availability and security completed for MPI (Dark et al, 2021; Bright et al, 2022).

Other assumptions made are noted in the relevant sections describing the assessment method.

1.4 Structure of this report

This report is structured as follows:

- In Section 2 the catchments and sub-catchments that have been used in the assessment are summarised, along their respective areas.
- The approach used for analysing water supply and demands under future climates is described in Section 3.
- Water demands from all sectors are summarised in Section 4. This section summarises the spatial distribution and source of current consented water takes, and estimated demands for irrigation, municipal and other uses, for both the current and future states.
- The estimated availability of both surface water and groundwater resources is summarised in Section 5, for both current and future states.
- The current water balance for surface water and groundwater is summarised in Section 6. For surface water this is addressed based on daily time-step analysis for the Waipaoa sub-catchments, which then informs a "sentinel month" approach for the other catchments.
- The future water balance is addressed in Section 7.

- Key conclusions are summarised in Section 8.

2 STUDY AREA

The study area encompasses seven catchments in Tairāwhiti. These catchments are:

- Waipaoa
- Waimata
- Hangaroa – Ruakituri (Southern)
- Motu
- Uawa
- Waiapu
- Wharekahika – Waikura (Northern).

We split the Greater Waipaoa area into nine sub-catchments as used in the 2013 Strategic Water Study (Aqualinc, 2013):

- Upper Waipaoa
- Upper Flats
- Mid Flats
- Lower Flats
- Te Arai
- Taruheru
- Waikohu
- Whakaahu
- Wharekopae.

These zones were based on surface water catchments, population distribution, and water demand. The smaller zones, particularly Upper, Mid and Lower Flats, Taruheru, and Te Arai reflect the high water use within these relatively small areas. We note that the Taruheru catchment does not discharge into the Waipaoa River, but it is considered here as part of the Greater Waipaoa area as it is part of the Poverty Bay Flats Freshwater Management Unit.

A map of the catchments is shown in Figure 2-1. The study area covers a land area of approximately 8,300 km^2. Approximately a quarter of the study area falls in the Greater Waipaoa area. Table 2-1 summarises the land area associated with each (sub-)catchment.

Table 2-1: Land areas of the study catchments and sub-catchments

(Sub-)catchment name	Area (ha)	% of total
Waipaoa	**225,835**	**27%**
Upper Waipaoa	*81,635*	*10%*
Upper Flats	*8,827*	*1%*
Mid Flats	*23,035*	*3%*
Lower Flats	*4,696*	*<1%*
Te Arai	*21,543*	*3%*
Taruheru	*9,449*	*1%*
Waikohu	*33,283*	*4%*
Whakaahu	*11,793*	*1%*
Wharekopae	*31,575*	*4%*
Waimata	64,757	8%
Motu	88,762	11%
Northern	77,838	9%
Southern	126,599	15%
Uawa	65,325	8%
Waiapu	180,841	22%
Total	**829,957**	

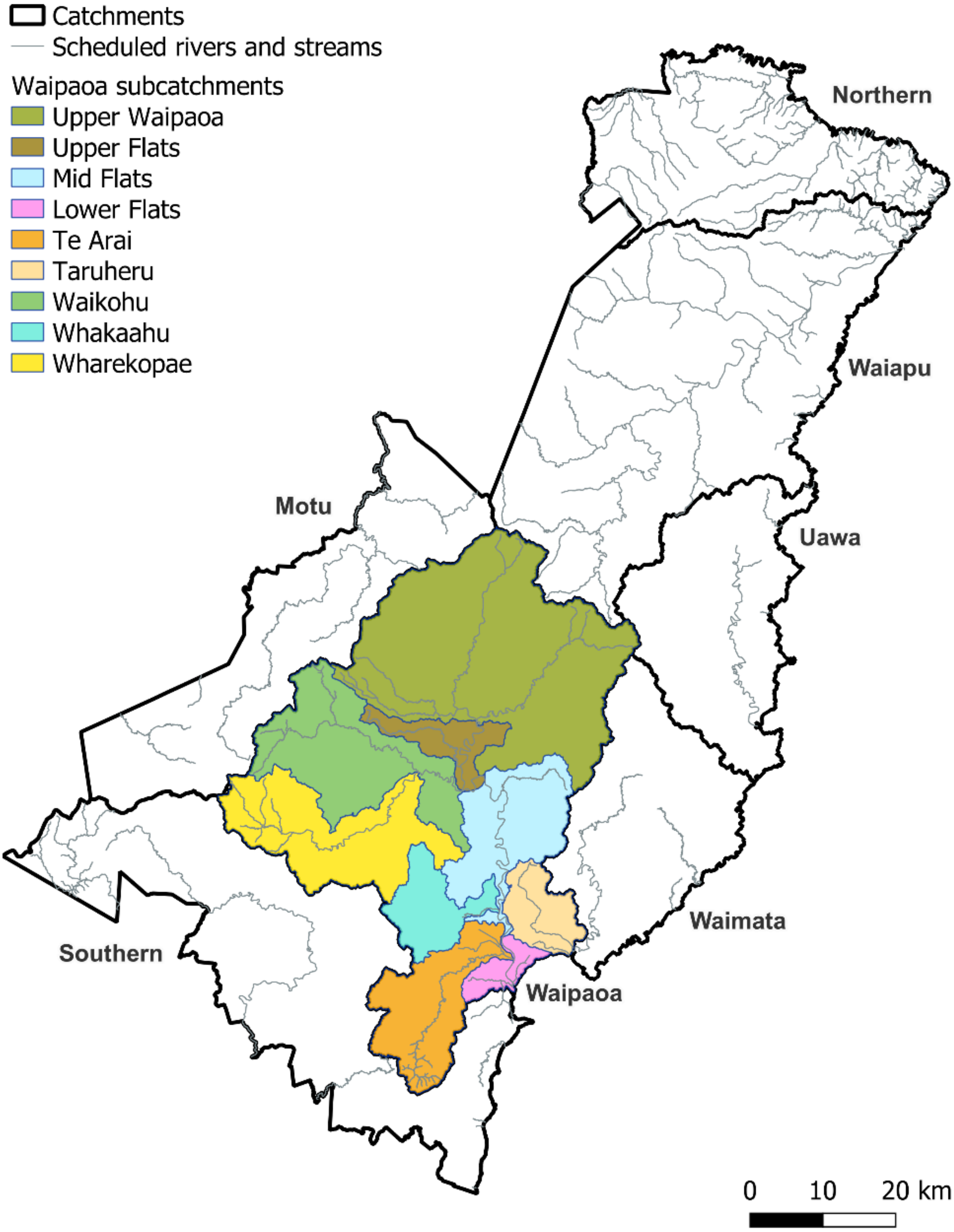

Figure 2-1: Study catchments and sub-catchments

3 CLIMATE CHANGE

The projected impacts of future climate on water demand and water availability that have been used in this assessment are based on the outputs of previous work that has been completed at both a regional and national scale (although we note that in both cases the same spatial resolution has been used).

Although the exact timeframes vary between studies, the “mid-century” period generally represents the 2040s and 2050s. Where appropriate, we have interpolated projected changes to generate results for the 2035, 2045 and 2055 analysis timeframes used in this assessment. Note that non-climate factors such as population changes also contribute to differences between the three future analysis timeframes.

Changes in rainfall will impact on both water supply and water demand. NIWA (2020) modelled changes in annual and seasonal rainfall for Tairāwhiti. For the mid-century period, annual rainfall totals are not expected to change greatly, however the seasonality is projected to change, with deceases of 5-15% in summer rainfall and increases of a similar magnitude in autumn and winter. The greatest changes are projected in northern parts of the region. Similar changes are expected for both RCP4.5 and RCP8.5; the main difference between the RCPs is that the decreases under RCP8.5 are expected to occur predominantly in spring rather than summer.

Results from several studies were combined to assess future water availability:

- Collins et al (2018) used downscaled climate model data to run NIWA’s hydrological model TopNet for two Tairāwhiti Rivers: Waipaoa and Waiapu. For the mid-century period this showed an 8% reduction in mean annual low flow (MALF) for the Waipaoa River, and no change in MALF for the Waiapu River.
- NIWA (2020) modelled changes in mean flow and MALF for Tairāwhiti rivers. Results are mapped, but specific changes for individual rivers are not reported. Relatively small reductions in mean flow are expected by mid-Century. MALF is expected to reduce in the southern part of the region, with northern catchments seeing much smaller changes (and increases in some cases).
- Changes in MALF for selected stream reaches were calculated by NIWA as an input to national-scale sensitivity analysis of water availability and security (Bright et al. 2022), using outputs of hydrological simulations completed for the Deep South Science Challenge. These results were consistent with the NIWA (2020) results.

Mid-century modelled changes in irrigation water demands were obtained from the findings of a national-scale analysis of the effects of climate change on irrigation supply and demand (Collins et al., 2022). In the national-scale analysis rainfall and potential evapotranspiration (PET) from downscaled climate models were used as inputs to Aqualinc’s soil moisture balance and irrigation simulation model, IrriCalc. The outputs are spatially-variable, with a grid spacing of approximately 5 km. This approach is consistent with the method used in national-scale assessment of water availability and security for MPI (Dark et al., 2021; Bright et al., 2022).

Our analysis of future demands in this assessment has been based on RCP6.0. We note that the regional-scale climate projections (NIWA, 2020) and other previous studies use RCP4.5 and RCP8.5. For the mid-century period, impacts on water supply and demand are expected to very similar under RCP4.5 and RCP6.0. Differences between the RCPs are more pronounced for the late-century period (beyond the analysis timeframe for this assessment).

4 DEMAND ASSESSMENT

Key findings from this section:

- Almost all consented abstractions in the study area are in the Waipaoa catchment, and almost all of these are for irrigation.
- Water demands in all other catchments are relatively small at present, with the exception of the demand for Gisborne City's municipal supply (from impounding dams in the Mangapoike catchment).
- Overall, the volume of consented surface water abstraction is approximately ten times the volume of consented groundwater abstraction.
- Climate change is projected to drive increased water demand from existing irrigation, and conversion of some areas from dryland to irrigated may create additional water demands in the future.
- Population growth is expected to drive increased demand for municipal water and private domestic supplies, with a 15% increase expected by mid-century.

The water demand assessment is based on information provided by GDC in November/December 2022. We note that some of the totals calculated here will change as consents are granted or expire. In the demand assessment, we have apportioned demand based on the (sub-)catchment where the demand is located.

4.1 Abstractive water takes

The GDC consents database shows that there are currently 179 consented water takes in the Waipaoa study area (99 from groundwater and 80 from surface water). Of the consented takes, 166 (93%) are for irrigation. There are 12 consents in other catchments (1 from groundwater and 11 from surface water), which are for irrigation or other/mixed uses.

Figure 4-1 and Figure 4-2 show the consented take rates for groundwater and surface water consents respectively. Table 4-1 summarises the number of consents and the consented abstraction associated with each groundwater and surface water allocation unit. We note that in some cases groundwater sources can be assigned to surface water allocation blocks, e.g., abstraction from the shallow fluvial aquifer is connected to the Waipaoa River. We have grouped the consents allocated to surface water units in Table 4-1 depending on whether they are from surface water or connected groundwater. Appendix A contains additional summary tables on the number and size of consents in each (sub-)catchment.

The location of water usage does not always correspond to the unit that water is allocated to. There are 23 consents spatially located in the Taruheru catchment which are directly linked to the Waipaoa River by either a bore taking water from a hydraulically connected aquifer or piping from an intake chamber in the Waipaoa River. The consents are therefore allocated to the Waipaoa freshwater management unit. Similarly, three consents in the lower Te Arai catchment are allocated to the Waipaoa freshwater management unit. The consents allocated to surface water units in the Te Arai and Taruheru sub-catchments are shown in Figure 4-3.

Some consents may utilise water for multiple activities such as stock water, frost protection, and domestic use as well as irrigation.

Table 4-1: Summary of current consents attached to allocation units as of November/December 2022. Consents allocated to surface water units can be from surface water (SW) or hydraulically connected shallow groundwater (GW; i.e. groundwater takes that can reduce surface water flow)

Allocation unit type	Allocation catchment	Type	Number of consents	Total consented rate of take (L/s)	Total daily limit (m^3)	Total annual limit (m^3)
	Consents in the Waipaoa study area:					
Groundwater	Deep Groundwater		32	585	35,713	2,236,761
	Te Hapara Sands		22	110	4,532	579,326
Surface water	Taruheru	SW	1	6	200	19,800
		GW	-	-	-	-
	Waipaoa A Block	SW	44	1,712	122,353	20,303,350
		GW	35	184	9,943	1,436,548
	Waipaoa B Block	SW	25	937	65,518	6,435,134
		GW	9	37	2,080	281,085
	Te Arai A Block	SW	6	65	3,920	235,390
		GW	-	-	-	-
	Te Arai B Block	SW	3	61	4,322	171,135
		GW	-	-	-	-
	Coastal	SW	1	5	432	25,000
	Consents in other catchments:					
Groundwater	Karakatuwhero (Northern)		1	5	432	157,680
Surface water	Coastal (Waimata)		3	49	3,564	738,624
	Karakatuwhero (Northern)		1	5	475	33,615
	Mangaheia (Uawa)		2	30	3,137	576,110
	Maraetaha (Southern)		2	28	1,290	106,337
	Waiapu		1	5	40	14,600
	Waikura (Northern)		1	5	423	3,650
	Waimata		1	5	451	59,300

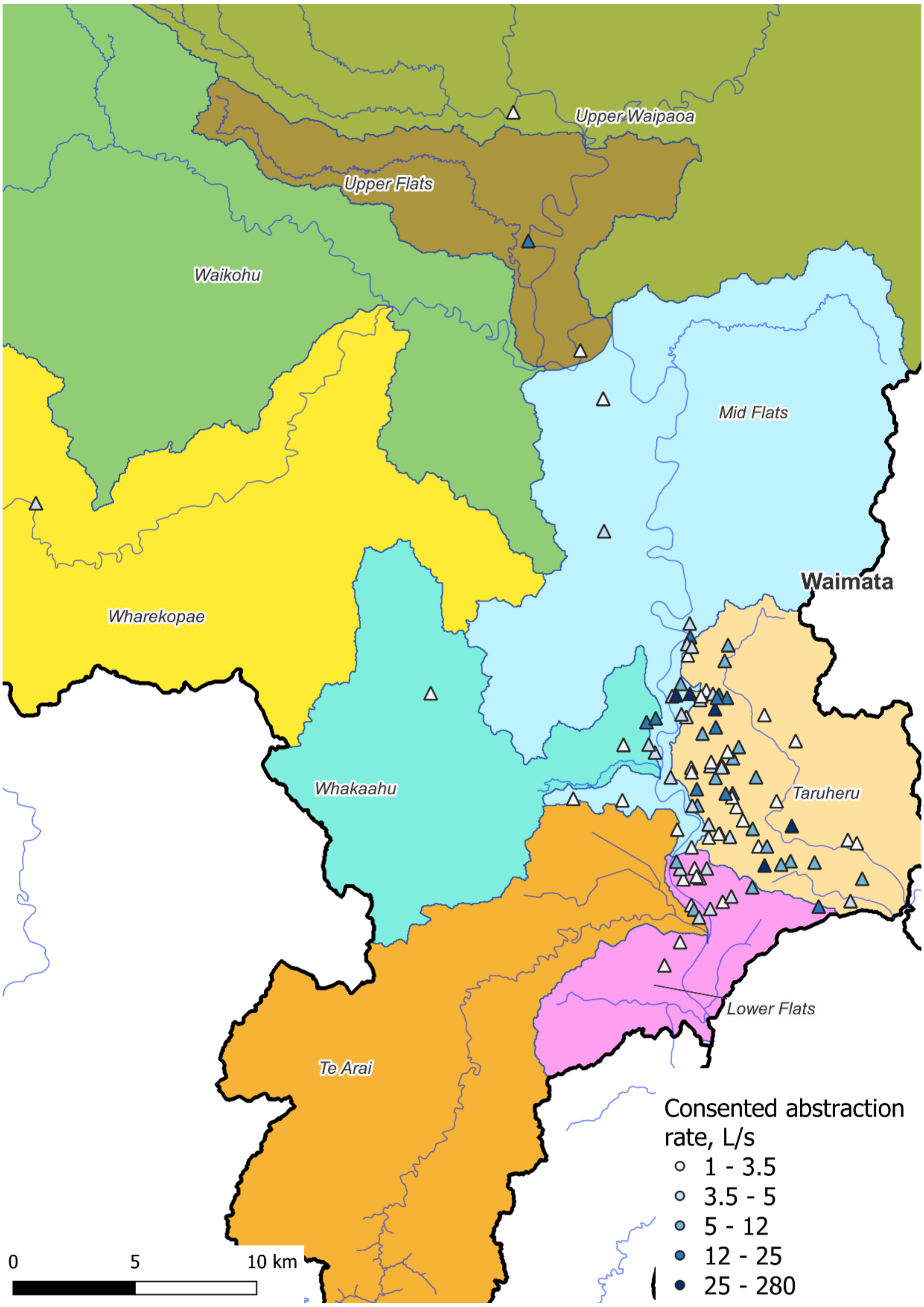

Figure 4-1: Consented abstraction rate and water source for current abstractive groundwater take consents in the Waipaoa area as of November/December 2022

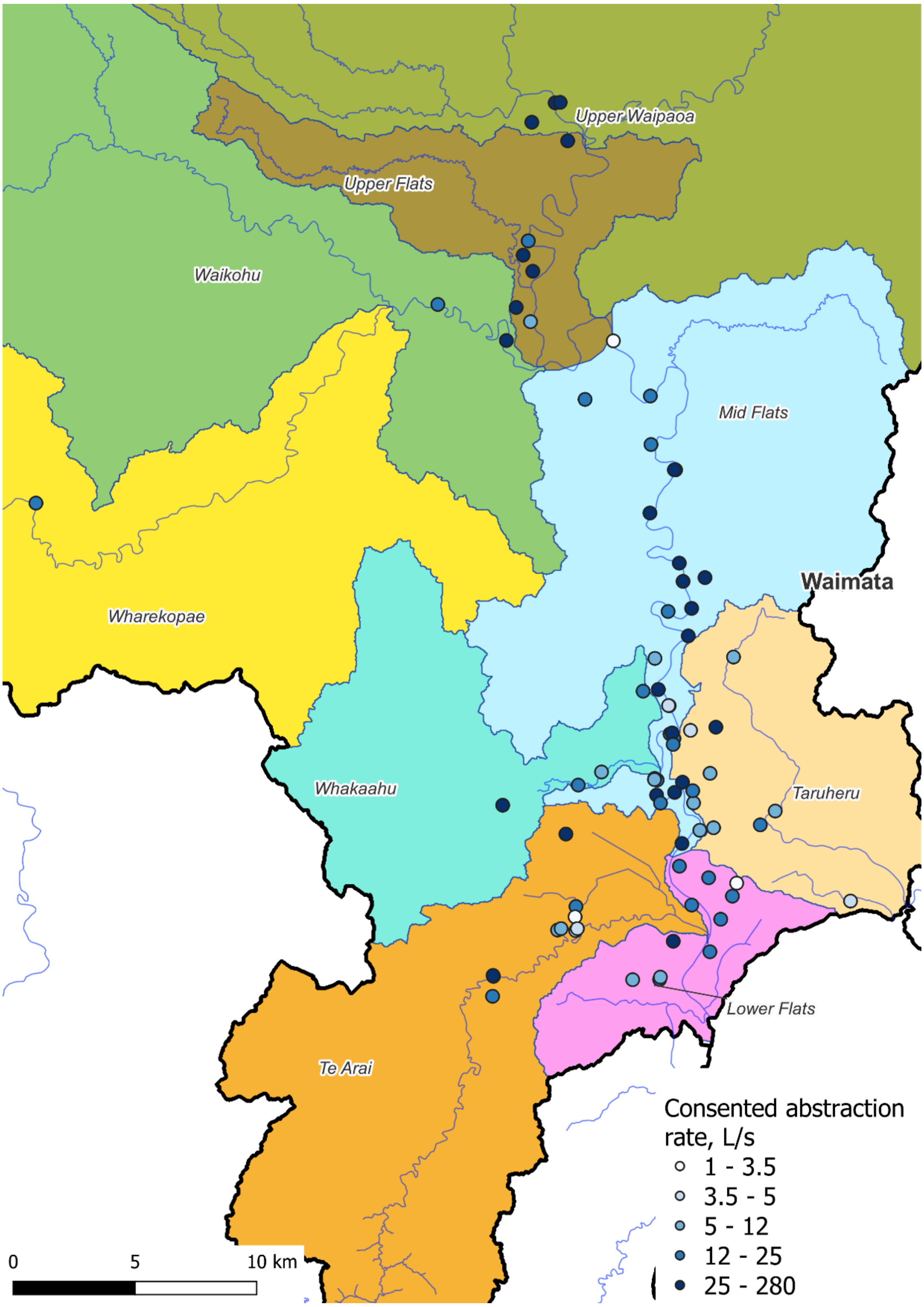

Figure 4-2: Consented abstraction rate and water source for current abstractive surface water take consents in the Waipaoa area as of November/December 2022

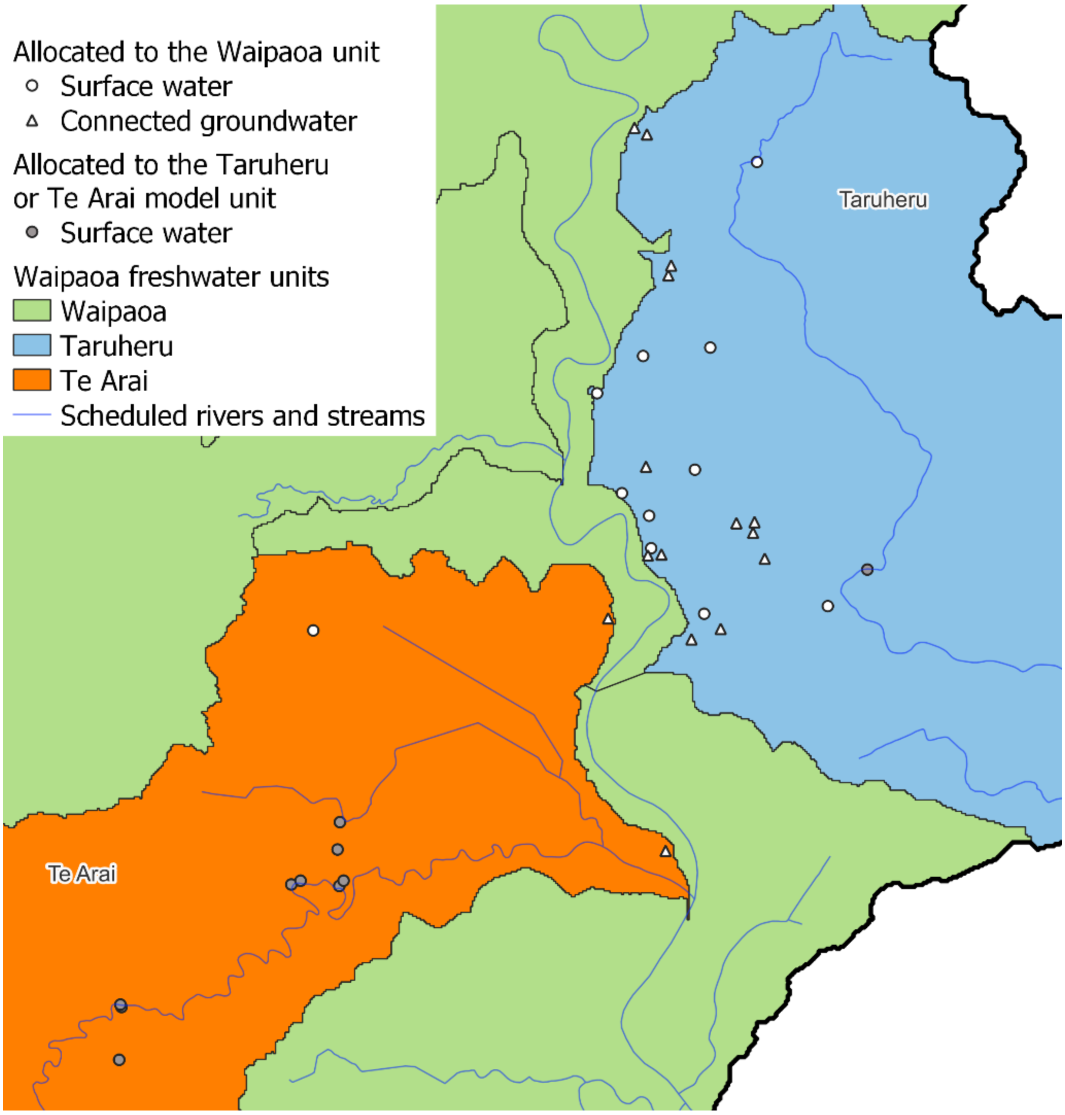

Figure 4-3: Consents allocated to surface water units in the Te Arai and Taruheru freshwater units as of November/December 2022

4.2 Irrigation water demand

4.2.1 Current irrigation demand

We estimated the currently irrigated area using the consents database provided by GDC and spatial mapping of consented irrigated areas provided by GDC. We excluded any polygons from the spatial mapping which related to expired consents as of November/December 2022 or did not have a match in the consents database provided.

Figure 4-4 shows the currently irrigated area and the allocation blocks that the irrigation consents were assigned to. This shows areas in the Te Arai and Taruheru catchments that are irrigated by water from the Waipaoa allocation unit, as mentioned previously.

The irrigated areas falling within each (sub-)catchment are summarised in Appendix B. The currently irrigated area is estimated at around 5,440 ha, all of which falls within the Waipaoa catchment, primarily the Mid Flats and Taruheru sub-catchments.

We obtained S-Map soil data from GDC for the Poverty Bay area, where most the current irrigation is located. We generalised the profile available water (PAW; that is, the amount of water a soil can hold for plant growth) values for the soils into four groups: 80 mm, 100 mm, 120 mm, and 140 mm. Irrigated areas without S-Map data were assumed to have a PAW of 100 mm. Figure 4-5 shows the assumed PAW values for the areas which are currently irrigated.

GDC provided information regarding the crop type associated with each consent. Where multiple crop types were provided for a given consent, we assumed the land use was evenly split between the crop types provided. The irrigated area of each crop type per catchment is summarised in Table 4-2. The crop types cannot be easily mapped as in some cases multiple land use types are assigned to the same parcel. Where the crop type is unknown, it has been modelled as pasture as a proxy, which results in conservatively high water demand estimates, We note that pasture is typically not actually irrigated in the region.

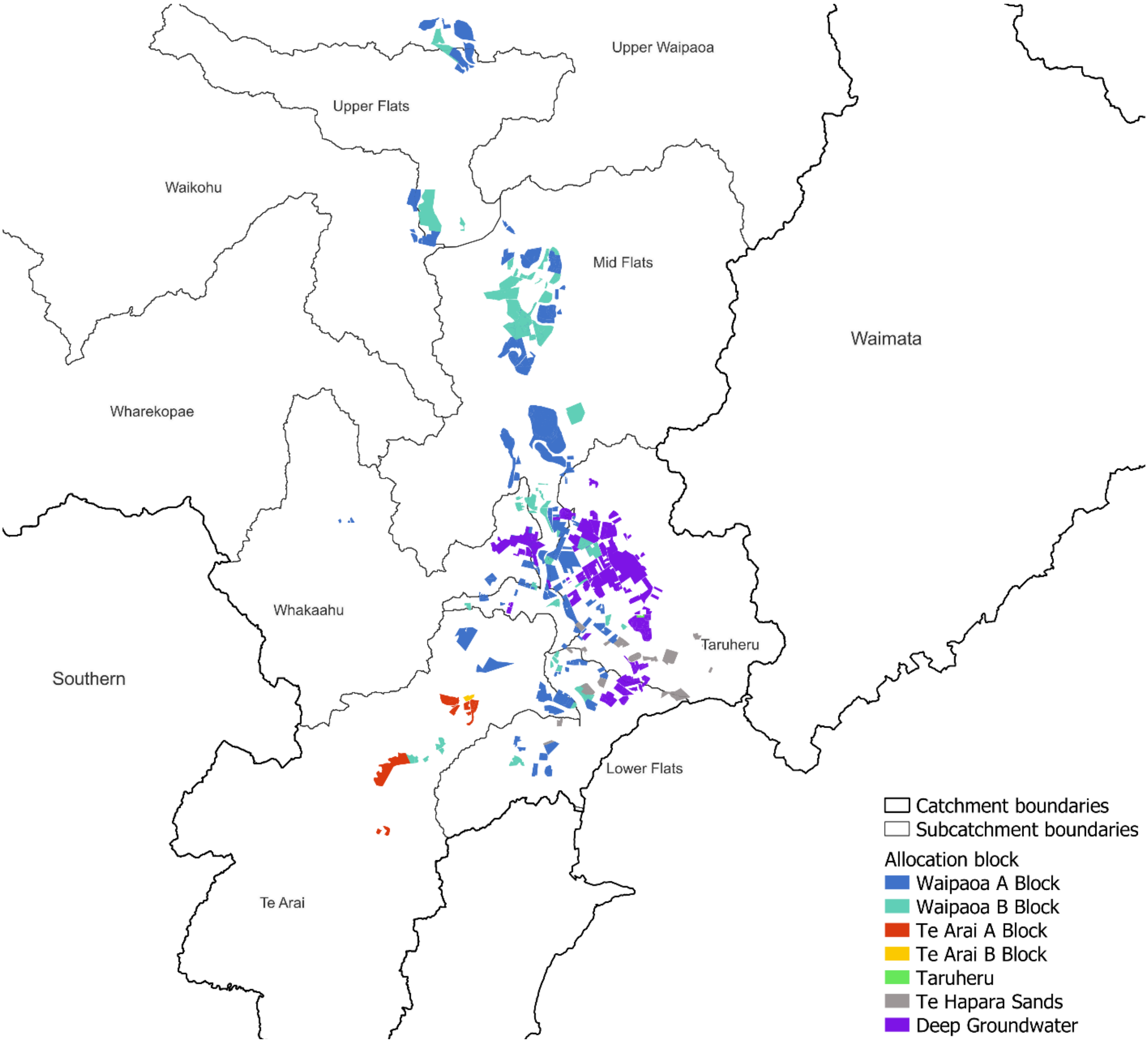

Figure 4-4: Allocation blocks for currently irrigated area in the Poverty Bay area

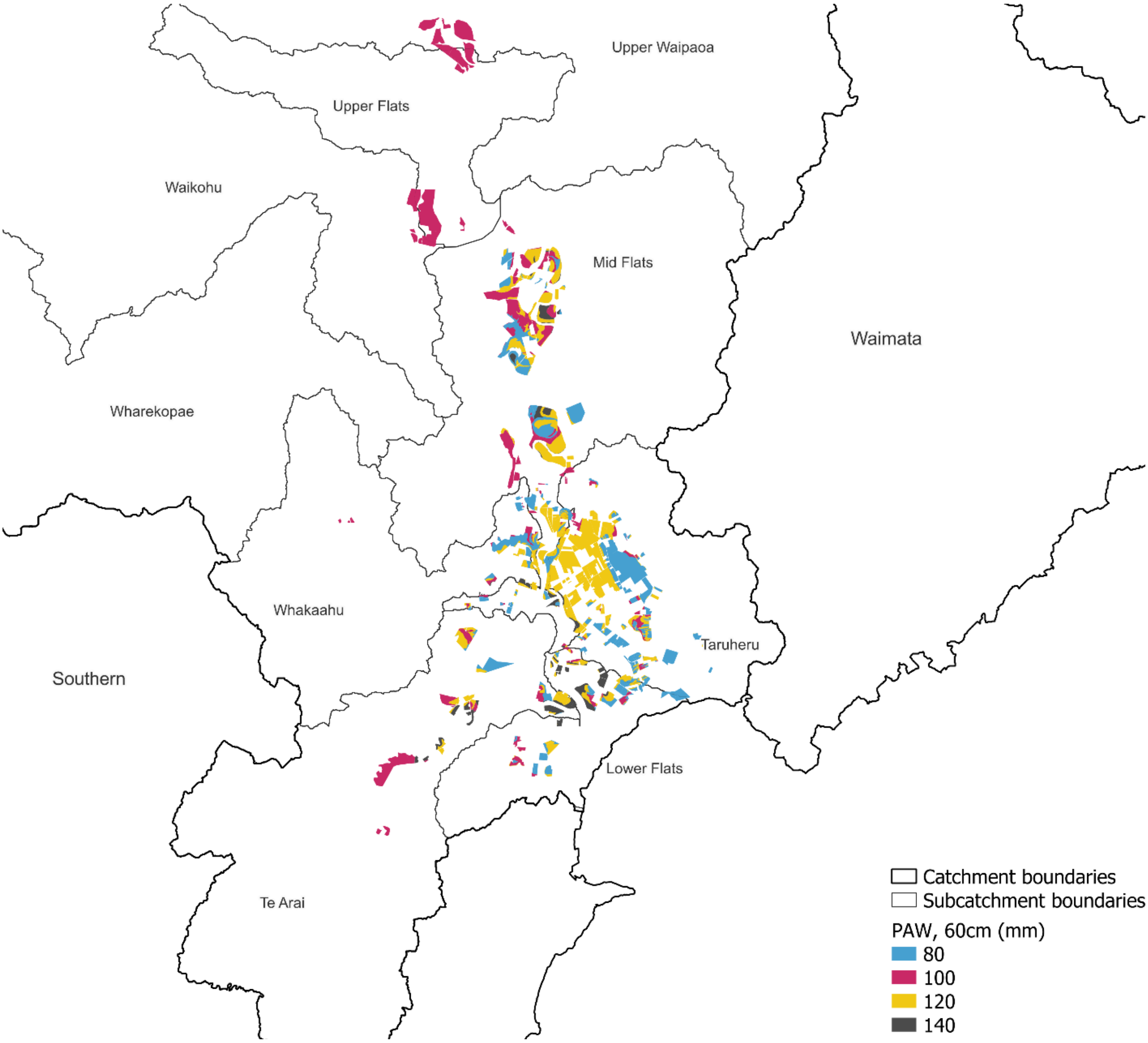

Figure 4-5: Profile Available Water (equivalent depth of water that can be held in soil for plant use, based on 60 cm root depth) values assumed for currently irrigated area in the Poverty Bay area.

Table 4-2: Summary of the percentage of the total irrigated area assigned to each crop type in each (sub-)catchment

	Total area (ha)	Unknown / Pasture	Veges	Grapes	Apples	Avocado	Maize	Citrus	Kiwifruit	Other
Lower Flats	469	-	-	-	5%	1%	-	25%	37%	31%
Mid Flats	2,222	31%	13%	4%	3%	1%	6%	5%	20%	18%
Taruheru	2,263	7%	6%	-	6%	0%	-	11%	16%	55%
Te Arai	653	9%	-	-	39%	-	-	4%	48%	-
Upper Flats	259	28%	10%	-	-	23%	13%	-	3%	23%
Upper Waipaoa	169	-	67%	-	-	-	-	-	27%	6%
Waikohu	105	64%	4%	-	-	1%	1%	-	-	31%
Whakaahu	326	9%	17%	-	28%	10%	12%	5%	19%	-

We modelled irrigation demand using climate data from 1991 – 2022 using Aqualinc's irrigation simulation model. We generated per-hectare irrigation demand for a range of representative crop types for the four PAW classes defined. The climate data was sourced from the CliFlo database (Gisborne AWS). Summary statistics for each crop / soil / climate combination are provided electronically.

Figure 4-6 shows the average daily modelled irrigation demand in each (sub-)catchment. The quantities shown are also provided in Table 4-3. We note that the irrigation demands presented in this section are partitioned based on the (sub-)catchment where the irrigated areas are located. As noted in Section 4.1, water connected to the Waipaoa freshwater management unit is used to supply irrigation in the Taruheru and Te Arai sub-catchments. The following section summarises the irrigation demand partitioning in more detail.

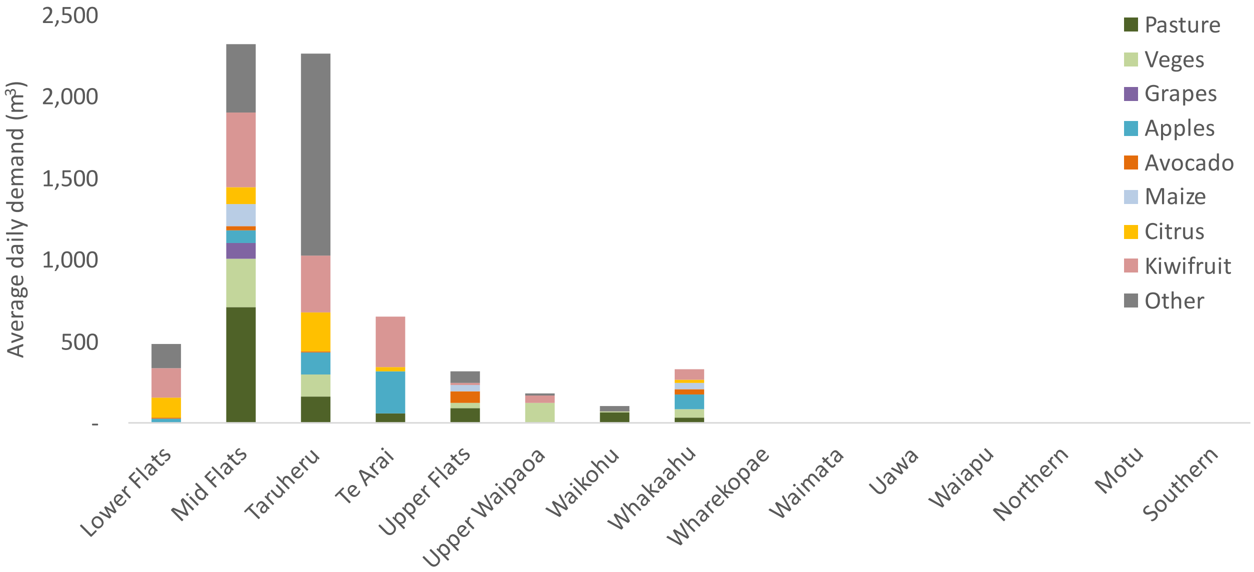

Figure 4-6: Current average daily irrigation demand grouped by (sub-)catchment and crop type

Table 4-3: Summary of the average daily demand associated with crop type in each (sub-)catchment

(Sub-) catchment	**Average daily demand (m^3)**								
	Unknown / Pasture	**Veges**	**Apples**	**Avo.**	**Maize**	**Citrus**	**Kiwi.**	**Other**	**Total**
Waipaoa	1,120	632	97	583	146	212	514	1,427	1,922
Lower Flats	-	-	-	24	7	-	123	180	152
Mid Flats	713	291	97	77	29	132	107	458	417
Taruheru	162	132	-	139	3	-	239	355	1,237
Te Arai	60	-	-	253	-	-	27	313	-
Upper Flats	89	30	-	-	72	40	-	10	74
Upper Waipaoa	-	120	-	-	-	-	-	49	10
Waikohu	67	4	-	-	1	1	-	-	32
Whakaahu	29	55	-	90	34	38	18	62	-
Wharekopae									
Waimata									
Uawa									
Waiapu									
Northern									
Motu									
Southern									
Total	1,120	632	97	583	146	212	514	1,427	1,922

4.2.2 Irrigation demand partitioning

We estimated the partitioned demand (that is, demand per (sub-)catchment) using the allocation block information from the consents database. Groundwater consents allocated to surface water bodies were considered as demands on surface water. Figure 4-7 shows the proportion of area irrigated by surface water allocation units and groundwater in each catchment. For other catchments without current irrigation, we based the partitioning on existing consents in the catchment. We note that some catchments had irrigation consents listed in the consents database but no irrigation polygons in the spatial dataset. For the Waiapu catchment, which does not have any existing irrigation consents, we assumed that future irrigation will likely be sourced from groundwater due to the groundwater units located in the catchment and there generally being greater reliability in groundwater takes as they are subject to less restrictions such as low flow conditions.

As the Waipaoa A Block is fully allocated, we assumed that future surface water irrigation demand in the Waipaoa management unit will be sourced from the Waipaoa B Block. We also assumed that future surface water demand in the Taruheru and Te Arai catchments will also be sourced from the Waipaoa B Block, as most of the existing irrigated area in these catchments is supplied by the Waipaoa allocation blocks.

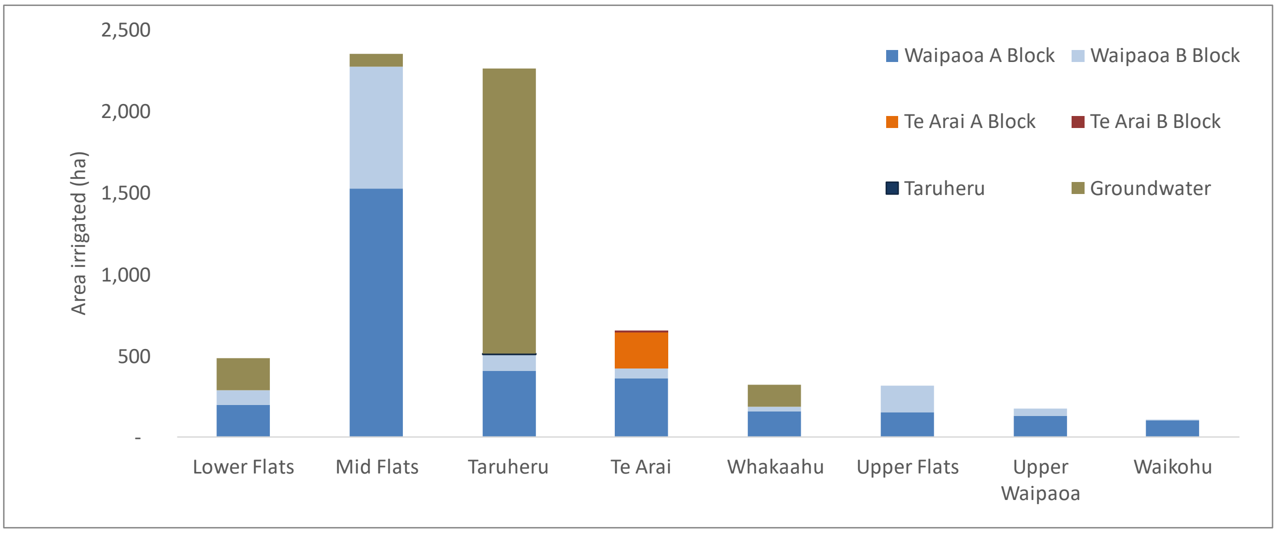

Figure 4-7: Areas irrigated by water from surface water allocation blocks or groundwater in each catchment where there is current irrigation

4.2.3 Future irrigation demand

To estimate future irrigation demand we considered:

- **Change in crop irrigation demand**: We obtained percentage changes in crop irrigation demand per hectare from previous projects (Dark et al., 2021; Collins et al., 2022) based on down-scaled IPCC5 climate projections for RCP 6.0 for the 2040s (2041 – 2060). The projected percentage changes in demand are shown in Figure 4-8. Where the irrigated areas did not fall within the coverage, we assumed values based on nearby grid squares. We assumed that the increase in demand was the same for 2035, 2045, and 2055.
- **Change in irrigated area**: We assumed that crop areas included in GDC's crop survey which do not fall within the current irrigation extent will be irrigated by 2055, without change in the surveyed crop types. The currently irrigated area, and the crop areas which are predicted to be irrigated by 2055 are shown in Figure 4-8. We assumed that the crop areas shown in the Motu catchment will not be included in the future irrigation due to the water conservation order on the Motu River. The areas are summarised in Appendix B. We assumed a linear increase in the irrigated area between 2022 and 2055, with the full un-irrigated crop area converting to irrigation by 2055. Our 2021 national-scale study (Dark et al., 2021) suggested that land use change in the region would likely arise from economic factors rather than climate change, so we have not included any land use change in the future projection.

The projected irrigation demand in each catchment is summarised in Appendix B. Figure 4-9 shows the average daily irrigation demand estimated for 2022 and the future scenarios. We assumed that the distribution between area irrigated by groundwater vs. surface water remained the same as estimated for present-day from the consents database. For the Waiapu catchment, which does not contain any current irrigation consents, we assumed future irrigation would be sourced from groundwater, as the majority of the un-irrigated cropping is located on alluvial Holocene deposits (see Section 5.2.1), and users are likely to prefer groundwater where it is available as supply is less likely to be constrained by factors such as low flow conditions.

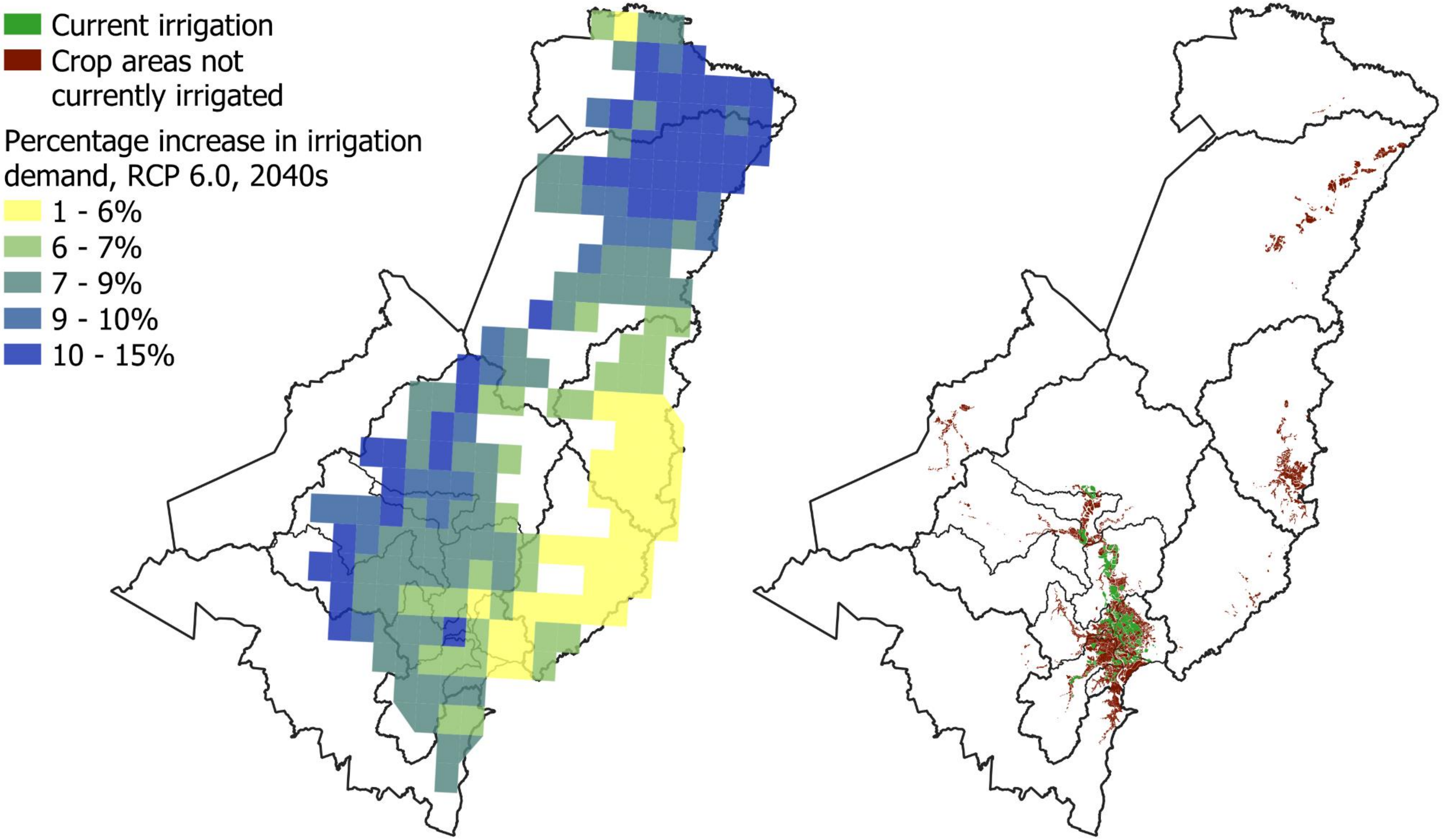

Figure 4-8: Projected irrigation demand increase for RCP 6.0 (2040s), and current irrigated area alongside potential future irrigated crops

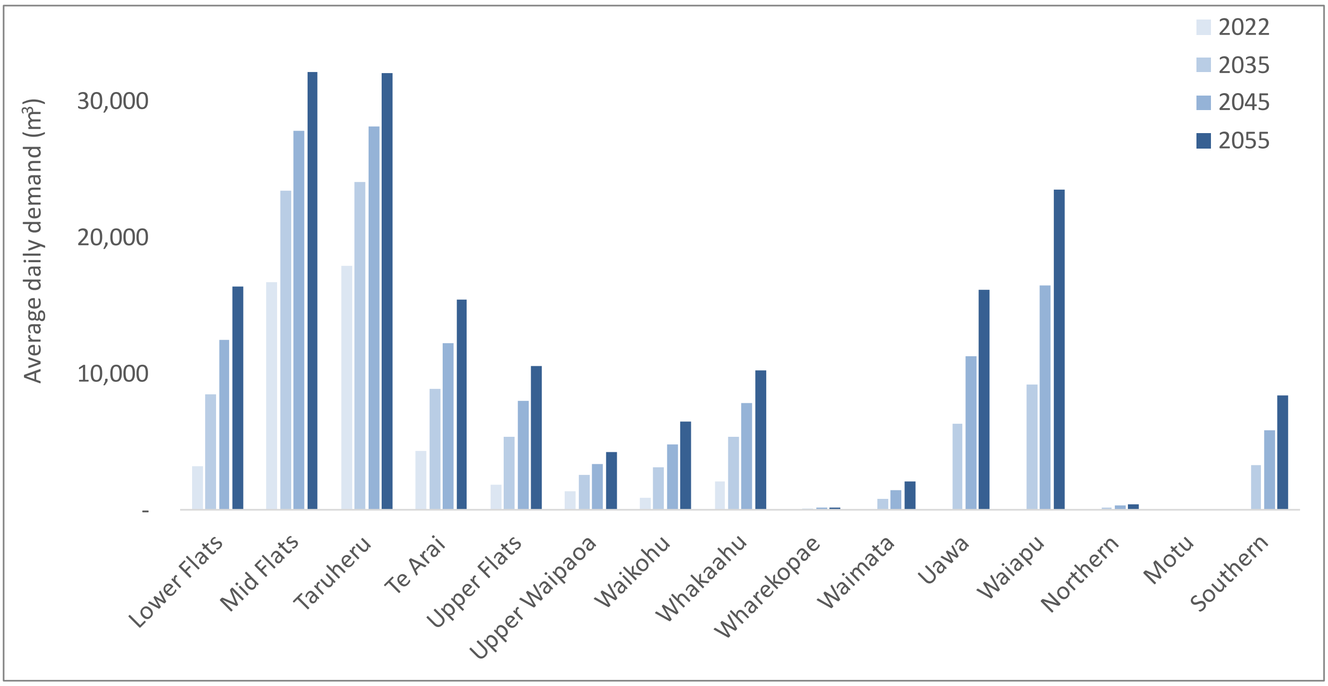

Figure 4-9: Average daily irrigation demand for 2022 and future scenarios, grouped by (sub-)catchment

4.3 Municipal water demand

4.3.1 Sources of data

The municipal water demand for each (sub-)catchment is based on the following information:

- Annual metered volumes provided by GDC for residential and other uses.
- Monthly volumes supplied by the Waingake, Waipaoa, Te Karaka, and Whatatutu water treatment facilities. For the Waingake and Waipaoa treatment plants, which supply Gisborne City, the supply was provided as a total amount and as an amount for industrial and commercial uses. The remainder was assumed to supply residential users, which are not all metered.
- Statistics New Zealand's (Stats NZ) 2018 census regional population and corresponding 5-yearly projections[2]. The Stats NZ projections extend to 2048; we have extrapolated these to 2055.
- Tairawhiti Housing and Business Capacity Assessment forecast population values.
- Stats NZ's 2018 resident population grid (cell size = 250 m)[3].

4.3.2 Current municipal demand

Reticulated networks supply water in the Gisborne City/Poverty Bay area, Te Karaka, and Whatatutu, which are all located in the Waipaoa study area. Figure 4-10 shows the estimated resident population distribution for 2018 across the study area on a 1 km grid. Most of the population is located in Gisborne City and the wider Poverty Bay area.

We used Stats NZ's resident population grid to estimate the proportion of population in each (sub-)catchment in 2018 and scaled these values to be proportionate to the Tairawhiti Housing and Business Capacity Assessment population. We overlaid this on GDC's reticulation network to estimate the proportion of the users supplied by reticulated networks vs. private domestic supplies which may not require consents.

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[2] Subnational population projections: 2018(base)–2048. 2018. Statistics New Zealand.

[3] New Zealand 2018 Estimated Resident Population Statistical Grid 250 metre (prototype), 2022. Statistics New Zealand.

The majority of users in the Upper Flats, Lower Flats, Te Arai, Taruheru, and Waimata (sub-)catchments are supplied by the reticulated network. In the Waipaoa catchment, we estimated that around 83% of users were on the Waingake and Waipaoa reticulation network, 2% of users were on the Whatatutu and Te Karaka reticulation networks, and 9% of users were un-reticulated. In the Waimata catchment, we estimated that around 87% of users were on the Waingake and Waipaoa reticulation network, with the remaining users un-reticulated.

We calculated the current municipal demand in each catchment on a monthly basis. The demand distribution was based on where the water was sourced from, rather than the location of users. We assumed a fixed daily demand in each month.

The following sections summarise the demand data used to develop the time series.

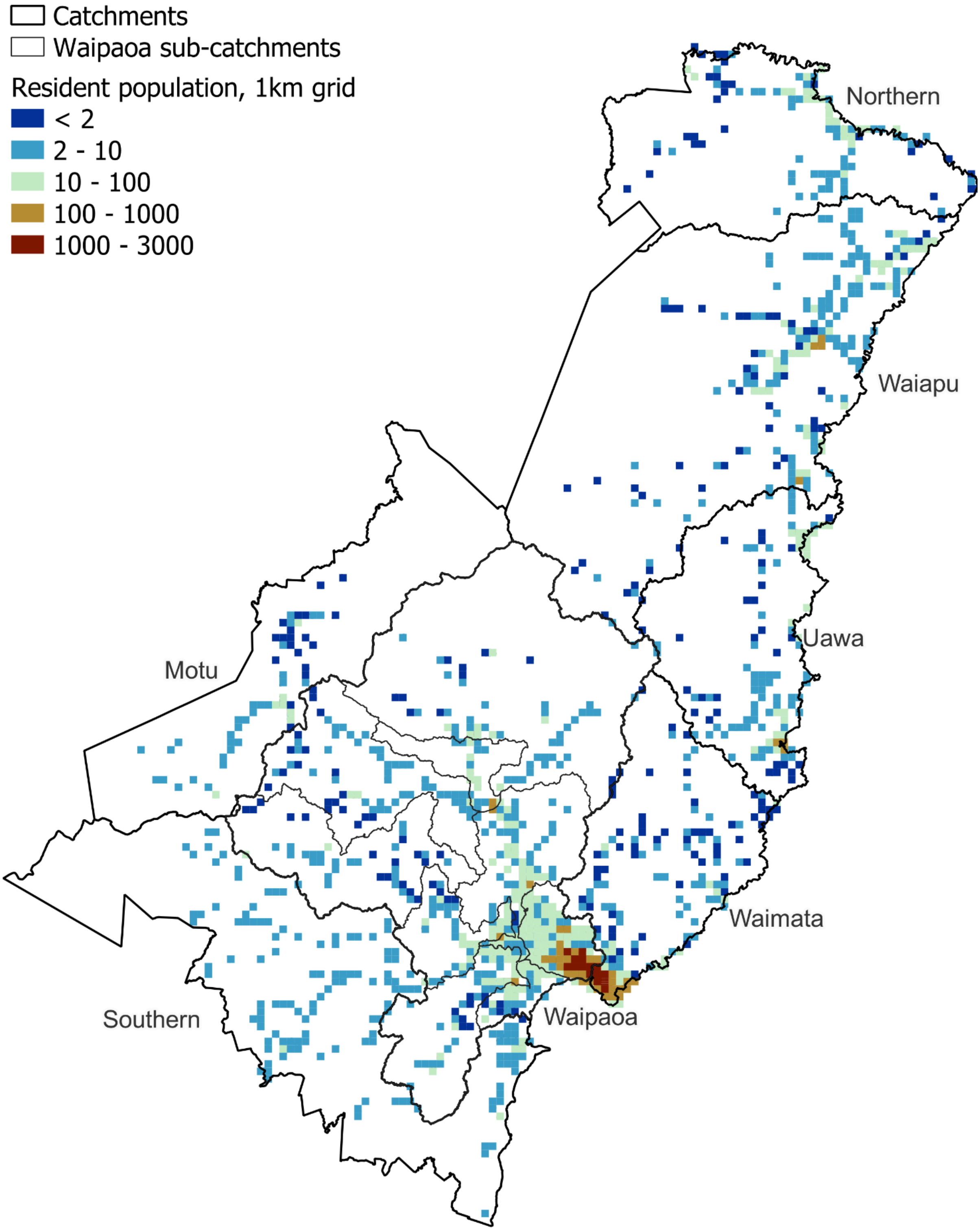

Figure 4-10: Estimated resident population on a 1 km x 1km grid

Te Karaka and Whatatutu

Te Karaka and Whatatutu are both located in the Upper Flats sub-catchment. The communities are supplied primarily by rainwater tanks at each property. The supply is supplemented by treated groundwater, which is hydraulically connected to the Waipaoa River. GDC provided data on the monthly supply from the treatment plants for 2019, 2020, and 2021. We used the average monthly demand over the three years of record. The demand at both sites is relatively consistent over the year. The average demand was 5,530 m^3/month at Te Karaka and 1,120 m^3/month at Whatatutu.

Waingake and Waipaoa treatment plants

Gisborne City and the majority of the metered residential and industrial sites are supplied by the Waingake and Waipaoa treatment plants. Waingake is the primary treatment plant and takes water from impounding dams in the Mangapoike sub-catchment, which is located in the Southern catchment. We note that the dams are impounded, so in reality the supply is dependent on rainfall and ephemeral streams filling up the dams. This makes the supply vulnerable to changes in rainfall patterns and cumulative rates; inadequate rainfall can reduce supply reliability and availability. GDC staff advise this treatment plant is 'hampered' by high sedimentation, and its significant distance from users, increasing vulnerability to damage, including from landslides

The Waipaoa treatment plant, which is located in the Mid Flats sub-catchment, acts as a back-up supply during emergencies and peak summer demand. According to GDC's records for 2013 – 2022, it has been used to supply water during November – April.. This supply is also vulnerable to changes in rainfall patterns and cumulative rates.

Figure 4-11 shows the estimated monthly supply from the treatment plants based on the 10 seasons of available data. The Waipaoa treatment plant supplies a peak of around 12% of the demand in February.

We used the supply distribution shown in Figure 4-11 to estimate the proportion of the monthly industrial and residential demand on the reticulated network which is sourced from the Southern catchment and Mid Flats sub-catchment. Our estimates incorporate the estimated water loss of 14.5%. Figure 4-12 shows the estimated distribution between industrial and residential uses for the Waingake and Waipaoa treatment plants. The following two sections summarise our methodology for estimating the monthly residential and industrial demand.

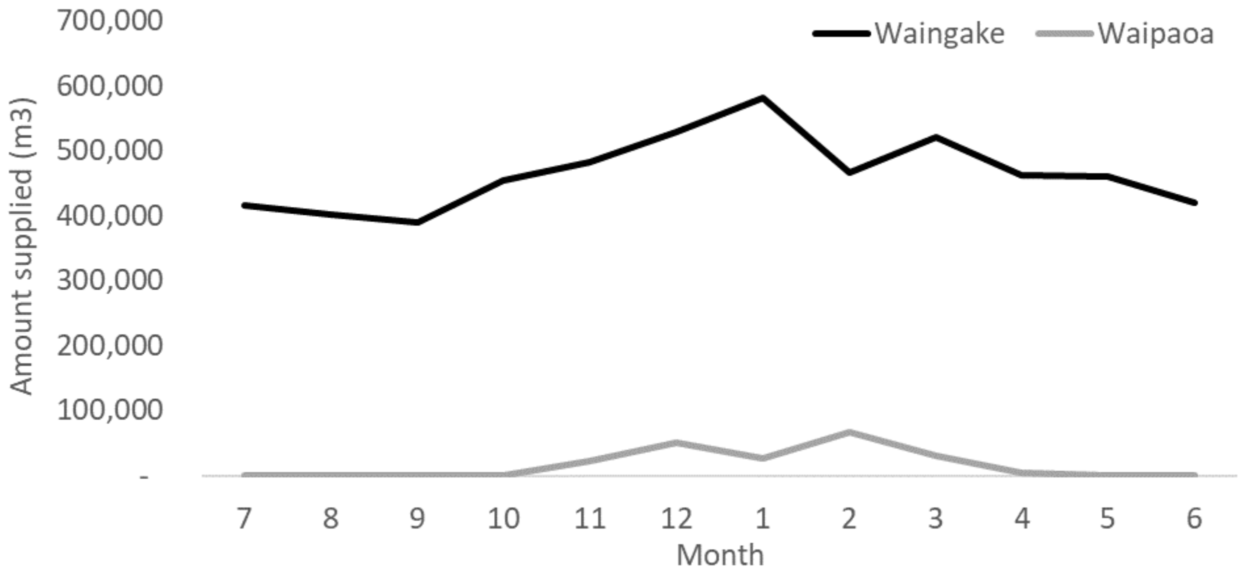

Figure 4-11: Monthly amount supplied by the Waingake and Waipaoa water treatment plants based on 2013 - 2022 supply data

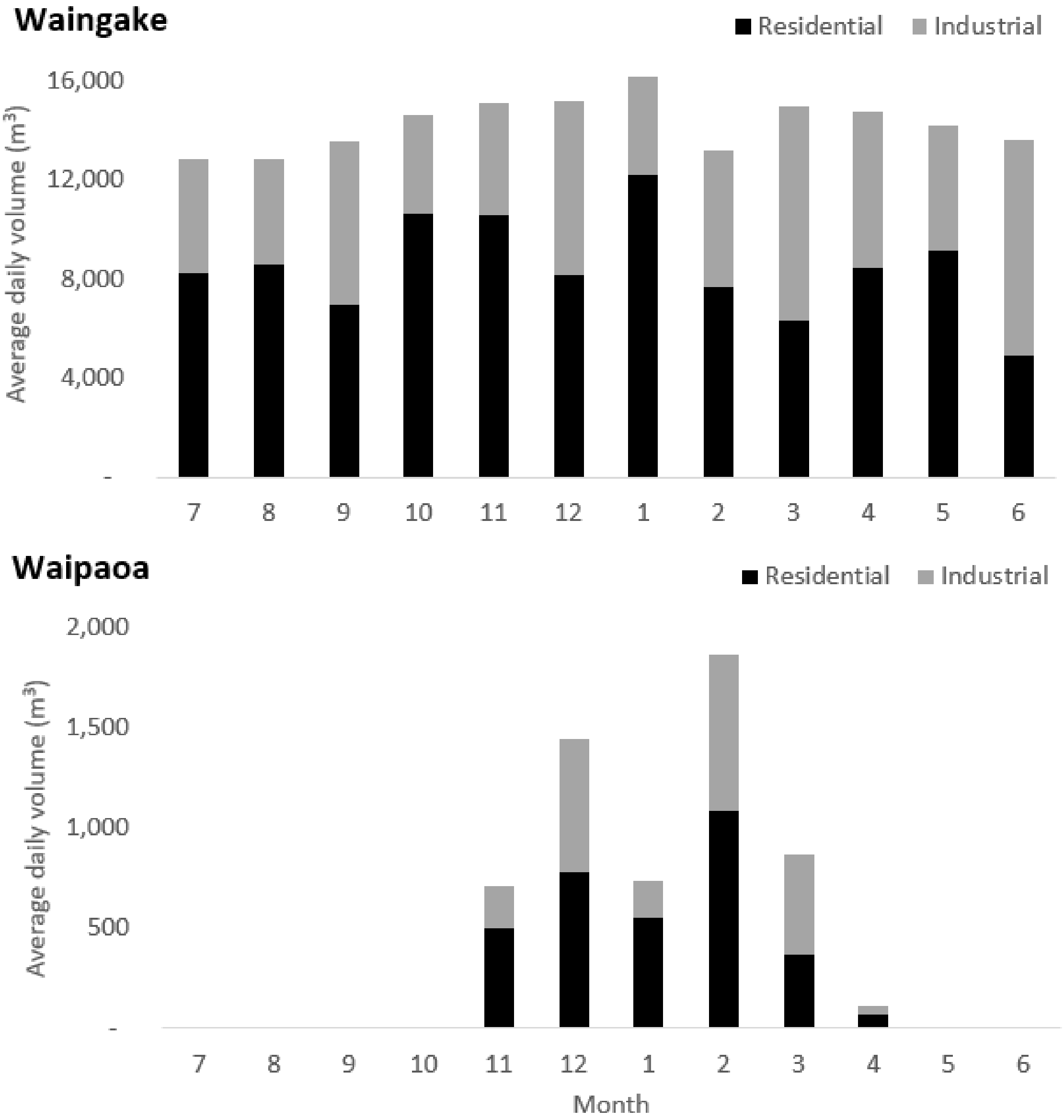

Figure 4-12: Estimated average daily volume supplied by the Waingake and Waipaoa treatment plants for residential and industrial uses

Industrial demand – reticulated

GDC provided monthly data on the industrial demand met by the reticulated network for 2021 and 2022, as shown in Figure 4-13. Given the relatively comparable monthly pattern between the two years of record and lack of information about the use associated with each metered supply, we have used the average monthly demand in our demand series.. The lack of accurate metering information for each industrial take means we are unable to accurately quantify the volumes of reticulated supply being used by industry beyond that described in Figure 4-13. We note that under the NPS-FM, water use for industrial purposes is a lower-order priority than drinking water, and therefore it will become increasingly important to be able to distinguish between potable and industrial uses within reticulated networks,

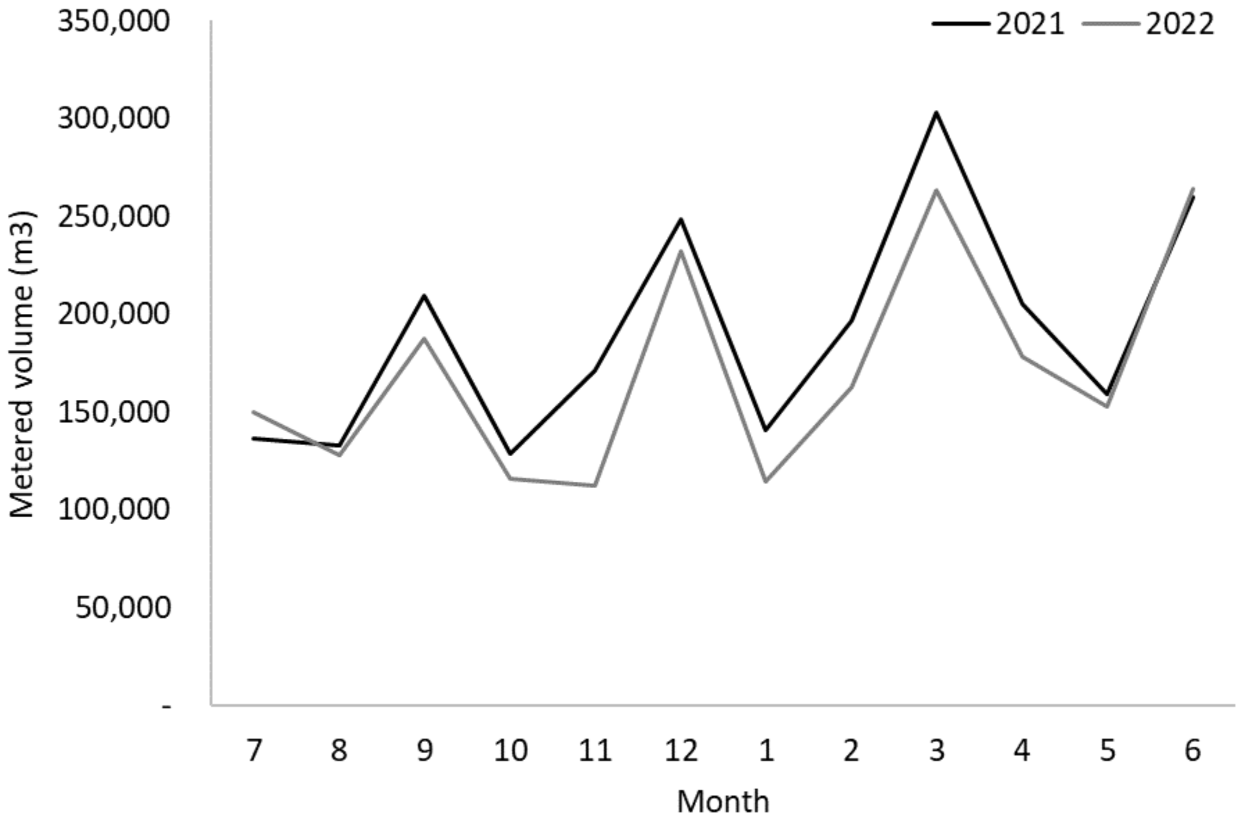

Figure 4-13: Monthly metered industrial demand supplied by Waingake and Waipaoa treatment plants for 2021 and 2022 seasons

Residential demand

GDC provided monthly residential demand data for users supplied by the Waingake and Waipaoa treatment plants. This included un-metered users in Gisborne City and some metered users. The residential demand for the reticulated network was calculated as the difference between the amount supplied by the treatment plants and the metered industrial use. Residential metering suggests that around 97% of the residential reticulated supply is unmetered.

Address data indicates that several metered users are not supplied by the reticulated network. In these cases, we have assumed that water was sourced from within the catchment where the consent was located (generally Taruheru or Te Arai). We estimated the monthly use for these users based on a generalised sinusoid seasonal distribution estimated from the monthly reticulated usage. We did not include these users in the supply-demand balance as the source of the water (surface water vs. groundwater) was unknown.

Figure 4-14 shows the estimated monthly demand for residential users supplied by the reticulated network, and the generalised demand distribution used to estimate usage for residential metered users not supplied by the reticulated network. The average residential demand per user was approximately 250 L/person/day, with a peak of approximately 360 L/person/day in January.

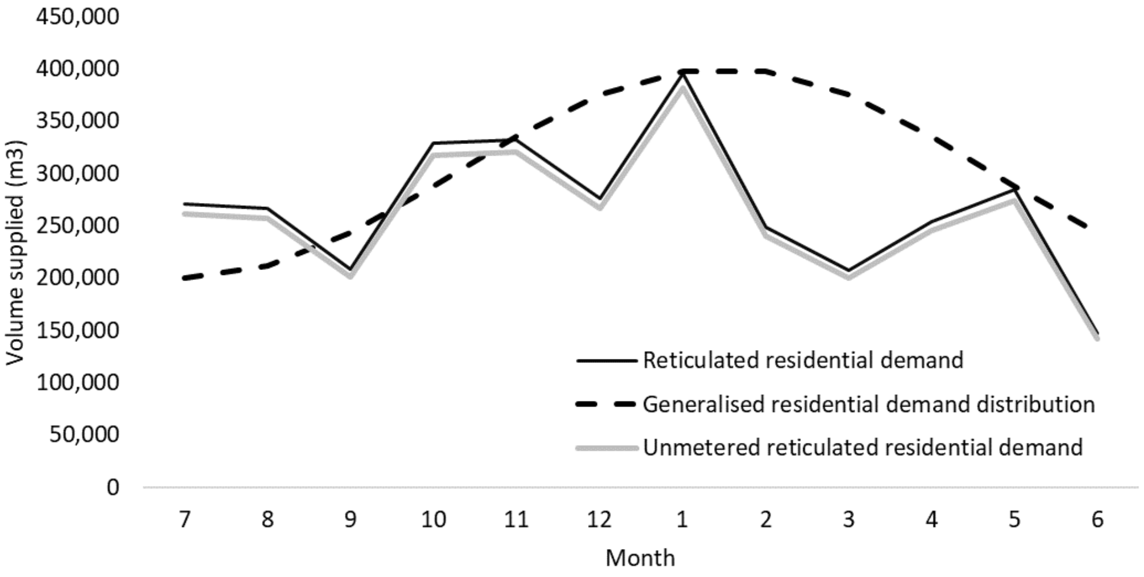

Figure 4-14: Monthly reticulated residential demand for the Gisborne City network and generalised sinusoid demand distribution

Total demand

The total monthly municipal demand was estimated for each (sub-)catchment by summing the demand from the sources summarised above. In the Waipaoa sub-catchment, the demand was concentrated in the Mid Flats sub-catchment, which supplies back-up industrial and residential demand for Gisborne City, and the Upper Flats catchment, which supplies Te Karaka and Whatatutu. The majority of the demand is sourced from the Southern catchment, which is the primary supply for Gisborne City. Figure 4-15 shows the estimated daily demand for each month, grouped by (sub-)catchment.

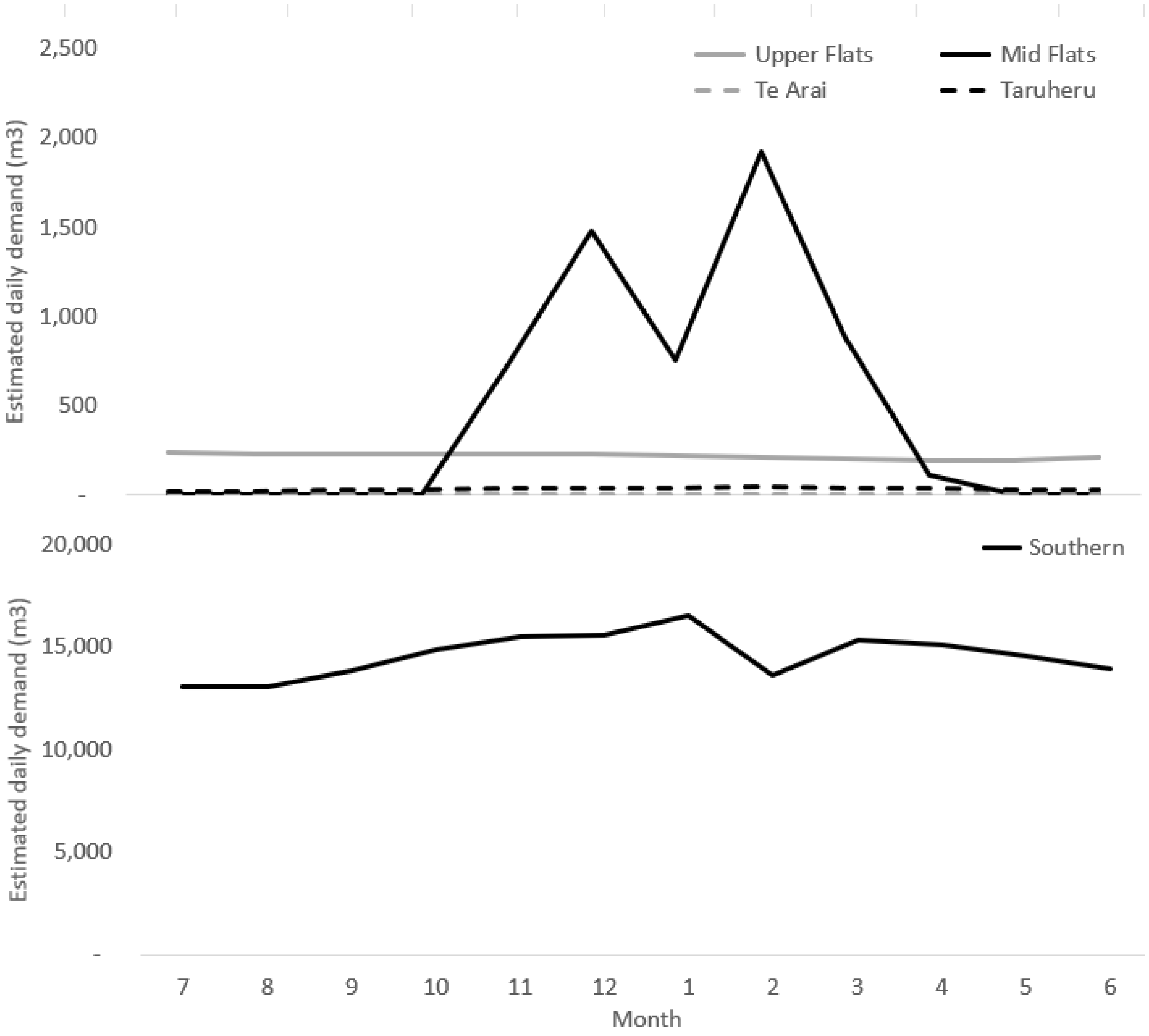

Figure 4-15: Estimated daily demand associated with reticulated water supplies, grouped by (sub-)catchment

4.3.3 Municipal demand partitioning

We assumed that all municipal demand was sourced from surface water. The abstractions for the Waingake and Waipaoa treatment plants are both from surface water, in the Southern and Mid Flats catchments respectively, and the Te Karaka and Whatatutu supplies are abstracted from stream-depleting groundwater. The municipal water takes were assigned to the primary allocation bands. The municipal demand was allocated to the catchments where the water was abstracted from.

4.3.4 Future municipal demand

We used projected population growth to estimate the municipal demand in 2035, 2045, and 2055.

Population growth for each (sub-)catchment was estimated based on the total population projections for the region, and the population growth prediction for Gisborne City. The population growth in rural areas outside Gisborne City was the difference between the regional growth (Tairīwhiti Housing and Business Capacity Assessment) and the growth in Gisborne City (StatsNZ).

Around 63% of the Gisborne City extent fell within the Taruheru sub-catchment, while the remaining 37% fell within the Waimata catchment. The city's population and associated growth were allocated to the Taruheru and Waimata catchments based on this ratio. The remaining population growth was allocated to the (sub-)catchments based on the 2018 population distribution, i.e., population growth was assumed to occur at the same rate in all rural areas.

Figure 4-16 shows the estimated population growth relative to the 2018 population in the region overall, in Gisborne City, and in other non-urban areas. Table 4-4 and Figure 4-17 summarise the estimated population in each (sub-)catchment for the years of interest (2022, 2035, 2045, and 2055). Appendix C contains a summary of the projected population growth.

The total regional population was projected to grow by 8,070 during the study period, with the majority of the population growth occurring in Gisborne City (Taruheru and Waimata). We note that this population is supplied primarily by impounding dams in the Southern catchment, with a back-up supply provided by the Waipaoa River (Mid Flats sub-catchment).

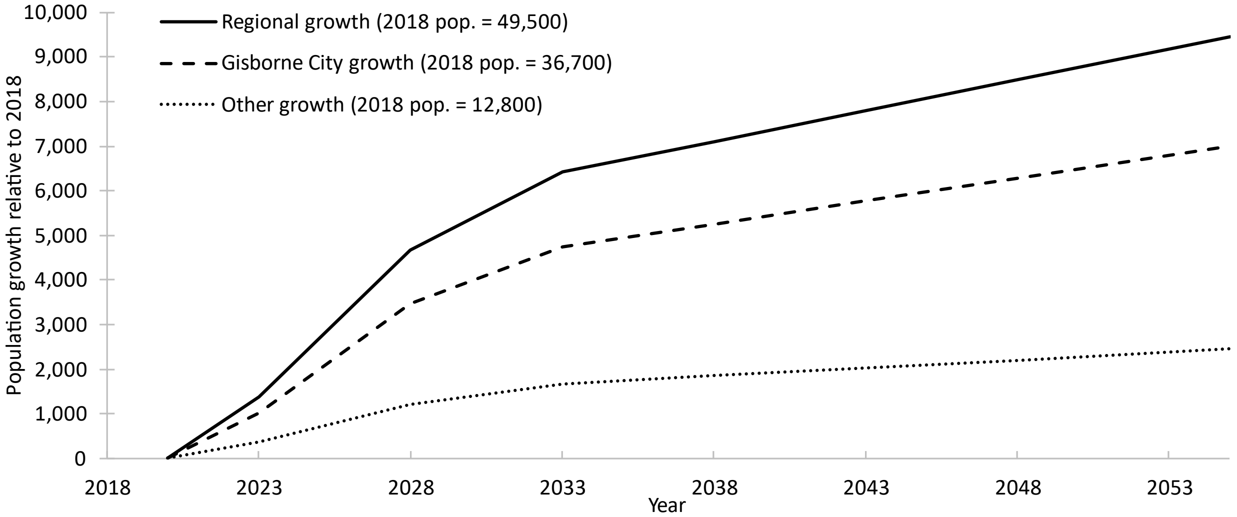

Figure 4-16: Estimated population growth using Tairīwhiti Housing and Business Capacity Assessment values relative to 2018 census population (StatsNZ)

Table 4-4: Summary of (sub-)catchment population projections. Total projected population values taken from Tairāwhiti Housing and Business Capacity Assessment. Population distribution taken from StatsNZ

(Sub-)catchment	2022	2035	2045	2055
Waipaoa	29,416	32,416	33,195	33,975
Upper Waipaoa	*478*	*527*	*539*	*552*
Upper Flats	*706*	*778*	*797*	*815*
Mid Flats	*1,216*	*1,340*	*1,372*	*1,404*
Lower Flats	*685*	*755*	*773*	*791*
Te Arai	*621*	*684*	*701*	*717*
Taruheru	*24,622*	*27,133*	*27,785*	*28,438*
Waikohu	*299*	*329*	*337*	*345*
Whakaahu	*588*	*648*	*663*	*679*
Wharekopae	*201*	*222*	*227*	*232*
Waimata	16,099	17,740	18,167	18,594
Uawa	1,909	2,103	2,154	2,204
Waiapu	2,471	2,722	2,788	2,853
Northern	975	1,075	1,100	1,126
Motu	337	372	381	390
Southern	873	962	985	1,008
Total	**52,080**	**57,390**	**58,770**	**60,150**

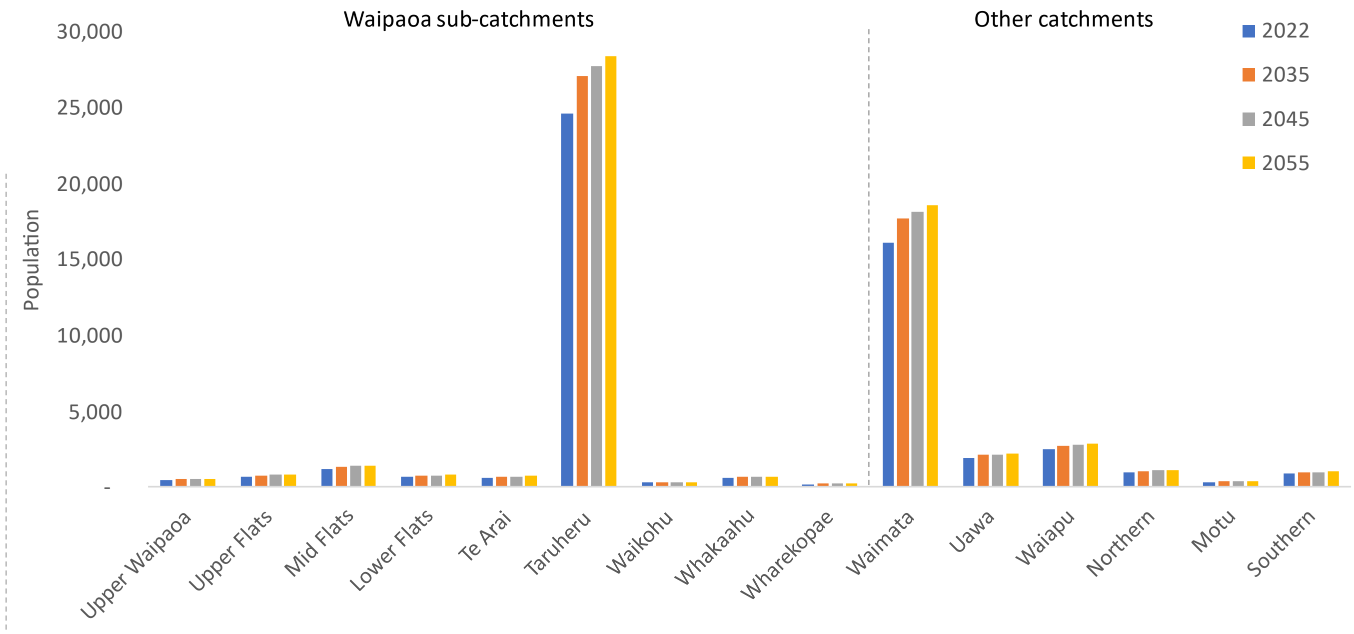

Figure 4-17: Estimated population growth, grouped by (sub-)catchment

When calculating future reticulated water demand, we assumed that the proportion of reticulated vs. non-reticulated users in each catchment and the ratio of water sourced from the Waipaoa and Waingake treatment plants remained the same. We assumed that both domestic and industrial demand increased at a rate proportional to population growth. Figure 4-18 shows the projected average daily municipal demand for 2022 and future scenarios in each (sub-)catchment. Further details on projected domestic demand are provided in Appendix C.

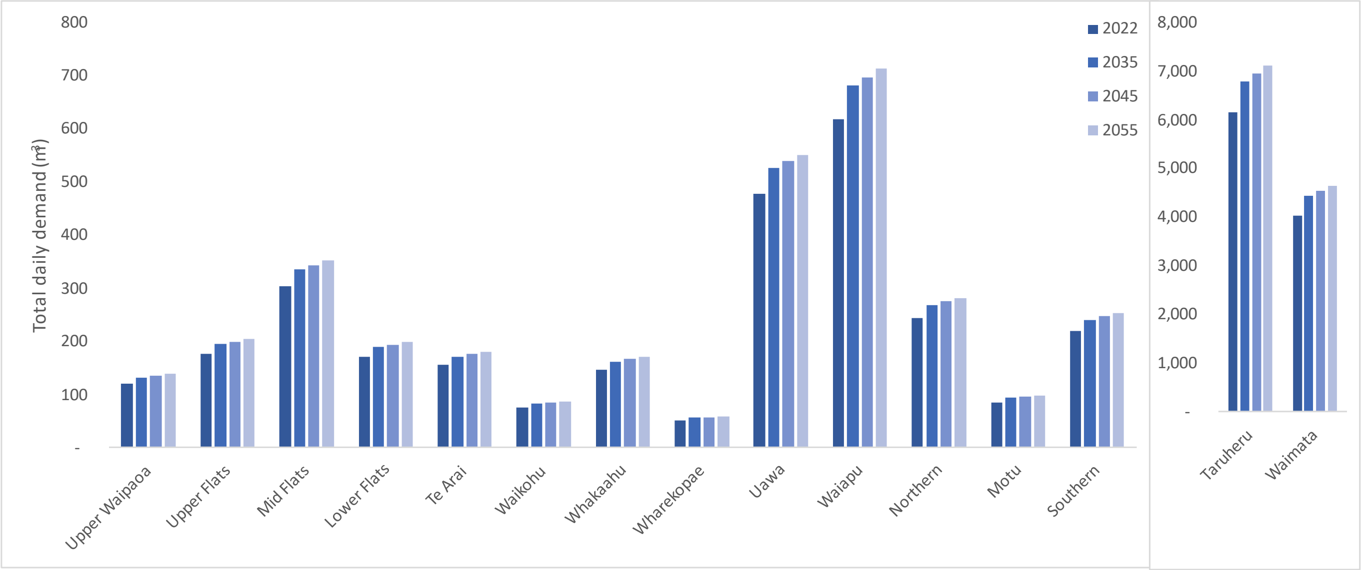

Figure 4-18: Projected average daily water demand for reticulated and private metered use. The demand is allocated to the catchment where the water is used.

4.4 Other consented demand

4.4.1 Current other consented demand

There are 14 consents in the region for uses other than municipal supply or irrigation. These include frost protection and other mixed uses.

There were nine surface water and three groundwater consents issues for mixed industrial uses. The uses were listed as ‘Drinking’, ‘Combined/Mixed’ and ‘Other’. GDC has stated that these uses cover small-scale irrigation, campgrounds, some domestic use, packhouses, shingle washing, and terrestrial aquaculture. As we do not have access to specific use details which could be used to establish a seasonal profile, we have assumed that water for these consents was abstracted at the maximum consented daily rate. The abstraction was assumed to occur in the sub-catchment where the consent was located. GDC’s consents for abstracting drinking water have already been accounted for in the municipal demand series.

There are two consents in the GDC consents database issued for frost protection, located in the Mid Flats sub-catchment. GDC staff have indicated that the frost protection consents have not been used in the last 10 years, and, if required, water for frost protection will generally be taken during the winter months when there is less pressure on water availability. NIWA (2020) also anticipate the number of frost days to decrease. We have therefore excluded frost protection from the water balance.

4.4.2 Partitioning of other consented demand

Other consented demands were partitioned based on the individual consent abstraction details as shown in Figure 4-19. Most of these consents are sourced from surface water.

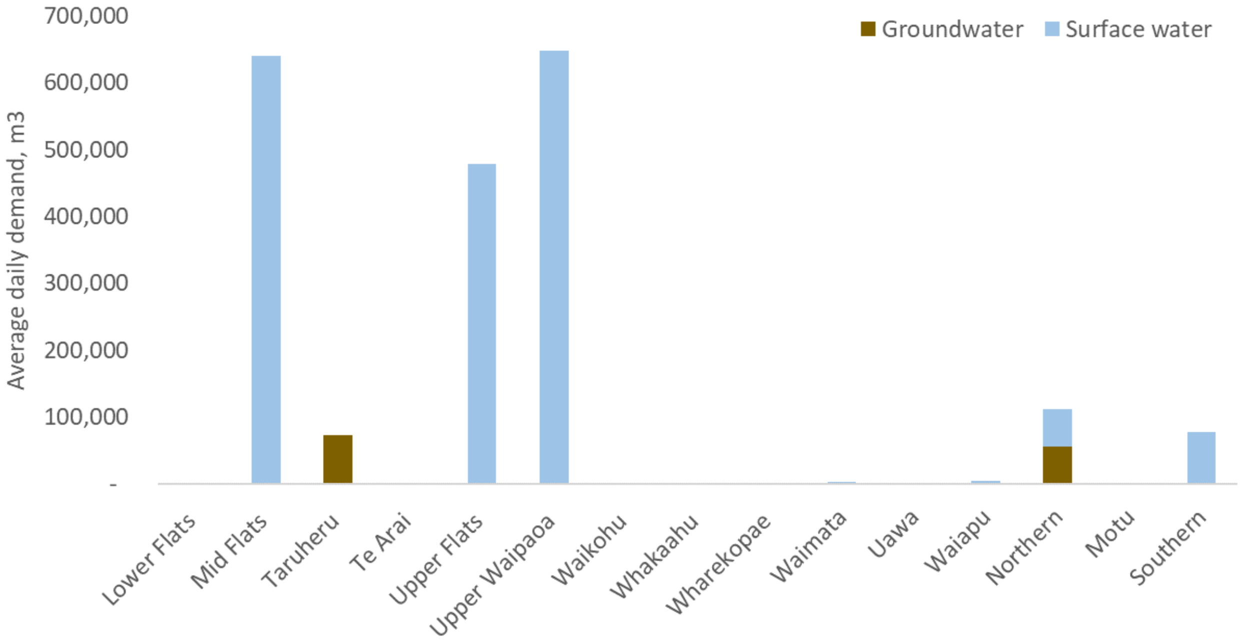

Figure 4-19: Estimated average daily demand for other consented uses

4.4.3 Future other consented demand

As noted above, other consented demand is comprised of water used for frost protection and water used for combined/mixed/other purposes. We have not included frost protection consents in the water balance as the actual demand associated with these consents is likely to be infrequent and difficult to model accurately.

Similar to industrial uses supplied by the municipal network, we assumed that the demand for other private consented uses not related to frost protection was scaled by the projected population in the (sub-)catchments where the consents were located. The population projection data can be found in Section 4.3.3. The projected daily demand for other consented uses (excluding frost protection) in each (sub-)catchment is shown in Figure 4-20.

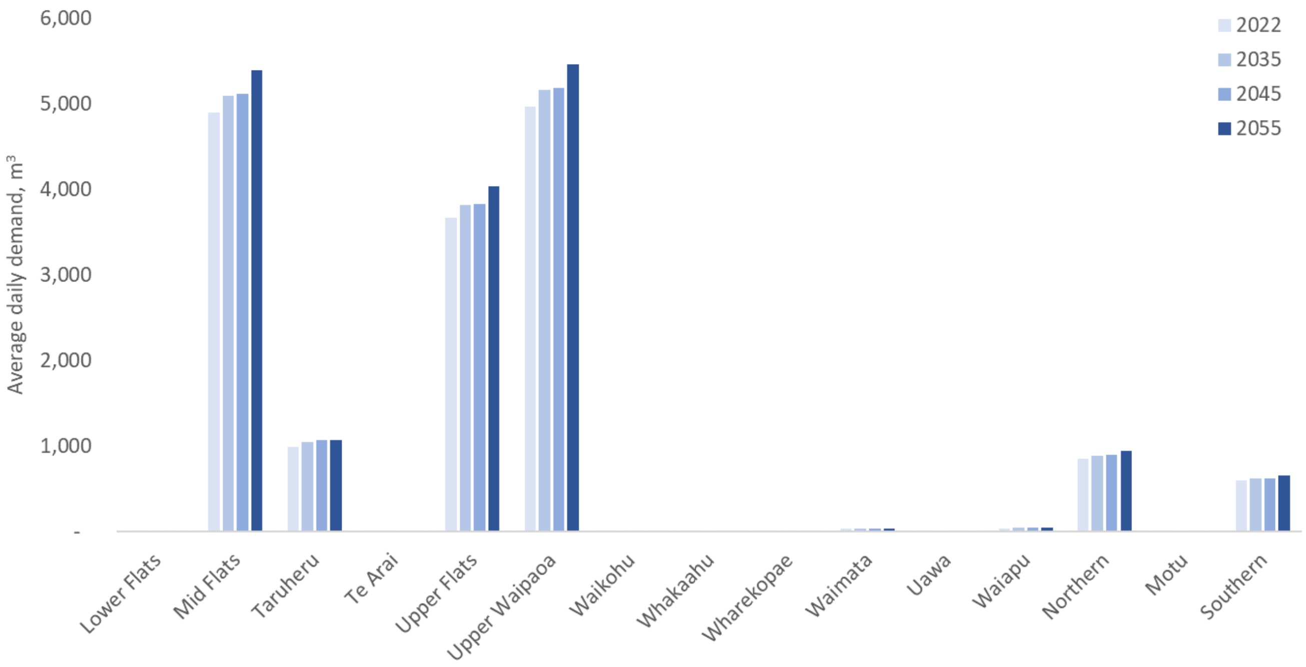

Figure 4-20: Projected average daily demand for private consented uses which are not related to frost protection

4.5 Other water demands

4.5.1 Livestock

GDC provided stock numbers for Waipaoa sub-catchments. For the remaining catchments we estimated the stock populations using the Stats NZ 2017 livestock numbers grid[4]. We scaled the 2017 populations to present-day using StatsNZ regional livestock populations for 2017 – 2021. We assumed that the spatial population distribution remained constant.

Figure 4-21 shows the estimated stock numbers in each (sub-)catchment. Sheep was generally the most numerous livestock, followed by cattle.

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[4] MfE, 2017. *Livestock numbers grid APS 2017*. Ministry for the Environment Data Service.

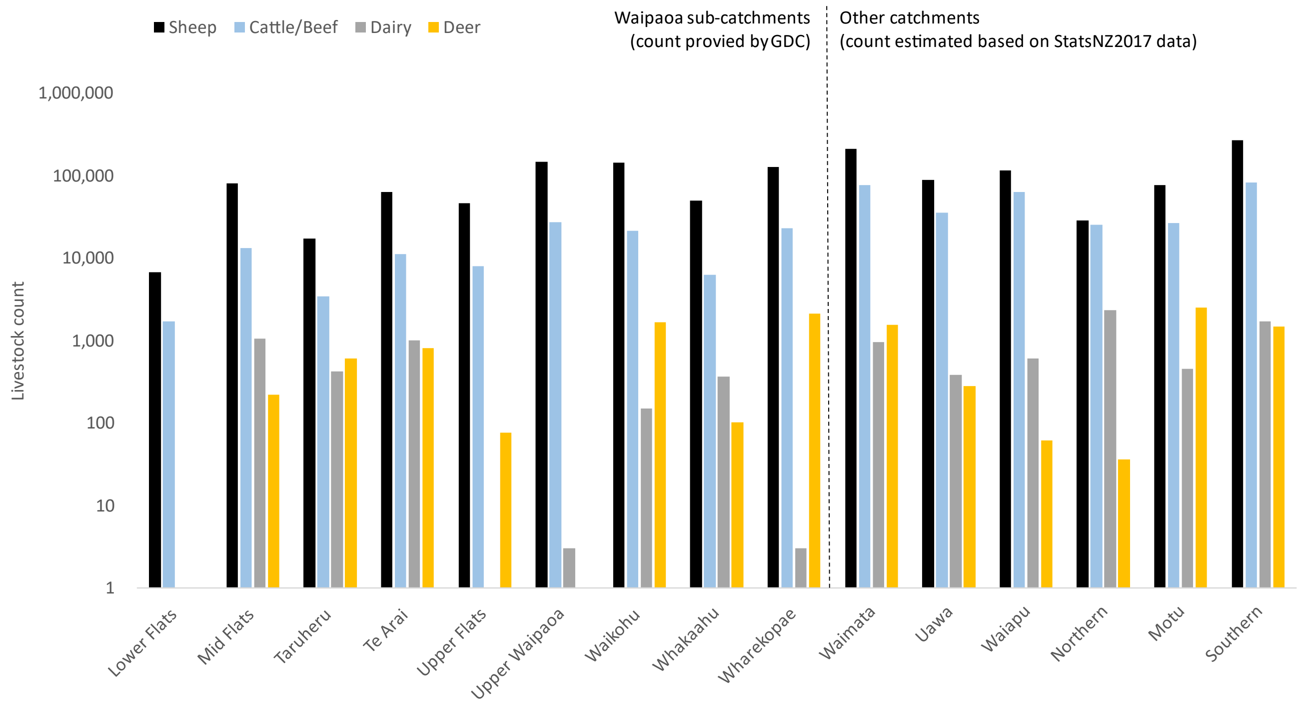

Figure 4-21: Estimated stock numbers grouped by (sub-)catchment. Note Y-axis is log-scale

Appendix D presents estimated livestock water demand values used for this study. We assumed that the peak demand applied during January and demand during the remaining months was set to satisfy the average demand. This is likely to be a conservative estimate of demand, as it is unlikely the peak demand would apply every day. The average daily demand for stockwater uses is summarised in Figure 4-22.

We did not include stockwater in our water balance assessment as stockwater takes are a permitted activity so not limited by surface or groundwater allocation planning rules. GDC indicated that stockwater is generally sourced from small springs, waterways, and rainfall runoff.

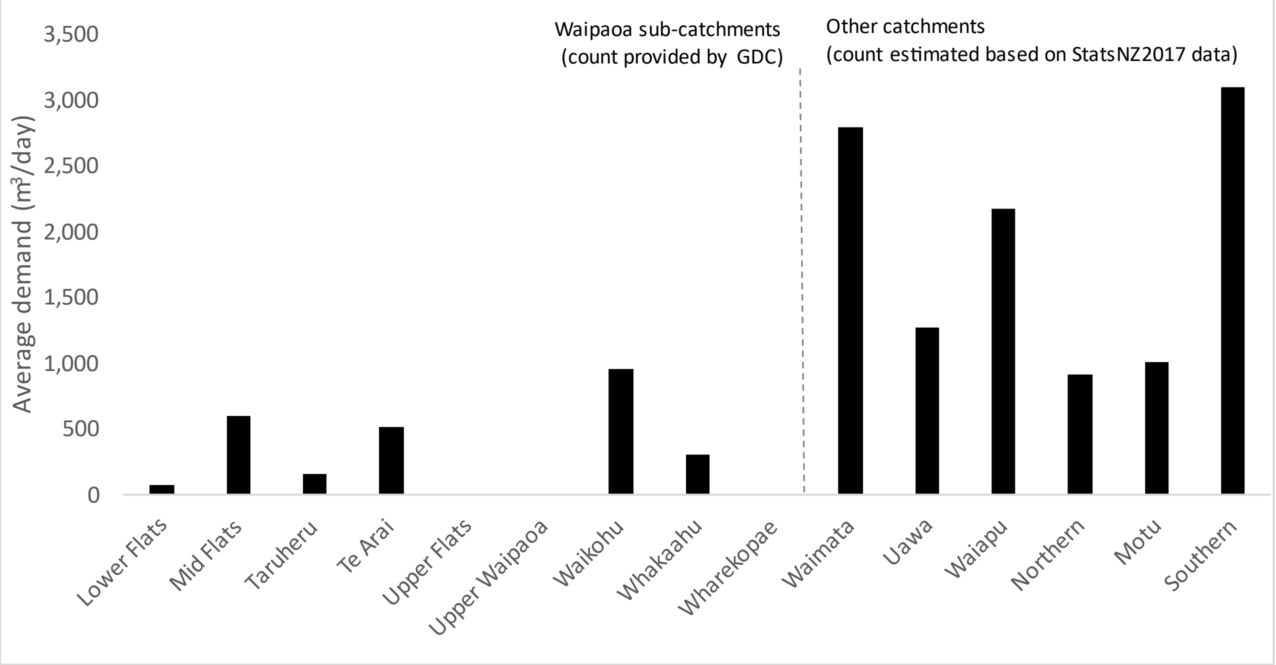

Figure 4-22: Average daily demand for stockwater, grouped by sub-catchment

4.5.2 Private domestic demand

We estimated the demand associated with private water takes which are not metered or on the reticulated network, and are too small to require a consent, using population data and the municipal demand trends. As noted in Section 4.3.2, we estimated the population served by reticulated and non-reticulated supplies using the StatsNZ gridded population data and GDC's reticulated network GIS layer. The estimated populations are summarised in Appendix C.

For the municipal demand we estimated the per capita domestic demand at 250 L/person/day. We have applied the same demand to private users. The average daily demand is summarised in Figure 4-23. This shows a higher demand outside the Waipaoa catchment, reflecting the lack of reticulated supply in these areas (i.e. in the Waipaoa catchment,domestic demand is more likely to be met from reticulated supply rather than private supply).

We did not include these abstractions in our water balance assessment as the source of the water was unknown (e.g., rainfall, stream-depleting groundwater, deeper groundwater).

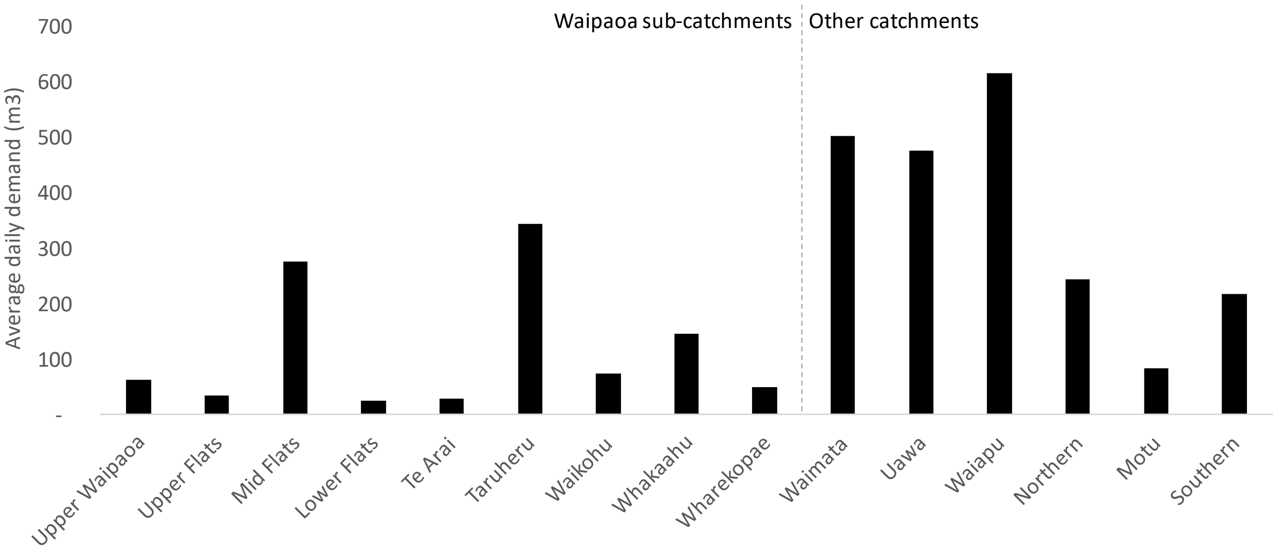

Figure 4-23: Average daily demand associated with private unmetered domestic uses, grouped by (sub-)catchment

Like municipal demand (Section 4.3.3), we estimated the future private domestic demand by scaling the demand calculated for 2022 by the projected population growth in each (sub-)catchment. Figure 4-24 shows the projected average daily demand.

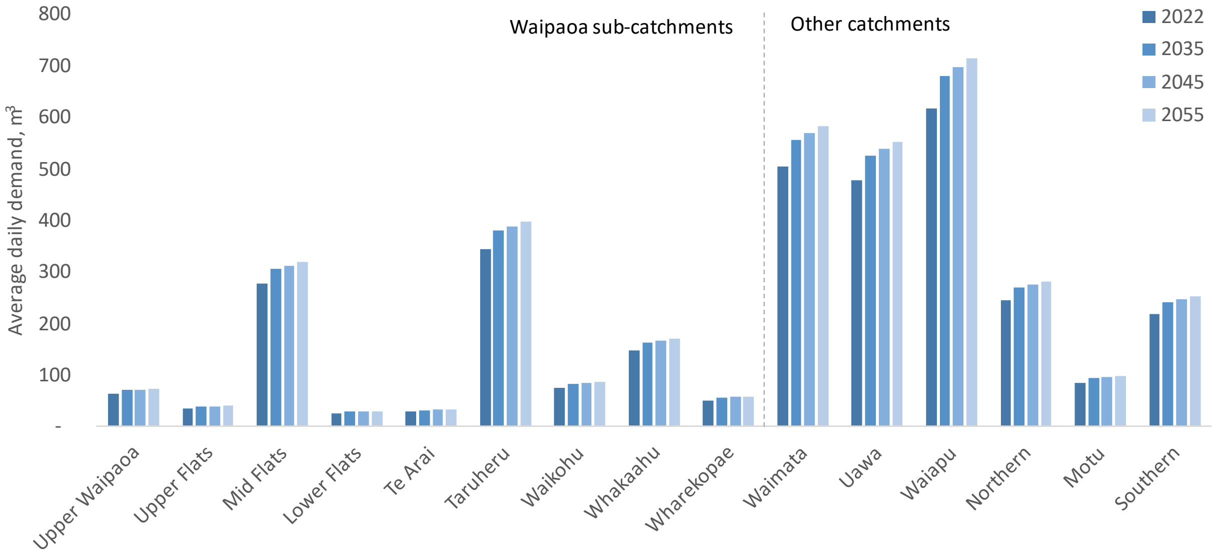

Figure 4-24: Projected average daily demand for un-reticulated drinking water, grouped by (sub-)catchment

4.6 Summary of water demands

Figure 4-25 summarises the annual water demand in each (sub-)catchment. The totals shown in the figure are summarised in Table 4-5. Demand categorised as “other” includes frost protection and mixed uses (see Section 4.4.1).

Irrigation generally constituted the majority of the demand in the Waipaoa study area, meaning water requirements are notably lower in the winter months when irrigation is not required. Other consented demands constituted a notable proportion of the total demand in the Mid Flats, Upper Flats, and Upper Waipaoa sub-catchments.

Outside the Waipaoa study area, where irrigation is less widespread, the main water demand is stockwater. The exception is the Southern catchment, which provides the majority of Gisborne City’s municipal drinking water and industrial use water.

For all water uses, the majority of demand is from surface water.

We estimated the total annual water demand in the Waipaoa study area to be approximately 27 Mm^3 per year. Aqualinc (2013) estimated the demand in the Greater Waipaoa area at approximately 36 Mm^3 per year. The differences in calculated volumes are largely caused by differences in assumptions and assessment methodology, rather than actual reductions in demand over the period between the two studies:

- A decrease in demand for reticulated water and other drinking water assumed to come from this catchment. We calculated reticulated water and drinking water demand at 6.3 Mm^3/year across Tairāwhiti, with 48% (3.0 Mm^3/year) of this demand coming from the Greater Waipaoa area, compared to the demand of 4.3 Mm^3 in Aqualinc (2013).
- A reduction in the estimated demand volume for irrigation. The 2022 irrigation water demand estimate is approximately 17.7 Mm^3 per year, compared to the demand of 29.9 Mm^3 estimated in 2013. We estimated the currently irrigated area at approximately 6,500 ha in the Waipaoa study area, compared to approximately 5,900 ha of irrigation estimated by Aqualinc (2013). However, the 2013 study used the 70th percentile estimated annual irrigation demand rather than statistics generated from daily timeseries modelling.

The additional data available for this assessment, relative to what was available in 2013, has enabled a greater level of accuracy and the ability to undertake daily time-stem modelling that better captures the dynamics of supply and demand. This has meant that some of the conservative assumptions from the 2013 project have been refined.

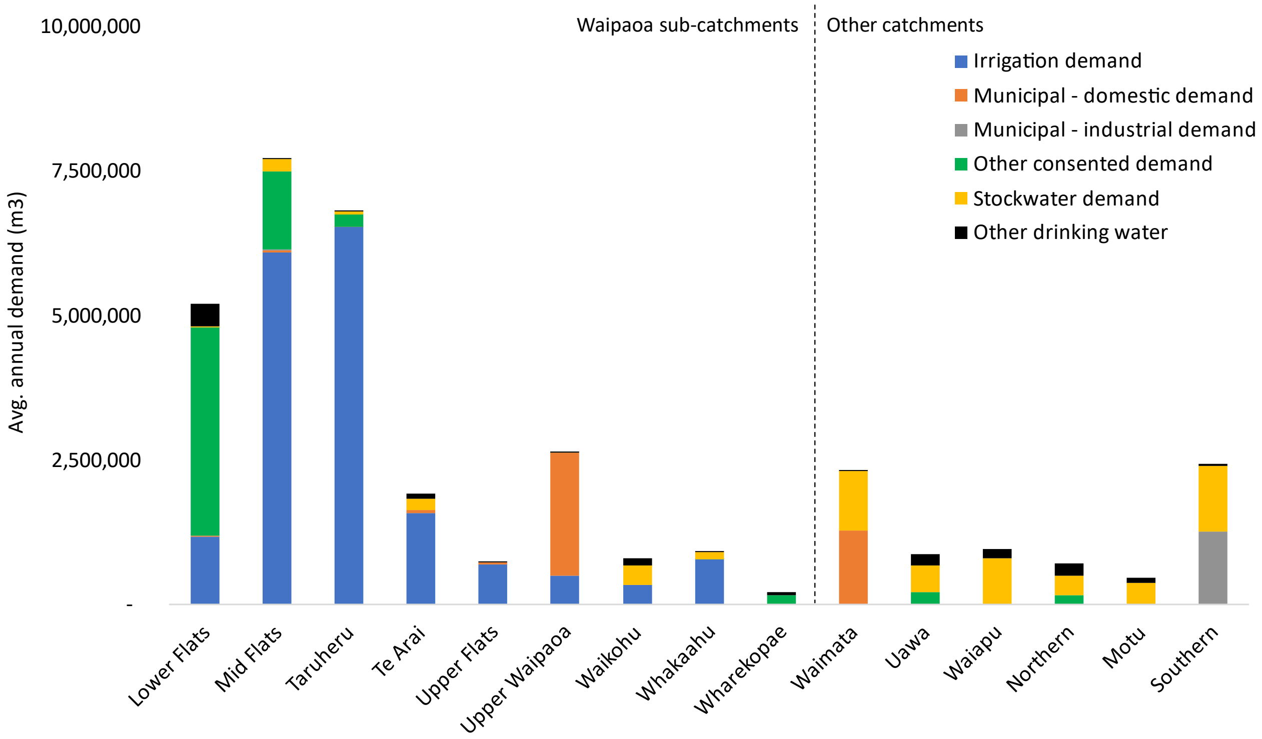

Figure 4-25: Annual water demand in each sub-catchment, grouped by water use

Table 4-5: Annual current state water demand summary . Municipal demands are based on metering data, the remaining demand are modelled based on reasonable use.

Catchment	Sub-catchment	Annual demand (m^3)						
		Irrigation	Municipal - domestic	Municipal - industrial	Other consents	Stockwater	Other drinking water	Total
Waipaoa	Lower Flats	1,163,522	20,500	-	3,605,583	23,725	381,320	**5,194,650**
	Mid Flats	6,099,244	33,676	18,133	1,341,137	217,046	23,120	**7,732,356**
	Taruheru	6,528,819	10,031	-	204,348	57,789	12,607	**6,813,593**
	Te Arai	1,585,044	53,146	-	-	187,037	100,927	**1,926,155**
	Upper Flats	684,561	46,330	-	-	-	9,367	**740,259**
	Upper Waipaoa	500,120	2,121,115	-	10,957	-	10,351	**2,642,543**
	Waikohu	330,870	-	-	-	349,202	125,682	**805,753**
	Whakaahu	774,838	-	-	14,609	111,985	27,279	**928,711**
	Wharekopae	-	-	-	154,640	-	53,628	**208,268**
Waimata		-	1,285,100	-	-	1,019,040	18,359	**2,322,499**
Uawa		-	-	-	219,140	463,600	183,934	**866,675**
Waiapu		-	-	-	-	792,193	174,153	**966,347**
Northern		-	-	-	157,781	332,405	225,436	**715,622**
Motu		-	-	-	-	366,210	88,980	**455,190**
Southern		-	-	1,267,514	-	1,131,577	30,774	**2,429,865**
Total		**17,667,018**	**3,569,898**	**1,285,647**	**5,708,195**	**5,051,810**	**1,465,917**	**34,748,485**

5 RESOURCE AVAILABILITY

Key findings from this section:

- The Waipaoa, Te Arai and Waiapu catchments have sufficient flow data for water availability to be calculated using a daily time-series model. Water availability for other catchments in the study area was estimated using monthly flow duration curves generated from a national flow statistics dataset.
- Surface water availability is typically at or close to 100% over winter and spring (June – October), and is lowest on average in January – February.
- Based on previous modelling, future surface water availability is expected to reduce in some catchments, but not all. The Waipaoa, Waimata and Southern-Maraetaha catchments area expected to have reduced water availability in the future due to an ~8% reduction in mean annual low flow.
- Within the Waipaoa catchment, consent information suggest the Makauri aquifer is fully allocated, the Te Hapara Sands aquifer is overallocated and the Matokitoki aquifer has available allocation. Most overallocation occurs within the Taruheru sub-catchment.
- Outside the Waipaoa catchment, groundwater availability, based on 30% of average annual rainfall recharge, exceeds current consented volumes.
- Average annual rainfall recharge is projected to decrease under climate change, resulting in lower groundwater availability except the Northern catchment where there is a minor increase. The largest reduction in rainfall is likely to be in the Taruheru sub-catchment,

5.1 Surface water

5.1.1 Surface water records

GDC provided timeseries of mean daily flow at a set of monitoring sites in the region. The locations of the sites are shown in Figure 5-1, along with currently irrigated areas and other crop areas, which are topographically suited to be irrigated in the future. If flow sites had mostly complete record spanning the modelling period (1992-2022), GDC data was used. If there was no or inadequate data, we estimated MALF and monthly availability using flow statistics at the recorder site from the national flow statistics dataset used in the national-scale water availability study (Dark et al., 2021). For the Greater Waipaoa area, we split the catchment into three model units, based on existing catchment plans.

We filled gaps in the flow records for Waipaoa at Kanakanaia and Te Arai at Pykes Weir using the available flow data on either side of the gaps and flow patterns at other sites over the same time period. Gaps were not observed during times of low flow during the modelling period (1992 – 2022). The Southern catchment had two model units reflecting agricultural (Maraetaha) and municipal (Mangapoike) pressures.

Table 5-1 summarises our approach by catchment. Where Table 5-1 shows different catchments to where GDC has recorders, this reflects the greatest potential for future water stress. We assumed, in accordance with the Policy C6.1.1 of the Tairāwhiti Resource Management Plan (TRMP), that the cease-take was MALF and the allocation 30% of MALF.

Table 5-1: Summary of surface water records and surface water availability modelling approach

Catchment	GDC data?	River	Site	Record length	Modelled?	Alternative model name
Waipaoa	Yes	Taruheru	Tuckers Rd Br	1981-2001; 2015-2022	Yes	
	Yes	Te Arai	Pykes Weir	1984-2022		
	Yes	Waipaoa	Kakakanaia	1966-2022		
Northern	Yes	Karakatuwhero	SH35 Br	2011-2023		
		Awatere			Yes	Northern-Sentinel (Figure 5-3)
Waiapu	Yes	Waiapu	Rotokautuku Br	1975-2023		
Waimata		Waiomoko			Yes	Waimata-Sentinel (Figure 5-2)
	Yes	Waimata	Goodwins Br	1978-2023		
Motu	Yes	Motu	Kotare Station Br	2016-2023	Yes	
Uawa		Uawa			Yes	
Southern		Wairoa	Marumaru			
		Mangapoike			Yes	Southern-Mangapoike (Figure 5-4)
	Yes	Maraetaha	No3 Br	1997-2023	Yes	Southern-Maraetaha

Appendix E compares measured to modelled average flow by month. This shows measured flow tends to exceed modelled flow in Waiapu, Waimata, and Motu catchments, meaning availability estimates will be conservative. In Northern, Taruheru, and Southern catchments, modelled availability exceeds that suggested by GDC data. This could result in overestimation of available water.

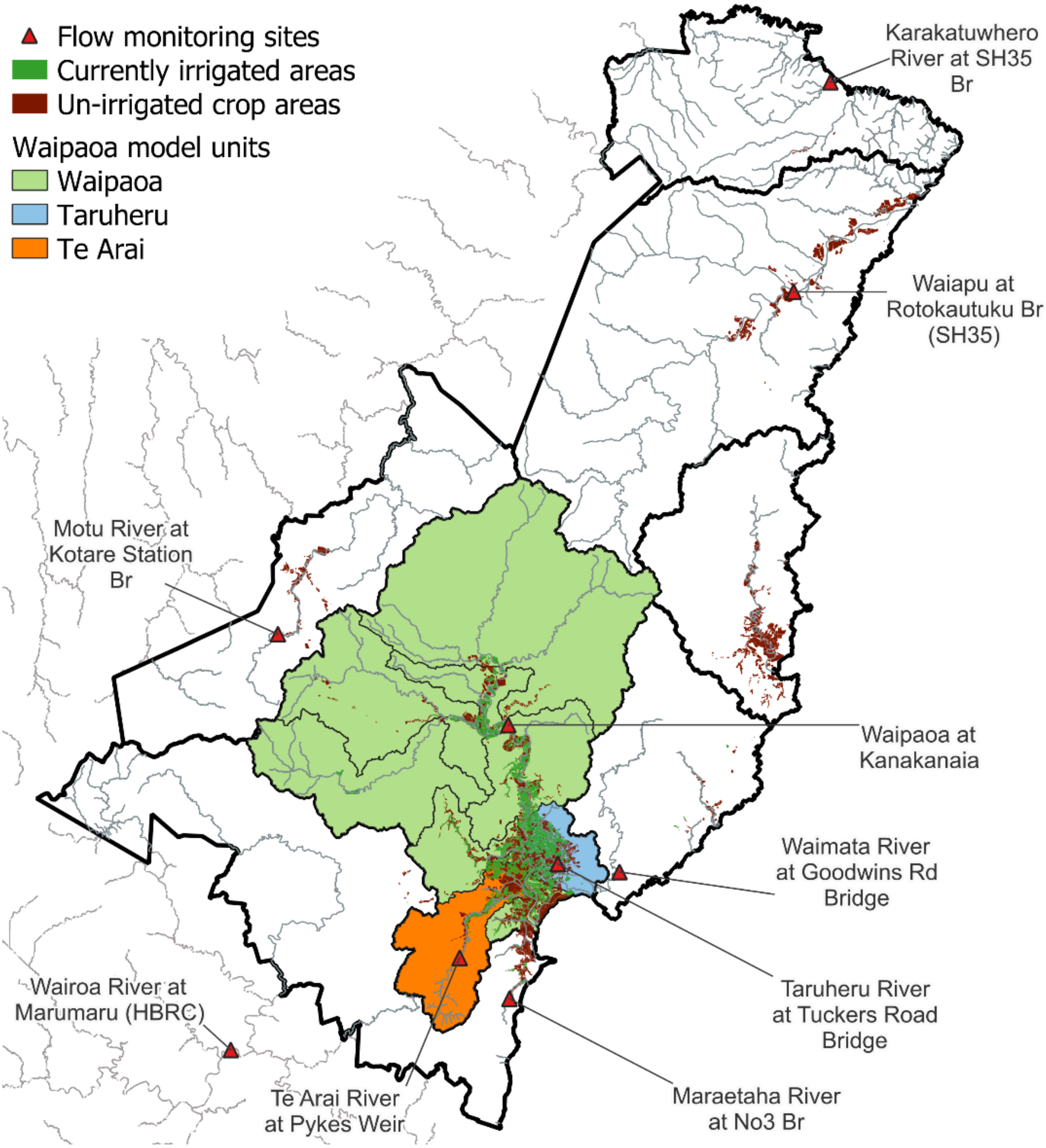

Figure 5-1: Flow monitoring sites used to assess surface water availability

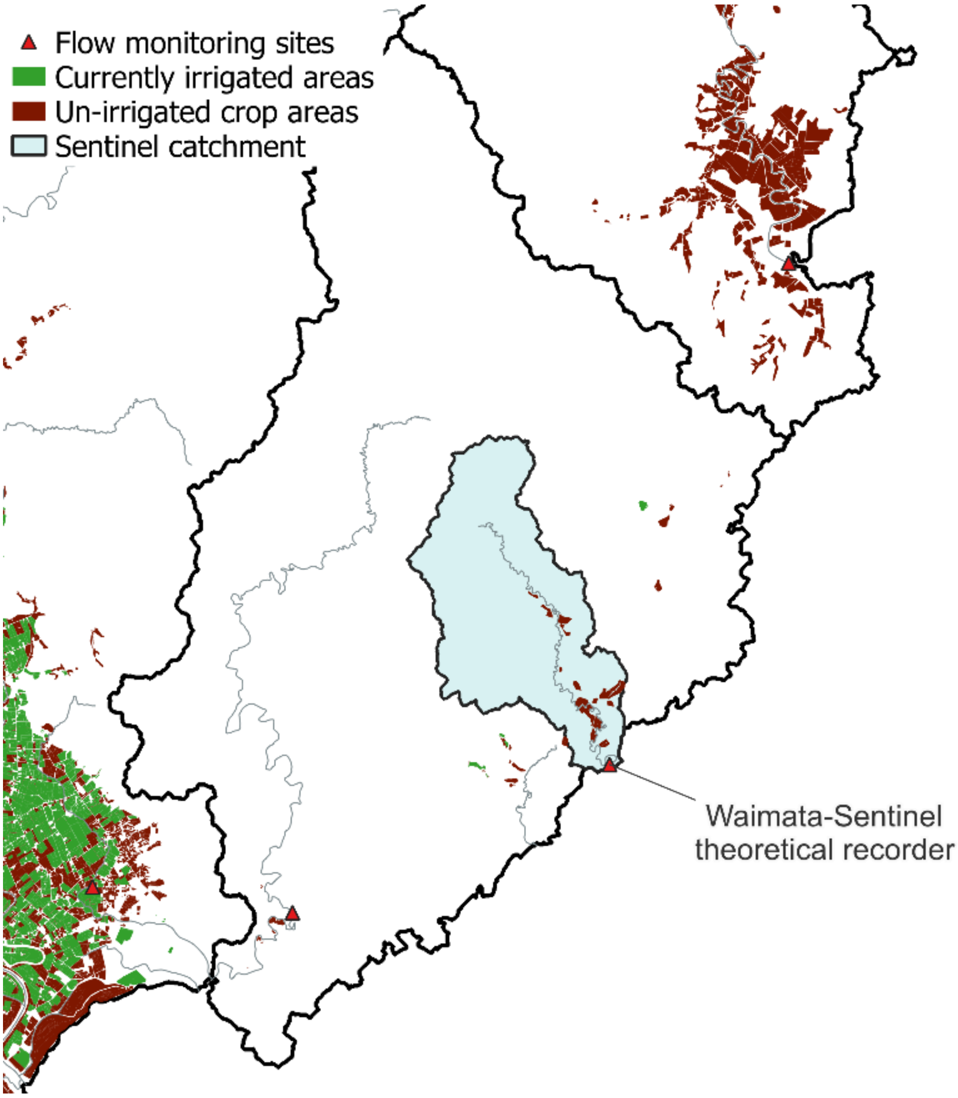

Figure 5-2: Sentinel sub-catchment selected from the Waimata catchment

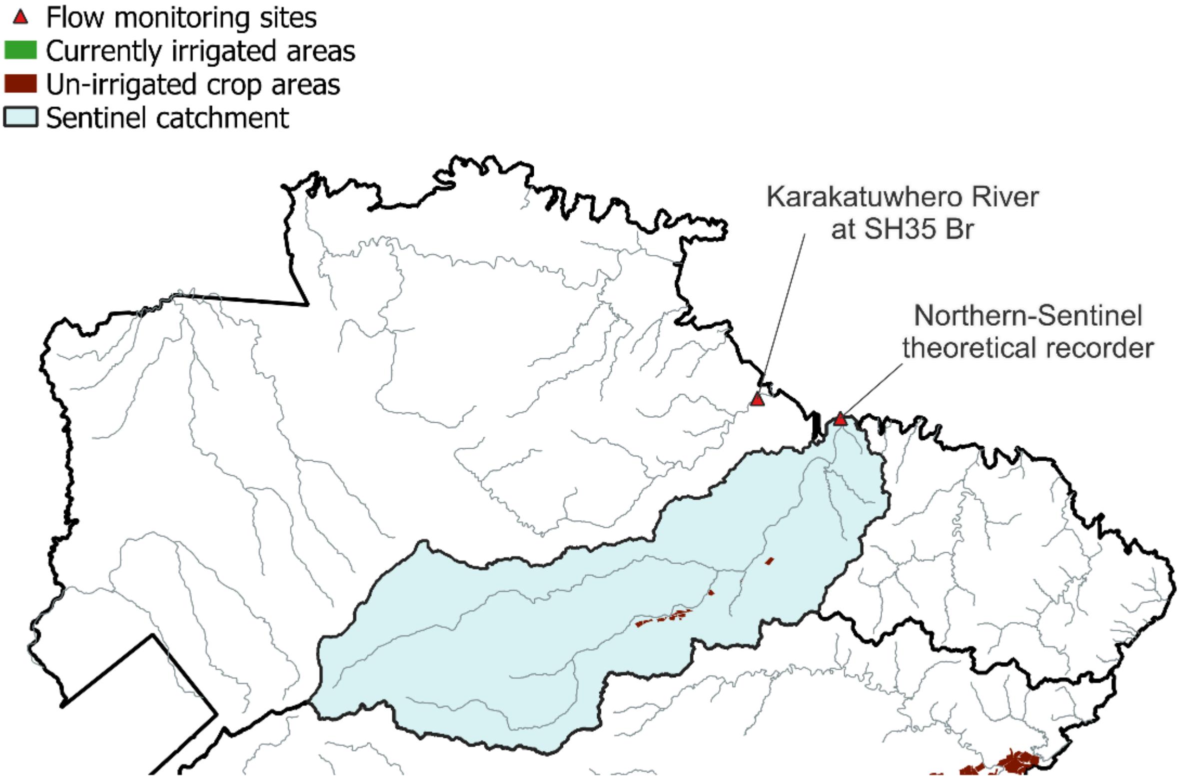

Figure 5-3: Sentinel sub-catchment selected from the Northern catchment

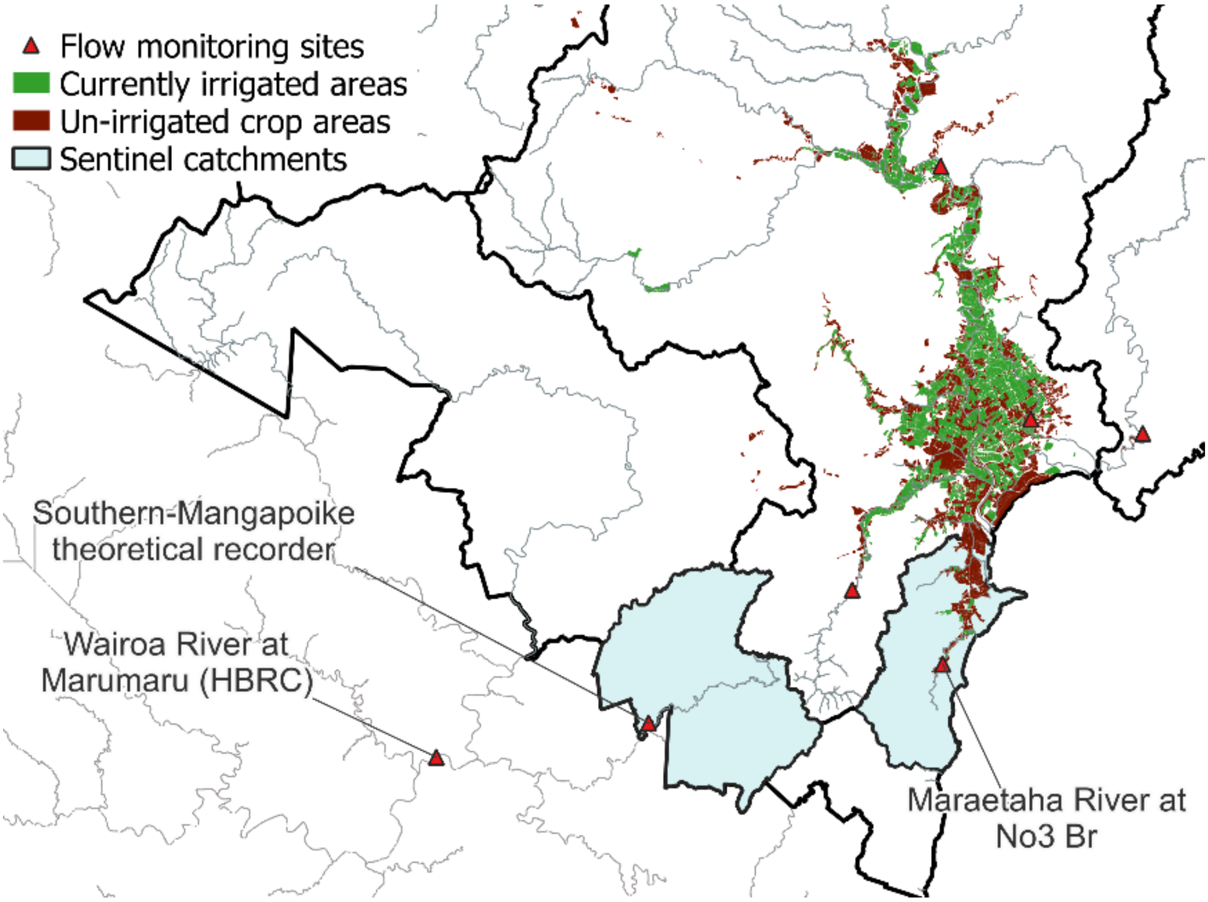

Figure 5-4: Sentinel catchments delineated in the Southern catchment

5.1.2 Naturalised flow records

The flow at some monitoring sites will be affected by abstraction upstream of the monitoring site. We have created naturalised flow records for these sites by adding back the estimated daily water takes for irrigation, municipal, and industrial water uses upstream of the recorder site.

For surface water sites without current irrigation, municipal, or industrial uses upstream of the recorder site (Te Arai, Taruheru, Northern-Sentinel, Waiapu, Uawa, Waimata-Sentinel, Southern-Maraetaha, Motu), we have used the raw flow record / flow statistics to calculate availability. We note that there are surface water consents mapped upstream of the Taruheru at Tuckers Road Bridge monitoring sites, but these consents source water from the Waipaoa River, as noted in Section 4.1.

The Waipaoa model unit has surface water irrigation consents upstream of the Kanakanaia monitoring site, while the Southern-Mangapoike catchment has Gisborne City's municipal supply abstraction upstream of the theoretical monitoring point. The following sections describe the methods used to naturalise the flow records.

Waipaoa

There are 18 consents assigned to the Waipaoa A or B Block which are upstream of Kanakanaia. We created a naturalised flow record for this site by adding back the estimated total water take each day. This involved the following steps and assumptions:

- We estimated the irrigated area associated with each consent using a combination of aerial photos, LINZ primary parcels, GDC and MfE irrigated area polygons, and the consent descriptions.
- We assumed a crop type for each area based on GDC's summer crop survey data from recent years.
- We calculated a daily irrigation demand associated with each consent based on the crop type and irrigated area. The PAW at all sites was in the 100 mm group.
- We limited the daily irrigation demand to the maximum rate allowed by the consent where it was greater.
- On days where the flow at Kanakanaia was below the A Band or B Band cease-take, we assumed that no water was taken from consents allocated to the band. If the flow was above the respective cease-takes, we assumed that the full demand had been abstracted.
- Based on advice from GDC, abstraction associated with the three drinking water consents was assumed to continue regardless of the flow at Kanakanaia.
- We added back the demand associated with the consents, limited by the consented rates and cease-take conditions, to the flow series.

Figure 5-5 shows the average recorded and naturalised flow rates at Kanakanaia during each month. The naturalisation process did not have a significant impact on the flow profile, as most of the catchment's water demands are downstream of the Kanakanaia recorder. The average naturalised flow rate was approximately 5 L/s higher than the recorded flow rate during the winter months, and approximately 60 L/s higher during the summer months.

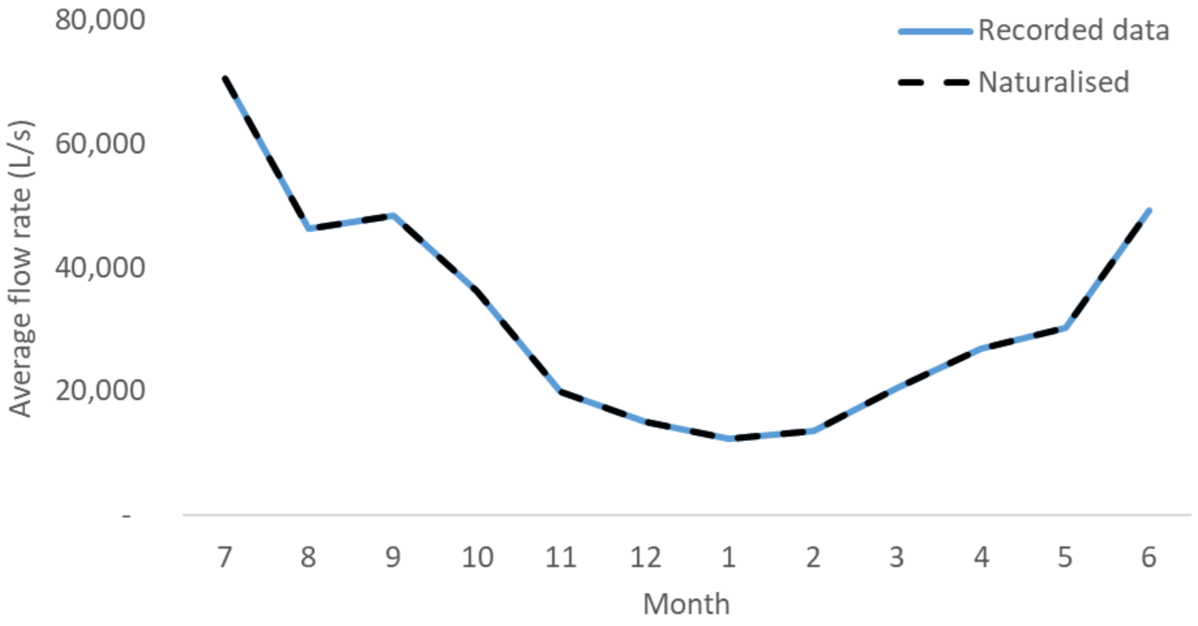

Figure 5-5: Estimated average flow rate during each month at the Waipaoa at Kanakanaia recorder for the recorded and naturalised flow timeseries. Up to 496 L/s can be taken upstream of this site

<u>Southern-Mangapoike</u>

We estimated the average flow at the Southern-Mangapoike theoretical recorder site during each month using monthly flow duration curves generated from the national flow statistics dataset and monthly scaling factors used in the national-scale water availability study (Dark et al., 2021). We used the flow duration curves to estimate the average flow rate at the catchment outlet during each month.

Water for Gisborne City's municipal supply is abstracted from the Mangapoike reservoirs at the top of the Mangapoike catchment. As this take is within the Mangapoike catchment, though not on the mainstem, this water needs to be accounted for. We estimated the rate of demand for this source as described in Section 4.3.2. We have assumed that, because the demand is for public drinking water supply, abstraction is allowed regardless of the flow in the river, i.e., there is no cease-take flow or allocation cap (note that this will not necessarily be the case under future allocation rules that give effect to Te Mana o te Wai). We calculated the naturalised flow at the theoretical Mangapoike recorder site by adding the estimated municipal demand onto the estimated flow at the recorder site on each day.

Figure 5-6 shows the estimated average flow rate during each month at the Southern-Mangapoike theoretical flow recorder for the raw and naturalised datasets. The naturalised flow rate was approximately 150 L/s higher than the raw flow rate during the winter months and approximately 190 L/s higher during the summer months.

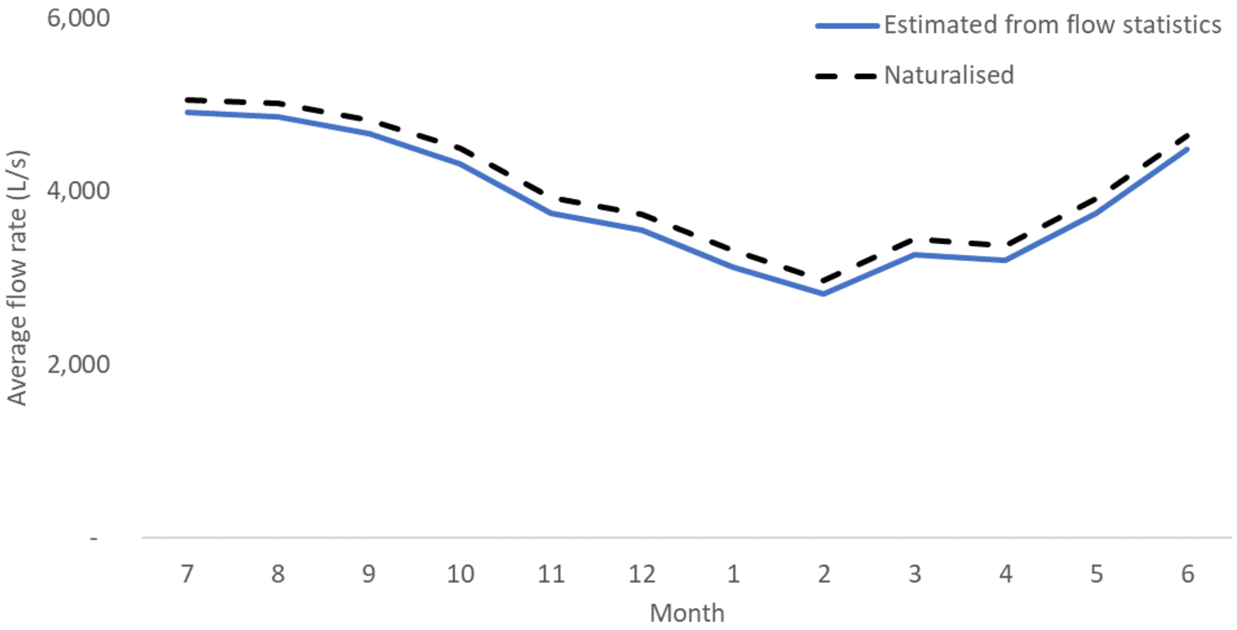

Figure 5-6: Estimated average flow rate during each month at the Southern-Mangapoike theoretical flow recorder for the raw and naturalised states

5.1.3 Surface water availability

Based on the flow records, cease-takes, and allocated volumes, we calculated daily availability time series for the surface water monitoring sites over the modelling period (hydrological years 1993 – 2022). This corresponds to the quantity of allocated water that is available for taking on each day (i.e. it is the availability within the allocation block(s)).

The allocation block rules are summarised in Table 5-2. For catchments without a catchment management plan defined, we used the allocation rules specified in Policy C6.1.1 of the Tairāwhiti Resource Management Plan: a cease-take flow of 100% of MALF and an allocation of 30% of MALF. The exception was the Southern-Mangapoike catchment. Approximately 97% of the current and projected future surface water demand in the catchment is abstracted from the Mangapoike reservoirs for Gisborne City’s municipal supply. We have therefore assumed that there was no cease-take or allocation cap in this model unit.

Table 5-2: Allocation block rules. Where limits are not set in the Tairāwhiti Resource Management Plan they have been calculated as described in text

Site	Block	Cease-take flow (L/s)	Allocation (L/s)
Waipaoa at Kanakanaia	A Block	1,300	2,000
	B Block	4,000	2,000
Te Arai at Pykes Weir	A Block	60	70
	B Block	220	100
Catchments without catchment management plans:			
Taruheru		48	14
Waimata-Sentinel		81	24
Uawa		1,671	501
Waiapu		8,449	2,535
Northern-Sentinel		1,252	376
Motu		510	153
Southern-Maraetaha		217	65
Southern-Mangapoike		-	-

Using the daily flow records and the allocation rules, we calculated the daily availability for the Waipaoa and Te Arai catchments in the A and B allocation blocks. We assumed that water uses within the Te Arai sub-catchment would be subject to availability based on flows at Pykes Weir, while water uses within the other Waipaoa sub-catchments (Upper Waipaoa, Waikohu, Whakaahu, Wharekopae, Upper Flats, Mid Flats, and Lower Flats) would be subject to availability based on flows in the Waipaoa River at Kanakanaia.

Figure 5-7 and Figure 5-8 summarise the average monthly availability for the Waipaoa and Te Arai allocation bands respectively (i.e., the percentage of the total allocation which is available for taking). The supply may be on partial or full restriction during these times. An availability of 100% means that the full amount allocated to the band is available for taking. Availability between 0% and 100% means that a portion of the full amount is available for taking, and an availability of 0% means that no water is available for taking.

We note that the Aqualinc (2013) study was completed before the Waipaoa and Te Arai catchment plans were formed. The 2013 study estimated the total allocable flow to be 5,263 L/s, compared the 4,170 L/s available according to the catchment plans.

Lower river flows over the summer months mean that the average reliability drops to a minimum of around 70% for the Waipaoa site and 45% for the Te Arai site, with some days where the rivers are fully restricted. During the winter period (June – October) the supply is close to 100% reliable as river flows rarely drop below the cease-take limits.

We note that we have assumed that the allocated water is always available for taking during high flows. However, during and following flood events surface water is generally highly sediment-laden, meaning taking water may not be economical due to the treatment requirements.

We used the same approach to calculate the available flow in the Waiapu River, which had a sufficient flow record to carry out a daily availability assessment for the 30-year modelling period.

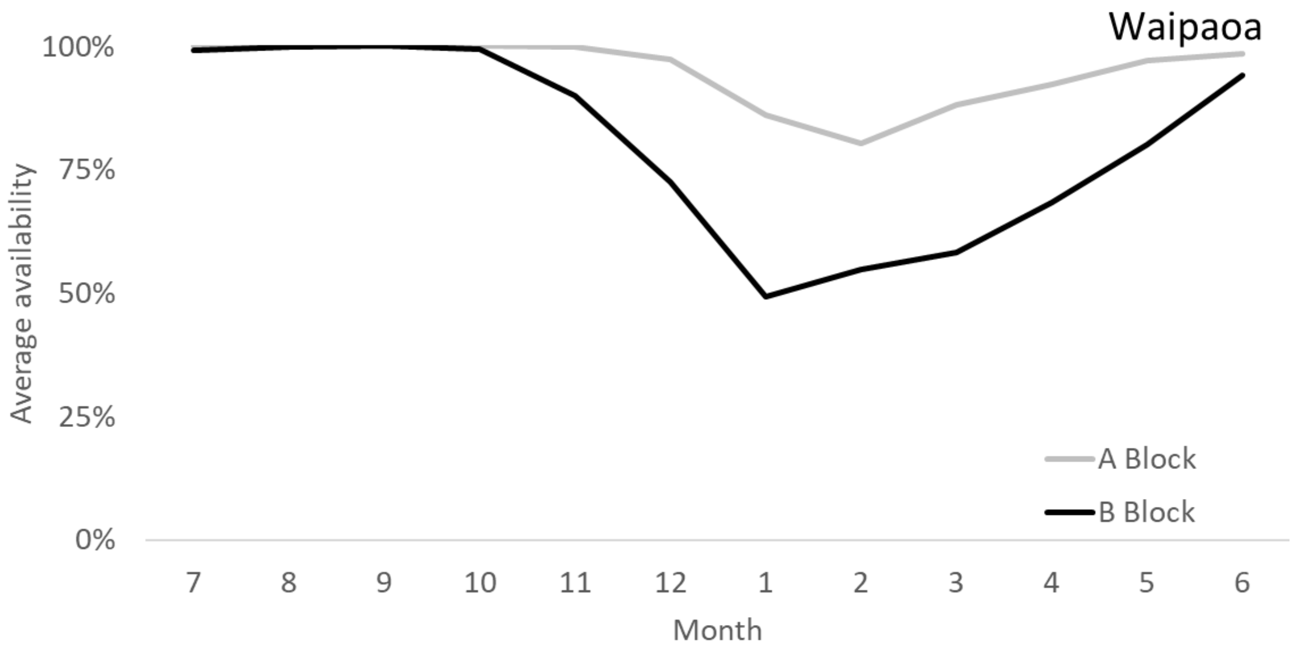

Figure 5-7: Average monthly availability for the Waipaoa allocation blocks

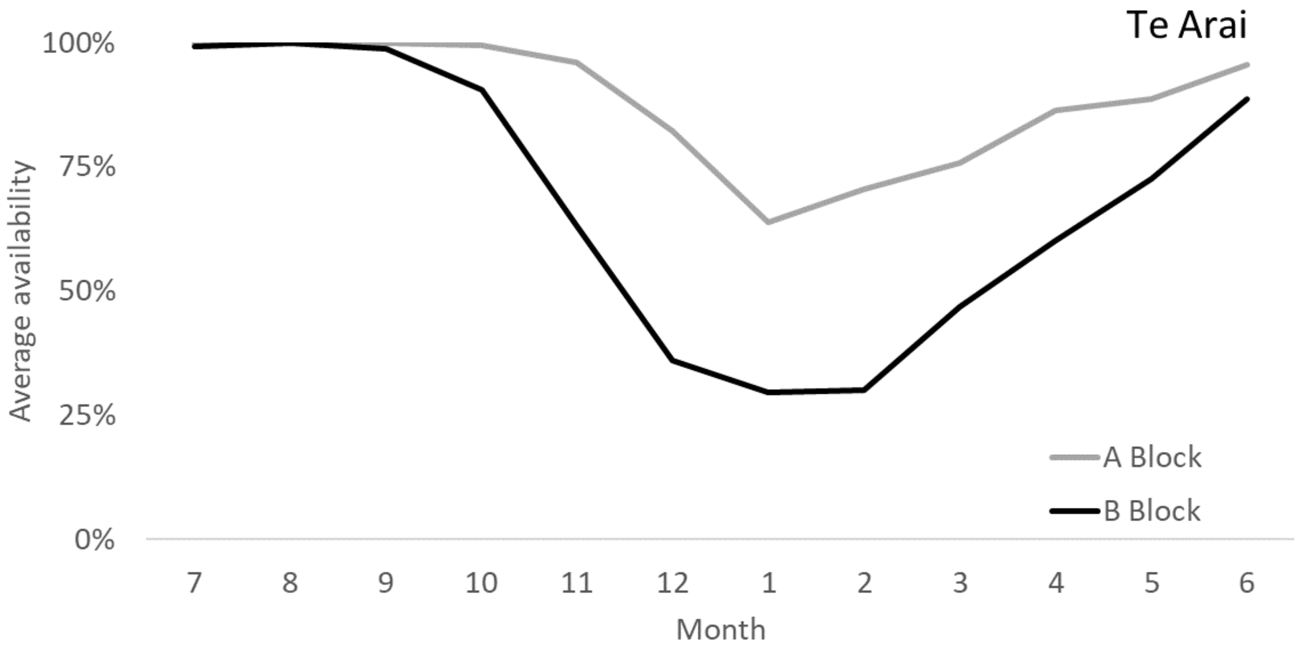

Figure 5-8: Average monthly availability for the Te Arai allocation blocks

For the other catchments, we generated monthly flow duration curves using values from the national flow statistics dataset and monthly scaling factors used in the national-scale water availability study (Dark et al., 2021). We used the flow duration curves to calculate the average availability during each month. An example flow duration curve is shown in Figure 5-9.

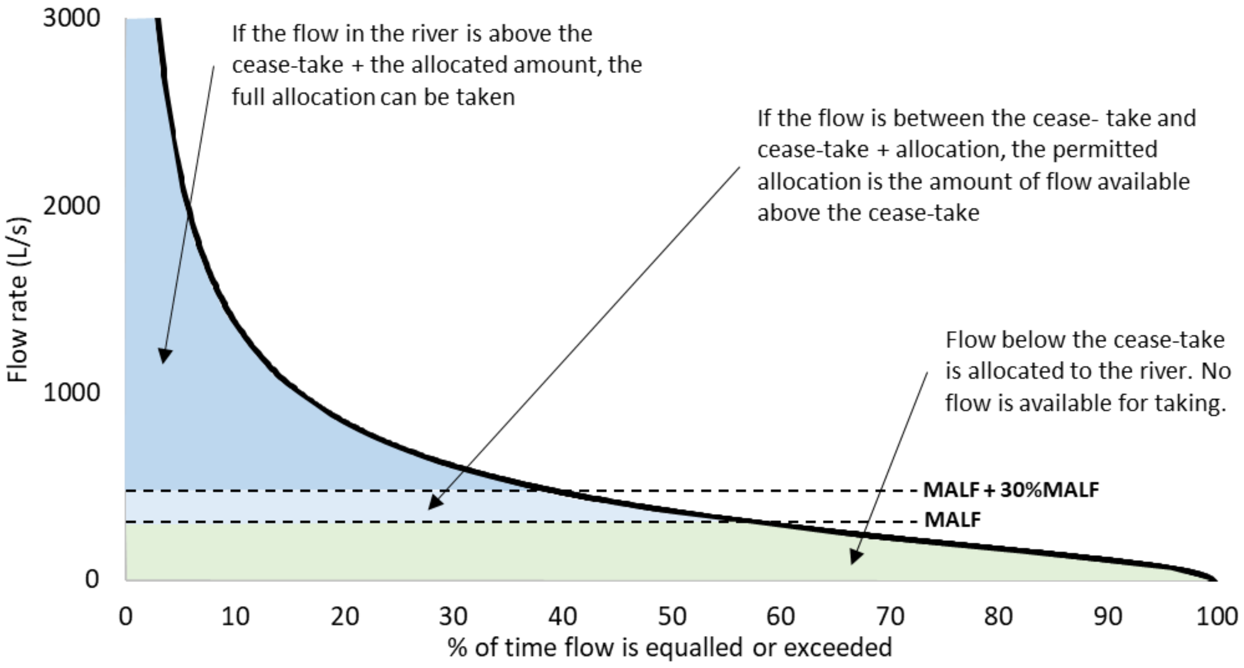

Figure 5-9: Example flow duration curve calculated from the national flow statistics dataset, demonstrating how surface water availability is estimated for rivers without daily flow data, assuming a cease-take of MALF and an allocation of 30% of MALF.

5.1.4 Future surface water availability

We calculated the future surface water availability in the sentinel month (the month where demand puts the most pressure on surface water availability) using scaled surface water flow rates. We assumed that the allocation policies were unchanged.

Collins, et al. (2018) reported projected percentage changes in mean flow and MALF between 1986-2005 and 2031-2050 for New Zealand rivers under climate change based on IPCC-5 and six Global Climate Models (GCMs). The analysis included the Waipaoa River and Waiapu River from Tairāwhiti. The multi-model median change in MALF estimated by the modelling was -8% for the Waipaoa River and 0% for the Waiapu River.

NIWA (2020) presented mid-century projections of estimated changes in MALF for river reaches in Tairāwhiti for RCP 4.5 and RCP 8.5. The report did not include specific values, but we used the general trends presented and data provided by NIWA as part of the national-scale water availability and storage project (Bright et al., 2022) to extend the values from Collins et al. (2018) to other catchments.

Based on the above characterisations, we assumed that the Northern, Uawa, Motu and Southern-Mangapoike sentinel catchments would have no change in MALF, similar to Waiapu. We assumed that the change in MALF would be -8% for the Waimata and Southern-Maraetaha catchments, similar to Waipaoa.

5.2 Groundwater

Stream depleting groundwater takes are allocated within surface water allocation blocks so are excluded from consideration within this section. Groundwater allocation and availability are reported as annual volumes.

5.2.1 Previous estimates of groundwater availability

Four previous investigations calculated groundwater availability for Tairāwhiti. Table 5-3 shows their calculated groundwater allocation limits.

Table 5-3 Previous calculations of groundwater availability at the catchment scale (note: sub-catchment scale was generally used in reporting)

Source	Allocation	Northern (Mm^3/year)	Waiapu (Mm^3/year)	Uawa (Mm^3/year)	Waimata (Mm^3/year)	Waipaoa (Mm^3/year)	Southern (Mm^3/year)
White, et al. (2012)	15% recharge	-	-	-	-	27.8	-
Aqualinc (2013)	0.5% rainfall	7	0.2	0.7	1.3	30.2	-
Schritter, et al. (2016)	15% recharge	5.3	35	6.1	-	-	0.3
	35% recharge	2.2	-	-	-	-	0.7
WGA (2022)	Current abstraction					3.0	

White et al. (2012) calculated groundwater availability for the Poverty Bay Flats based on Ministry for the Environment (2008) guidelines[5] of 15% of recharge for shallow coastal aquifers and 35% for all other aquifers. This method was applied to coastal Holocene alluvial areas in 2016 by Schritter et al. Both investigations identified areas and/or aquifers where no groundwater should be allocated to preserve stream flows and prevent seawater intrusion.

Aqualinc (2013) calculated groundwater availability based on 0.5% annual average rainfall across each catchment, not aquifer extent. The exception is the Poverty Bay Flats in the Waipaoa catchment, where a value of 12.8 Mm^3/year was used. This value was attributed to work by NIWA (2009); however, this figure does not appear in the report; NIWA reports total consented allocation for the Poverty Bay Flats as 22.3 Mm^3/year, with 11.5 Mm^3/year of this allocated from the Makauri aquifer.

WGA (2022) also modelled different groundwater management scenarios (including different abstraction) of the Poverty Bay Flats aquifers. These abstraction values are significantly lower than previous calculations because WGA's approach was on quantifying current use, not calculating maximum volume of water available for use.

5.2.2 Groundwater allocation rules

The TRMP 2020 allocates water based on Freshwater Management Units (FMUs). Under Part DF1.4.3 of the TRMP, within the Poverty Bay Flats Freshwater Management Unit (FMU), no new allocation is allowed from Deep Groundwater (Makauri and Matokitoki aquifers), and allocation is capped at current for the Te Hapara Sands aquifer. Table DF1.4.3.2 of the TRMP sets specific reduced allocation targets for these aquifers. These are reproduced in Table 5-4.

Table 5-4 Tairāwhiti Resource Management Plan Table DF1.4.3.2 target allocations for the Poverty Bay Flats

Aquifer	2020 allocation target (m^3/year)	2025 allocation target (m^3/year)
Makauri Aquifer	1,892,160	1,702,944
Matokitoki Aquifer	630,720	567,648
Te Hapara Sands	295,000	

No other groundwater allocation limits are specified in the TRMP. In this case, the default allocation limit in the TRMP under policy C6.1.1.6 is the greater of

a) 30% of the mean annual low flow as calculated by GDC for surface water and groundwater that has a direct hydraulic connection to surface waterways, or 30% of annual average rainfall recharge for groundwater that does not directly affect a surface waterway; or

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[5] Proposed National Environmental Standard on Ecological Flows and Water Levels. Was never progressed.

b) The total allocation from the catchment on the date that the decision on Freshwater Plan is released, less any resource consents surrendered, lapsed, cancelled, or not replaced.

5.2.3 Consented groundwater allocation

Table 5-5 shows current consented allocation based on information provided to Aqualinc by GDC. Most groundwater is allocated in the Taruheru sub-catchment. There is one consent for groundwater take outside the Waipaoa Catchment. Based on 2020 allocation targets (Table 5-4), the Makauri aquifer is fully allocated (100%), the Matokitoki is at 55% allocation, and Te Hapara Sands is overallocated (197%). Based on 2025 allocation targets, current allocation puts the Makauri aquifer at 111% and the Matokitoki aquifer at 61% of target allocation.

Table 5-5: Consented groundwater allocation (values are in m^3/year)

Aquifer	Lower Flats sub-catchment	Mid Flats sub-catchment	Taruheru sub-catchment	Whakaahu sub-catchment	Northern catchment	*Total aquifer allocation*
Makauri		141,914	1,650,781	100,166		*1,892,861*
Matokitoki			344,900			*343,900*
Te Hapara	251,581	35,800	291,945			*579,326*
Karakatuwhero					157,680	*157,680*
Total catchment allocation	*251,581*	*177,714*	*2,286,626*	*100,166*	*157,680*	*2,973,767*

5.2.4 Calculated groundwater availability

5.2.4.1 Waipaoa catchment

Within the Waipaoa catchment the TRMP sets inconsistent groundwater allocation units and groundwater quantity zones as shown in Table 5-6. Existing consented abstraction from the Waipaoa shallow aquifers is all allocated within surface water blocks, so is excluded from groundwater availability assessment.

For this assessment we assume the Te Hapara Sands and deep groundwater aquifers have availability equal to the TRMP 2020 allocation limits. We assume this allocation is evenly distributed across the aquifer extents as shown in Figure 5-10. The 2020 TRMP allocations were partitioned to sub-catchments based on relative aquifer extent. For example, 2% of the Makauri aquifer is within the Te Arai sub-catchment, so it is assigned 2% of the Makauri aquifer allocation. This information is plotted in Figure 5-11 alongside consented allocation (from Table 5-5).

Figure 5-11 shows a variable picture in terms of partitioned groundwater availability on an aquifer scale at the sub-catchment level. Groundwater allocation tends to exceed partitioned availability in the Te Hapara Sand and Makauri aquifers at the sub-catchment level, except for the Makauri aquifer in the Mid Flats sub-catchment. This sub-catchment also has consented allocation from Te Hapara Sands without having a mapped aquifer extent. Both Makauri and Te Hapara Sand aquifers. The Matokotoki aquifer is only mapped within the Taruheru sub-catchment where avaiaibility exceeds consented allocation. At a sub-catchment level, consented allocation in the Whakaahu, Taruheru, and Lower Flats sub-catchments exceed partitioned demand. At an aquifer level, the Makauri and Te Hapara Sand aquifers are overallocated, and the Matokitoki aquifer has water available. On the balance of all consented allocation and TRMP 2020 groundwater allocation limits there is 793 m^2/year of groundwater available within the Waipaoa catchment.

Table 5-6 Comparison between Poverty Bay Flats aquifers and TRMP allocation units and water quantity zones

Aquifer	TRMP Table DF1.4.3.2 groundwater allocation unit	TRMP Figure DF1.15 Poverty Bay Flats groundwater quantity zone	2020 groundwater allocation (m^3/year)
Te Hapara Sand Aquifer	Te Hapara Sands		295,000
Waipaoa Gravels Aquifer		Waipaoa shallow aquifers	
Shallow Fluvial Deposits			
Local Pumicious Sand Deposit			
West Saline Aquifer			
Makauri Gravel Aquifer	Deep groundwater	Deep groundwater	1,892,160
Matokitoki Gravel Aquifer			630,720

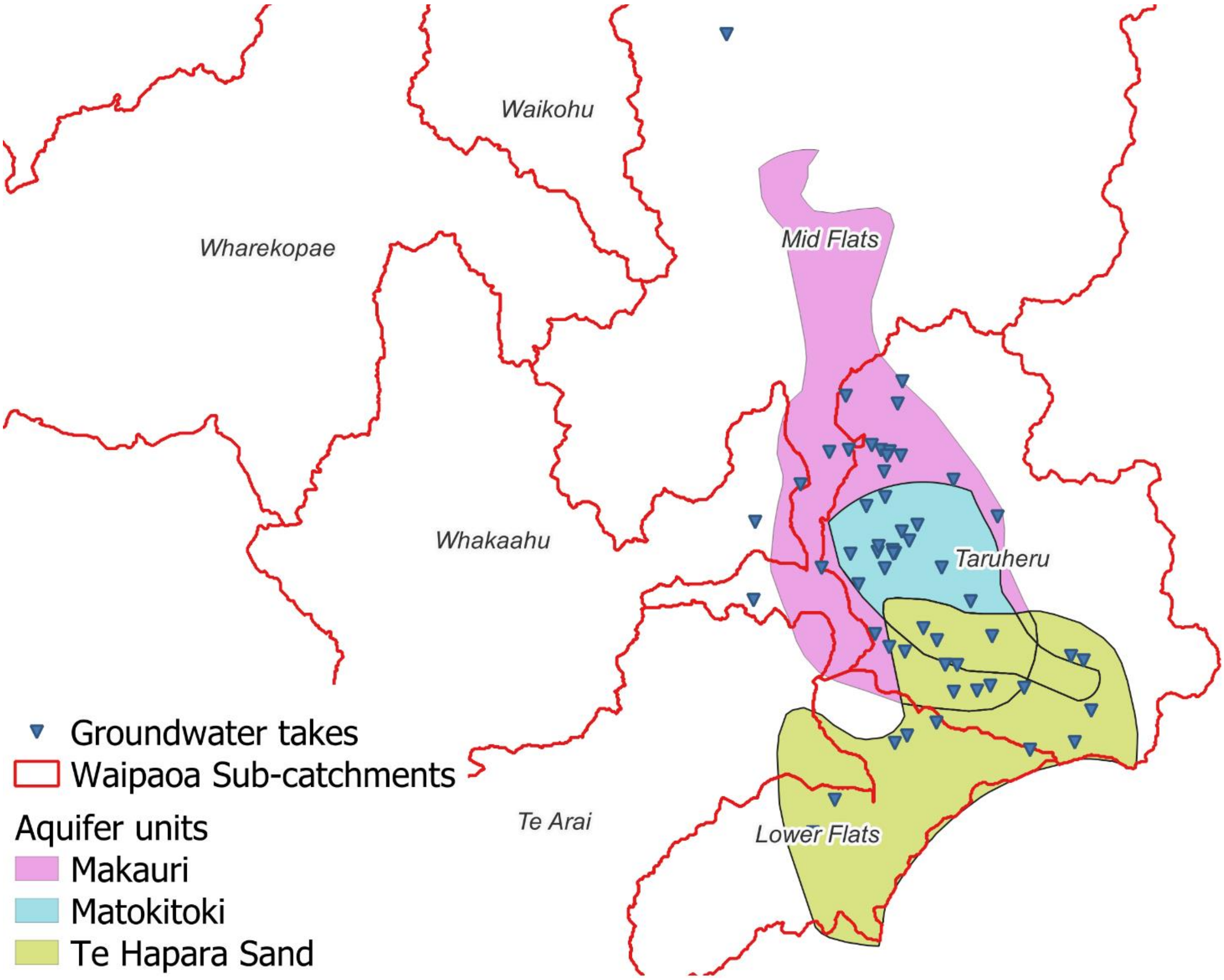

Figure 5-10 Waipaoa aquifer units, sub-catchments, and consented groundwater takes

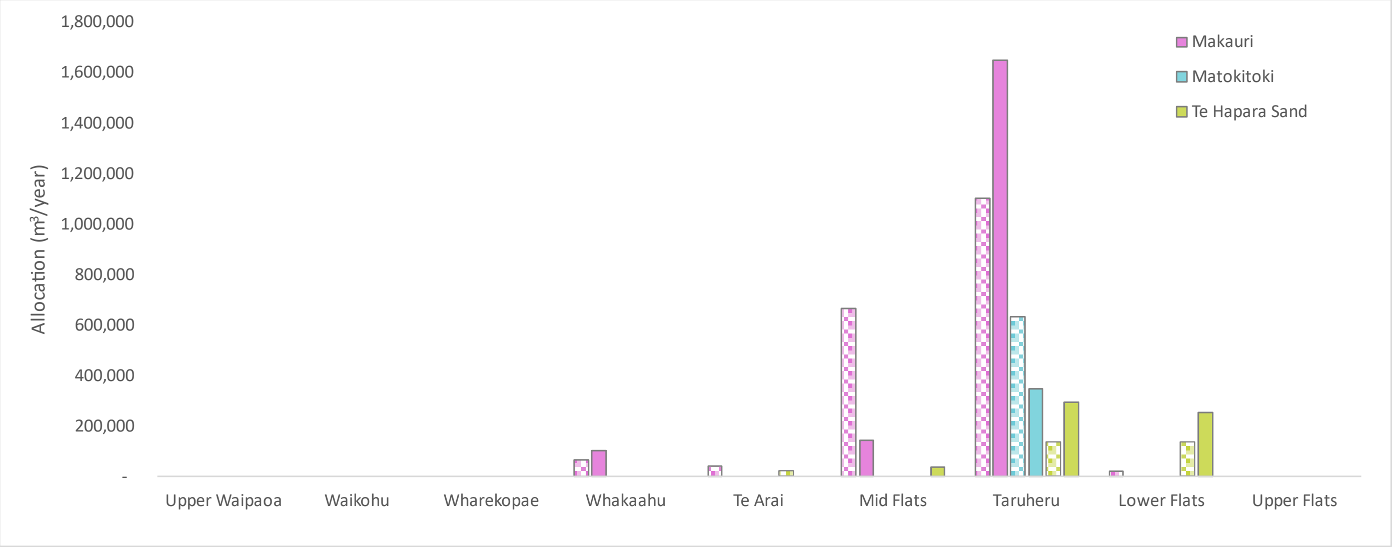

Figure 5-11 Partitioned groundwater allocation (textured bars, using TRMP 2020 groundwater allocation limits) compared to consented allocation (solid bars) per aquifer by Waipaoa sub-catchment

5.2.4.2 Remaining catchments

Groundwater availability as 30% recharge for all catchments except Waipaoa) was calculated as per TRMP policy C6.1.1.6.a using net aquifer area per catchment (as determined using GIS layers provided by GDC[6]) and area weighted[7] average annual recharge using recharge values determined by Dark, et al. (2021). Note net aquifer extent reflects the maximum potential extent of aquifers based on the provided layers. Figure 5-12 shows aquifer extent relative to catchments. GDC has advised they expect this extent to be reduced with completion of SkyTEM survey work, which would reduce calculated groundwater availability.

Table 5-7 shows groundwater availability consistent with TRMP policy C6.1.1.6 by catchment. There are no mapped aquifers in the Motu catchment, so there is no groundwater available. Under policy C6.1.1.6 the greater of 30% recharge or consented allocation is the allocation limit, thus availability as 30% recharge should be considered the allocation limit for these catchments. This suggests significant potential for increased groundwater abstraction on current state. Availability estimates are much higher than previous estimates by Tschritter et al. (2016). This was expected, as Tschritter et al. (2016) generally used 15% recharge to determine availability and had instances of recommending nil groundwater availability at the sub-catchment level to preserve stream baseflow and prevent seawater intrusion.

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[6] 'Poverty_Bay_Flats_Aquifers', 'tairawhiti_catchments'

[7] Using an area weighted average rather than an average enables calculation of a more accurate average recharge rate as it gives greater consideration to the recharge rate of larger areas. I.e., if 90% of an aquifer extent has recharge rate X and 10% has recharge rate Y, the weighted average would be close to rate X, whereas an average would split the difference.

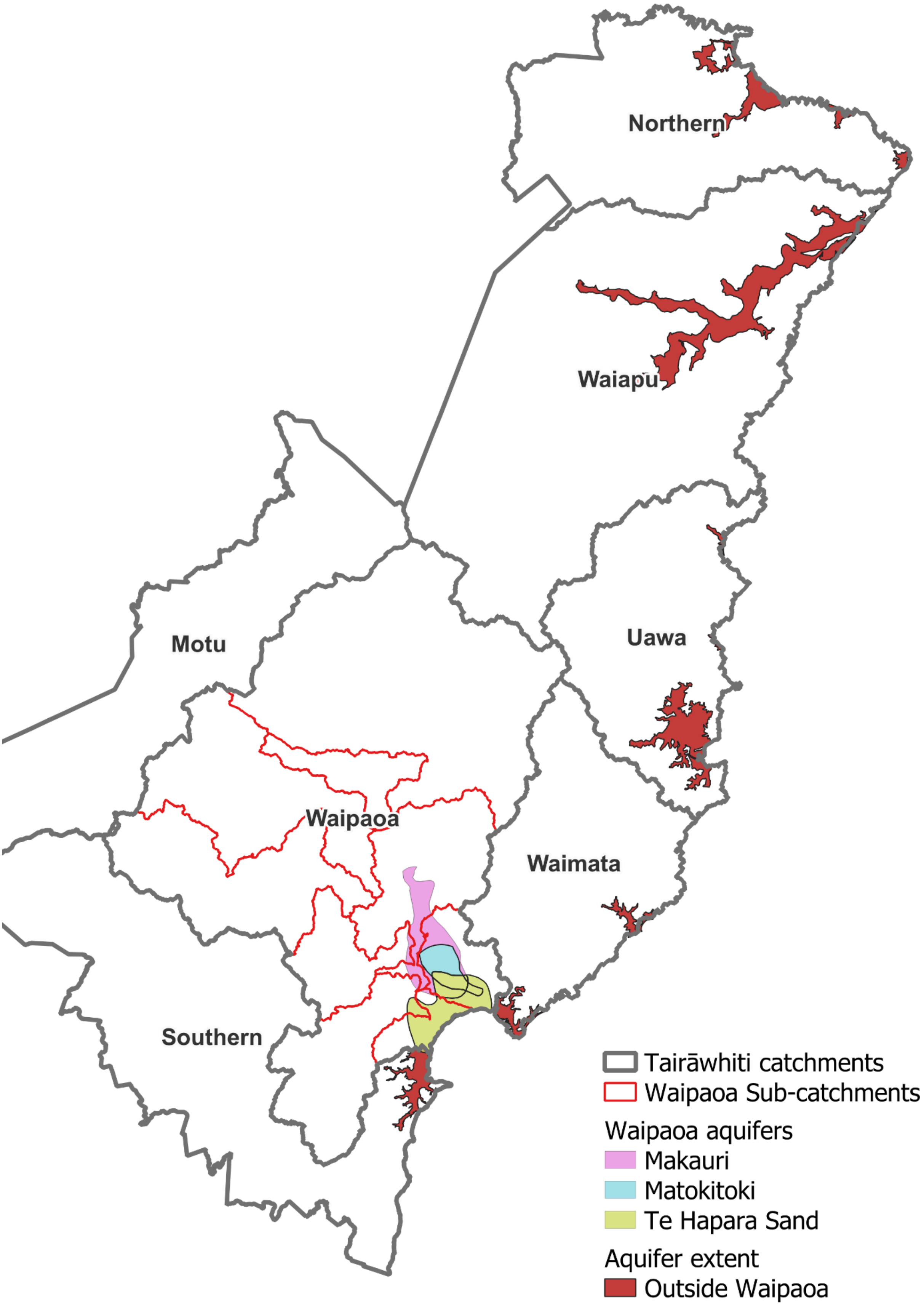


Figure 5-12 Aquifer extent relative to Tairāwhiti (sub-)catchments

Table 5-7 Groundwater availability as 30% recharge (Dark, et al., 2021) by surface water catchment (excluding Waipaoa) and consented allocation

Catchment	Maximum aquifer area (m^2)	Area weighted average recharge (mm/year)	Availability as 30% recharge (m^3/year)	Consented allocation (m^3/year)
Northern	33,170,710	816	8,118,911	157,680
Waiapu	111,183,036	1,076	36,310,816	0
Uawa	47,074,649	676	8,251,065	0
Motu	0	-	-	0
Waimata	15,924,267	496	1,129,113	0
Southern	18,369,356	466	2,392,489	0

5.2.5 Future groundwater availability

Future groundwater availability was calculated using changes in recharge under RCP6 calculated by Collins et al. (2022). Figure 5-13 shows recharge is generally expected to decrease across much of the area, with the largest decreases in the upper Waipaoa catchment by 2035. Increases in recharge are anticipated in the Northern catchment.

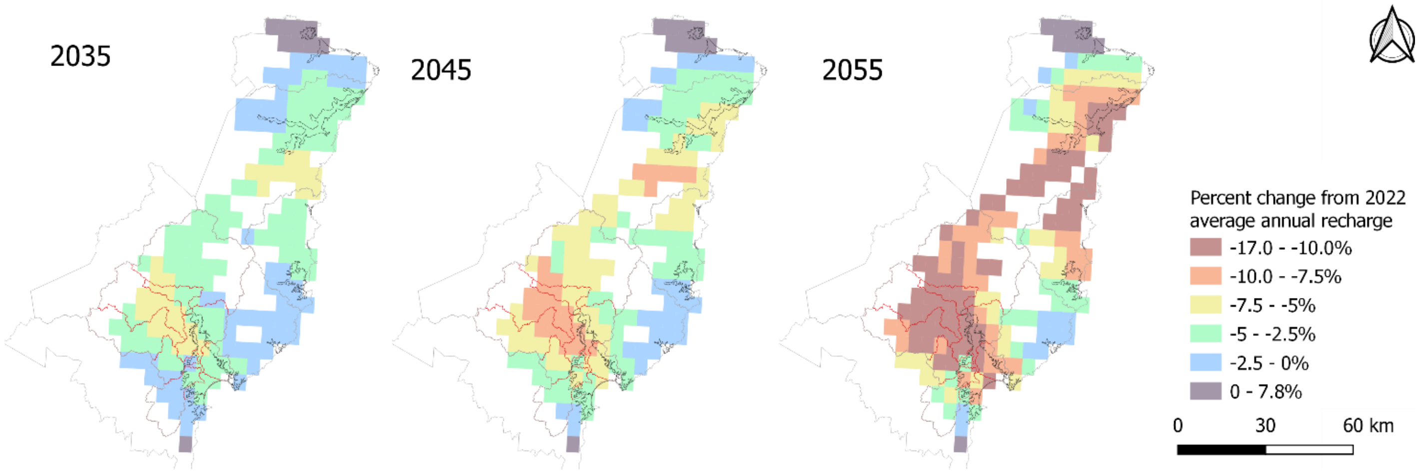


Figure 5-13 Percent change in annual average recharge from 2022 at 2035, 2045 and 2055 under RCP6 based on estimates by Collins, et al. (2022)

The changes in recharge in Figure 5-13 were applied to the 2025 TRMP allocation limits to forecast groundwater availability in the Waipaoa catchment, and used to update the calculations performed in Section 5.2.4 to estimate future groundwater availability for the remaining catchments.

Appendix F shows the numerical changes in groundwater availability while Figure 5-14 and Figure 5-15 plots forecast groundwater availability against current consented allocation. Available groundwater is expected to decrease consistent with decreasing rainfall. This increases pressure in already overallocated areas. Data does not suggest more areas will become overallocated by 2055. The exception is the Northern catchment, where increasing rainfall is projected to increase groundwater availability by <1% by 2055. The Makauri aquifer is anticipated to have the largest reduction in recharge. This is concerning given it has the largest consented use. Within the Waipaoa catchment, groundwater availability within the areas shown in Figure 5-10 can be expected to decrease by 3-5% by 2035, 5-8% by 2045 and by 8-14% by 2055. Groundwater availability in the remaining catchments (excluding Northern) can be expected to decrease by 2-4% by 2035, 2-5% by 2045, and 4-9% by 2055.

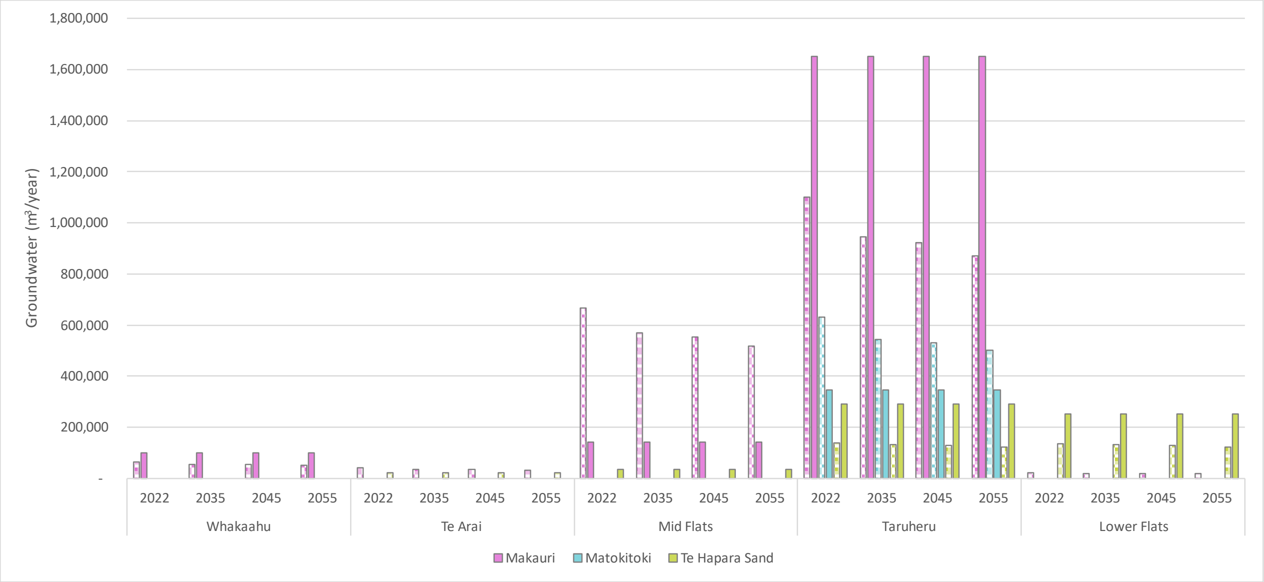


Figure 5-14 Groundwater allocation (solid bars) and availability (textured bars) per aquifer by Waipaoa sub-catchment. Availability for 2022 is 2020 TRMP allocation limits partitioned by relative aquifer extent in each sub-catchment. Availability for 2035 onwards uses partitioned 2025 allocation limits reduced proportional to changes in recharge under RCP6.0 as calculated by Collins, et al. (2022)

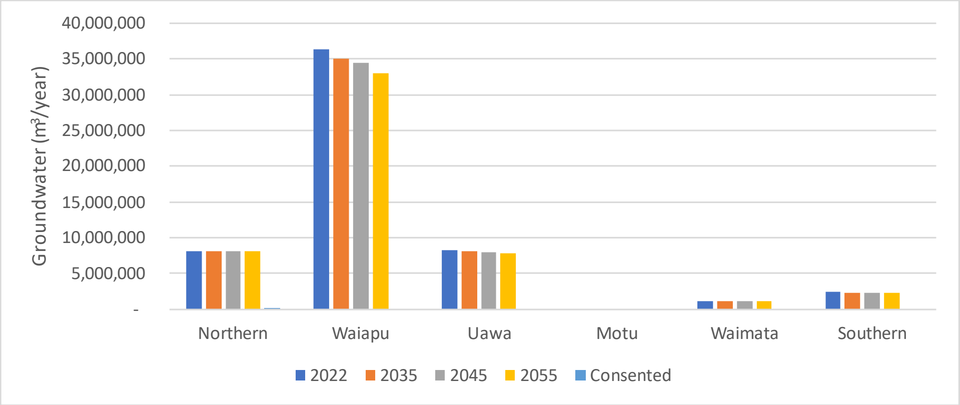


Figure 5-15 Forecast groundwater availability within the remaining catchments based on changes in recharge under RCP6 (Collins et al., 2022) and current consented allocation (barely visible, in the Northern catchment)

5.2.6 Groundwater summary

White et al. (2012) and Tschritter et al. (2016) calculated groundwater availability as 15% and 35% of rainfall recharge to groundwater based on proposed National Environmental Standards (Ministry for the Environment, 2008). Aqualinc (2013) estimated groundwater availability as 0.5% of average annual rainfall across catchments and Waipaoa sub-catchments. WGA (2022) estimated current groundwater allocation. At a coarse scale, Aqualinc estimates of availability tended to be lower than Tschritter et al. (2016) and White et al. (2012) estimates. However, the discretisation of White et al. (2012) and Tschritter er al (2016) estimates identify areas where nil groundwater should be considered available to preserve stream flows and prevent seawater intrusion.

In the TRMP no new allocation is permitted within the Waipaoa catchment, with targeted reductions in allocation in 2020 and 2025. No other formal groundwater allocation limits for Tairāwhiti are set. For all other areas, the default groundwater allocation limit in the TRMP (policy C6.1.1.6) is the greater of 30% average annual rainfall recharge or total consented allocation.

Groundwater availability in the Waipaoa catchment was calculated by partitioning the 2020 allocation targets to sub-catchments proportional to Makauri, Matokitoki, and Te Hapara Sands aquifer extents.The Makauri and

Te Hapara Sand aquifer are over allocated. Overallocation will worsen with further reductions in availability for the Makauri aquifer in 2025.

Groundwater availability was calculated consistent with TRMP policy C6.1.1.6 for the remaining catchments. In all cases 30% recharge exceeded consented allocation. Groundwater availability significantly exceeds consented allocation in the remaining catchments, except the Motu where there are no mapped aquifers.

Estimates of future availability shows reductions in groundwater availability across all catchments except the Northern catchment, where availability could increase by <1% by 2055. The largest reductions in reliability coincide with the areas of highest consented groundwater use. At a catchment scale, forecast availability exceeds current consented allocation, however this picture can change at smaller scales (e.g. sub-catchment, aquifer). Though calculations suggest there is groundwater available, they do not provide for other outcomes or values, such as calculation of limits that support and preserve ecological flows. Actual allocation as part of an integrated planning framework may need to be lower, as identified by White, et al (2012), Schritter, et al. (2016), and WGA (2022). If not accounted for, the indicated reduction in groundwater availability could see these values compromised.

6 SUPPLY-DEMAND BALANCE

Key findings from this section:

- For the Waipaoa and Te Arai catchments the supply-demand balance calculated from a daily time-step model shows that while on average supply might exceed demand, deficits may still exist in a month due to demand exceeding available supply on a daily basis.
- Using January as a “sentinel month”, demand exceeds supply in the Waipaoa A block, the Te Arai A and B blocks, and is close to the available supply in the Waipaoa B block.
- Under a future supply-demand scenario the Waimata, Uawa and Southern-Maraetaha catchments are projected to change from a positive supply-demand balance (supply exceeds demand) to a negative balance.
- We calculated that Tairāwhiti has a 52.3 Mm^3/year groundwater surplus.
  - The Waipaoa catchment is calculated to be 3.7 Mm^3/year in deficit on an average annual basis. Five Waipaoa sub-catchments have groundwater use. Three of these are in deficit.
  - Regional surplus is driven by large calculated groundwater availabilities in the remaining catchments. This is driven by large mapped aquifer extents. Feasibility and values considerations may mean this calculated surplus is not available for use in reality.

The previous sections of this report summarised the water demand and resource availability respectively. This section assesses the water availability against the demand estimates, to investigate whether there is an imbalance between demand and supply. In this supply-demand modelling, we have apportioned surface water demand based on the allocation unit the water is taken from. The model incorporates groundwater availability, surface water availability, and demands partitioned between groundwater and surface water.

For surface water, we used a daily time-step model over a 30-year modelling period (1993 – 2022) to estimate the timing, duration, magnitude, and frequency of significant deficits and surpluses.

For groundwater, we used an annual water balance.

As noted in Section 0, we identified surface water sentinel catchments or sub-catchments for some catchments in the study area (Northern, Waimata, Southern) which consisted of several discrete surface water units. To carry out the supply-demand balance, we calculated the proportion of the surface water demand which was located in the sentinel catchment.

6.1 Surface water balance

We carried out a daily water balance for Waipaoa and Te Arai surface water allocation units in the Waipaoa catchment, with the aim of identifying a “sentinel month” As noted in Section 0, we have assumed that water availability is determined by flows in Te Arai at Pykes Weir and Waipaoa at Kanakanaia. As such, we have based on the surface water supply-demand model on the catchment units shown in Figure 6-1.

We note that ‘availability’ refers to the amount of water within the relevant allocation bands that can be taken on a given day to fulfil demand, rather than additional water in the band which hasn’t been allocated, or additional availability outside the set allocation limit. The surface water balance does not account for how the available water is distributed between specific consents.

For each day during the 30-year modelling period (1993 – 2022), we compared the total surface water demand in each model unit to the total availability based on the allocation rules. From this timeseries we obtained estimates of the monthly average deficit, surplus, days of deficit, and length of deficit.

Figure 6-2 and Figure 6-3 show the average daily supply and demand during each month, for the Waipaoa and Te Arai model units respectively. The demand is partitioned by use. When demand exceeds supply on a given day, the system is in deficit. The maximum available daily supply was around 345,000 m^3 for the Waipaoa catchment and around 15,000 m^3 for the Te Arai catchment. As noted previously, we have not accounted for flood events where water is unable to be abstracted due to high sediment loading.

Figure 6-2 and Figure 6-3 show that **on average** the Waipaoa and Te Arai allocation bands can meet demand, but deficits occurred on some days during each month, highlighting the importance of timescale. Days of partial restriction can result in deficits, particularly due to the increased irrigation demand in the summer months. The daily water balance for an example month is shown in Figure 6-4. On most days, supply exceeded demand, meaning that there was a surplus of water. However, on some days demand exceeded supply due to allocation rules, resulting a deficit. Figure 6-4 demonstrates how, a month can have supply exceed demand on average, but still have days within that month where demand exceeds supply.

Figure 6-5 shows the average daily deficit volume during each month (the average only includes days when there is a deficit). Although on average the Waipaoa and Te Arai catchment supplies were able to meet demand, there were some days during the summer months where flow restrictions meant that demand could not be met. The largest deficit generally occurs during January. Although the A Block water is more likely to be available, there was also more demand in the A Block for both Waipaoa and Te Arai, meaning that during some months the average deficit in the A Block was greater than the deficit in the B Block.

Figure 6-6 shows the average number of days per month where there was a demand deficit, and Figure 6-7 shows the average surplus length (the number of consecutive days where demand can be met by the available supply). Although the largest deficits generally occurred in January, there were relatively long periods of deficit in February, particularly in the Waipaoa catchment. We note that we have associated the deficit length with the month that the deficit ends, so some extended deficit periods recorded for February may have begun in January.

The monthly series suggest that the most pressure on availability occurs in January. Therefore, as discussed in the following section, we have used January as the sentinel month, with demand and availability during this month used to assess the pressure on catchments in the Waipaoa study area and the rest of the region.

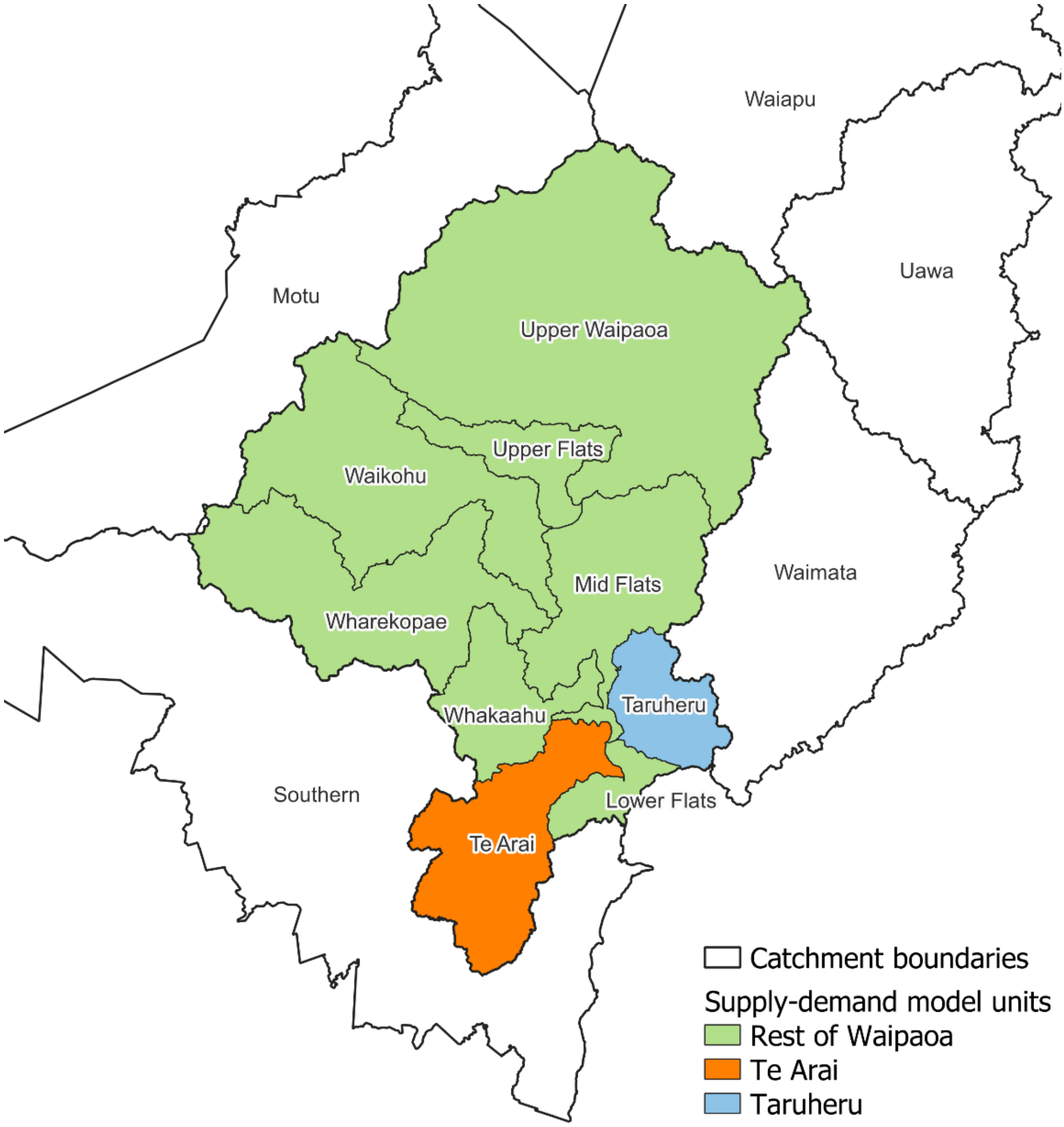
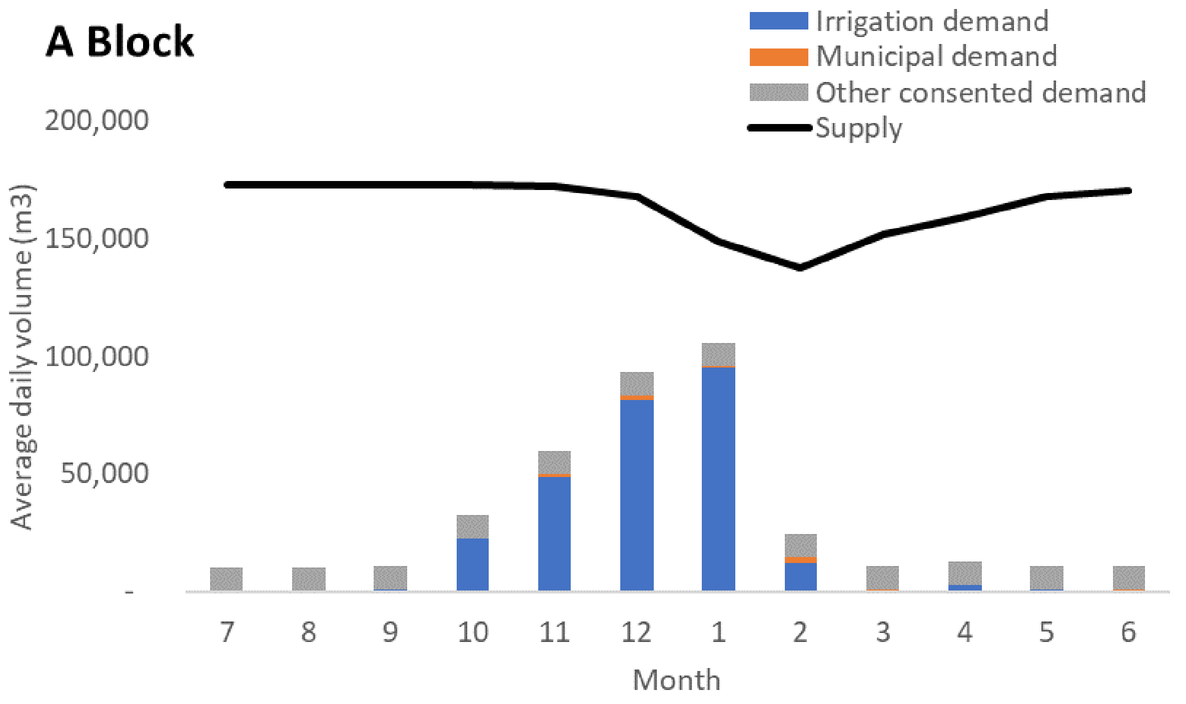


Figure 6-1: Catchment units used in for the supply-demand model for the Waipaoa study area.



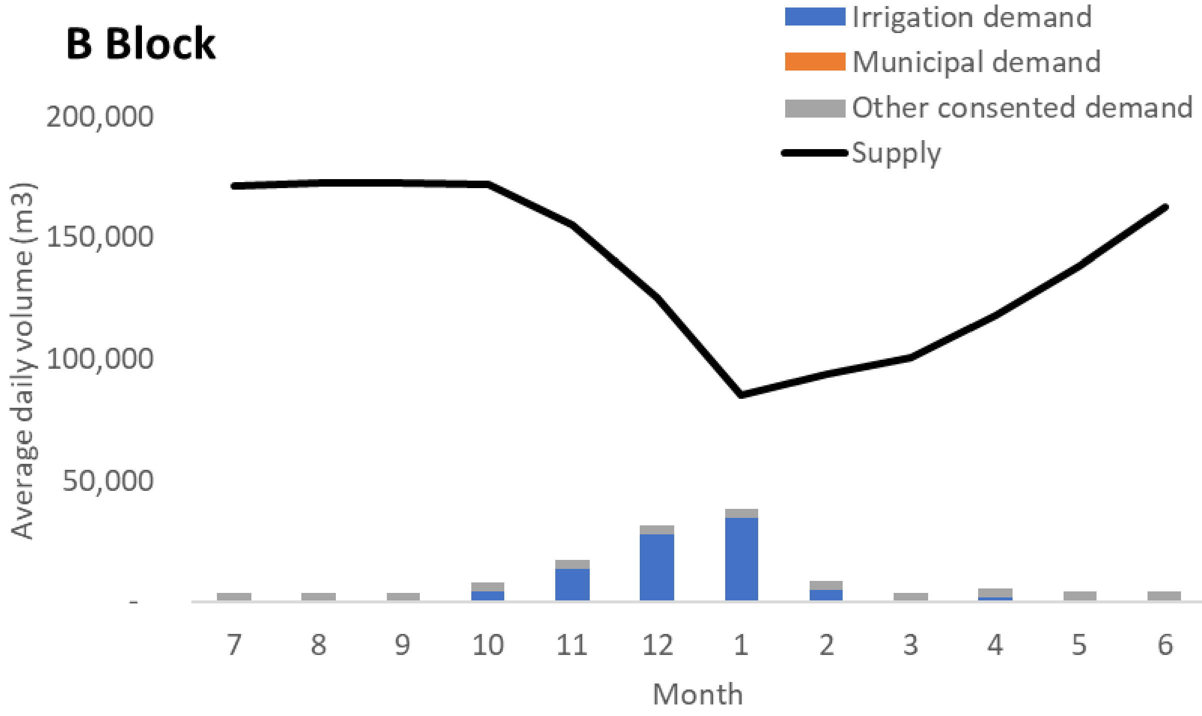


Figure 6-2: Surface water supply and demand for Waipaoa model unit, average daily volume per month. The demand is partitioned by use and the balance is partitioned by allocation block

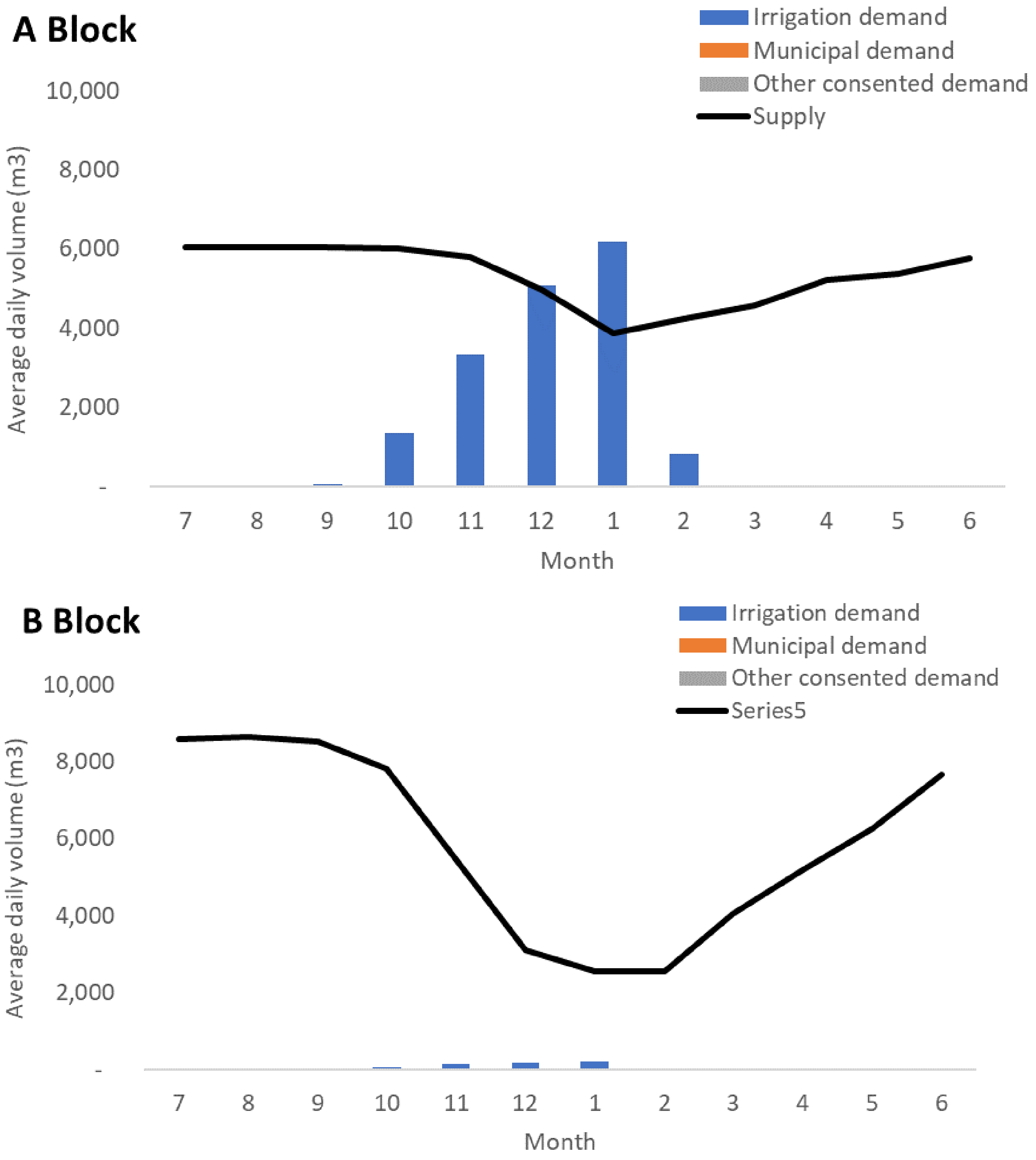


Figure 6-3: Surface water supply and demand for Te Arai model unit, average daily volume per month. The demand is partitioned by use and the balance is partitioned by allocation block

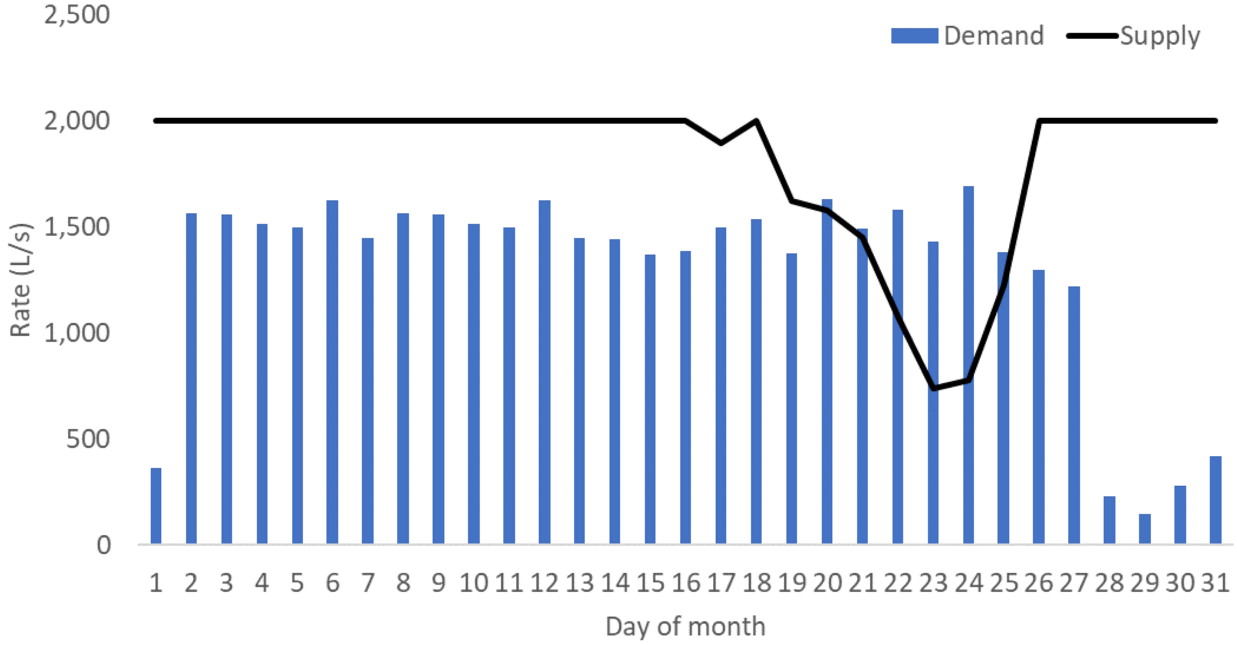


Figure 6-4: Example surface water balance during a month

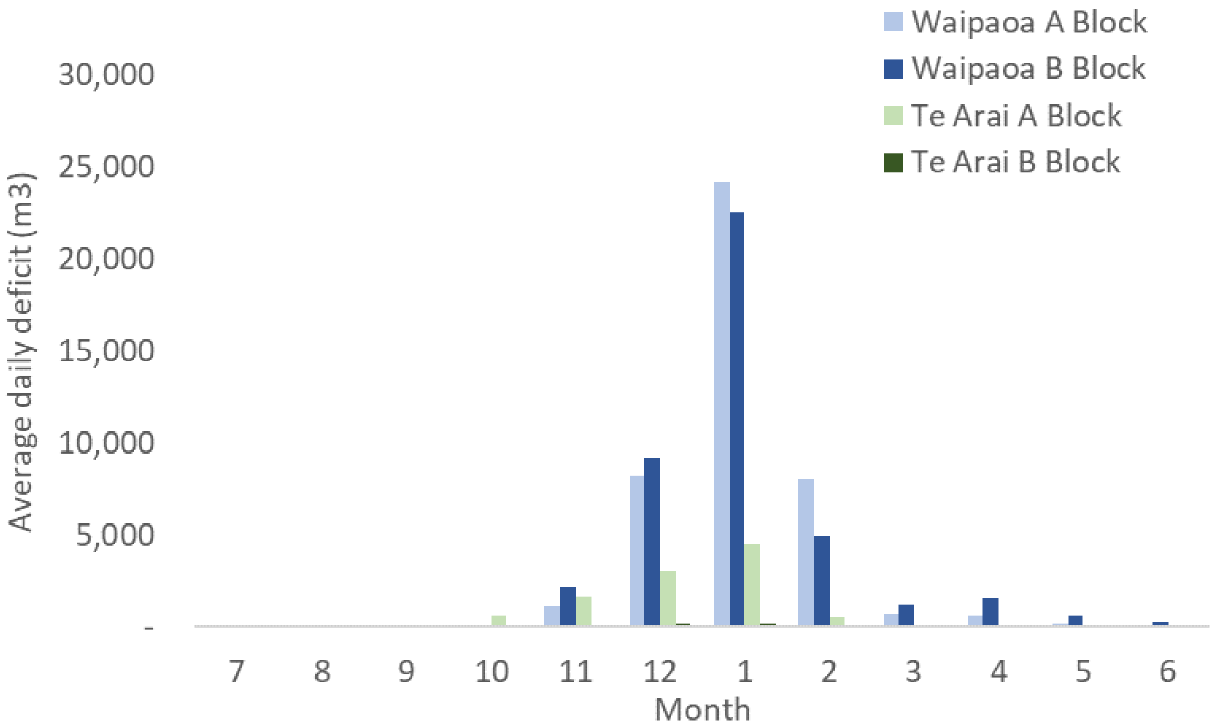


Figure 6-5: Average daily deficit during each month for surface water supply-demand model units. The average is calculated only from days when there are deficits.

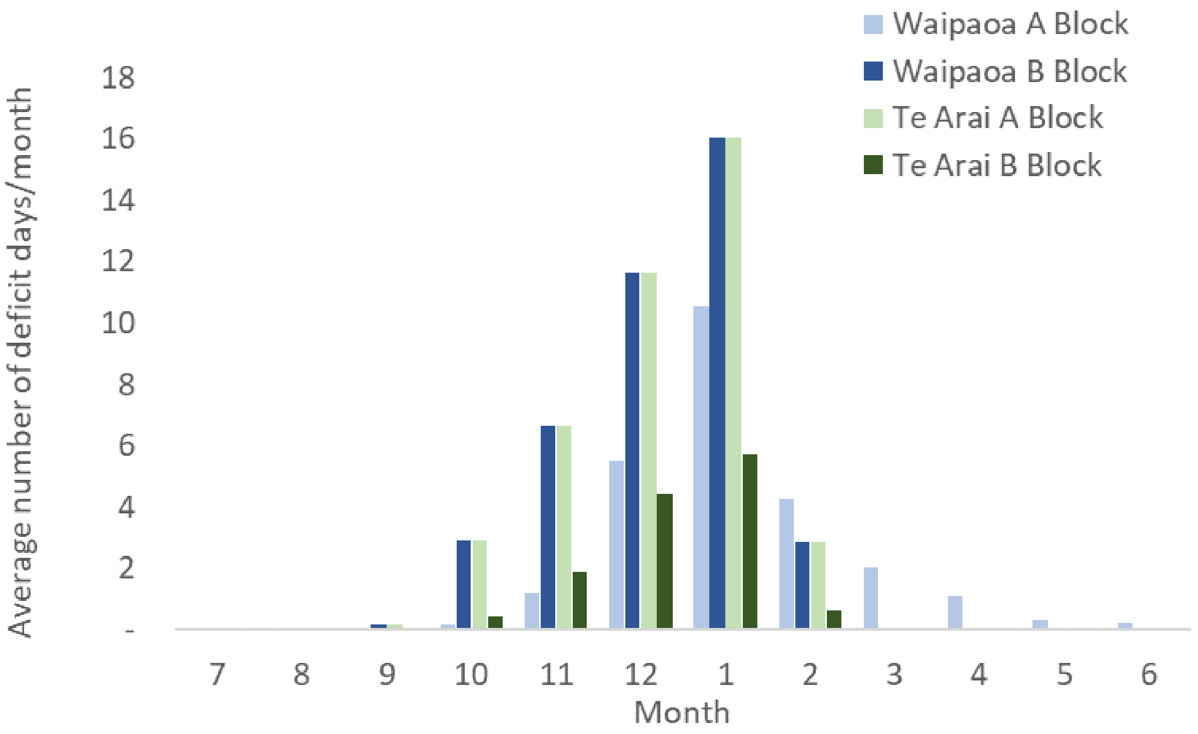


Figure 6-6: Average number of surface water deficit days (demand exceeds supply) per month for supply-demand model units

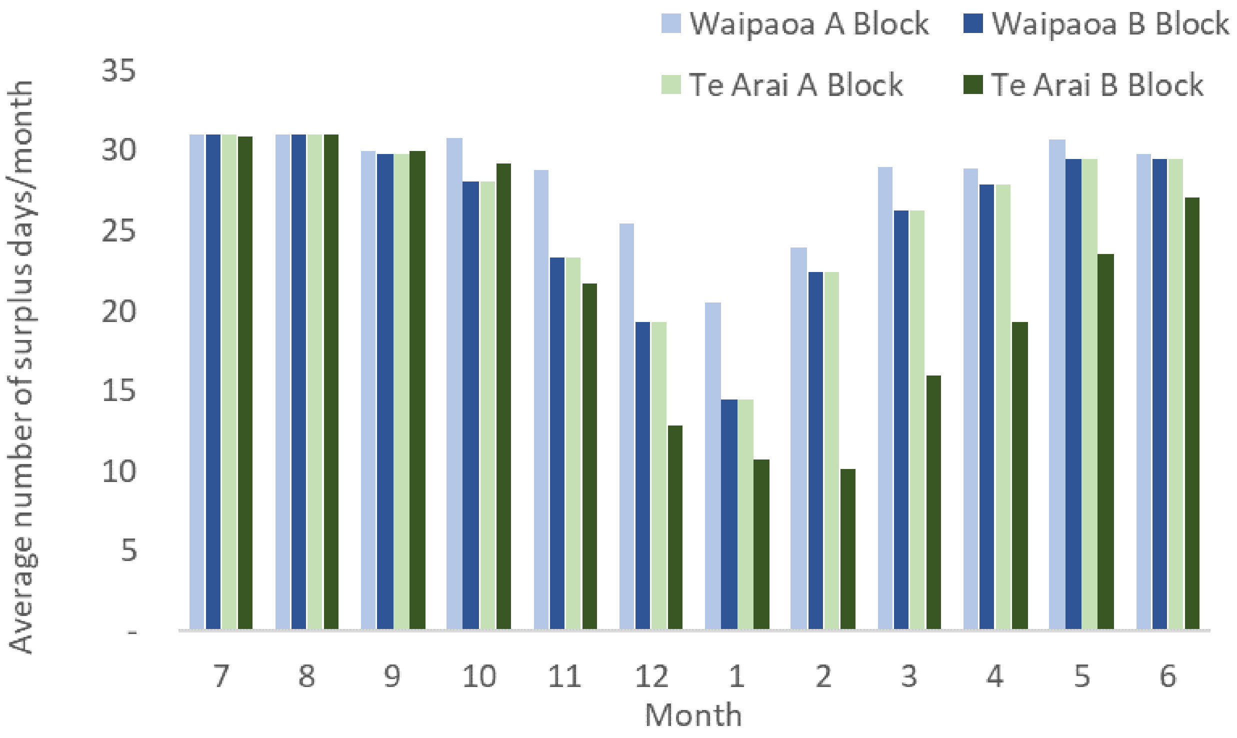


Figure 6-7: Average length of surface water surplus period (consecutive days where supply exceeds demand) during each month for supply-demand model units

6.2 Surface water balance: Sentinel month

To investigate water balances for other catchments and future scenarios, we used water balances in a sentinel month, during which demand puts the most pressure on surface water availability.

To select the sentinel month, we have selected statistics to represent demand and availability in each surface water allocation unit:

- **Sentinel demand:** We calculated the highest 7-day demand in the month for each year of the 30-year modelling period and took the average for each demand type (irrigation, municipal, other consents, stockwater). The aggregated demand statistic was calculated as the sum of the demand statistics calculated for each demand type.
- **Sentinel availability:** We calculated the lowest 7-day availability in the month for each year of the 30-year modelling period and took the average.

Figure 6-8 and Figure 6-9 show how the sentinel demand and sentinel availability vary during the year for the Waipaoa and Te Arai allocation units. January had both the lowest sentinel availability due to low summer river flows, and the highest sentinel demand due to irrigation requirements. In general, the sentinel demand exceeded the sentinel availability. We have selected January as the sentinel month, noting that demand may also exceed availability in other summer months, particularly November, December, and February.

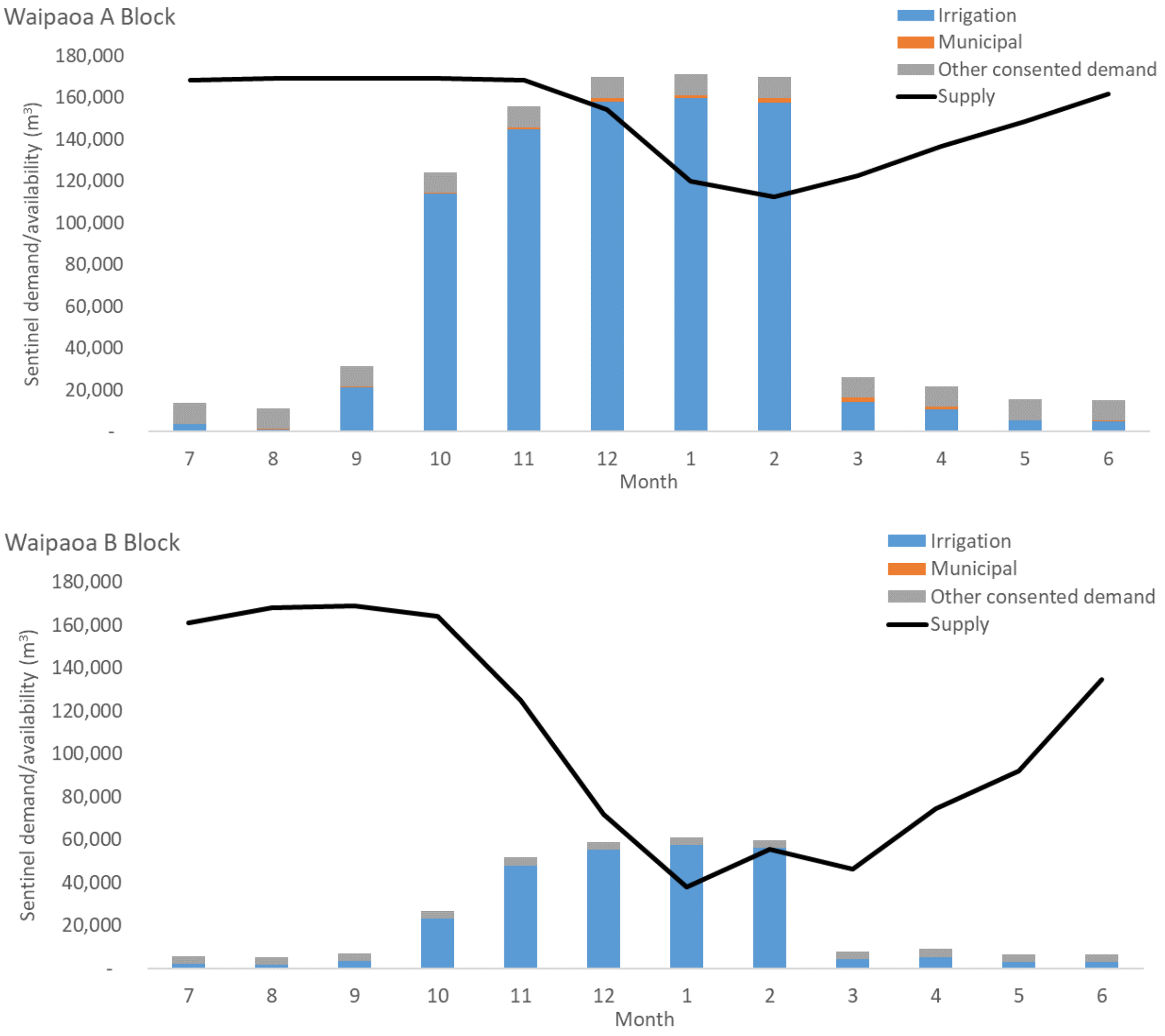


Figure 6-8: Sentinel demand and availability for each month for the Waipaoa allocation unit (A and B Blocks)

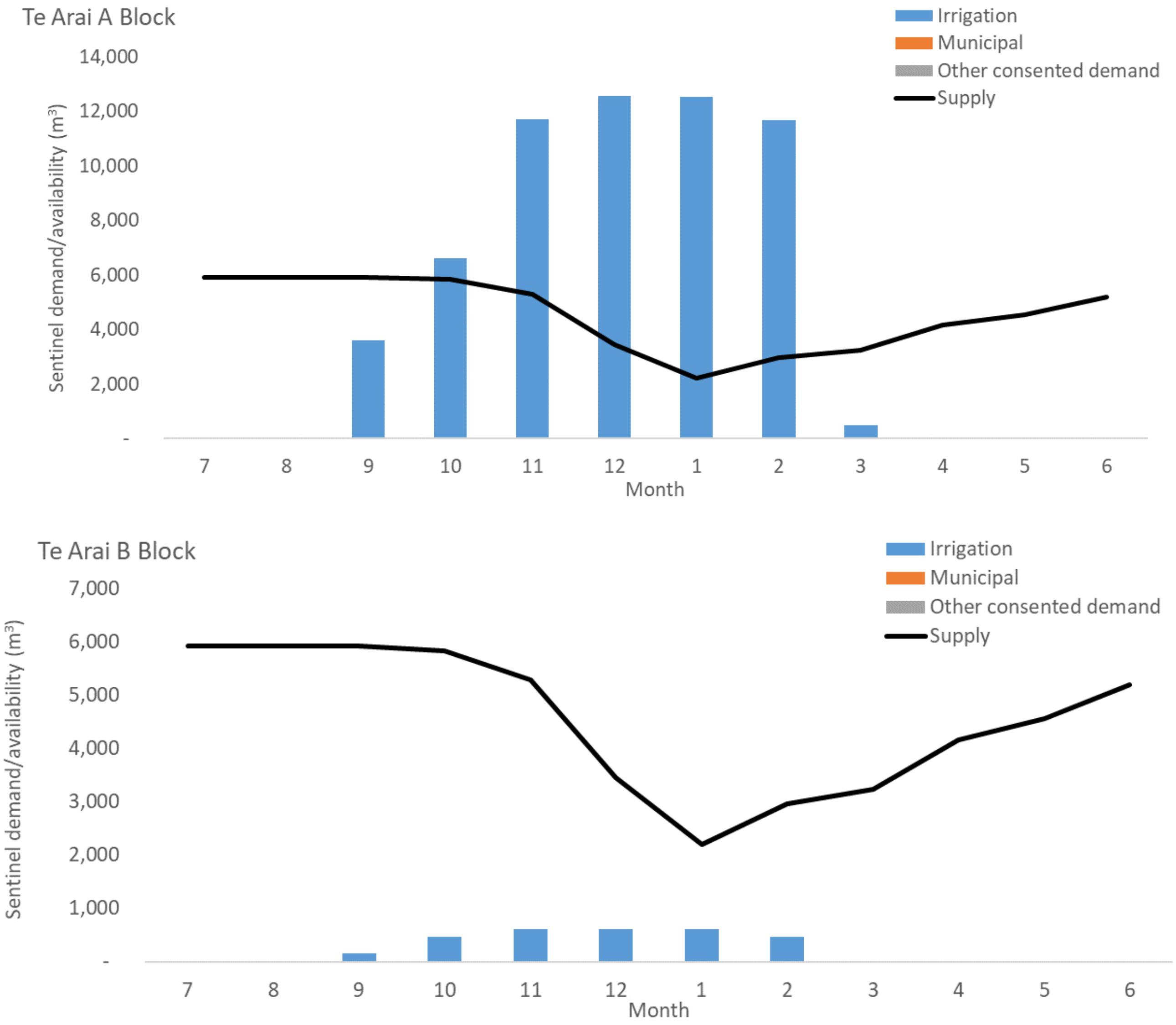


Figure 6-9: Demand and availability statistic for each month for the Te Arai allocation unit

Based on the findings for the Waipaoa model units, we selected January as the sentinel month. Figure 6-10 and Table 6-1 show the average overall water balance (demand and available supply) for January for all the surface water model units.

On an average basis, the amount of the allocated volume available during January was sufficient to meet demand. However, as noted previously, there were deficits on some days during the month where the river supply was unavailable or restricted due to the allocation rules.

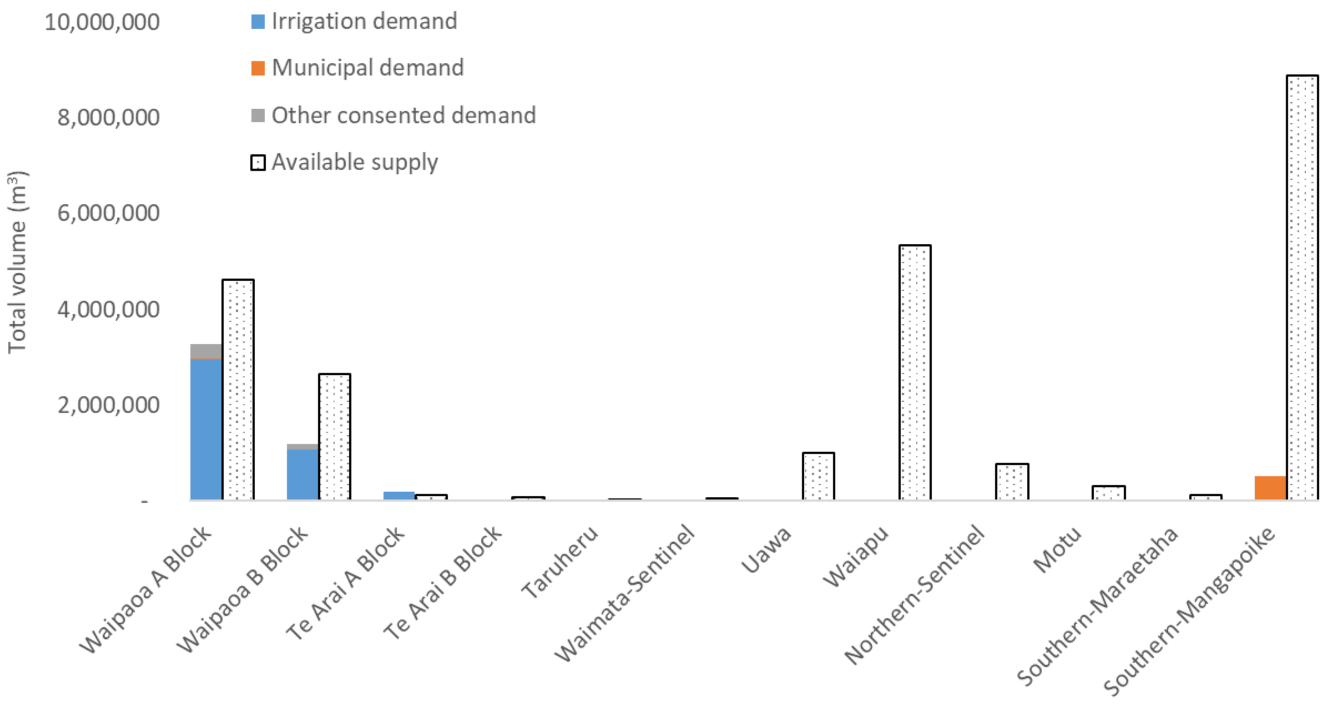


Figure 6-10: Average total demand and supply during the sentinel month (January) for each of the surface water balance catchments

Table 6-1: Average total demand and available supply in each surface water unit during the sentinel month (January)

Unit	Total demand by use (m³)			Total demand (m³)	Available supply (m³)
	Irrigation	Municipal	Other consents		
Waipaoa A Block	2,943,904	30,139	306,032	3,280,074	4,609,237
Waipaoa B Block	1,069,941	-	113,832	1,183,773	2,640,110
Te Arai A Block	192,063	-	-	192,063	119,655
Te Arai B Block	6,920	-	-	6,920	78,900
Taruheru	5,091	-	-	5,091	33,936
Waimata-Sentinel	-	-	-	-	50,443
Uawa	-	-	-	-	1,006,723
Waiapu	-	-	1,240	1,240	5,348,974
Northern-Sentinel	-	-	-	-	763,956
Motu	-	-	-	-	310,671
Southern-Maraetaha	-	-	18,600	18,600	123,807
Southern-Mangapoike	-	512,658	-	512,658	8,892,052

We also calculated the sentinel demand and sentinel availability for each of the surface water model unit. Figure 6-11 and Table 6-2 summarise the values for each model unit and the resultant sentinel water balance.

The sentinel demand is greatest in model units where there is widespread irrigation (Waipaoa, Te Arai, Taruheru) and in the Southern-Mangapoike catchment where the majority of Gisborne City’s municipal supply is sourced from.

The sentinel demand exceeded the sentinel availability in the Waipaoa A Block, the Te Arai A Block, and the Te Arai B Block. The sentinel demand was close to the sentinel availability in the Waipaoa B Block.

The remaining catchments, with the exception of Taruheru and Southern-Mangapoike, do not currently have irrigation, municipal, or other consented demands assigned to the allocation blocks.

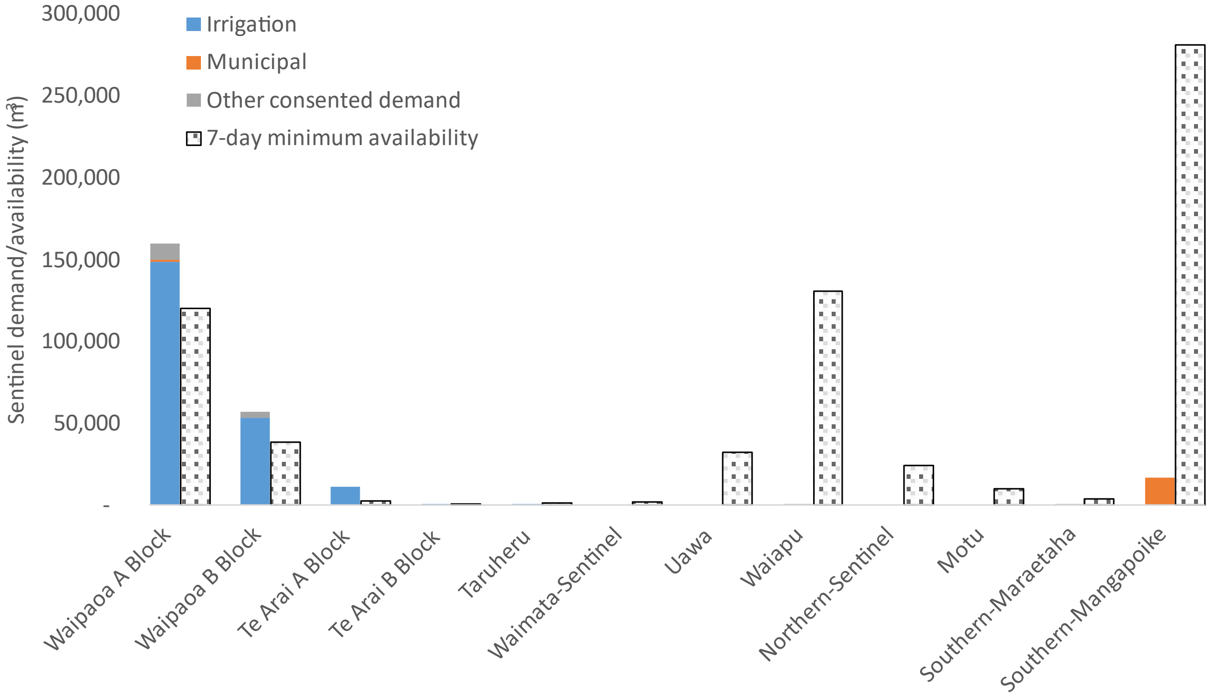


Figure 6-11: Demand and availability for the sentinel month (January) in each allocation unit

Table 6-2: Demand and availability for the sentinel month (January) in each allocation unit

Unit	Sentinel demand (m^3)			Total sentinel demand (m^3)	Sentinel availability (m^3)	Balance (m^3)
	Irrigation	Municipal	Private industrial			
Waipaoa A Block	123,940	1,609	9,872	135,420	119,869	-15,551
Waipaoa B Block	32,433	-	3,672	36,105	37,989	1,884
Te Arai A Block	3,713	-	-	3,713	2,204	-1,509
Te Arai B Block	471	-	-	471	132	-339
Taruheru	227	-	-	227	1,072	845
Waimata-Sentinel	-	-	-	-	1,593	1,593
Uawa	-	-	-	-	31,798	31,798
Waiapu	-	-	40	40	130,357	130,317
Northern-Sentinel	-	-	-	-	23,761	23,761
Motu	-	-	-	-	9,813	9,813
Southern-Maraetaha	-	-	600	600	3,911	3,311
Southern-Mangapoike	-	16,537	-	16,537	280,865	264,327

Table 6-3 shows the average annual surface water supply and demand for each allocation unit in Waipaoa and the other catchments. On average, there is sufficient water in the allocation blocks to fulfil the units' water demands.

Table 6-3: Average annual surface water balance

Unit	Annual demand (m^3)	Annual available supply (m^3)	Balance (m^3)
Waipaoa A Block	12,000,885	59,988,467	47,987,582
Waipaoa B Block	4,034,188	50,853,011	46,818,823
Te Arai A Block	516,506	1,949,570	1,433,064
Te Arai B Block	19,942	2,148,785	2,128,843
Taruheru	14,535	433,851	419,316
Waimata-Sentinel	-	642,064	642,064
Uawa	-	13,122,959	13,122,959
Waiapu	14,609	72,858,863	72,844,253
Northern-Sentinel	-	9,696,190	9,696,190
Motu	-	4,081,641	4,081,641
Southern-Maraetaha	219,140	1,647,240	1,428,100
Southern-Mangapoike	5,320,133	128,266,845	122,946,712
Waipaoa A Block	12,000,885	59,988,467	47,987,582

6.3 Groundwater balance

The groundwater supply-demand balance was based on annual totals of supply and demand, in accordance with the groundwater allocation period. Balances were calculated for each (sub-)catchment for each year of the modelling period (1993 – 2022). The supply is fixed during each year, but the demand is subject to variability associated with the irrigation demand. The groundwater supply in each Waipaoa sub-catchment was set to the sum of the partitioned aquifer allocation. In the remaining catchments, supply was set at 30% recharge.

We note that the Upper Waipaoa, Waikohu, Wharekopae, and Motu (sub-)catchments had no groundwater allocation or demand as these areas do not overlap any groundwater allocation units.

Figure 6-12 shows the average annual groundwater demand compared to the available supply for each (sub-)catchment. Where supply was greater than demand, there was a surplus of groundwater available. Where supply was less than demand, there was a deficit. Figure 6-13 and Table 6-4 summarise the average annual deficit or surplus in each sub-catchment. Across all the Waipaoa sub-catchments, we estimated a total deficit of 3.7 million m^3.

Overall, we estimated a total groundwater surplus of approximately 52.3 million m^3 in the region, primarily due to groundwater resources in the Waiapu catchment which had an estimated surplus of 36.3 million m^3. We note that this is a theoretical maximum availability based on Plan rules, and doesn't reflect the feasibility of accessing water from aquifers in all catchments.

Groundwater demands were related to primarily related to irrigation uses, with some minor use from other private consents.

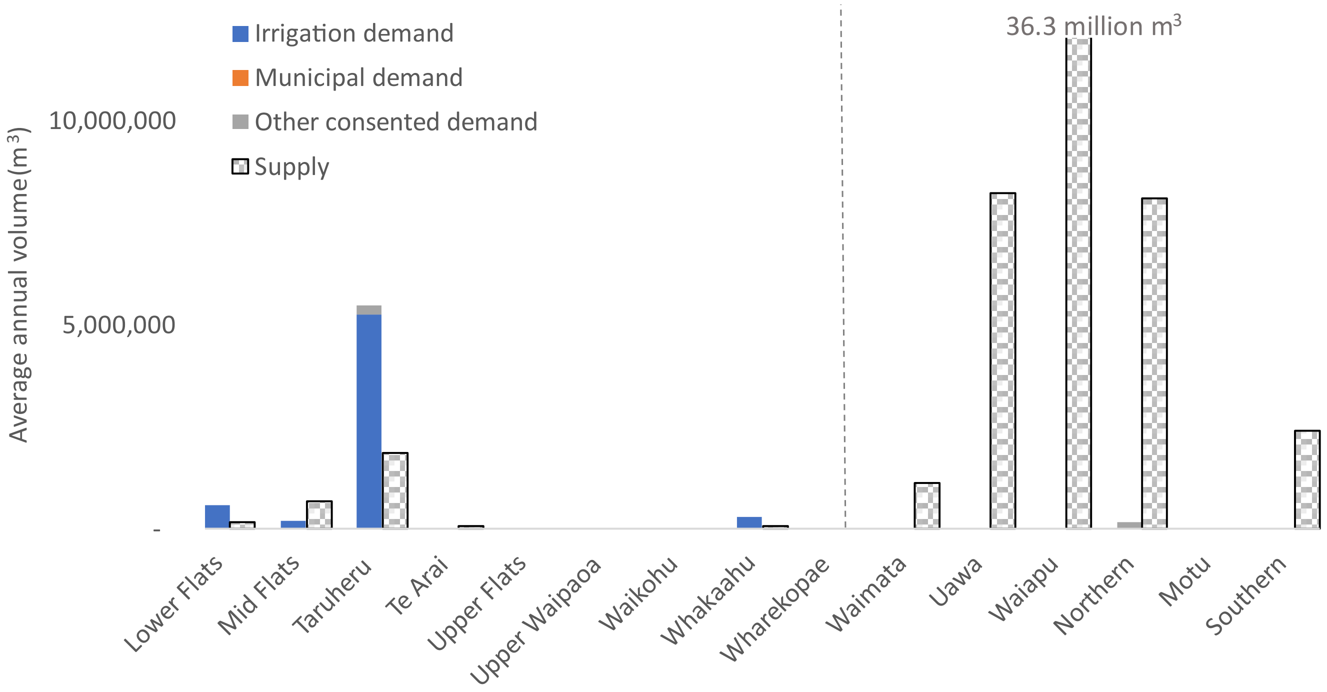


Figure 6-12: Average annual groundwater balance, grouped by sub-catchment. Note that the groundwater supply for the Waiapu catchment was approximately 35.9 million m^3, but we have limited the axis extent to improve data visibility for other (sub-)catchments.

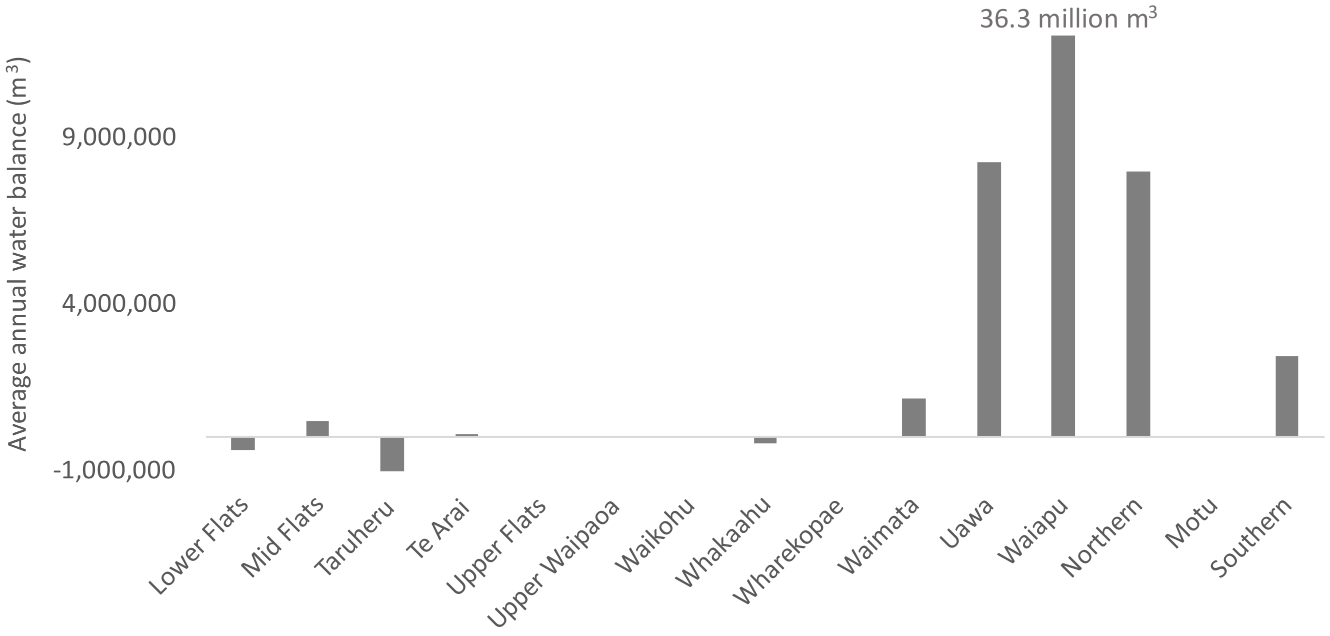


Figure 6-13: Average annual groundwater surplus/deficit for each sub-catchment. Deficits are negative and surpluses are positive. Note that the groundwater surplus for the Waiapu catchment was approximately 36.3 million m^3, but we have limited the axis extent to improve data visibility for other (sub-)catchments.

Table 6-4: Summary of the average annual groundwater surplus or deficit in each sub-catchment.

Sub-catchment	Annual surplus (m^3)	Annual deficit (m^3)
Lower Flats	-	402,892
Mid Flats	478,625	-
Taruheru	-	3,606,577
Te Arai	61,650	-
Upper Flats	-	-
Upper Waipaoa	-	-
Waikohu	-	-
Whakaahu	-	226,677
Wharekopae	-	-
Waimata	1,129,113	-
Uawa	8,251,065	-
Waiapu	36,310,816	-
Northern	7,961,131	-
Motu	-	-
Southern	2,392,489	-
Total	**56,584,888**	**4,236,147**

7 FUTURE PROJECTIONS

7.1 Key assumptions

To investigate the patterns and magnitude of potential changes in the water balances over the next 30 years, we estimated future demand and availability of surface water and groundwater resources in the years 2035, 2045, and 2055.

The methods and assumptions used to scale the demand and availability series are described previously, in Section 3 and Section 5 respectively. As there is considerable uncertainty about some of the drivers of future land use change and water resource development, it was necessary to make the following key assumptions:

- Demand partitioning between groundwater and surface water remained constant.
- The proportion of the demand located in the sentinel catchments (where relevant) remained constant.
- The proportion of the surface water irrigation demand in the Taruheru and Te Arai catchments supplied by the Waipaoa unit remained constant.
- Any crop areas which were not currently irrigated were linearly converted to irrigation between 2022 and 2055, with no change to the crop type.
- Municipal and other consented demand increased proportional to projected population growth.
- There was no change in stockwater demand.
- Surface water availability during the sentinel month decreased proportional to projected decreases in MALF.
- Groundwater availability remained fixed at the 2020 allocation target in the Poverty Bay Flats FMU. Outside the FMU, where allocation is set at 30% of recharge, allocation was proportional to projected changes in recharge.

7.2 Future surface water balance

We calculated surface water demand and availability statistics in the sentinel month (January) for the future projection scenarios to compare with the sentinel demand and availability calculated for the present.

Figure 7-1 shows the sentinel demand for the present and future scenarios in each (sub-)catchment, divided by water use. In the Waipaoa study area, the demand increased most significantly in the Waipaoa B Block, as the crop areas which were assumed to convert to surface water irrigation were allocated to this allocation block. Demand increases in the other Waipaoa model units (Waipaoa A Block, Te Arai, Taruheru) were mainly due to increases in water demands for existing irrigated crops, municipal uses, and other consented uses. These increases were relatively small relative to the existing demand. Demand in the other catchments increased with each future scenario in Taruheru, Waimata-Sentinel, Uawa, Northern-Sentinel, and Southern-Maraetaha as cropped areas converted to surface water irrigation. The municipal demand allocated to the Southern-Mangapoike catchment also increased with each future scenario.

Figure 7-2 shows the sentinel availability for the present and future scenarios for each (sub-)catchment. The same multiplier was used to scale availabilities for future scenarios, meaning the sentinel availability was constant for the three future scenarios. The availability decreased by 8% compared to present-day for the Waipaoa model units, the Waimata-Sentinel catchment, and the Southern-Maraetaha catchment, and was unchanged compared to present-day for the remaining catchments.

Figure 7-3 shows the sentinel water balance (the difference between the sentinel demand and sentinel availability) for the surface water units. A negative balance means that the sentinel demand exceeds the sentinel supply.

Table 7-1 summarises the sentinel surface water balance (sentinel demand, sentinel supply, and water balance) shown in the figures.

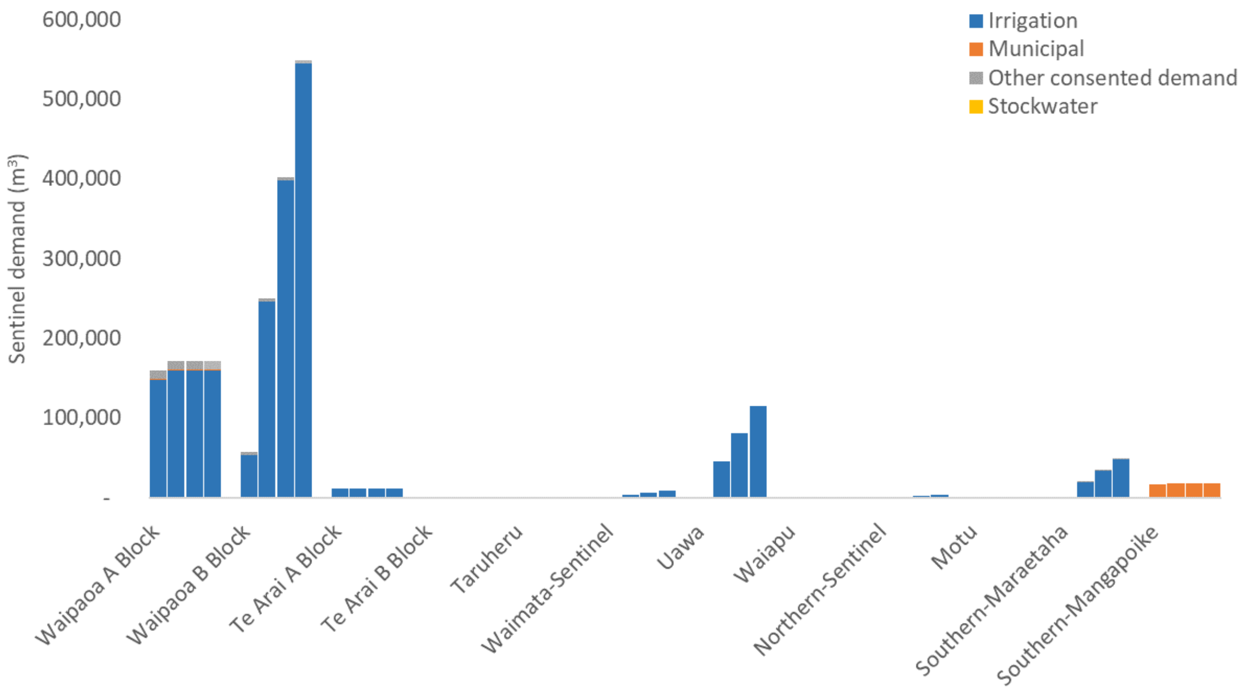


Figure 7-1: Sentinel demand for each sub-catchment for present and future scenarios. The bars represent the present (2022), 2035, 2045, and 2055.

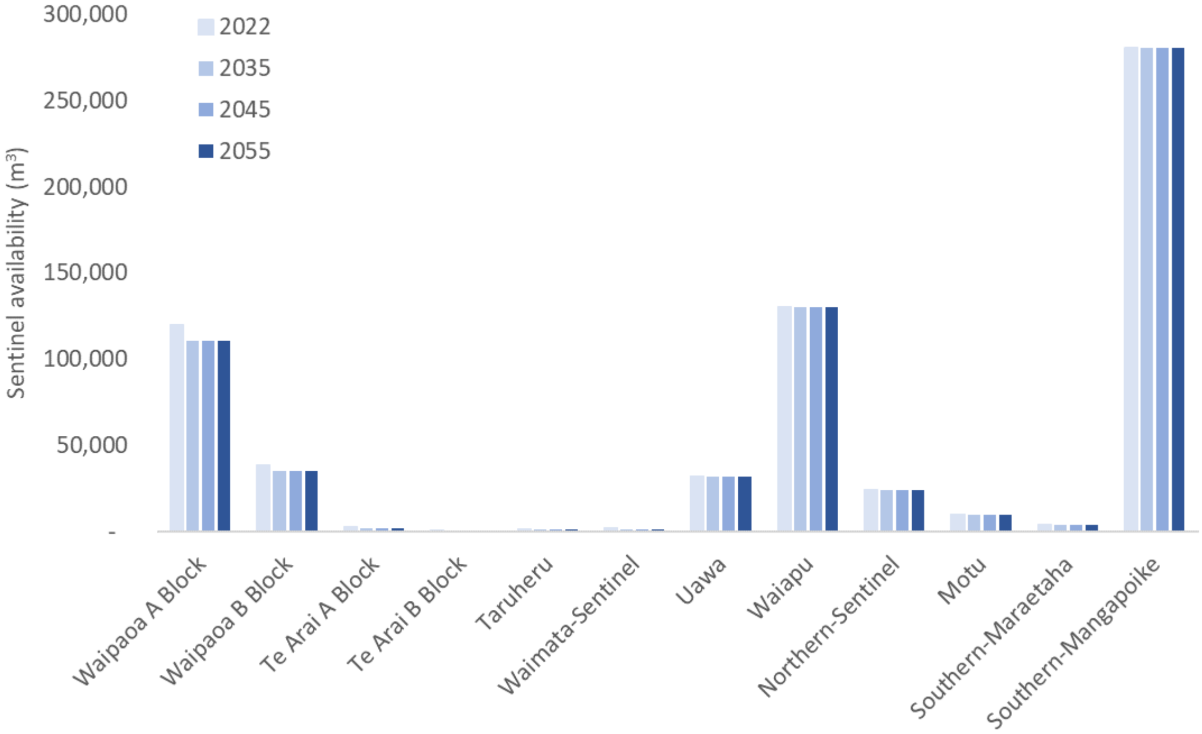


Figure 7-2: Sentinel availability for each sub-catchment for present and future scenarios

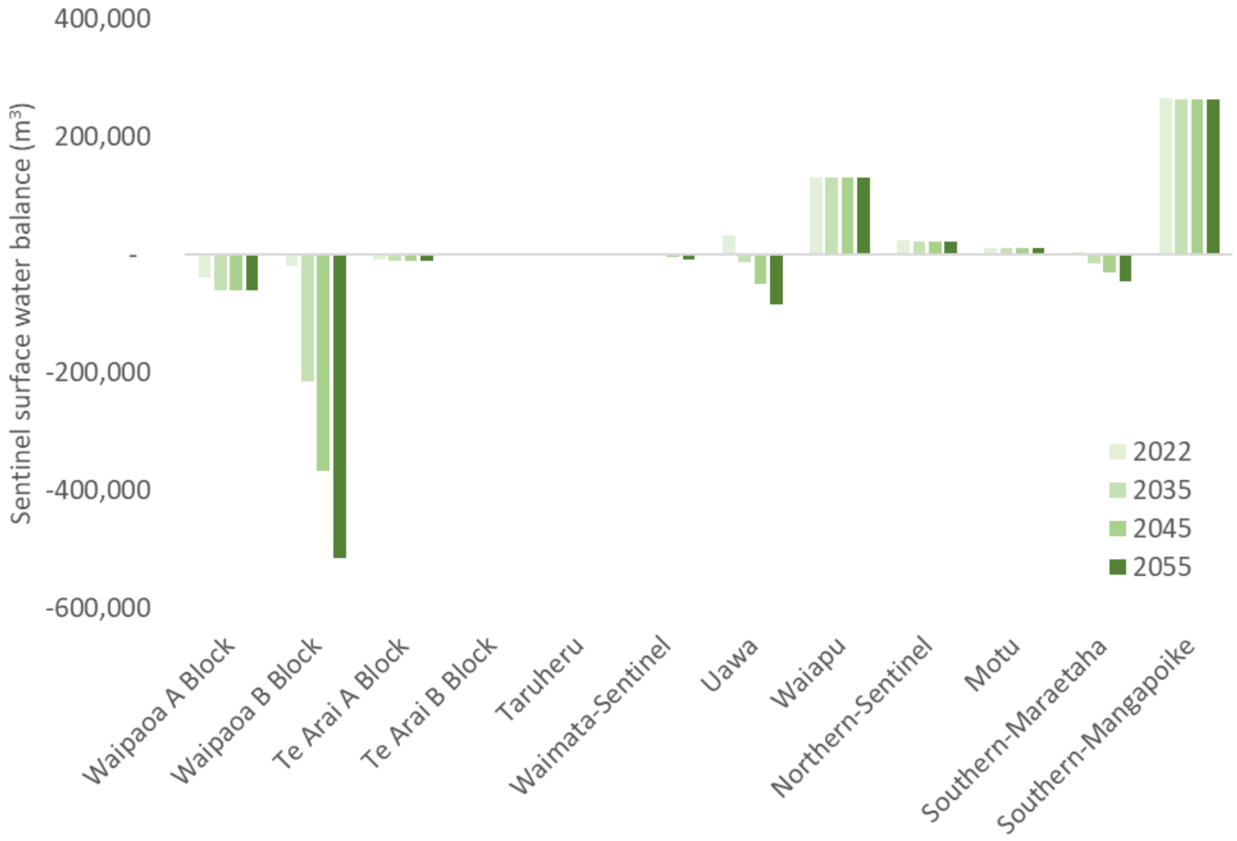


Figure 7-3: Sentinel water balance for surface water (sub-)catchments

Table 7-1: Sentinel surface water demand, supply, and water balance per (sub-)catchment for present-day and future scenarios

	2022			2035			2045			2055		
	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)
Waipaoa A Block	159,663	119,869	-39,794	170,945	110,280	-60,666	171,017	110,280	-60,737	171,590	110,280	-61,310
Waipaoa B Block	56,903	37,989	-18,914	250,507	34,950	-215,557	401,880	34,950	-366,930	548,684	34,950	-513,734
Te Arai A Block	11,071	2,204	-8,867	11,905	2,028	-9,877	11,905	2,028	-9,877	11,905	2,028	-9,877
Te Arai B Block	471	132	-339	504	122	-382	504	122	-382	504	122	-382
Taruheru	227	1,072	845	240	986	746	240	986	746	240	986	746
Waimata-Sentinel	-	1,593	1,593	3,682	1,466	-2,216	6,608	1,466	-5,142	9,440	1,466	-7,974
Uawa	-	31,798	31,798	45,046	31,798	-13,248	80,852	31,798	-49,053	115,503	31,798	-83,704
Waiapu	40	130,357	130,317	42	130,357	130,315	42	130,357	130,315	44	130,357	130,313
Northern-Sentinel	-	23,761	23,761	1,192	23,761	22,569	2,139	23,761	21,622	3,056	23,761	20,705
Motu	-	9,813	9,813	-	9,813	9,813	-	9,813	9,813	-	9,813	9,813
Southern-Maraetaha	600	3,911	3,311	19,627	3,598	-16,029	34,735	3,598	-31,138	49,387	3,598	-45,789
Southern-Mangapoike	16,537	280,865	264,327	17,509	280,865	263,355	17,729	280,865	263,135	17,872	280,865	262,993

7.3 Future groundwater balance

We calculated the annual groundwater demand and availability for the future projection scenarios to compare to the average annual demand and availability estimated for the present.

Because the groundwater balance was carried out on an annual basis, we used the average annual water balance to assess potential changes in the water balance in the future rather than identifying a sentinel month. There is insufficient information to conduct this analysis on a smaller time scale. Approaching the groundwater balance in this manner means each month assumes all groundwater is being taken and so results are precautionary.

Figure 7-4 shows the average annual water demand in each (sub-)catchment for the current state and future scenarios. The primary water use was irrigation. There was a notable projected increase in water demand in the Waiapu catchment, which has a large area of cropping that is not currently irrigated. The area was projected to be fully supplied by groundwater due to the groundwater resources present in the Waiapu catchment. We note that while the calculations in this assessment indicate that groundwater is available, the feasibility of accessing it as a water supply would require further investigation.

Figure 7-5 shows the estimated average annual groundwater supply in each (sub-)catchment for the current state and future scenarios. The groundwater supply within the Waipaoa catchment is estimated to decrease by 5-15% by 2035, by 7-17% by 2045 and by 11-13% by 2055 from current availability. In the other catchments, supply is estimated to decrease by no more than 9% by 2055.

Figure 7-6 and Figure 7-7 show the average annual groundwater balance for each (sub-)catchment for the current state and future scenarios. Catchments which currently have a groundwater surplus (demand exceeds supply) are anticipated to maintain the surplus in future scenarios. Future scenarios indicate an increase in deficit and a decrease in availability.

Table 7-2 contains the annual supply, demand, and water balance totals presented in the figures.

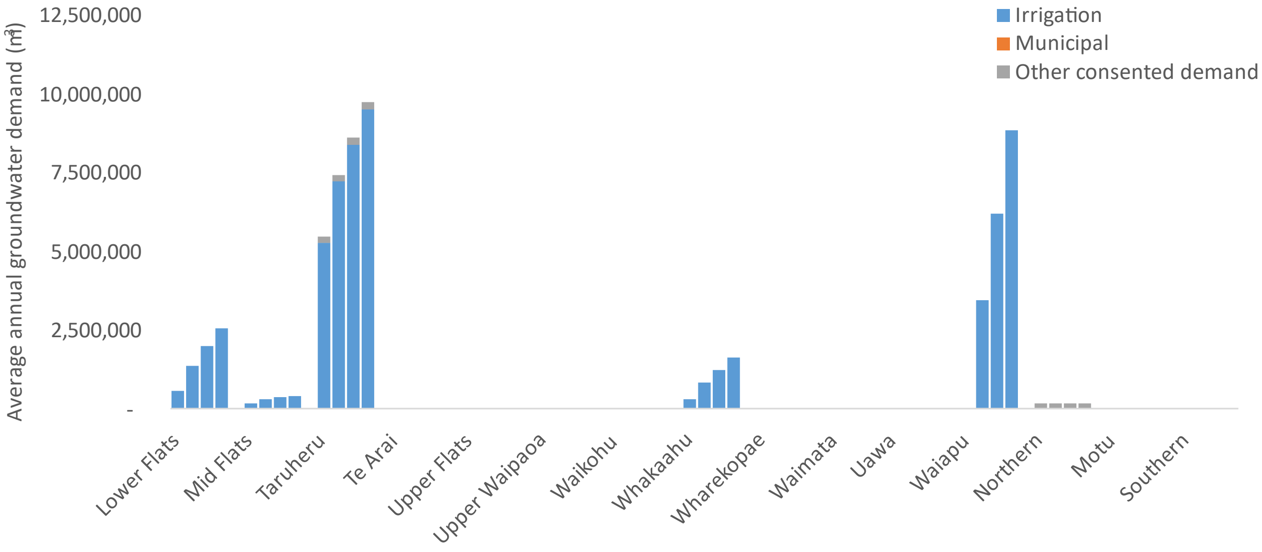


Figure 7-4: Average annual groundwater demand, divided by (sub-)catchment and use type. The bars represent the current and future scenarios (2022, 2035, 2045, and 2055).

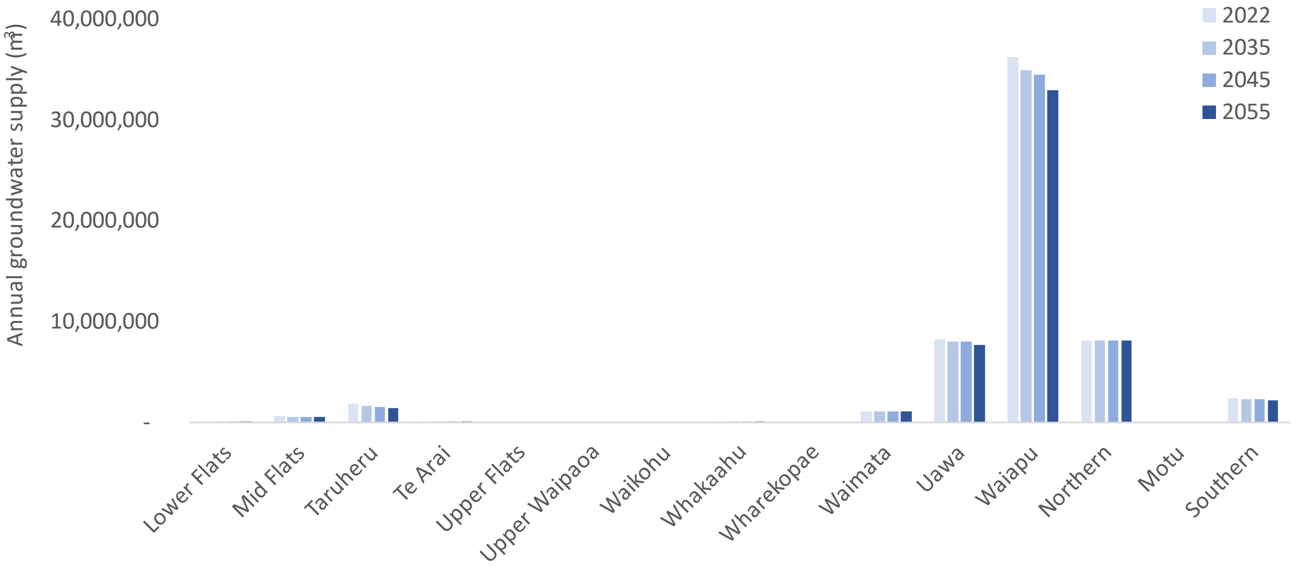


Figure 7-5: Average annual groundwater supply, divided by (sub-)catchment. The bars represent the current and future scenarios (2022, 2035, 2045, and 2055).

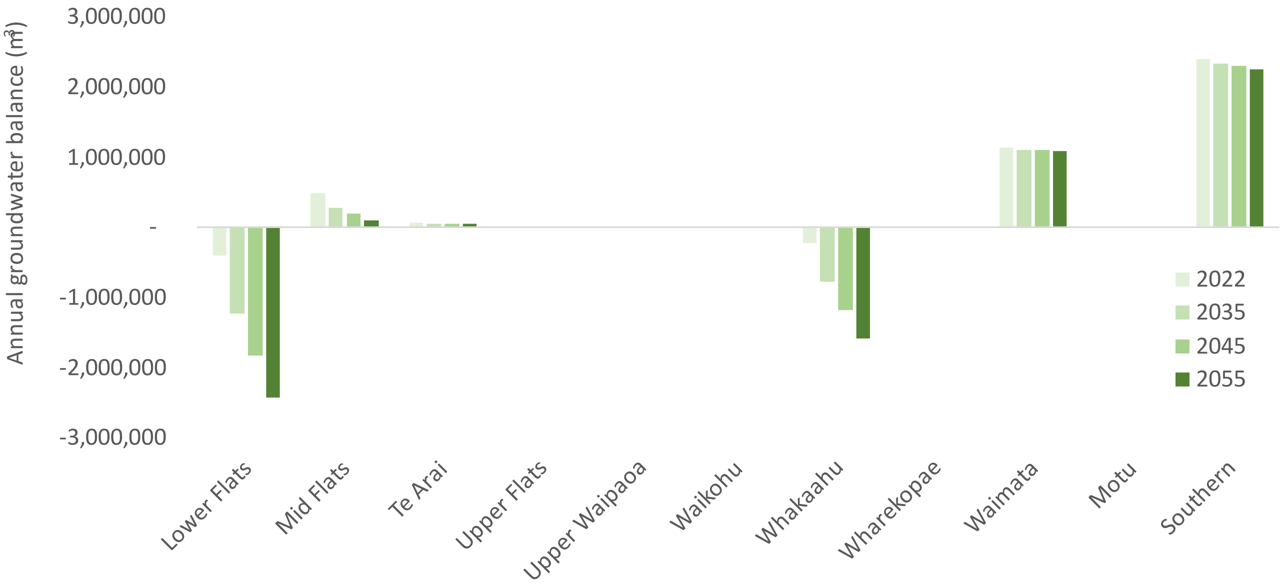


Figure 7-6: Average annual groundwater balance for (sub-)catchments with groundwater balances ≤ 3 Mm³/year. The bars represent the current and future scenarios (2022, 2035, 2045, and 2055).

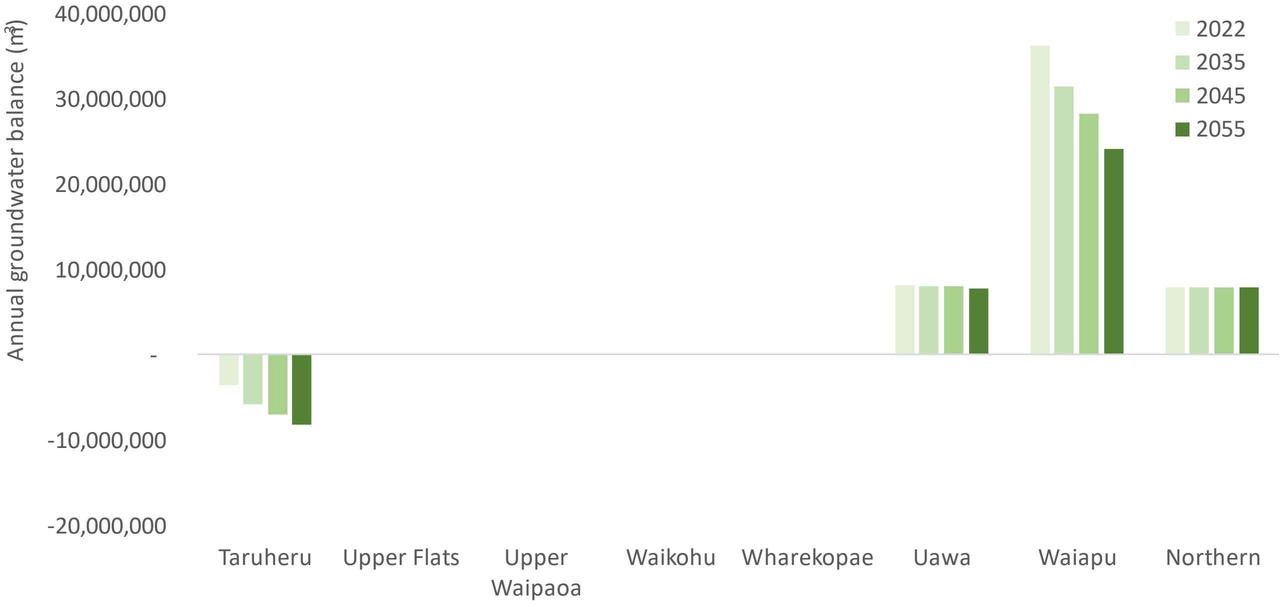


Figure 7-7: Average annual groundwater balance for (sub-)catchments with groundwater balances > 3 Mm^3/year. The bars represent the current and future scenarios (2022, 2035, 2045, and 2055).

Table 7-2: Total annual groundwater demand, supply, and water balance per (sub-)catchment for present-day and future scenarios

	2022			2035			2045			2055		
	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)	Demand (m^3)	Supply (m^3)	Balance (m^3)
Lower Flats	559,438	156,546	-402,892	1,374,908	149,074	-1,225,834	1,982,830	146,014	-1,836,816	2,571,142	139,981	-2,431,160
Mid Flats	187,967	666,592	478,625	290,284	569,623	279,339	356,712	552,486	195,774	420,998	516,509	95,512
Taruheru	5,475,373	1,868,796	-3,606,577	7,440,514	1,621,308	-5,827,721	8,615,615	1,580,390	-7,046,311	9,751,109	1,493,315	-8,273,241
Te Arai	-	61,650	61,650	-	55,392	55,392	-	54,109	54,109	-	51,465	51,465
Upper Flats	-	-	-	-	-	-	-	-	-	-	-	-
Upper Waipaoa	-	-	-	-	-	-	-	-	-	-	-	-
Waikohu	-	-	-	-	-	-	-	-	-	-	-	-
Whakaahu	290,974	64,296	-226,677	838,137	54,973	-783,164	1,243,629	53,748	-1,189,881	1,636,041	50,596	-1,585,444
Wharekopae	-	-	-	-	-	-	-	-	-	-	-	-
Waimata	-	1,129,113	1,129,113	-	1,109,843	1,109,843	-	1,101,657	1,101,657	-	1,080,197	1,080,197
Uawa	-	8,251,065	8,251,065	-	8,056,658	8,056,658	-	8,004,931	8,004,931	-	7,757,572	7,757,572
Waiapu	-	36,310,816	36,310,816	3,452,015	35,001,425	31,549,409	6,195,925	34,516,889	28,320,964	8,851,322	32,986,977	24,135,655
Northern	157,781	8,118,911	7,961,131	168,439	8,138,413	7,960,036	172,955	8,139,952	7,953,724	185,175	8,168,415	7,974,454
Motu	-	-	-	-	-	-	-	-	-	-	-	-
Southern	-	2,392,489	2,392,489	-	2,338,360	2,338,360	-	2,308,829	2,308,829	-	2,255,083	2,255,083
Total	**6,671,533**	**59,020,274**	**52,348,741**	**13,564,298**	**57,095,070**	**43,512,318**	**18,567,666**	**56,459,005**	**37,866,979**	**23,415,786**	**54,500,110**	**31,060,092**

8 CONCLUSIONS

8.1 Water demands

- Based on resource consent data provided by GDC in November 2022, an annual volume of approximately 33 million cubic metres is consented for abstraction. Approximately 90% of this is from surface water.
- On an instantaneous rate basis, 3,134 l/s is consented for abstraction from surface water, and 700 l/s is consented for abstraction from groundwater.
- The majority of Tairawhiti's consented abstraction (93% by number of consents) occurs in the Waipaoa catchment.
- Soil moisture balance modelling was used to estimate daily irrigation water demand. This method is considered more robust than relying on measured water use, as measurements are only available over a relatively short timeframe.
- In the Waipaoa catchment, irrigation represents the greatest proportion of the current water demands. The existing high-value land uses require a high level of water supply security.
- Demands from other catchments are relatively small at present, which the exception of the Gisborne City municipal demand, which is supplied from the Southern catchments.
- Uses of water that do not require resource consents are estimated to be very small in comparison to the consented volume.
- Differences between the current demand volumes estimated in this study and previous estimates from Aqualinc (2013) are due to both changes in irrigated area, and refinements in the estimation method.
- Future irrigation demands are projected to increase across all catchments in the study area (with the exception of the Motu catchment) due to crop demand increasing under future climate projections, and the assumption that currently-unirrigated crops will be irrigated in the future.
- Municipal and other non-irrigation demands are projected to increase in line with population growth projections, with a 15% increase projected by mid-century, however these increases are relatively small (in terms of volumes and rates) compared to projected increases in irrigation demand.

8.2 Water availability

- Surface water availability, within existing allocation blocks, has been estimated in all study catchments. Under the Tairāwhiti Resource Management Plan (TRMP), up to 4,170 l/s is able to be allocated for abstractive use from surface water resources in the Waipaoa and Te Aria catchments. In this assessment we have estimated that a further 3,668 l/s can be allocated from surface water resources in other catchments where specific allocation limits have not yet been set.
- The actual availability of the allocated water at any given time depends on river flows. Where sufficient river flow data exists, a daily time-series of availability has been calculated.
- In catchments where there are consented abstractions upstream of the flow recorder locations, a naturalised flow record has been created; the changes due to naturalisation are relatively small.
- For catchments with insufficient flow data to apply the daily time-series approach, a flow duration curve approach was used to estimate monthly water availability.
- Over winter and spring (June – October), surface water is typically at or close to 100% availability, although during high flow periods it may not be possible / desirable to take sediment-laden water. Surface water availability is typically lowest in January – February. Average supply security over

this period is around 70% for the Waipaoa River and 45% for the Te Arai River. Supply security at this level during key parts of the growing season is a potential challenge for high-value land uses that rely on highly reliable water supplies.

- Future water availability is likely to decrease in some of the study catchments (Waipaoa, Waimata and Southern-Maraetaha) under projected future climates, and remain the same in others.
- Groundwater availability has been calculated using TRMP allocation limits in the Waipaoa catchment and as 30% of average annual rainfall recharge elsewhere. Groundwater availability exceeds demand outside the Waipaoa catchment. Within the Waipaoa catchment demand on the Te Hapara Sand and Makauri aquifers generally exceeds availability, especially in the Taruheru sub-catchment.
- The groundwater resource is currently in a state of decline in the areas where it is used most intensively. This situation is likely to continue without specific interventions. Groundwater availability is likely to reduce under future climate projections.
- Projected decreases in average annual recharge under future climates would result in a reduction in groundwater availability in all catchments except the Northern catchment. The largest decrease in availability coincides with the highest demand.

8.3 Supply-demand balance

- For catchments where sufficient data existed (Waipaoa and Te Arai), a daily supply-demand balance model was implemented. On an **average** monthly basis (i.e. comparing the volumes of supply and demand over a month) these catchments have sufficient water to meet demands, however on a daily basis there are shortfalls in supply, particularly in the peak of summer. Water supply surpluses (i.e., available water exceeds demand) on an annual or monthly basis may mask shorter-term supply shortfalls.
- Results from the daily time-series supply-demand modelling were used to select January as a “sentinel month” for analysis of the supply-demand balance in other catchments.
- Using the sentinel month approach, demand exceeds surface water supply in the Waipaoa A Block, the Te Arai A Block, and the Te Arai B Block, and was close to the available supply in the Waipaoa B Block.
- The groundwater supply-demand balance was assessed on an annual volume basis. Demand exceeded supply in the Lower Flats, Taruheru and Whakaahu sub-catchments, with supply exceeding demand everywhere else.
- In areas where a groundwater supply surplus has been calculated, there is no guarantee that groundwater is economically accessible. The estimates of available volume may change in future as the available information changes (for example, updated aquifer extents based on SkyTEM surveys).
- A future supply-demand balance scenario was developed, based on the future projections of the various components of demand, and estimated future water availability. Supply-demand balances were estimated for 2035, 2045 and 2055.
- Several catchments (Waimata, Uawa, Southern-Maraetaha) are projected to change from a slightly positive surface water supply-demand balance under the current state assessment to a negative balance in the future.
- The largest changes (reduction) in the surface water supply-demand balance are projected for the Waipaoa B block, with the changes predominantly driven by changes in irrigation water demand.
- The largest changes (reduction) in the groundwater supply-demand balance are projected for the Lower Flats sub-catchment, which sees a substantial increase in deficit. The Waiapu catchment also has a large reduction in availability though remains in a positive balance.

- Allocating more water to maintaining or improving the health of rivers results in less water available for abstractive use. It should be noted that if allocation rules are revised to give effect to Te Mana o te Wai as part of implementing the NPS-FM 2020, the rates and volumes of water available in the future could be less than modelled in this assessment.

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Appendix A: Abstractive consents

Table A.1: Summary of the number of surface water and groundwater abstraction consents in each (sub-)catchment

(Sub)catchment	Source	Combined	Drinking	Frost protection	Irrigation	Other
Waipaoa		3	5	2	166	2
Upper Waipaoa	*WG*	-	*2*	-	-	-
	WS	*1*	-	-	*2*	-
Upper Flats	*WG*	-	*1*	-	*1*	-
	WS	*1*	-	-	*7*	-
Mid Flats	*WG*	-	-	-	*16*	-
	WS	*1*	*1*	*2*	*25*	-
Lower Flats	*WG*	-	-	-	*17*	-
	WS	-	-	-	*11*	-
Te Arai	*WG*	-	-	-	*2*	-
	WS	-	-	-	*10*	-
Taruheru	*WG*	-	-	-	*54*	*2*
	WS	-	*1*	-	*10*	-
Waikohu	*WG*	-	-	-	-	-
	WS	-	-	-	*2*	-
Whakaahu	*WG*	-	-	-	*3*	-
	WS	-	-	-	*4*	-
Wharekopae	*WG*	-	-	-	*1*	-
	WS	-	-	-	*1*	-
Waimata	WG	-	-	-	-	-
	WS	-	-	-	3	1
Uawa	WG	-	-	-	-	-
	WS	-	-	-	2	-
Waiapu	WG	-	-	-	-	-
	WS	-	1	-	-	-
Northern	WG	-	-	-	-	-
	WS	-	-	-	1	1
Motu	WG	-	-	-	-	-
	WS	-	-	-	-	-
Southern	WG	-	-	-	-	-
	WS	1	-	-	1	-
	Total	**4**	**6**	**2**	**173**	**4**

Table A.2: Summary of the instantaneous consented abstraction rate (L/s) of surface water and groundwater abstraction consents in each (sub-)catchment

(Sub)catchment	Source	Combined	Drinking	Frost protection	Irrigation	Other
Waipaoa		156	211	363	2,956	10
Upper Waipaoa	*WG*	-	*2*	-	-	-
	WS	*58*	-	-	*100*	-
Upper Flats	*WG*	-	*4*	-	*13*	-
	WS	*43*	-	-	*193*	-
Mid Flats	*WG*	-	-	-	*115*	-
	WS	*56*	*5*	*363*	*1,072*	-
Lower Flats	*WG*	-	-	-	*82*	-
	WS	-	-	-	*184*	-
Te Arai	*WG*	-	-	-	*7*	-
	WS	-	-	-	*175*	-
Taruheru	*WG*	-	-	-	*626*	*10*
	WS	-	*200*	-	*143*	-
Waikohu	*WG*	-	-	-	-	-
	WS	-	-	-	*84*	-
Whakaahu	*WG*	-	-	-	*52*	-
	WS	-	-	-	*81*	-
Wharekopae	*WG*	-	-	-	*4*	-
	WS	-	-	-	*24*	-
Waimata	WG	-	-	-	-	-
	WS	-	-	-	54	0.4
Uawa	WG	-	-	-	-	-
	WS	-	-	-	30	-
Waiapu	WG	-	-	-	-	-
	WS	-	5	-	-	-
Northern	WG	-	-	-	-	-
	WS	-	-	-	5	5
Motu	WG	-	-	-	-	-
	WS	-	-	-	-	-
Southern	WG	-	-	-	-	-
	WS	17	-	-	11	-
	Total	**173**	**216**	**363**	**3,056**	**15**

Table A.3: Summary of the daily consented abstraction (m^3) of surface water and groundwater abstraction consents in each (sub-)catchment

(Sub)catchment	Source	Combined	Drinking	Frost protection	Irrigation	Other
Waipaoa		13,440	17,821	23,740	193,098	560
Upper Waipaoa	*WG*	-	*137*	-	-	-
	WS	*4,968*	-	-	*8,150*	-
Upper Flats	*WG*	-	*300*	-	*630*	-
	WS	*3,672*	-	-	*10,851*	-
Mid Flats	*WG*	-	-	-	*5,019*	-
	WS	*4,800*	*104*	*23,740*	*75,796*	-
Lower Flats	*WG*	-	-	-	*4,127*	-
	WS	-	-	-	*15,642*	-
Te Arai	*WG*	-	-	-	*446*	-
	WS	-	-	-	*11,742*	-
Taruheru	*WG*	-	-	-	*37,613*	*560*
	WS	-	*17,280*	-	*7,833*	-
Waikohu	*WG*	-	-	-	-	-
	WS	-	-	-	*3,755*	-
Whakaahu	*WG*	-	-	-	*3,170*	-
	WS	-	-	-	*5,905*	-
Wharekopae	*WG*	-	-	-	*345*	-
	WS	-	-	-	*2,074*	-
Waimata	WG	-	-	-	-	-
	WS	-	-	-	3,985	30
Uawa	WG	-	-	-	-	-
	WS	-	-	-	3,137	-
Waiapu	WG	-	-	-	-	-
	WS	-	40	-	-	-
Northern	WG	-	-	-	-	-
	WS	-	-	-	475	423
Motu	WG	-	-	-	-	-
	WS	-	-	-	-	-
Southern	WG	-	-	-	-	-
	WS	600	-	-	690	-
	Total	**14,040**	**17,861**	**23,740**	**201,385**	**1,013**

Appendix B: Irrigation

The table over page summarises the consented irrigated area distribution of different crops by (sub-)catchment.

For irrigation demand modelling, we aggregated the crop types identified in the consents database into generalised groups with similar irrigation management. The table below summarises the demand modelling assigned to common crop types.

Table B.1: Assumed irrigation demand group for crop types identified in the 2021 survey.

Crop type from survey	Assigned crop category
[Null]	Other
Apples and Pears	Apples and Pears
Avocados	Avocados
Baleage	Pasture
Cauliflower/Broccoli	Vege
Chicory	Pasture
Citrus	Citrus
Clover	Pasture
Courgettes	Vege
Feijoa	Citrus
Flowers	Vege
Forage rape	Pasture
Grapes	Grapes
Kiwifruit	Kiwifruit
Leafy Turnip	Pasture
Lettuce/Cabbage	Vege
Lucerne	Pasture
Maize/Sweetcorn	Maize
Not Visible	Other
Olives	Avocados
Other	Other
Pasture/Unused	Pasture
Persimmon	Citrus
Pine Nursery	Other
Plantain/Chicory	Pasture
Pomegranate	Citrus
Poplar/Willow Nursery	Other
Squash	Vege
Stonefruit	Apples and Pears
Strawberries	Apples and Pears
Tamarillo	Citrus
To Be Planted	Vege
Tomatoes	Vege

Table B.2: Area of irrigated crop grouped by (sub-)catchment

(Sub)catchment	**Pasture**	**Veges**	**Grapes**	**Apples**	**Avocado**	**Maize**	**Citrus**	**Kiwifruit**	**Other**	**Total**
Waipaoa	1,120	632	97	583	146	212	514	1,427	1,922	6,654
Lower Flats	-	-	-	24	7	-	123	180	152	487
Mid Flats	713	291	97	77	29	132	107	458	417	2,322
Taruheru	162	132	-	139	3	-	239	355	1,237	2,266
Te Arai	60	-	-	253	-	-	27	313	-	653
Upper Flats	89	30	-	-	72	40	-	10	74	315
Upper Waipaoa	-	120	-	-	-	-	-	49	10	179
Waikohu	67	4	-	-	1	1	-	-	32	105
Whakaahu	29	55	-	90	34	38	18	62	-	326
Wharekopae	-	-	-	-	-	-	-	-		**-**
										-
Waimata	-	-	-	-	-	-	-	-		**-**
Uawa	-	-	-	-	-	-	-	-		**-**
Waiapu	-	-	-	-	-	-	-	-		**-**
Northern	-	-	-	-	-	-	-	-		**-**
Motu	-	-	-	-	-	-	-	-		**-**
Southern	-	-	-	-	-	-	-	-		**-**
Total (ha)	1,120	632	97	583	146	212	514	1,427	1,922	6,654

The irrigation water demand values for different modelled crops are listed below.

Table B.3: Annual irrigation demand and drainage modelled for 1 ha, grouped by crop type and PAW

PAW	Crop	90th percentile annual drainage (m^3)	Max. annual drainage (m^3)	90th percentile annual demand (m^3)	Max. annual demand (m^3)
80	Pasture	796	992	4,035	5,100
	Vege	935	1,095	4,390	5,100
	Grapes	986	1,152	1,173	1,408
	Apples	843	1,022	3,460	4,100
	Avocado	914	1,080	2,280	2,900
	Maize	904	1,072	300	600
	Citrus	833	1,006	3,070	3,600
	Kiwifruit	893	1,041	3,420	3,750
100	Pasture	787	978	3,735	4,800
	Vege	916	1,081	4,090	4,900
	Grapes	978	1,144	1,080	1,320
	Apples	819	1,003	3,250	3,900
	Avocado	896	1,070	2,090	2,800
	Maize	901	1,072	150	300
	Citrus	810	987	2,950	3,600
	Kiwifruit	877	1,012	3,285	3,750
120	Pasture	771	935	3,600	4,650
	Vege	890	1,042	3,900	5,100
	Grapes	975	1,142	994	1,254
	Apples	798	974	3,070	3,700
	Avocado	887	1,051	2,080	2,700
	Maize	901	1,072	135	150
	Citrus	792	959	2,750	3,400
	Kiwifruit	869	1,011	3,150	3,600
140	Pasture	756	907	3,585	4,650
	Vege	885	1,038	3,890	5,100
	Grapes	970	1,133	928	1,188
	Apples	789	946	2,860	3,600
	Avocado	877	1,032	1,980	2,600
	Maize	901	1,072	-	150
	Citrus	784	949	2,560	3,100
	Kiwifruit	855	997	3,000	3,600

The following table lists the estimated total irrigable area and current irrigated area by (sub-)catchment. The current irrigated area has been estimated using GDC’s consent records, and we have included a comparison to MfE’s 2020 irrigated area mapping. For future scenarios, we assumed that all areas listed in the most recent crop survey which are not currently irrigated will begin to convert to irrigation.

Table B.4: Irrigable and irrigated area grouped by (sub-)catchment

(Sub-) catchment	**Consented irrigated area (ha)**	**MfE 2020, irrigated area (ha)**	**Straightforward irrigable area (ha)**	**Possible irrigable area (ha)**	**Cropped areas not currently irrigated (ha)**
Waipaoa	6,467	10,476	32,956	18,147	12,413
Lower Flats	*469*	*1,117*	*4,536*	*6,487*	*2,088*
Mid Flats	*2,222*	*2,682*	*2,296*	*684*	*2,218*
Taruheru	*2,263*	*2,691*	*5,980*	*1,543*	*2,358*
Te Arai	*653*	*1,688*	*3,122*	-	*2,321*
Upper Flats	*259*	*912*	*3,612*	*725*	*1,103*
Upper Waipaoa	*169*	*196*	*4,827*	*419*	*349*
Waikohu	*105*	*373*	*3,749*	*3,600*	*691*
Whakaahu	*326*	*698*	*2,034*	*642*	*1,259*
Wharekopae	-	*117*	*2,801*	*4,047*	*25*
Waimata	-	30	32,960	18,147	275
Uawa	-	-	6,724	5,152	2,785
Waiapu	-	-	8,029	2,589	2,449
Northern	-	-	15,917	17,045	92
Motu	-	-	8,577	5,121	-
Southern	-	117	7,963	4,383	2,674
Total (ha)	**6,467**	**10,623**	**86,644**	**63,833**	**20,688**

Table B.5: Estimated future annual irrigation water demand by (sub-)catchment

	Year	Irrigation demand (m³/year)															
		Waipaoa															
		Lower Flats	Mid Flats	Taruheru	Te Arai	Upper Flats	Upper Waipaoa	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
Surface water	2022	623,196	6,086,845	1,307,710	1,632,089	704,879	514,964	340,690	498,575	-	-	-	-	-	-	-	
	2035	1,812,048	8,514,330	1,833,700	3,341,795	2,015,481	966,255	1,175,050	1,193,851	31,941	306,115	2,368,436	-	61,387	-	1,229,527	61,387
	2045	2,723,931	10,108,605	2,183,856	4,600,374	3,009,471	1,284,956	1,815,739	1,709,932	57,331	549,436	4,251,039	-	110,183	-	2,206,844	110,183
	2055	3,606,398	11,651,451	2,522,716	5,818,353	3,971,397	1,593,377	2,435,760	2,209,365	81,901	784,909	6,072,912	-	157,404	-	3,152,634	157,404
Ground water	2022	574,860	193,426	5,414,886	-	-	-	-	299,261	-	-	-	-	-	-	-	
	2035	1,374,908	290,284	7,223,991	-	-	-	-	838,137	-	-	-	3,452,015	4,621	-	-	4,621
	2045	1,982,830	356,712	8,396,250	-	-	-	-	1,243,629	-	-	-	6,195,925	8,293	-	-	8,293
	2055	2,571,142	420,998	9,530,695	-	-	-	-	1,636,041	-	-	-	8,851,322	11,848	-	-	11,848
All	**2022**	1,198,056	6,280,272	6,722,596	1,632,089	704,879	514,964	340,690	797,835	-	-	-	-	-	-	-	
	2035	3,186,956	8,804,615	9,057,691	3,341,795	2,015,481	966,255	1,175,050	2,031,988	31,941	306,115	2,368,436	3,452,015	66,008	-	1,229,527	66,008
	2045	4,706,761	10,465,317	10,580,106	4,600,374	3,009,471	1,284,956	1,815,739	2,953,561	57,331	549,436	4,251,039	6,195,925	118,476	-	2,206,844	118,476
	2055	6,177,540	12,072,448	12,053,410	5,818,353	3,971,397	1,593,377	2,435,760	3,845,405	81,901	784,909	6,072,912	8,851,322	169,251	-	3,152,634	169,251

Appendix C: Domestic water demand

Table C.1: Estimated population projections by (sub-)catchment

Year	Waipaoa															
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
Reticulated supply																
2022	225	568	110	582	508	23,245	-	-	-	14,083	-	-	-	-	-	**39,321**
2035	248	626	121	642	559	25,615	-	-	-	15,519	-	-	-	-	-	**43,330**
2045	254	641	124	657	573	26,231	-	-	-	15,892	-	-	-	-	-	**44,372**
2055	259	656	127	673	586	26,847	-	-	-	16,266	-	-	-	-	-	**45,414**
Non-reticulated supply																
2022	253	138	1,106	103	113	1,377	299	588	201	2,016	1,909	2,471	975	337	873	**12,759**
2035	279	152	1,219	113	125	1,518	329	648	222	2,221	2,103	2,722	1,075	372	962	**14,060**
2045	286	156	1,248	116	128	1,554	337	663	227	2,275	2,154	2,788	1,100	381	985	**14,398**
2055	293	160	1,277	119	131	1,591	345	679	232	2,328	2,204	2,853	1,126	390	1,008	**14,736**
Total																
2022	478	706	1,216	685	621	24,622	299	588	201	16,099	1,909	2,471	975	337	873	52,080
2035	527	778	1,340	755	684	27,133	329	648	222	17,740	2,103	2,722	1,075	372	962	57,390
2045	539	797	1,372	773	701	27,785	337	663	227	18,167	2,154	2,788	1,100	381	985	58,770
2055	552	815	1,404	791	717	28,438	345	679	232	18,594	2,204	2,853	1,126	390	1,008	60,150

Table C.2: Estimated average daily water demand projections by (sub-)catchment. Note that the demand is based on the location of users rather than the source of the water.

Year	Waipaoa															
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
Reticulated supply, avg. daily demand (m^3/day)																
2022	56	142	27	146	127	5,811	-	-	-	3,521	-	-	-	-	-	9,830
2035	62	156	30	160	140	6,404	-	-	-	3,880	-	-	-	-	-	10,832
2045	63	160	31	164	143	6,558	-	-	-	3,973	-	-	-	-	-	11,093
2055	65	164	32	168	147	6,712	-	-	-	4,066	-	-	-	-	-	11,353
Non-reticulated supply, avg. daily demand (m^3/day)																
2022	63	35	277	26	28	344	75	147	50	504	477	618	244	84	218	3,190
2035	70	38	305	28	31	379	82	162	55	555	526	681	269	93	241	3,515
2045	71	39	312	29	32	389	84	166	57	569	538	697	275	95	246	3,600
2055	73	40	319	30	33	398	86	170	58	582	551	713	282	97	252	3,684
Total, avg. daily demand (m^3/day)																
2022	120	176	304	171	155	6,156	75	147	50	4,025	477	618	244	84	218	13,020
2035	132	194	335	189	171	6,783	82	162	55	4,435	526	681	269	93	241	14,347
2045	135	199	343	193	175	6,946	84	166	57	4,542	538	697	275	95	246	14,693
2055	138	204	351	198	179	7,109	86	170	58	4,648	551	713	282	97	252	15,037

Table C.3: Estimated peak daily water demand projections by (sub-)catchment

Year	Waipaoa															
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
Reticulated supply, peak daily demand (m^3/day)																
2022	81	204	40	210	183	8,368	-	-	-	5,070	-	-	-	-	-	14,156
2035	89	225	44	231	201	9,221	-	-	-	5,587	-	-	-	-	-	15,599
2045	91	231	45	237	206	9,443	-	-	-	5,721	-	-	-	-	-	15,974
2055	93	236	46	242	211	9,665	-	-	-	5,856	-	-	-	-	-	16,349
Non-reticulated supply, peak daily demand (m^3/day)																
2022	91	50	398	37	41	496	108	212	72	726	687	889	351	121	314	4,593
2035	101	55	439	41	45	546	119	233	80	800	757	980	387	134	346	5,062
2045	103	56	449	42	46	560	121	239	82	819	775	1,004	396	137	355	5,183
2055	105	57	460	43	47	573	124	244	84	838	794	1,027	405	140	363	5,305
Total, peak daily demand (m^3/day)																
2022	172	254	438	247	224	8,864	108	212	72	5,796	687	889	351	121	314	18,749
2035	190	280	482	272	246	9,768	119	233	80	6,387	757	980	387	134	346	20,660
2045	194	287	494	278	252	10,003	121	239	82	6,540	775	1,004	396	137	355	21,157

Year	Waipaoa															Total
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	
2055	199	294	506	285	258	10,238	124	244	84	6,694	794	1,027	405	140	363	21,654

Table C.4: Estimated annual water demand projections by (sub-)catchment

Year	Waipaoa															
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
Reticulated supply, annual demand (m^3/year)																
2022	20,500	51,809	10,031	53,146	46,330	2,121,115	-	-	-	1,285,100	-	-	-	-	-	3,588,031
2035	22,590	57,091	11,053	58,565	51,054	2,337,377	-	-	-	1,416,125	-	-	-	-	-	3,953,855
2045	23,133	58,464	11,319	59,973	52,282	2,393,589	-	-	-	1,450,182	-	-	-	-	-	4,048,943
2055	23,676	59,837	11,585	61,381	53,509	2,449,786	-	-	-	1,484,229	-	-	-	-	-	4,144,004
Non-reticulated supply, annual demand (m^3/year)																
2022	23,120	12,607	100,927	9,367	10,351	125,682	27,279	53,628	18,359	183,934	174,153	225,436	88,980	30,774	79,671	1,164,269
2035	25,478	13,892	111,218	10,322	11,406	138,496	30,060	59,096	20,231	202,688	191,910	248,421	98,052	33,912	87,794	1,282,974
2045	26,090	14,226	113,892	10,570	11,680	141,826	30,783	60,517	20,717	207,562	196,525	254,395	100,410	34,728	89,906	1,313,829

Year	Waipaoa															
	Upper Waipaoa	Upper Flats	Mid Flats	Lower Flats	Te Arai	Taruheru	Waikohu	Whakaahu	Wharekopae	Waimata	Uawa	Waiapu	Northern	Motu	Southern	Total
2055	26,703	14,560	116,566	10,818	11,955	145,156	31,506	61,938	21,204	212,435	201,139	260,368	102,768	35,543	92,016	1,344,675
Total, annual demand (m^3/year)																
2022	43,620	64,416	110,958	62,513	56,681	2,246,797	27,279	53,628	18,359	1,469,035	174,153	225,436	88,980	30,774	79,671	4,752,300
2035	48,067	70,983	122,271	68,887	62,460	2,475,873	30,060	59,096	20,231	1,618,813	191,910	248,421	98,052	33,912	87,794	5,236,829
2045	49,223	72,691	125,211	70,543	63,962	2,535,416	30,783	60,517	20,717	1,657,744	196,525	254,395	100,410	34,728	89,906	5,362,771
2055	50,379	74,397	128,151	72,199	65,464	2,594,942	31,506	61,938	21,204	1,696,665	201,139	260,368	102,768	35,543	92,016	5,488,679

Appendix D: Livestock water demand

Table D.1: Average and peak water demand per head for various livestock categories

Stock category	**Demand (L/c/d** **Peak daily**	 **Average daily**	 **Shed (August – April inclusive)**
Dairy cattle			
Milking cows	72	36	70
Dry cows	45	30	70
Yearling	36.5	18	70
Beef cattle			
Cows	45	30	
Yearling	36.5	18	
Sheep			
Ewes	4.2	2.1	
Hoggets	3.9	2	
Deer			
Adult	11	5.7	
Yearling	7	3.6	

Table D.2: Estimated average distribution of stock

Stock	**%**
Dairy cows	
Dairy cows and heifers (over 2 years) in milk or calf	75%
Dairy cows and heifers (over 2 years) NOT in milk or calf	3%
Rising 1 year old dairy heifers and heifer calves	20%
Dairy bulls to be used for breeding	2%
Beef cattle	
Adult cows and bulls	40%
Yearlings	55%
Sheep	
Ewes	67%
Hoggets	33%
Deer	
Adult deer	60%
Yearling deer	40%

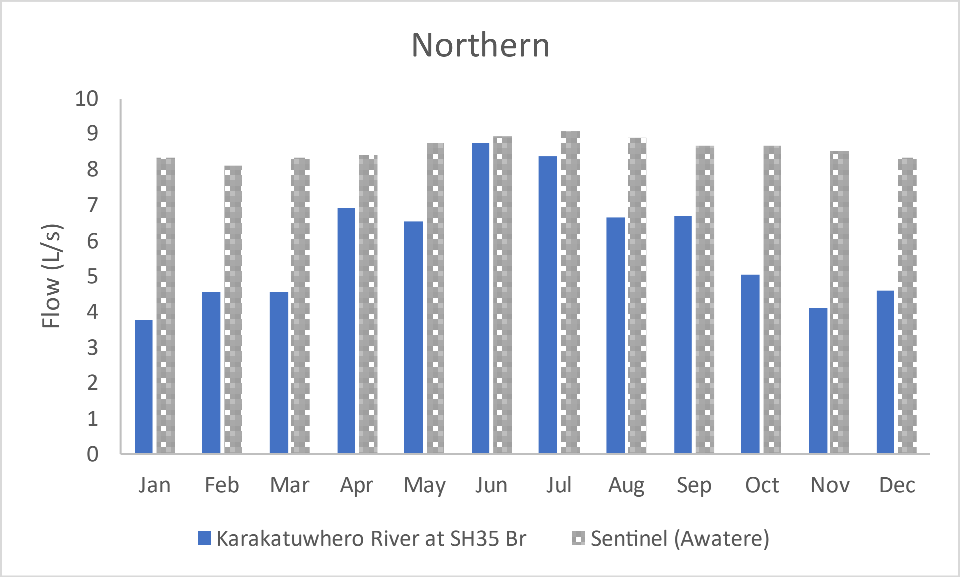
Table D.3: Estimated livestock population count per (sub-)catchment

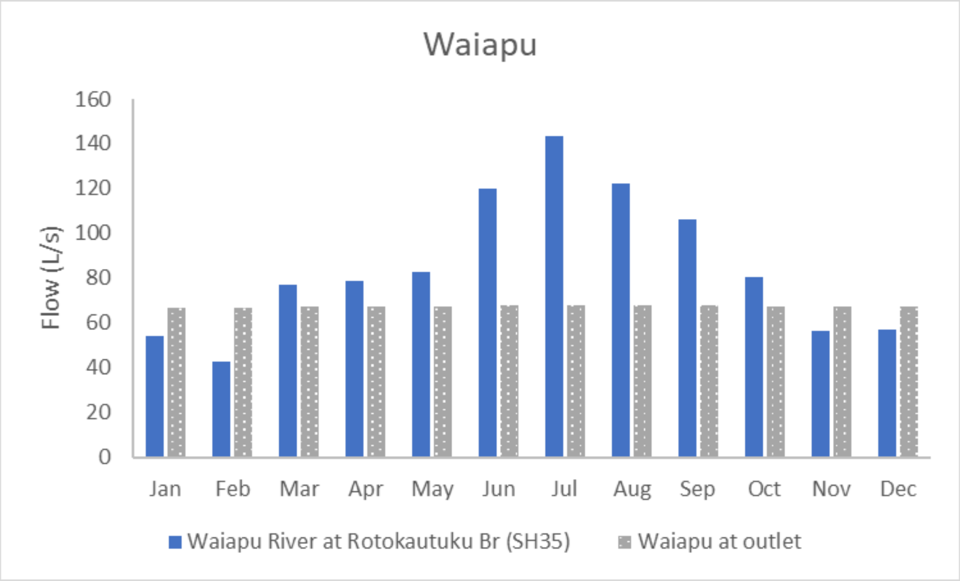
	Waipaoa															
	Lower Flats	**Mid Flats**	**Taruheru**	**Te Arai**	**Upper Flats**	**Upper Waipaoa**	**Waikohu**	**Whakaahu**	**Wharekopae**	**Waimata**	**Uawa**	**Waiapu**	**Northern**	**Motu**	**Southern**	**Total**
Sheep	6,790	80,219	17,332	64,190	46,366	150,100	145,011	49,545	128,565							
Cattle	1,693	13,432	3,442	11,248	7,962	27,136	21,426	6,307	22,969							
Dairy	-	1,060	427	1,012	1	3	150	365	3							
Deer	-	220	610	805	76	-	1,681	102	2,120							

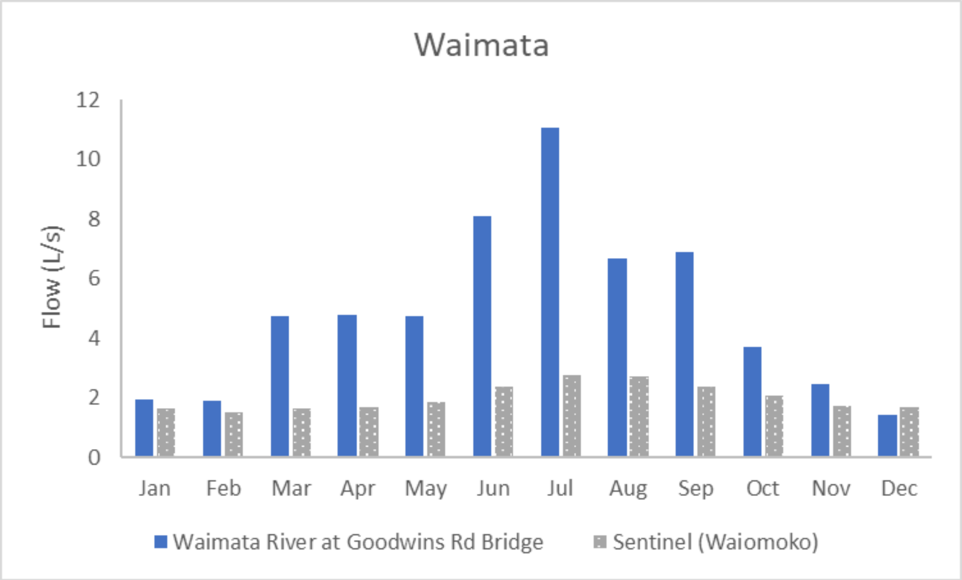
Table D.4: Estimated average and peak livestock water demand by (sub-)catchment

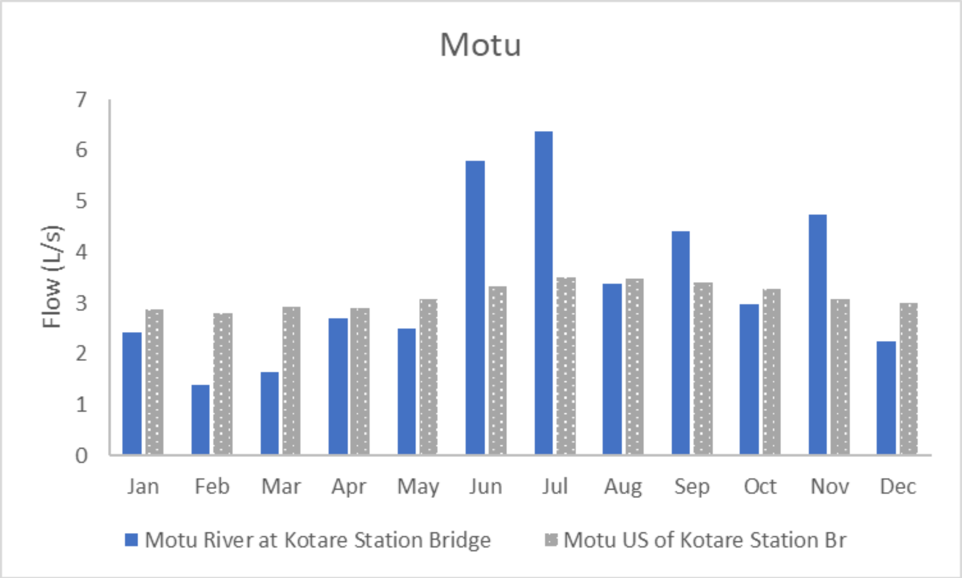
	Waipaoa															
	Lower Flats	**Mid Flats**	**Taruheru**	**Te Arai**	**Upper Flats**	**Upper Waipaoa**	**Waikohu**	**Whakaahu**	**Wharekopae**	**Waimata**	**Uawa**	**Waiapu**	**Northern**	**Motu**	**Southern**	**Total**
Average daily demand (m^3/day)																
	51	495	128	415	271	905	782	253	779							
Peak daily demand (m^3/day)																
	343	3,871	875	3,133	2,205	7,189	6,788	2,296	6,167							
Annual average demand (m^3/year)																
	18,656	180,700	46,675	151,624	98,772	330,190	285,412	92,252	284,395							

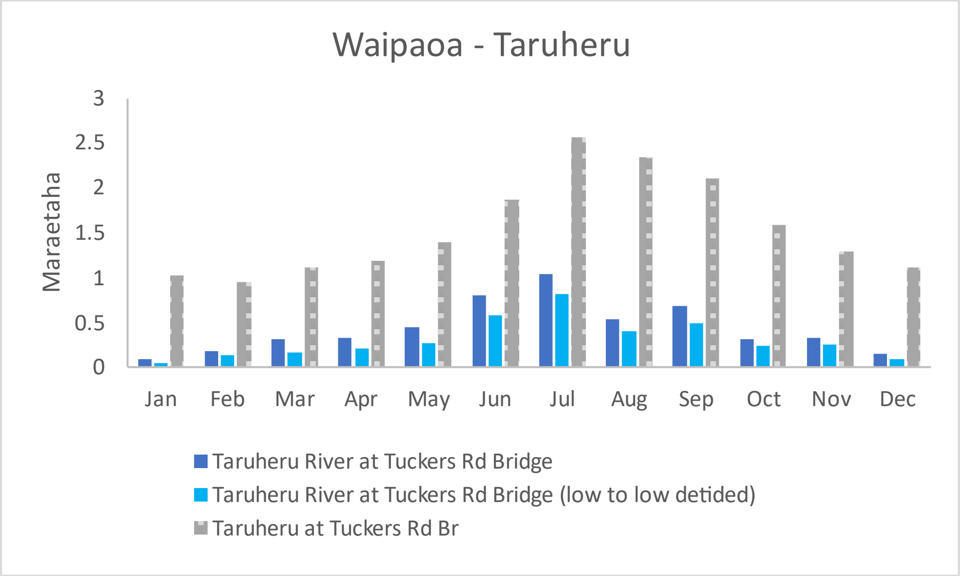
Appendix E: Comparison of measured (blue bars) and modelled (grey bars) average instantaneous flow per month

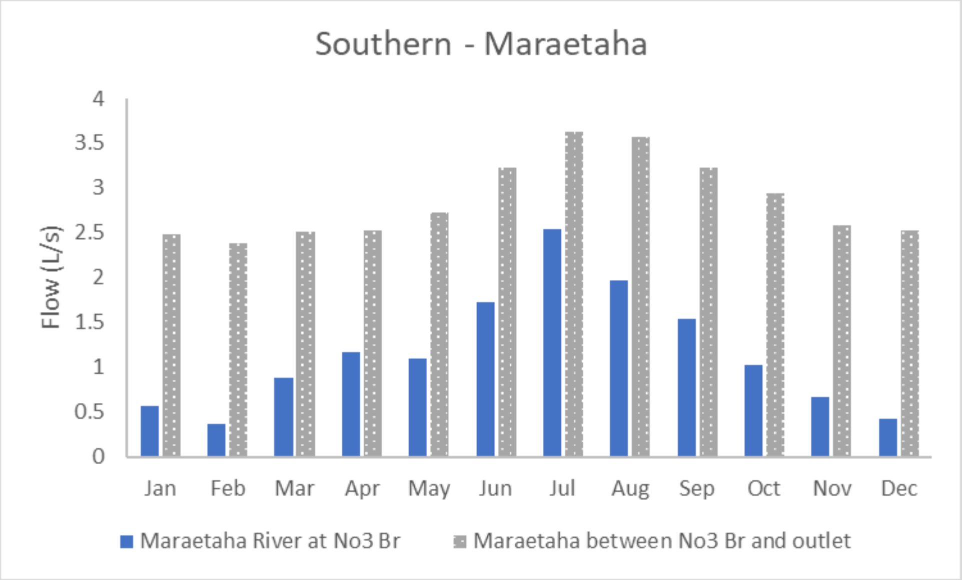


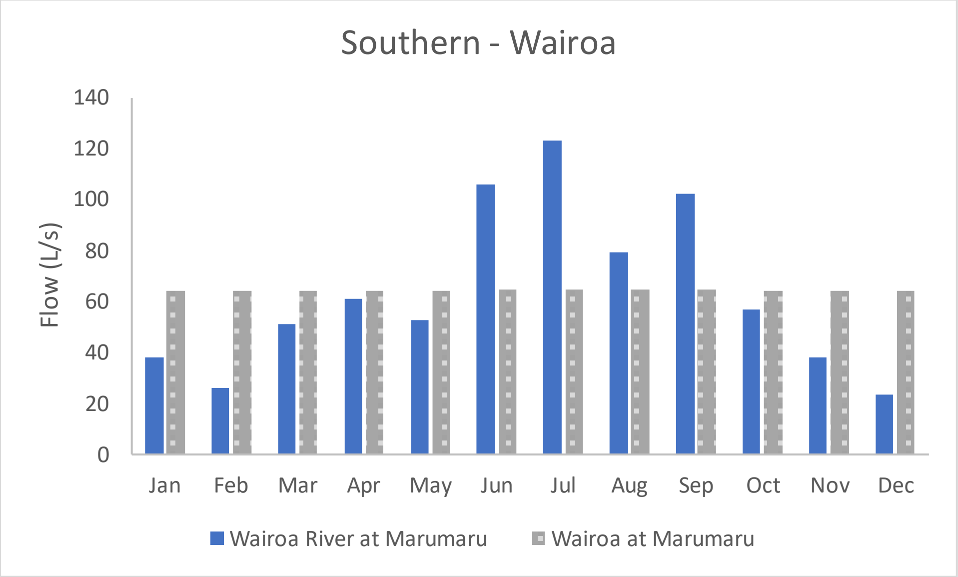



Waimata
Flow (L/s)
0
2
4
6
8
10
12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Waimata River at Goodwins Rd Bridge
Sentinel (Waiomoko)


Motu
Flow (L/s)
0
1
2
3
4
5
6
7
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Motu River at Kotare Station Bridge
Motu US of Kotare Station Br


Waipaoa - Taruheru
Maraetaha
0
0.5
1
1.5
2
2.5
3
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Taruheru River at Tuckers Rd Bridge
Taruheru River at Tuckers Rd Bridge (low to low detided)
Taruheru at Tuckers Rd Br


Southern - Maraetaha
Flow (L/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Maraetaha River at No3 Br
Maraetaha between No3 Br and outlet


Southern - Wairoa
Flow (L/s)
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Wairoa River at Marumaru
Wairoa at Marumaru

Appendix F: Estimated Future groundwater availability

Table 7-3 Current and forecast groundwater availability for all catchments except Waipaoa based on current recharge as calculated by Dark, et al. (2021) and changes in recharge under RCP6 (Collins et al., 2022) in m^3/year

Catchment	Groundwater availability (m^3/year)				Percent change in recharge since 2022		
	2022	2035	2045	2055	2035	2045	2055
Northern	8,118,911	8,138,413	8,139,952	8,168,415	0.24%	0.26%	0.61%
Waiapu	36,310,816	35,001,425	34,516,889	32,986,977	-3.61%	-4.94%	-9.15%
Uawa	8,251,065	8,056,658	8,004,931	7,757,572	-2.36%	-2.98%	-5.98%
Motu	-	-	-	-	-	-	-
Waimata	1,129,113	1,109,843	1,101,657	1,080,197	-1.71%	-2.43%	-4.33%
Southern	2,392,489	2,338,360	2,308,829	2,255,083	-2.26%	-3.50%	-5.74%

Table 7-4 Current and forecast groundwater availability for the Waipaoa catchment in m^3/year. Availability for 2022 is 2020 TRMP allocation limits partitioned by relative aquifer extent in each sub-catchment. Availability for 2035 onwards uses partitioned 2025 allocation limits reduced proportional to changes in recharge under RCP6.0 as calculated by Collins, et al. (2022)

	Year	Aquifer	Upper Waipaoa	Waikohu	Wharekopae	Whakaahu	Te Arai	Mid Flats	Taruheru	Lower Flats	Upper Flats	Total aquifer
Groundwater availability (m3/year)	**2022**	**Makauri**				57,867	35,663	599,932	990,849	18,633		1,702,944
		Matokitoki							567,648			567,648
		Te Hapara Sand					22,025		137,132	135,843		295,000
		Sum sub-catchment				*57,867*	*57,687*	*599,932*	*1,695,630*	*154,476*		*2,565,592*
	2035	**Makauri**				54,973	34,026	569,623	946,465	18,076		1,623,163
		Matokitoki							543,386			543,386
		Te Hapara Sand					21,367		131,458	130,998		283,822

	Year	Aquifer	Upper Waipaoa	Waikohu	Wharekopae	Whakaahu	Te Arai	Mid Flats	Taruheru	Lower Flats	Upper Flats	Total aquifer
		Sum sub-catchment				*54,973*	*55,392*	*569,623*	*1,621,308*	*149,074*		*2,450,371*
	2045	**Makauri**				53,748	33,152	552,486	921,943	17,730		1,579,059
		Matokitoki							530,064			530,064
		Te Hapara Sand					20,957		128,383	128,284		277,624
		Sum sub-catchment				*53,748*	*54,109*	*552,486*	*1,580,390*	*146,014*		2,386,747
	2055	**Makauri**				50,596	31,191	516,509	869,842	17,152		1,485,291
		Matokitoki							501,725			501,725
		Te Hapara Sand					20,274		121,748	122,829		264,851
		Sum sub-catchment				*50,596*	*51,465*	*516,509*	*1,493,315*	*139,981*		*2,251,867*
Percent change in recharge between 2022 and:	**2035**	**Makauri**					-2.99%		-4.14%	-3.57%		
		Matokitoki							-4.27%			
		Te Hapara Sand					-2.99%		-4.14%	-3.57%		
	2045	**Makauri**				-7.12%	-7.04%	-7.91%	-6.95%	-4.85%		
		Matokitoki							-6.62%			
		Te Hapara Sand					-4.85%		-6.38%	-5.56%		
	2055	**Makauri**				-12.56%	-12.54%	-13.91%	-12.21%	-7.95%		
		Matokitoki							-11.61%			
		Te Hapara Sand					-7.95%		-11.22%	-9.58%		