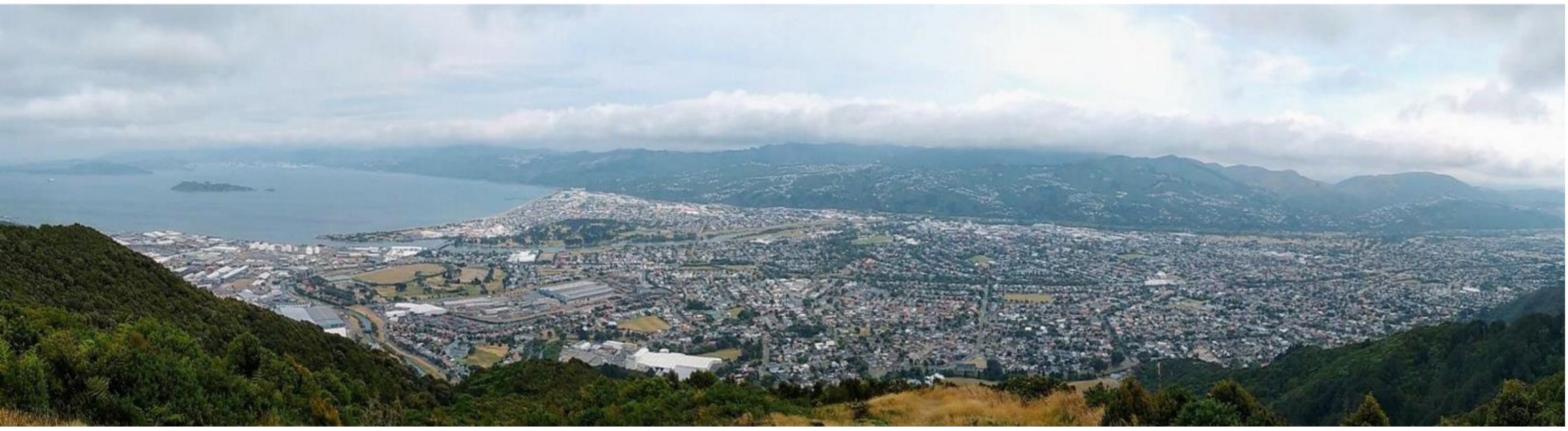
greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Whaitua te Whanganui-a-Tara



Overview of the Wellington metropolitan water supply network and consideration of future pressures on infrastructure

Photo: Taken from Te Whiti Riser, overlooking Te Awa Kairangi (Hutt River) and the Waiwhetu Aquifer beneath Lower Hutt.

Report prepared by:	J Blyth and G Williams	12/6/2020
Report reviewed by:	Wellington Water and Greater Wellington Regional Council staff	19/6/2020
Final version released:	27 July 2020	

DISCLAIMER

This report has been prepared by an independent contractor (James Blyth, Collaborations) on behalf of Greater Wellington Regional Council (GWRC) and a Wellington Water Limited employee (Geoff Williams), for the purposes of providing advice to Whaitua Te Whanganui-a-Tara Committee.

In preparing this report, the authors have used the best currently available data and have exercised all reasonable skill and care in presenting and interpreting these data. Nevertheless, Collaborations, GWRC and Wellington Water do not accept any liability, whether direct, indirect, or consequential, arising out of the provision of the data and use of the associated information within this report for any other purpose. Furthermore, as GWRC and Wellington Water endeavour to continuously improve data quality, amendments to data included in, or used in the preparation of, this report may occur without notice at any time.

GWRC and Wellington Water requests that if excerpts or inferences are drawn from this report for further use, due care should be taken to ensure the appropriate context is preserved and is accurately reflected and referenced in subsequent written or verbal communications. Any use of the data and information enclosed in this report, for example, by inclusion in a subsequent report or media release, should be accompanied by an acknowledgement of the source and discussion with the authors. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the data and project and subsequently re-evaluation of the report conclusions and recommendations.

The report may be cited as:

Blyth, J. M. & Williams, G. 2020. Overview of the Wellington metropolitan water supply network and consideration of future pressures on infrastructure. Prepared for the Whaitua Te Whanganui-a-Tara Committee on behalf of Greater Wellington Regional Council and Wellington Water Limited.

Executive summary

Whaitua Te Whanganui-a-Tara Committee is making recommendations relating to the water supply system. This report addresses:

- Pressure on infrastructure from population increase and climate change
- Infrastructure constraints associated with eco-hydrological scenarios (such as changes to minimum flows or greater abstraction)
- Options to help meet future water demands

The water supply system is operated by Wellington Water, within regulatory limits set by Greater Wellington. It includes a range of water supply, treatment and distribution networks serving a population of ~425,000 people across Wellington City, Lower Hutt City, Porirua City and Upper Hutt City.

Water sources

The urban water supply is abstracted from:

- the Waiwhetu aquifer that underlies Lower Hutt and extends below Wellington Harbour. The aquifer becomes the primary supply through summer (when river levels decline).
- Three rivers, being the Wainuiomata River, Orongorongo River, and the Hutt River at Kaitoke Weir.

It is important that these sources are protected from contamination. In particular, the aquifer may be vulnerable to contamination due to the presence of urban land use above the aquifer, and recharge from the lower reaches of Te Awa Kairangi (Hutt River) which also drain urban land use in Upper Hutt.

The Macaskill Lakes provide raw water storage for ~2-3 months' of supply at normal summer usage. There are concerns that this is insufficient storage and thus that with future population growth, there will be increasing pressures on the water supply network's resilience.

Wellington Water abstractions

There are restrictions on Wellington Water's river abstractions to allow for ecological outcomes. The restrictions limit the water that can be taken during low flow periods, which typically occur at the height of summer when demand is the highest.

There are also limits on how much water can be taken from the aquifer. These limits manage risk from salt water intrusion which, in the future, are likely to increase from sea level rise from climate change.

Wellington Water operate the current infrastructure well below the restrictions on an annual basis (around 60% of the annual average limit), although maximum daily limits are occasionally reached throughout the year.

Wellington Water takes less water than allowed to provide redundancy in the system. An example is where abstraction is required to cease for maintenance reasons and to account for unplanned failures in the network. Inadequate source redundancy could create a supply shortfall that would have significant social and economic implications, particularly in relation to public health.

The water supply network

The majority of the piped water supply network is generally less than 70 years old, and primarily made up of cast iron and asbestos cement pipes. There will be significant financial requirements for pipe replacements in the next 20 years.

Amount of water currently required

As specified by its client councils, Wellington Water aims to supply potable water to meet the average demand in a 1:50 year drought. Currently, due to a constraint at Te Marua water treatment plant (Te Marua WTP), only a level of service (LOS) equivalent to a 1:15 year drought is being met.

Average daily abstraction to meet demand is ~151 million litres per day and additional abstraction above this occurs primarily to turn over water in the Macaskill Lakes (to maintain water quality), with excess water returned to the Hutt River. The 2018/19 gross daily demand per person (including commercial and residential use) is ~357 L/p/day, with residential demand estimated to be ~220 L/p/d. By contrast, Auckland Cities residential demand is ~160 L/p/d. The 2018/19 average daily demand proportioned to ~22% for commercial use, 57% residential and ~21% non-revenue water (water abstracted and lost from the network through leakage).

It is planned to upgrade Te Marua WTP in 2021, so that the current water supply infrastructure can support Wellington's current population and growth over the next ten years to 2030, at the 1:50 year LOS. Over the next 100 years the problem will get significantly worse with average demand expected to be 80% greater than the current average daily demand.

Wellington Water has commenced programmes of work to reduce the daily demand and improve network efficiency (i.e. leak detection and reduction) as the first priorities over any large capital projects (such as storage dams/lakes). Reducing gross demand by 10% could defer large storage projects until 2043.

Wellington Water has identified six work programmes to reduce demand by 2026. These include many improvements to the water network through leak detection, pipe renewals, and smart technologies to improving water use with domestic and commercial customers (through new technologies and smart metering) and promoting water sensitive houses.

Scenarios

Incorporated within this report are four scenarios that were considered by an expert ecological panel (Thompson *et al.* 2020). The hydrological modelling for the ecological panel was ecologically focussed (on impacts within the rivers), and thus did not incorporate network demand or infrastructure constraints, simply assuming 100% of available water was abstracted and utilised. In reality, this would never occur due to network risk and infrastructure constraints. To provide more nuanced infrastructure information for this report, each scenario was also assessed through Wellington Water's Sustainable Yield Model (SYM) which models the dynamic interaction between water flow in the natural and built environment.

The outputs of the four scenarios simulated in SYM were then considered to understand the potential effects these could have on the ability to meet demand, and what water supply options might be available to help meet future demands.

The scenarios were:

- maximum use of existing allocation (100% abstraction of maximum consented amounts available under the GWRC natural resources plan)
- decreased allocation (with a higher minimum flow at surface water takes) and finally,
- increased allocation (to theoretical maximums in the Waiwhetu aquifer and a lower minimum flow at surface water takes).

A 'naturalised' flow (all abstractions 'turned off') scenario was also simulated as a reference baseline to show the extent of eco-hydrological change from abstraction, however was not intended to be considered as a likely scenario to meet water supply.

The naturalised flow scenario

Whilst the naturalised flow is unlikely to occur in practice, some consideration was given to alternate water sources. Salt water desalination would be a potential option, although would require significant capital outlay likely exceeding $1B, with large OPEX costs; in particular, annual power costs could be up to 8 times greater than current potable network usage.

The maximum allocation scenario

The maximum allocation scenario showed this could provide sufficient water until approximately 2070, if combined with Te Marua WTP upgrades, a 20% demand reduction and a new off-river storage lake.

The decreased allocation scenario

Implementing a higher minimum flow on the three rivers and thus decreasing the allocation for Wellington Water would immediately reduce the LOS based on current infrastructure. This could be offset with Te Marua WTP upgrades and demand reduction of around 10%. Construction of additional offline storage would still be required by 2030 under this scenario unless further demand reduction could be achieved. As an example, if the ~$250 M third lake at Te Marua was constructed along with the treatment plant upgrades and the 10% gross demand reduction achieved, demand (due to population growth) would be met to ~2048 when additional source capacity would be required, .

The increased allocation scenario

The final scenario considered increased allocation based on:

- the maximum safe abstraction from the Waiwhetu aquifer before saline intrusion occurs and;
- a lower minimum flow in the rivers, such as 400 L/s at Kaitoke Weir in the Hutt River.

A number of supply options were considered with this scenario to align with the Committee's 100 year vision, for indicative purposes only (these may or may not be the options considered). If all the following were achieved, projected average demand could be met to ~2115 and a population of 765,000:

- 20% gross demand reduction,
- a new off-river storage lake,
- an on-river storage dam,
- a borefield upgrade that provided more water from the aquifer, and
- Te Marua WTP upgrade.

Comparing the scenarios

Figure 1 shows a summary of three allocation scenarios and the population supported (naturalised flow has not been presented as was considered unlikely to occur). There are numerous water supply options that can be considered, and this exercise is intended to provide a snapshot of the infrastructure constraints the whaitua is likely to face with future population growth, and possible solutions.

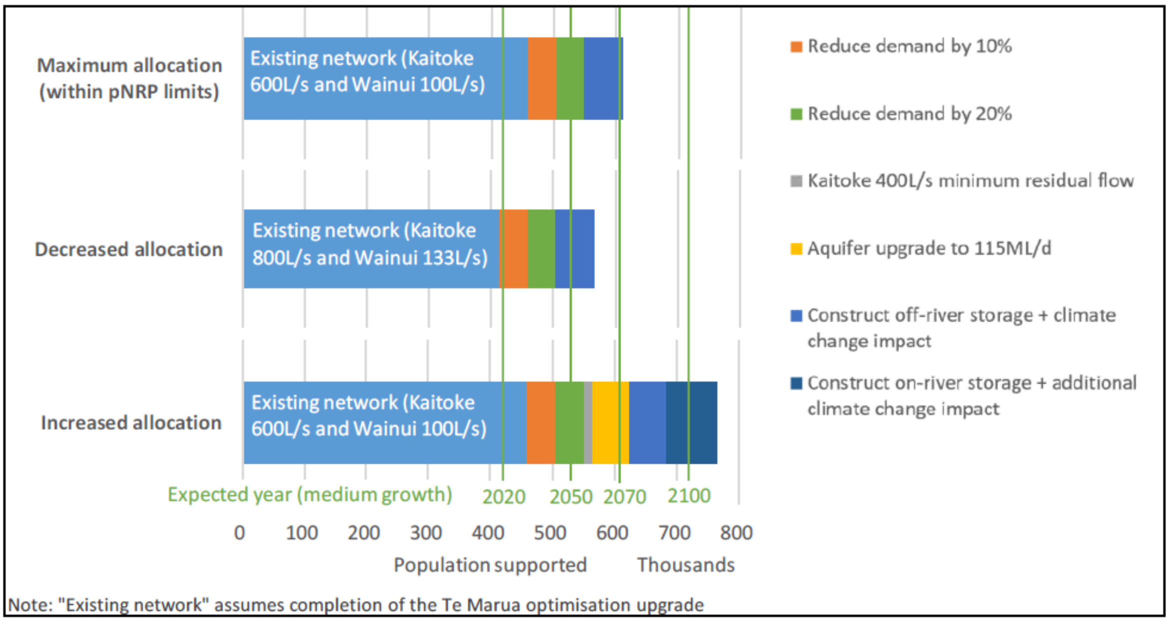


Figure 1 Allocation scenarios and population supported

Looking forwards

Councils have expressed a clear preference to conserve water rather than construct new infrastructure although increasing supply capacity may still be required to meet growth in the longer term.

There are ranges of future options that can be considered, additional to the supply/demand strategies already in place. The intent of these reports wasn’t to model every possibility, only to present the potential supply shortfalls that will face Wellington over the next 100 years. Deferring large capital projects will provide benefits in terms of promoting sustainable water use and reduced carbon footprint, however at some point in the near future consideration of a new water supply source or storage scheme will be necessary. A range of high level options have been discussed in this report including storage, water recycling (wastewater reuse), local harvesting (stormwater and rainwater) and seawater desalination.

Contents

1. Introduction

1.1 Background and objectives

This report provides an overview of the potable water network issues and challenges within the Whaitua Te Whanganui-a-Tara. The primary audience for this report is the Whaitua Committee.

The potable (drinking) water network makes up one component of the ‘three waters’. Abstraction and use of water is a fundamental requirement for human health and economic prosperity; however, with increasing demands from population and economic growth, water supply sources face increasing pressures from abstraction. The subsections below provide high level summaries on the main challenges the network faces within the Whaitua, including aspects such as the condition and makeup of the network assets, regulations and drinking water reforms, and strategies to optimise the water network through demand management or infrastructure upgrades.

Finally, the report will also consider the infrastructure implications of some of the Whaitua Flow/Allocation Scenarios, which were considered by an Expert Panel relative to some of the National Objective Framework (NOF) attribute states within the National Policy Statement for Freshwater Management (NPSFM 2014, amended in 2017) and also wider ecosystem health of rivers and streams that may be affected by abstraction. The Expert Panel considered the effects on a number of ecological metrics at various river locations, as a response to scenarios (such as increased or decreased abstraction) (see Thompson *et al.* 2020). This report is written following the context of the Whaitua’s 100 year vision.

2. Current water abstraction and policy settings

2.1 Regulatory framework

2.1.1 Current framework and Wellington Water makeup

As described in Blyth (2020), within this Whaitua, Wellington Water Limited (‘Wellington Water’) manage and operate the three waters network across three stakeholders; Hutt, Upper Hutt and Wellington City Councils. A proportion of rates are allocated to Wellington Water annually, in addition to revenue that is received from occasionally charging third parties for work performed. In 2018 and 2019 the total revenue (covering the three waters) was ~$154 Million and ~$136 Million, respectively (Wellington Water Limited 2019). There was a decline in 2019 due to the deferral of some large planned CAPEX projects.

CAPEX expenditure is intended to provide a snapshot of the investment over 2 years, however it should be noted that this may not reflect the level of service provided. Expenditure can vary across regions and cities depending on a range of factors, such as water resource availability, climate and topography. Wellington has the benefit of large source protected river catchments and a high yielding aquifer close to the city, which has meant reduced requirements for large storages.

Under this funding framework, Wellington Water can undertake strategic planning but cannot modify the funding regime except through recommendations and long-term planning with stakeholders.

The Water Performance Report (Water New Zealand 2020) details the various infrastructure costs for the three waters networks annually. Over two years (2018 and 2019), the average capital expenditure for the potable (drinking) water network per property in Wellington was ~$232, 14% less than the average across 5 cities, and ~35% less than Auckland. See Table 1.

Table 1. Average annual capital expenditure on the potable network (per property) over 2018 and 2019 financial years.

City/Entity	$/year/property	Difference (from 2 year average)
Auckland	$313	16%
Tauranga	$309	14%
Hamilton	$309	14%
2 year average (5 towns)	$270	-
Wellington Water	$232	-14%
Christchurch	$188	-31%

Wellington Water works across a number of local and central government regulations, however the primary legislation that influences water supply service delivery (including meeting environmental and public health requirements) is shown in Figure 2.

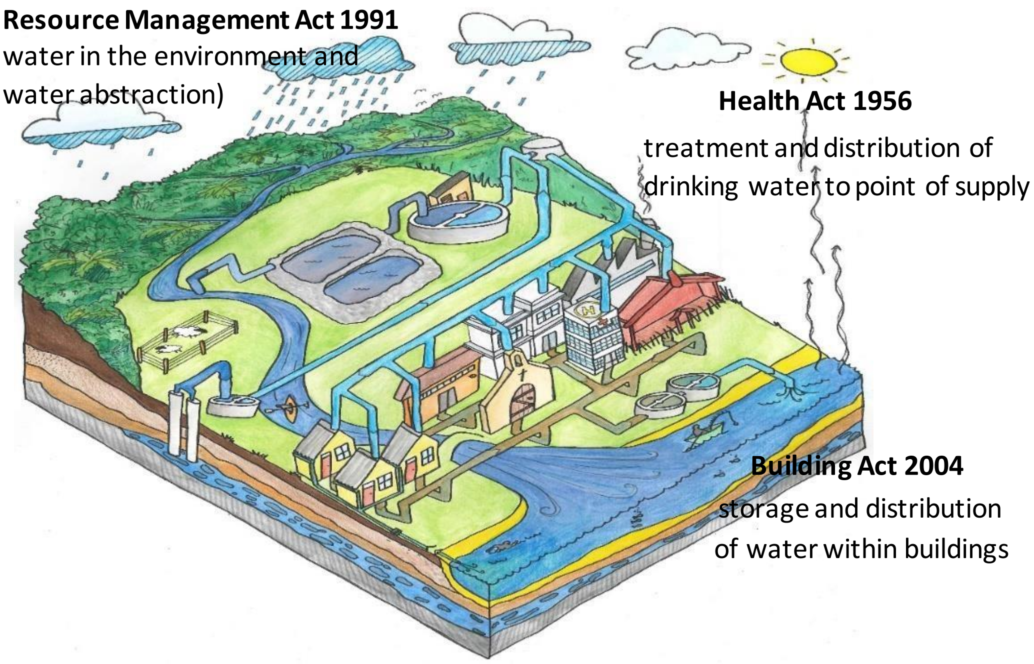


Figure 2 Key water legislation

The legislative framework means that the responsibility for managing water moves from Regional Councils to Water Utility providers at the point of abstraction, then to Territorial Authorities from the point of supply (property boundary) to the point of use (i.e. within buildings), back to Water Utility providers for wastewater collection and treatment, and then back to Regional Councils for discharge to the environment. The three waters components of the legislation were not drafted from a holistic “source to sea” perspective and there are many cases where the requirements result in ownership of risks not falling with decision-makers. Examples include:

- Regional Councils are responsible for setting water allocation limits (RMA) but Water Utility providers are responsible for maintaining a continuous supply (Health Act).
- Regional Councils are responsible for managing source water quality (RMA) but Water Utility providers are responsible for delivering safe drinking water (Health Act).
- Territorial Authorities are responsible for managing backflow risks from properties (Building Act) but Water Utility providers are responsible for delivering safe drinking water (Health Act).

The above examples are illustrative and there are many more that contribute overall to a responsibility framework that is inefficient and increases risk to public health. Resolving a number of these issues is the subject of the Government Three Waters Review discussed below.

2.1.2 Three waters review

The Three Waters Review is a cross-government initiative led by the Minister of Local Government. The review began in 2017 and ran in parallel to the latter stages of the Government Inquiry into Havelock North Drinking Water, which was set up following the campylobacter outbreak in 2016 (resulting in up to 4 deaths and 5,500 people being ill) (DIA 2020). The focus of the review has been on:

The review considers three essential aspects of the three waters (DIA 2020):

1. Health and safety: safe drinking water, safe disposal of wastewater and effective stormwater drainage.
2. Prosperity: adequate supply of cost effective three waters services for housing, businesses and community services.
3. Environment: well managed extraction of drinking water, and careful disposal of wastewater and stormwater.

Central Government has started work on establishing the new Water Services Regulator - Taumata Arowai. A Water Services Bill is planned to be introduced to parliament in 2020. The Bill is expected to introduce new regulatory requirements for water utility companies, Regional Councils and Territorial Authorities. Central Government has also confirmed its commitment to partnering with local government to consider options for transitioning councils to new service delivery arrangements (DIA 2020).

2.1.3 Action for Healthy Waterways

Central Government is looking at ways to improve management of freshwater in New Zealand. Current proposals are outlined in *Action for healthy waterways: Our proposals, your views*, which will seek to update the existing NPSFM 2017 (amended) and incorporate new national environmental standards.

Whilst this process is underway, it does identify that the future importance of our drinking water supplies could likely be considered in a holistic manner that encompasses ecology, water quality, and cultural values. A significant component of Te Mana o Te Wai framework is a values hierarchy, with primacy given to the health of the water body, then human needs (drinking water), then other water uses (e.g. that address wider social and economic values).

2.2 Source protection and catchment management

The importance of the Hutt and Wainuiomata/Orongorongo rivers as a clean and reliable source of water for Wellington's growing community was recognised in the late 1800's. An essential part of maintaining the quality and quantity of water over the years has been the ownership, protection and active management of the land to achieve good water supply outcomes.

Water supply and environmental outcomes have very good alignment because a healthy catchment is needed to produce safe water. Protection of land for current and future water supplies has resulted in extremely good water quality and preservation of a high level of ecological health. This contrasts significantly with adjacent and sub-catchment land subject to urban development, farming and forestry. The current situation with protected catchments in this Whaitua is extremely rare both nationally and internationally.

Water supply source protection is discussed below and is a key issue for the Committee because it is hugely beneficial for the community water supply while contributing significantly to achieving long term ecological outcomes.

2.2.1 Water collection areas management plan

The surface water collection areas are actively managed to protect their long term health to ensure they supply consistently high quality water. A plan[1] is in place that focuses on management of the water catchments of the Hutt and Wainuiomata/Orongorongo rivers upstream of the water intakes. The plan defines the primary purposes of water collection area management as:

- Supplying water to meet drinking water quality standards to the Wellington metropolitan areas and minimise water treatment
- Minimising risks of water supply contamination to be compatible with the objectives of the Water Safety Plans as mandated by the Health Act
- Providing a naturally resilient water catchment area through the maintenance of healthy catchment ecosystems to optimise water supply.

The water collection areas also have intrinsic biodiversity value and offer some opportunities for recreation activities. This is recognised in the plan with other purposes for water collection area management identified as:

- Protect and enhance the regionally significant biodiversity values.
- Provide for limited recreation activities.

[1] Hutt and Wainuiomata/Orongorongo Water Collection Areas Management Plan

Figure 3 shows the parts of the catchment covered by the management plan as well as areas designated for future water collection.

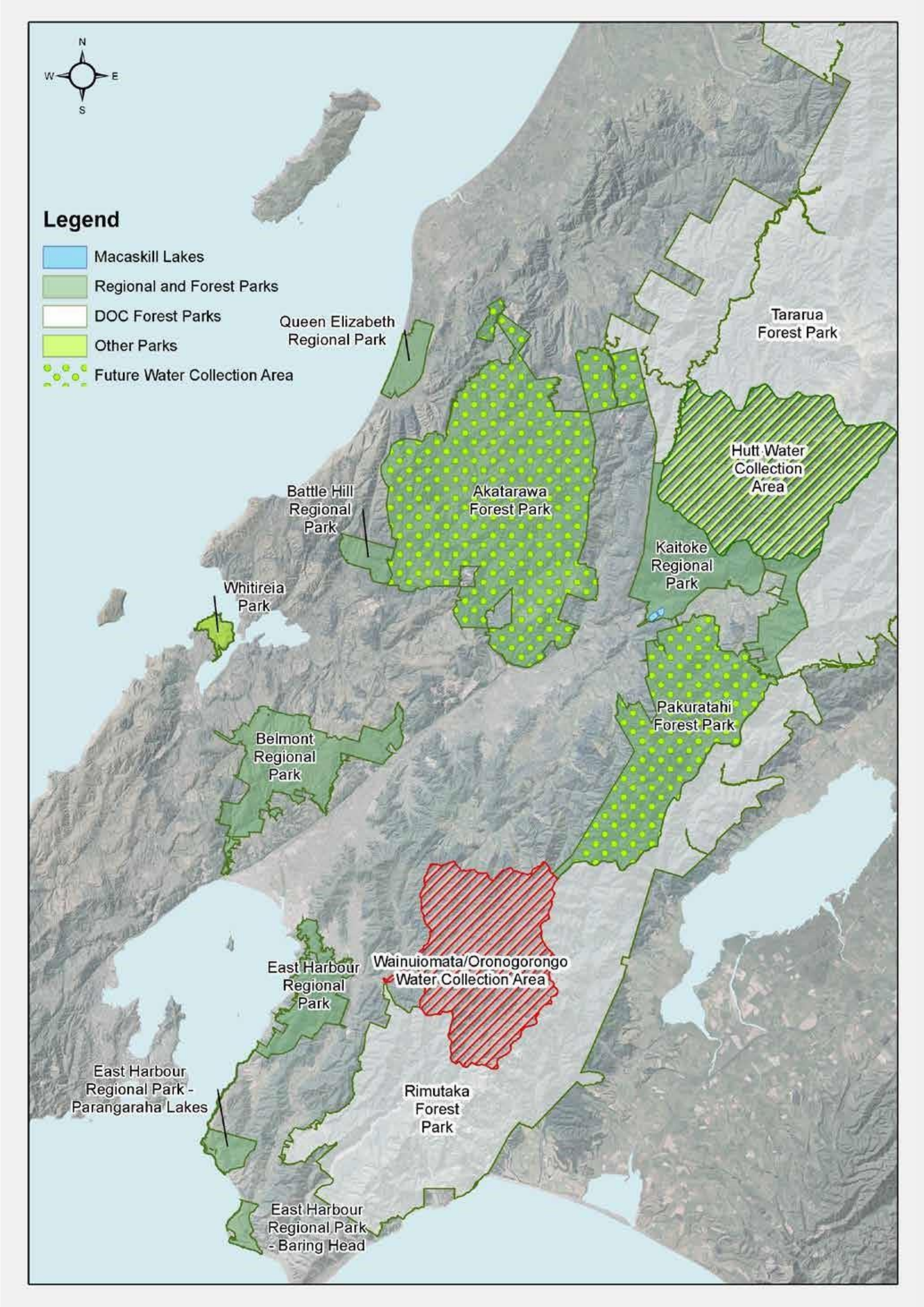


Figure 3 Designated water collection areas for existing and future surface water sources

2.2.2 Waiwhetu aquifer

A catchment assessment completed in 2008 reviewed contamination risks for the Waiwhetu aquifer[2]. At the time it was assumed that the Waiwhetu aquifer was protected by a continuous confining layer and the risk of contamination from shallow groundwater was low. This was shown to be incorrect, with the discovery of bacterial contamination in 2016/17. Subsequent investigations revealed that the confining layer was actually thin and not continuous in the Waterloo bore field area, exposing a significant geological vulnerability[3]. It was also shown that operation of bore pumps along Knights Rd creates a widespread drawdown effect across much of central Hutt City. The combination of poor aquifer confining properties and strong potential for downward flow has significantly changed the risk profile for the Waiwhetu aquifer. Figure 4 shows the five key areas of water supply risk management and the significant vulnerability created by source protection uncertainty.

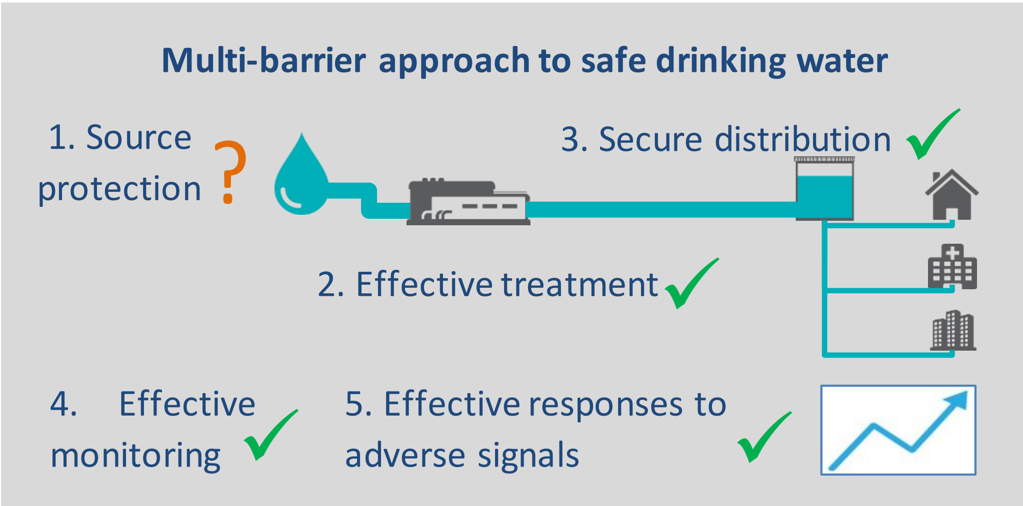


Figure 4 Current multi-barrier approach to safe drinking water for the Waiwhetu aquifer source

GWRC's proposed natural resources plan (pNRP) has recognised some of the aquifer source-related risks by expanding the '*groundwater supply protection area'* to include the entire Lower Hutt valley floor. This area has greater restrictions within the plan around development and discharges of contaminants.

The pNRP also includes a newly defined area called the '*Hutt community drinking water supply catchment area'* that recognises that contaminants discharged anywhere in the wider catchment may flow through the catchment and affect aquifer water quality via recharge from the Hutt river (see Figure 5). Permitted activities are not restricted in this area, however discharges requiring resource consent will be assessed against plan policies (policy P69) relating to National Environmental Standards for Sources of Human Drinking Water 2007.

[2] Waiwhetu aquifer catchment assessment [550545]

[3] GWRC aquifer investigation Stage 1 Final Report - Waiwhetu Groundwater Quality Assessment

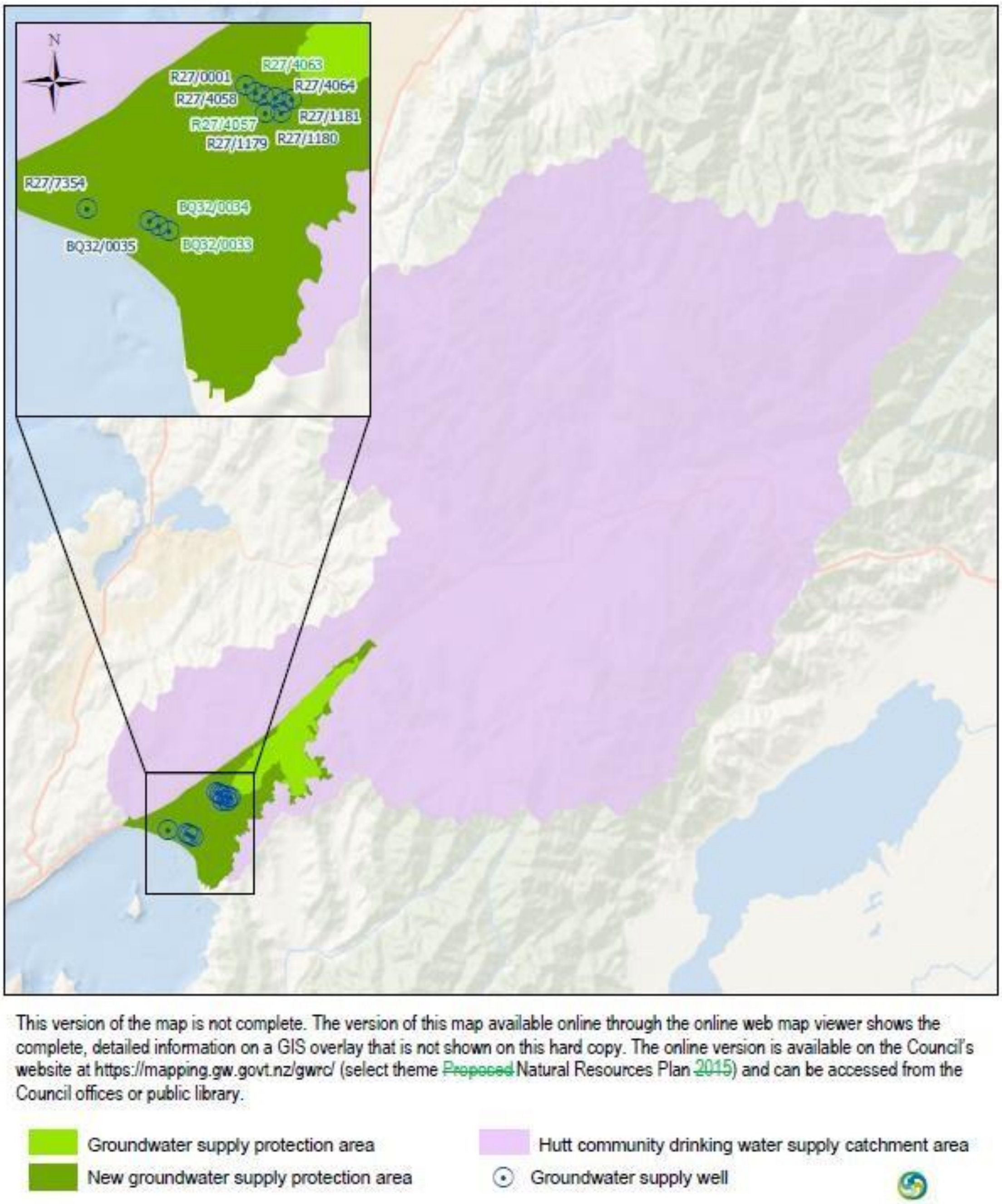


Figure 5 Groundwater community drinking water supply protection areas

There remain significant unmitigated water quality risks that will require a collaborative approach between Wellington Water, Greater Wellington Regional Council (GWRC) and Hutt City Council (HCC) to resolve and manage appropriately. Figure 6 shows the staged response to the increased aquifer vulnerability, and the status of key work streams. This will work across the regulatory (and planning) frameworks to identify the best ways to protect the aquifer given the constraints of the urban environment.

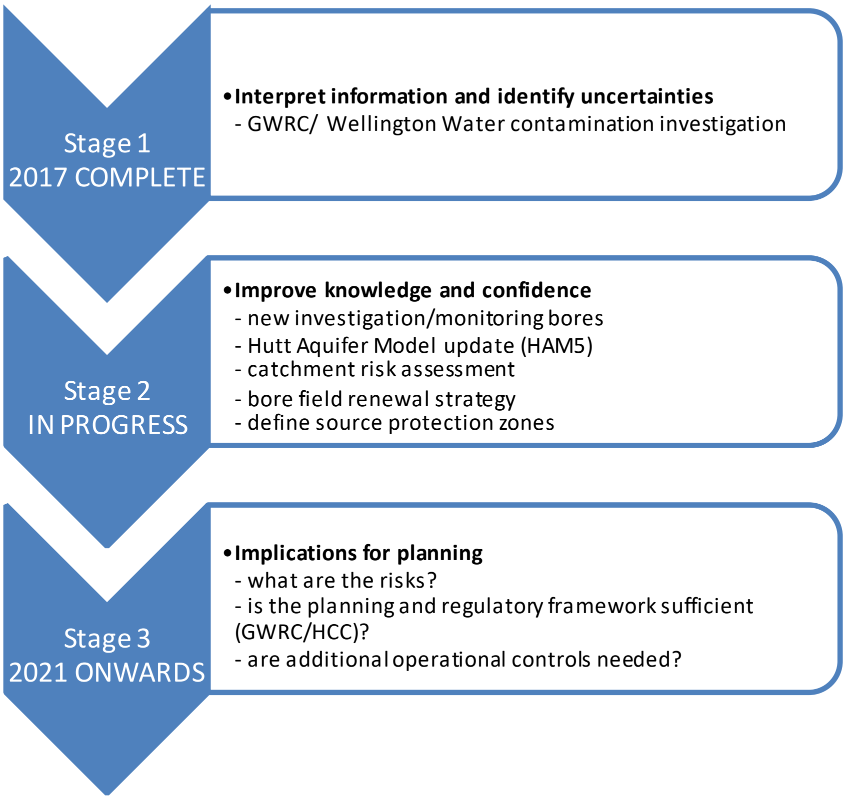


Figure 6 Staged response to addressing increased aquifer vulnerability

2.3 Current state of drinking water infrastructure

2.3.1 Water infrastructure

The water supply to the four cities in the Wellington regional metropolitan area comes from three sources:

- The headwaters of the Hutt River, abstracted from an intake at Kaitoke weir, treated at Te Marua Water Treatment Plant (WTP), while raw water is also stored in the Macaskill lakes for use during summer.
- The Wainuiomata and Orongorongo catchments, abstracted from river and their tributary stream intakes and treated at the Wainuiomata WTP.
- The Hutt Valley artesian groundwater system, primarily extracted and treated at the Waterloo WTP although there is a standby treatment plant at Gear Island, Petone.

The typical breakdown of supply from each WTP on an annual basis is Te Marua 42%, Waterloo 45% and Wainuiomata 12%. During summer when the rivers recede, Waterloo WTP accounts for up to 70% of the whole network's supply on a daily basis, with the Wainuiomata (and Orongorongo) supplies being restricted the earliest.

Figure 7 shows the extent of the water supply network including catchments, water abstraction points, treatment plants and the main distribution pipes and pumps.

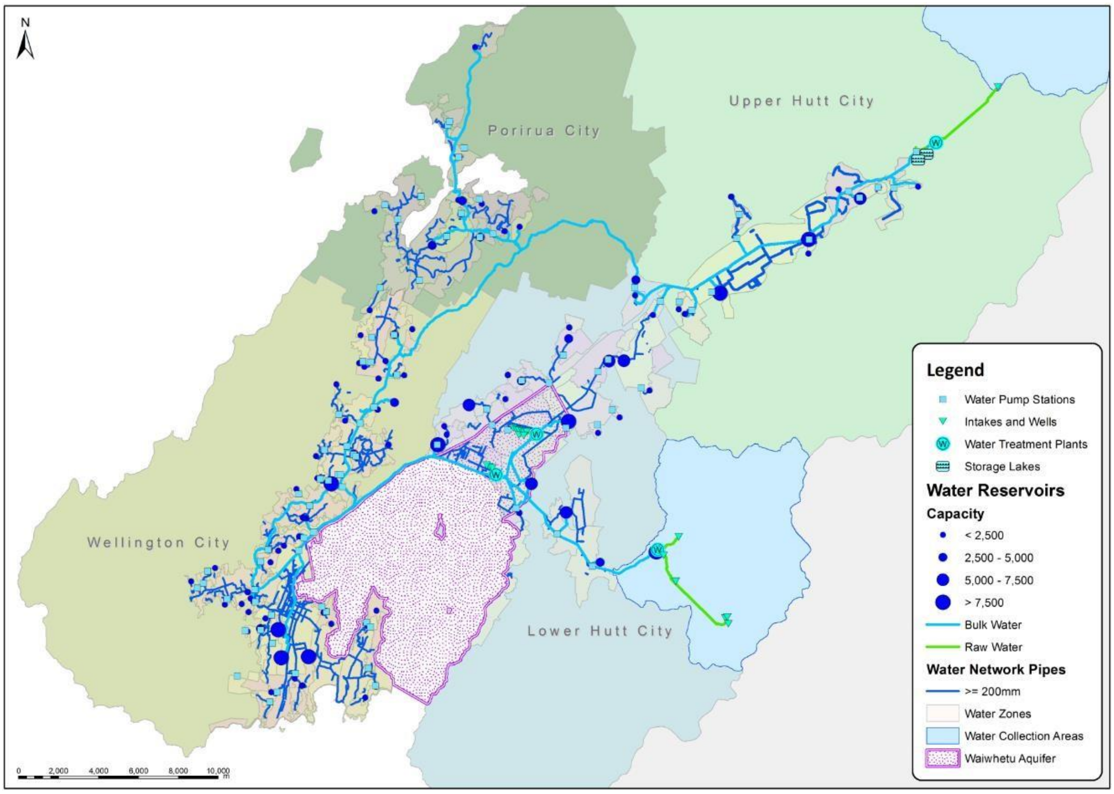


Figure 7 Regional water supply network

The total asset value of water supply infrastructure across the five councils comprising the Wellington regional metropolitan area is approximately $3 Billion. Table 2 shows a summary of the numbers of assets by type, and Figure 8 shows how the total asset value is spread across these assets. The majority of the total investment in water supply infrastructure is in the pipe network (around 75%).

Table 2. Water supply asset type summary

Asset Type	Total
Pipes (km)	2,378
Pump Stations (no.)	89
Water Storages (no.)	180
Water Treatment Plants (no.)	4
Tunnels (km)	9.4

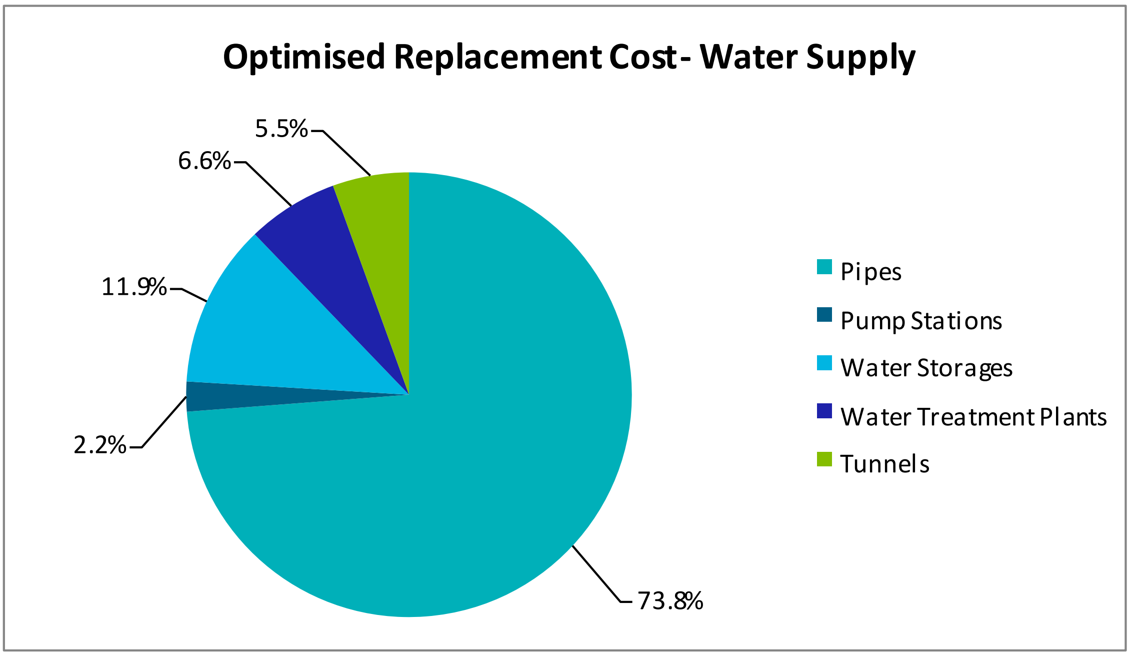


Figure 8 Water supply network replacement cost by asset type

Figure 9 shows the pipe age and material profile. The majority of the water supply network is less than 70 years old, and the majority of the pipes older than 70 years are made from cast iron. Cast Iron pipes can last over 100 years but are fragile and vulnerable in an earthquake. Asbestos cement pipes typically have shorter lives of 80 years or less and are also fragile. Renewal of aging asbestos cement pipes represents a significant financial challenge over the next 10-20 years.

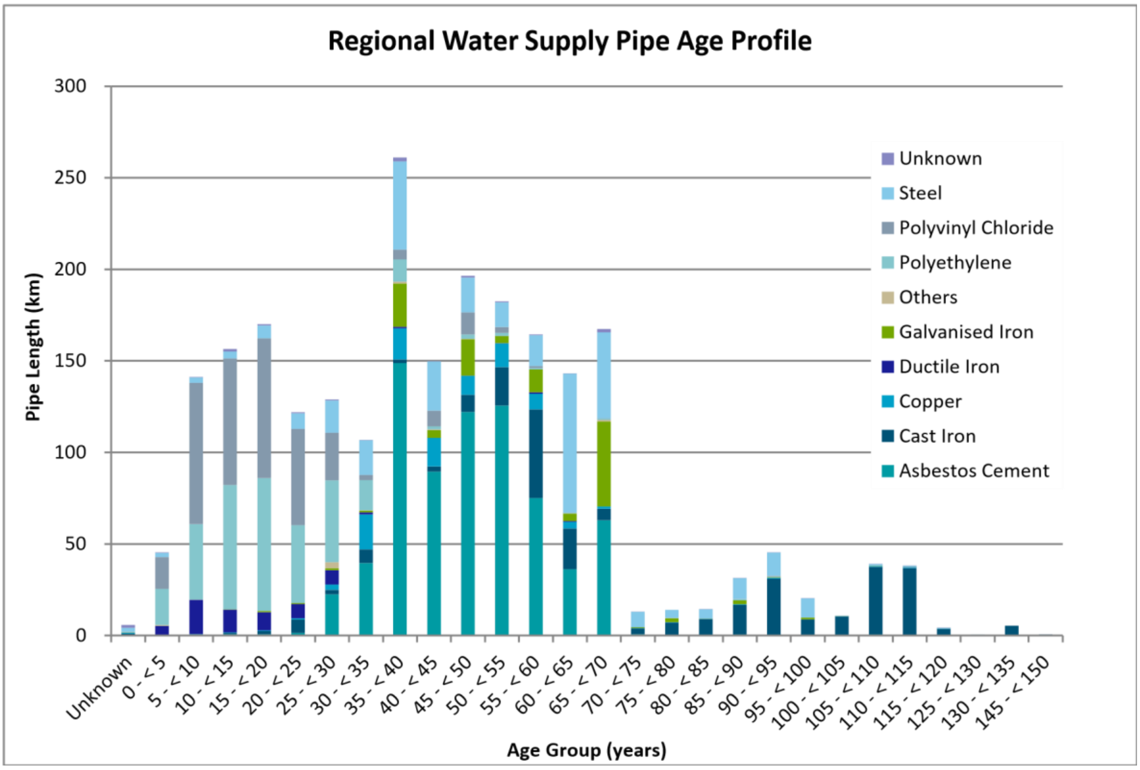


Figure 9 Pipe age profile showing length and material

2.3.2 Water takes

The water sources described below include water catchments, intakes / well structures and water treatment plants. The Hutt River water collection area covers 8,963 hectares of mountainous terrain at the southern edge of the Tararua Ranges. The quantity of water taken from the river is limited by Resource Consents to ensure sufficient water remains to maintain the health of the river.

Figure 10 Kaitoke intake on the Hutt River

On days when not all the water taken from the river is required for supply, some is diverted to the Macaskill storage lakes at Te Marua. The lakes have a combined usable capacity of 3,350 ML (where 1 megalitre (ML) is equivalent to 1,000,000 litres). Stored water is pumped back to Te Marua WTP when river flows are too low to meet demand, or when the Kaitoke intake has to be turned off during river fresh events – typically a day or two following most rainfall events.

Figure 11 Te Marua treatment plant and Macaskill lakes

The Wainuiomata/Orongorongo water collection area is part of the Remutaka Ranges to the east of Wainuiomata. The catchment covers 7,601 hectares. As with the Hutt River supply the quantity of water taken from the Wainuiomata and Orongorongo Rivers is limited by Resource Consents to ensure sufficient water remains to maintain the health of the rivers.

Figure 12 Wainuiomata treatment plant

Land upstream of all river abstraction points supplying Te Marua WTP and Wainuiomata WTP is owned and managed by GWRC. The forested catchment lands have been under the control of GWRC or its predecessor authorities for many years, with active control of pest plants and animals and strictly controlled public access. A comprehensive description of the catchments and the management framework is provided in GWRC 2016. The quality of the water coming from these catchments is very high and the contamination risks are low.

The confined Waiwhetu aquifer is a highly transmissive alluvial gravel sheet beneath Lower Hutt and the Wellington harbour. It is recharged from the Hutt River downstream of Taita gorge and becomes confined by a layer of fine material above the gravels at around Kennedy Good Bridge. The Waiwhetu aquifer is artesian meaning it is pressurised and water from a bore will flow naturally to the surface. The confining layer known as the aquitard extends to the heads of the Wellington Harbour, and helps to protect the aquifer from contamination by shallow groundwater and salt water intrusion. Natural filtering of the water while underground as well as the positive artesian pressure also help protect the quality of the water. Figure 13 shows a diagram of the Hutt aquifer system including the Waiwhetu aquifer.

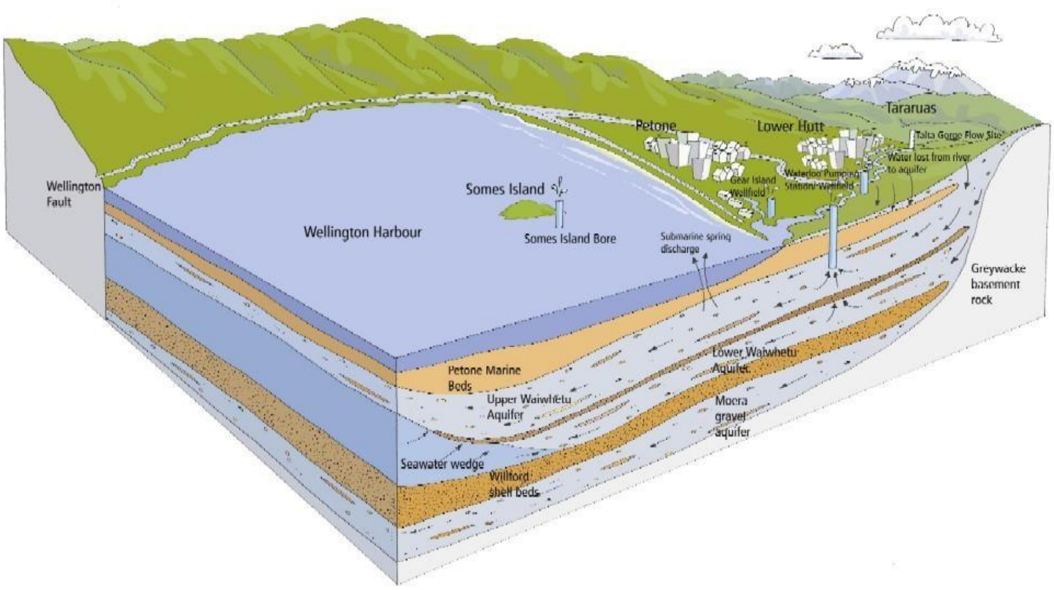


Figure 13 Diagram of the Hutt aquifer system showing the Waiwhetu aquifer

Until 2017, the Waiwhetu aquifer was considered a secure groundwater source and water supplied to the Hutt Valley from Waterloo WTP was not treated for microbiological contamination, with no chlorination or ultraviolet light treatment. Following *E.coli* contamination in late 2016 and early 2017 and after extensive investigations, it was concluded the source could no longer be considered secure. All water leaving the treatment plant is now disinfected with chlorine and ultraviolet light.

The Waterloo WTP shown in Figure 14 does not include treatment processes to remove chemical contaminants (for example, Bisphenol A or BPA). Retrofitting the plant to achieve this would be costly and is unlikely to be possible on the existing site. Subsequently, catchment source protection areas are highly important for ensuring good drinking water quality while reducing infrastructure and treatment costs.

Figure 14 Waterloo treatment plant

Maintaining overall water supply capacity above expected demand is critical to mitigate the serious consequences of shortfall during droughts and operational outages. Table 3 is a summary of average annual water take volumes for the period 2003-2019. The purpose of this table is to show the extent to which consented takes are utilised with current infrastructure.

Table 3. Seven day average annual water abstraction and demand summary for the period 2003/04 to 2018/19 (ML/d)[4]

Description[4]	Consented Water Take	Average	Maximum	Minimum
Wainuiomata and Orongorongo	60 reducing to 0*	25	48	2
Hutt River at Kaitoke	150 reducing to 0*	92	140	16
Artesian Aquifer (Waterloo and Gear Island)[5]	115 reducing to 0** on a daily basis and 83.1 annually	64	87	45
Total abstraction	325 to 0 (daily) and 293 (annual)	181	242	100
Total demand	-	146***	173	132

* subject to river low flow limits,

** subject to aquifer saline intrusion limits.

*** less than the 151 ML/d average demand presented in report as is calculated off a 7-day average annual abstraction over a longer timeframe. Additional water abstracted (versus the average demand) is primarily used at the Macaskill Lakes for water quality improvement.

Observations from Table 3 are:

- Average annual abstraction across the four catchment water sources is around 60% of the total annual consented water take. However, this does not imply there is substantial headroom for further take available, because the consented water takes are constrained by low flow limits during summer.

- Average abstraction is about 25% greater than average demand. This is mainly to provide for flushing and turn-over of the Macaskill Lakes during winter[6]. Without regular flushing the lakes would develop significant water quality issues and become unusable. This is a relatively common water supply issue – particularly with off-river storages like the Macaskill Lakes.

- Daily total abstraction reduces to around 100 ML/d each summer due to low flow consent limits. Low flow limits in the resource consents result in Wainuiomata WTP having to be shut down most summers and the take at

[4] day mean annual flows averaged over the period 2003/04-2018/19. Calculation methodology is equivalent to calculating a Mean Annual Low Flow for rivers except applied to max values as well as min)

[5] Most of the abstraction is at Waterloo WTP. Gear Island WTP is a standby treatment plant.

[6] The bulk water network has very low leakage levels – estimated at less than 2%, or within the accuracy of the metering equipment.

Kaitoke reducing to 20 ML/d or less. The saline intrusion limit (expressed as a groundwater level trigger) is also a constraint for aquifer abstraction and results in aquifer pumping being reduced during critical periods during summer. When abstraction is constrained to less than demand, the balance is met by drawing on storage in the Macaskill Lakes.

- The wide range between maximum and minimum water takes show that the consent limits are well utilised operationally. Instantaneous values would be expected to show 100% utilisation at times, but in this case 7-day averages have been given to highlight a more generalised pattern. Figure 15 below illustrates how surface water consents are fully utilised during summer where declining river flows requires increasing use of Macaskill Lake storage. During the summer of 2007/8 total supply from rivers dropped to only 15 ML/d in early March 2008. Similar patterns occur in most dry summers.
- Usage of river sources decreases significantly in summer and increases in winter. The opposite is true for the aquifer. Aquifer utilisation increases significantly in summer to preserve Macaskill Lake storage during droughts.

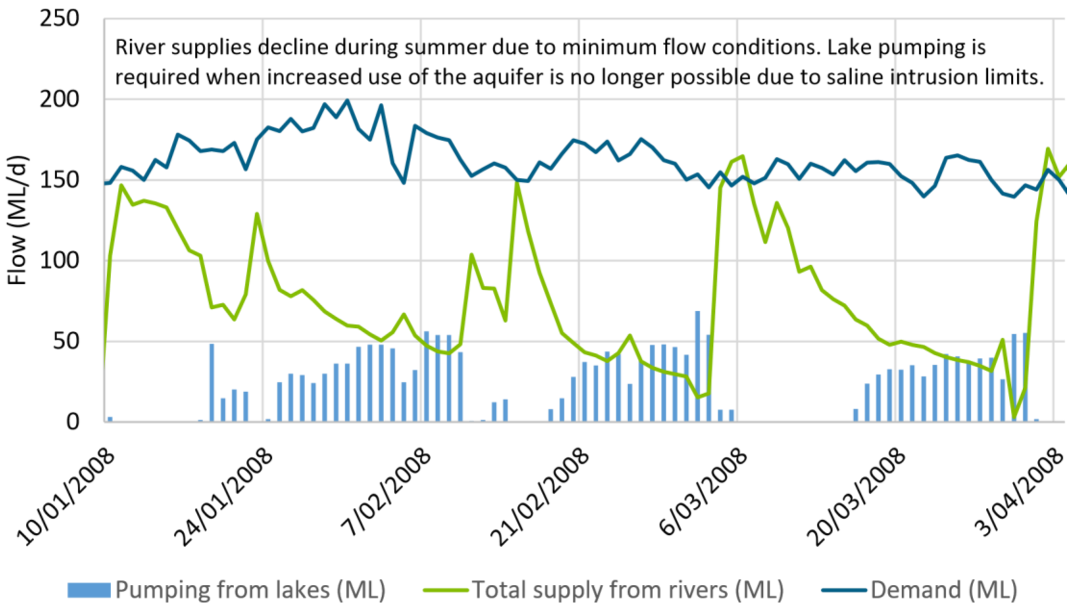


Figure 15. Example showing the daily demand and water supply from rivers from 2008. The demand generally exceeds 150 ML/d, however river supply (green line) decreases due to flow restrictions, resulting in makeup water from the Macaskill storage lakes (and the Waiwhetu Aquifer, which hasn't been presented).

Reliability modelling has shown that the current water supply infrastructure is operating at about 90% of the safe limit. This is discussed further below but shows that there is only limited ability to increase consent utilisation without building additional infrastructure such as offline storages.

3. Sustainable water supply

A safe, reliable and sustainable water supply is fundamental to achieving public health and the social, cultural, environmental and economic prosperity of the region. However, water in the Wellington Region is limited, and distribution and consumption should occur in a way that avoids wastage and encourages efficient use of water.

A strategic case was recently completed which identified key problems preventing achieving a sustainable water supply, as well as opportunities and benefits.

3.1 The strategic case

Wellington Water aligns their activities with three high level customer outcomes and 12 service goals as set out in the Three Waters Strategy. Having a sustainable water supply contributes to all three high level outcomes, which are specifically:

- Safe and healthy water
- Resilient networks support Wellingtons economy
- Respectful of the environment

The Sustainable Water Supply strategic case identified three key problem statements (drivers for change):

- **demand for water will exceed capacity to supply** - current water consumption and a growing population will lead to water shortages by 2030 under existing infrastructure
- **Wellingtons water sources and networks are vulnerable** - threats to vulnerable water sources and networks are compromising our ability to maintain supply
- **there may be less water available for us to use** – potential reduction in the current water take to meet environmental needs may constrain ability to supply community and customer needs.

A sustainable water supply will be present when the following benefits are realised:

- appropriate water available to support economic, social, environmental and cultural wellbeing
- improved efficiency of supply across the whole network
- improved environmental outcomes at source

The following sections describe the key level of service provided to the community and quantifies the extent of the most significant problem facing sustainable water supply - demand for water exceeding supply capacity.

3.2 Level of service (LOS)

The drought resilience level of service is: *Sufficient water is available to meet normal demand except in a drought with a severity of greater than or equal to 1 in 50 years*. Normal demand includes routine odds/evens watering restrictions during daylight savings.

Figure 16 shows how the drought resilience performance of the network will change as population and demand increases.

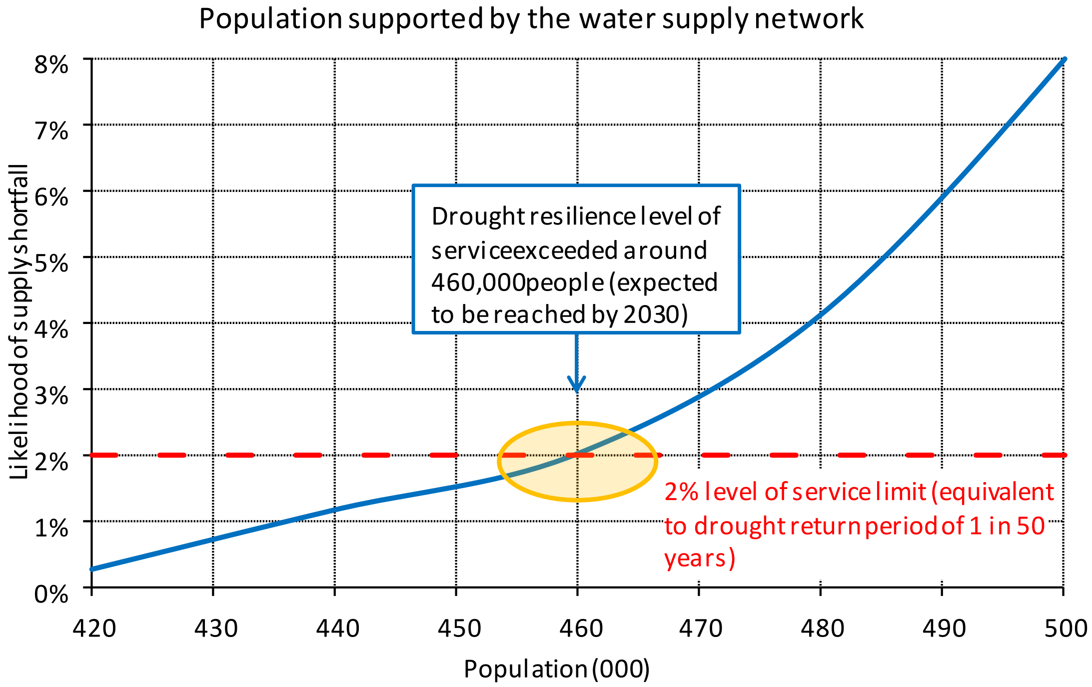


Figure 16 Drought resilience performance of the water supply network (inclusive of Te Marua upgrade to 125 ML/d). As the population increases above 460,000, the level of service and drought resilience will decrease.

At the current population of around 425,000 people there is a shortfall probability of around 8% compared with the standard of no more than 2% (1 in 50 year return period). This is because of a significant treatment constraint at Te Marua WTP identified during the response to the Waterloo aquifer contamination. The network is currently vulnerable to a relatively frequent drought of less than 15 year return period. Without intervention, the likelihood of demand shortfall is expected to continue increasing significantly with population growth. With Te Marua WTP upgraded to remove the treatment constraint (planned for 2021), the maximum supported population is 460,000 people. This upgrade is expected to cost over $15 M and take at least 3 years to implement.

3.3 Population growth and demand projections

Figure 17 shows the most recent population estimates and projections using two sources of demographic data (Forecast ID and Statistics NZ). From this it can be estimated that the maximum supported population of 460,000 will occur around 2030 under the base projection (Forecast ID), or as soon as 2026 under the high growth scenario (Stats NZ High).

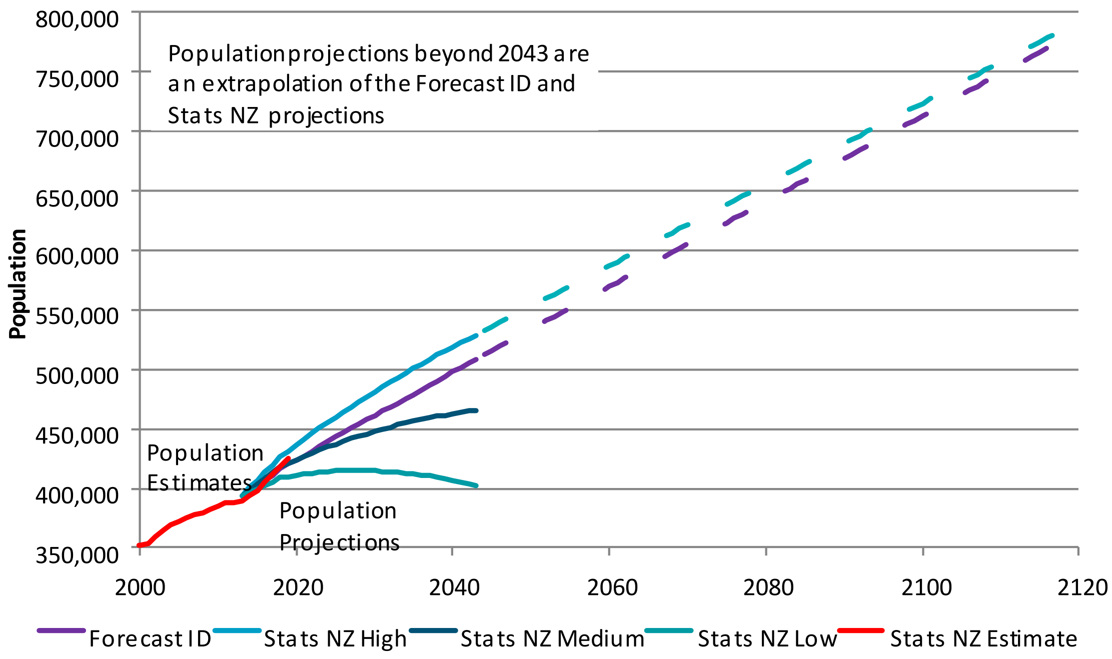


Figure 17 Population estimates and projections

It is too soon to predict the effect of the Covid-19 pandemic on population growth and demand for water. The housing shortage prior to the pandemic and need for economic stimulus may see a short term increase in Government initiated housing projects. There was a significant decline in demand following the 1987 stock market crash and associated departure of wet industries. This is not expected to occur this time given there is little in the way of wet industries operating. Net migration and broader economic factors are likely to be the dominant drivers in the longer term.

Figure 18 shows how the above population projections and the current per capita demand of around 357L/p/d translates to predicted demand over the next 100 years.

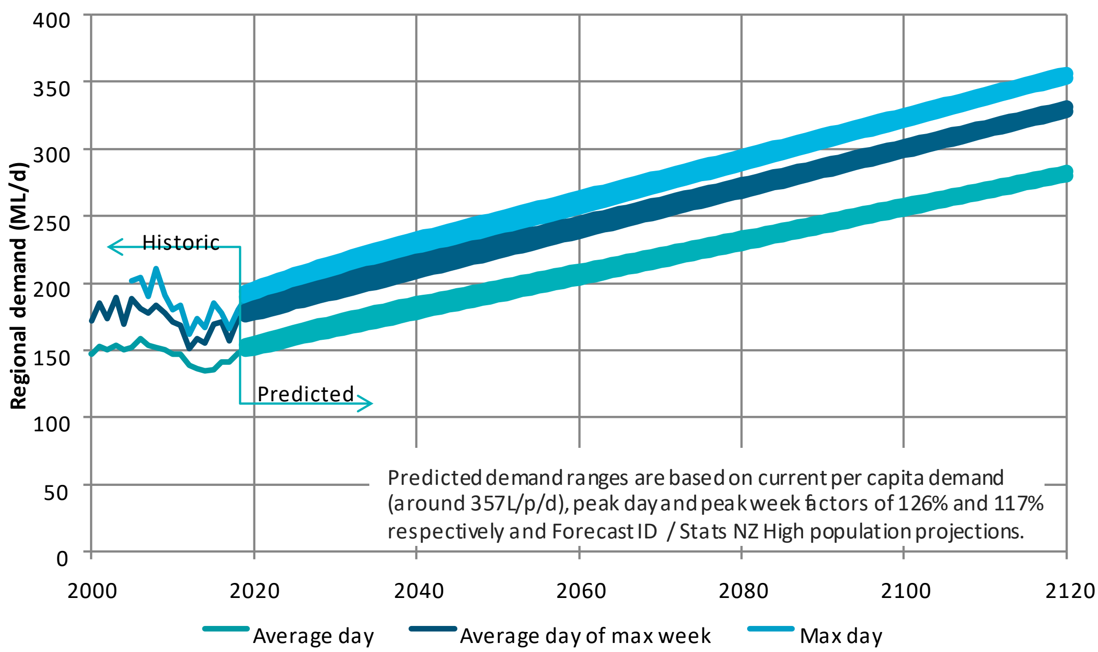


Figure 18 Regional demand for water

Figure 18 shows average demand has increased from 135ML/d to 151ML/d over the last 5 years. In simplified terms the network capacity is reached at an average demand of around 172 ML/d[7]. Current demand therefore represents nearly 90% of the network capacity.

If demand per person remains the same then average demand is predicted to increase to 160-166 ML/d within two LTP cycles (20 years). This is 93-97% of the network capacity and highlights the urgent need for action.

Over the next 100 years the problem will get significantly worse with average demand expected to increase to around 280 ML/d (~85% greater than the current average daily demand). This represents a demand shortfall of over 100 ML/d on average (more in summer).

3.4 Where the water goes

With relatively limited end-use metering in the network (especially of residential consumers) the understanding of where the water is being used in Wellington is relatively coarse. Wellington Water's current understanding of where the water is going is shown in Figure 19.

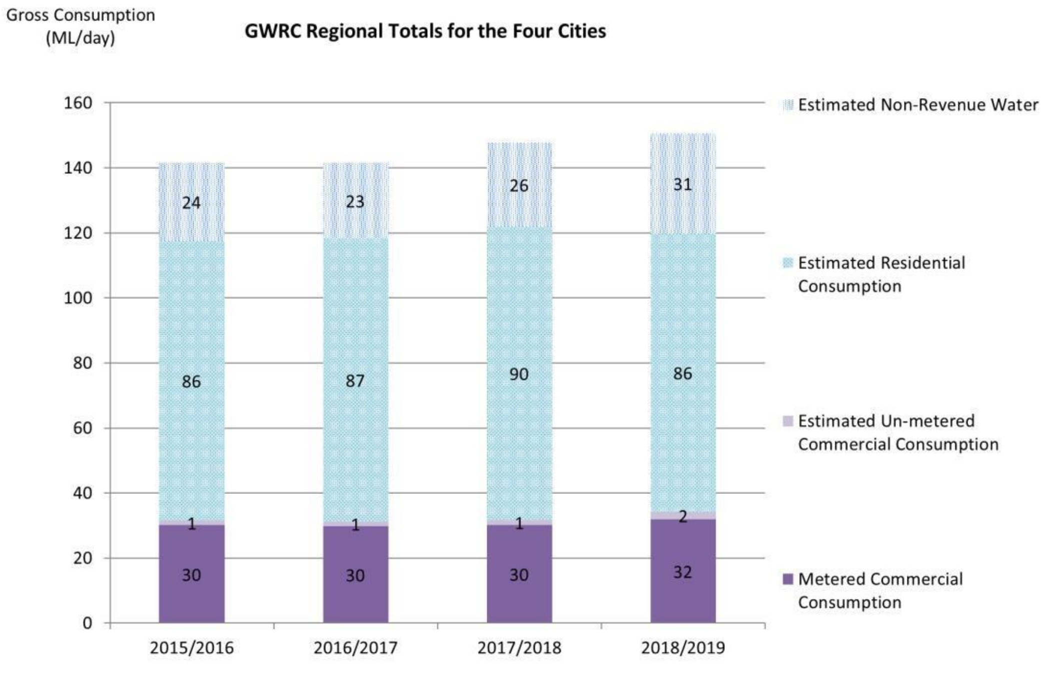


Figure 19 Water demand by demand group for the Wellington Metropolitan Region

Approximately 20% of water demand is expected to be leakage and other 'non-revenue water'. Non-revenue water is water that has been abstracted but is then lost before reaching the customer, and may include raw water and treated water. Comparisons against suitable global benchmarks suggests this level is relatively high.

[7] This is derived from a maximum supported population of 460,000 people at the level of service limit and a modelled regional gross per capita demand of 374 L/p/d.

Residential consumption is estimated at approximately 60% of total water demand. At around 220 litres per person per day in 2017/18, this is well above other large NZ cities (i.e. Auckland is about 160 L/p/d) and global benchmarks (Melbourne and the UK average are about 150 L/p/d). There is no reason to suggest Wellington has specific water requirements that would account for this difference.

Commercial demand makes up the remainder of the total. The top 50 customer groups account for more than half of this demand. Although these customers face volumetric water charges intended to incentivise efficient water use, it is unlikely that they will have adopted good water-efficient practice as water will typically represent a relatively small component of input costs compared to other inputs such as raw materials, labour and power consumption.

3.5 Conserve verses construct

There are two potential responses to the sustainable water challenge:

- **Conserve** the water available by improving efficiency across the network and in the way the water is used.
- **Construct** more infrastructure to respond to high consumption and growth.

Consultation with Councils gave a clear preference to conserve water as much as possible. It was noted that Wellington Water should also plan for an increase in supply capacity in the event that demand reduction does not achieve the required savings.

3.6 Approach to reducing demand

Reducing demand would need to start immediately to be confident of deferring the need for an expensive new water storage. Wellington Waters demand reduction target is to see gross per capita demand reduce by 10% from 360 L/p/d to 320 L/p/d by 2026. This would reduce average demand by around 15 ML/day. This is a highly ambitious target but if achieved would see development of a new water storage deferred to 2043.

It is anticipated that the majority of the savings will come from the network, especially leakage. The network's leakage is above good practice benchmarks[8], and actions to reduce the level of leakage are directly within Wellington Water and councils control. Analysis conducted for the 'economic level of leakage' study has suggested that leakage could theoretically be reduced to about 12 ML/day (from ~31 ML/d) if all economic activities are pursued (i.e. where the cost of the intervention is less than the value of the water saved). In practice the saving will be less, but it does suggest that there is a significant opportunity. This was a theoretical study and subsequently requires further research and investigation, however based on the current population (~425,000 people) leakage improvements could achieve the 10% gross demand reduction (~44 L/p/d).

Savings from commercial customers are expected to be the next biggest opportunity. By working closely together with Wellington Waters largest customers it should be possible

[8] Our estimated 31 ML/day of water loss across 2,900 km of network is ~11 m3/day/km. Anglian Water was achieving 4.8 m3/day/km in 2017, making them the third best performer in the UK for this metric.

to achieve savings. There is a relatively small number of these customers and there is access to meter data to support the analysis and discussions.

Residential customers are anticipated to be the most difficult to obtain savings from, despite their relatively high usage. There are several hundred thousand of them, who all use and engage with water in different ways. There are limited direct connections to them, and they have limited awareness and trust in Wellington Water.[9] Also, there is little data to support Wellington Water interactions with them and to provide feedback on their behaviours.

Wellington Water have undertaken a high level cost assessment for indicative purposes only that targets reaching low levels of leakage through implementation of technological approaches (such as water metering and monitoring). This was estimated to be ~$260-330 million (Wellington Water Limited 2020).

Figure 20 maps' Wellington Waters water demand, highlights some of the challenges associated with addressing the demand, and provides examples of some of the proposed approaches.

[9] In our 2019 customer engagement survey 21% of people had an unprompted awareness of Wellington Water, recall of our marketing activities ranged from 3-16%, and 36% of people who had an interaction rated us as excellent or very good. There has also been little, if any, change in reported water efficient behaviour over the last three years.

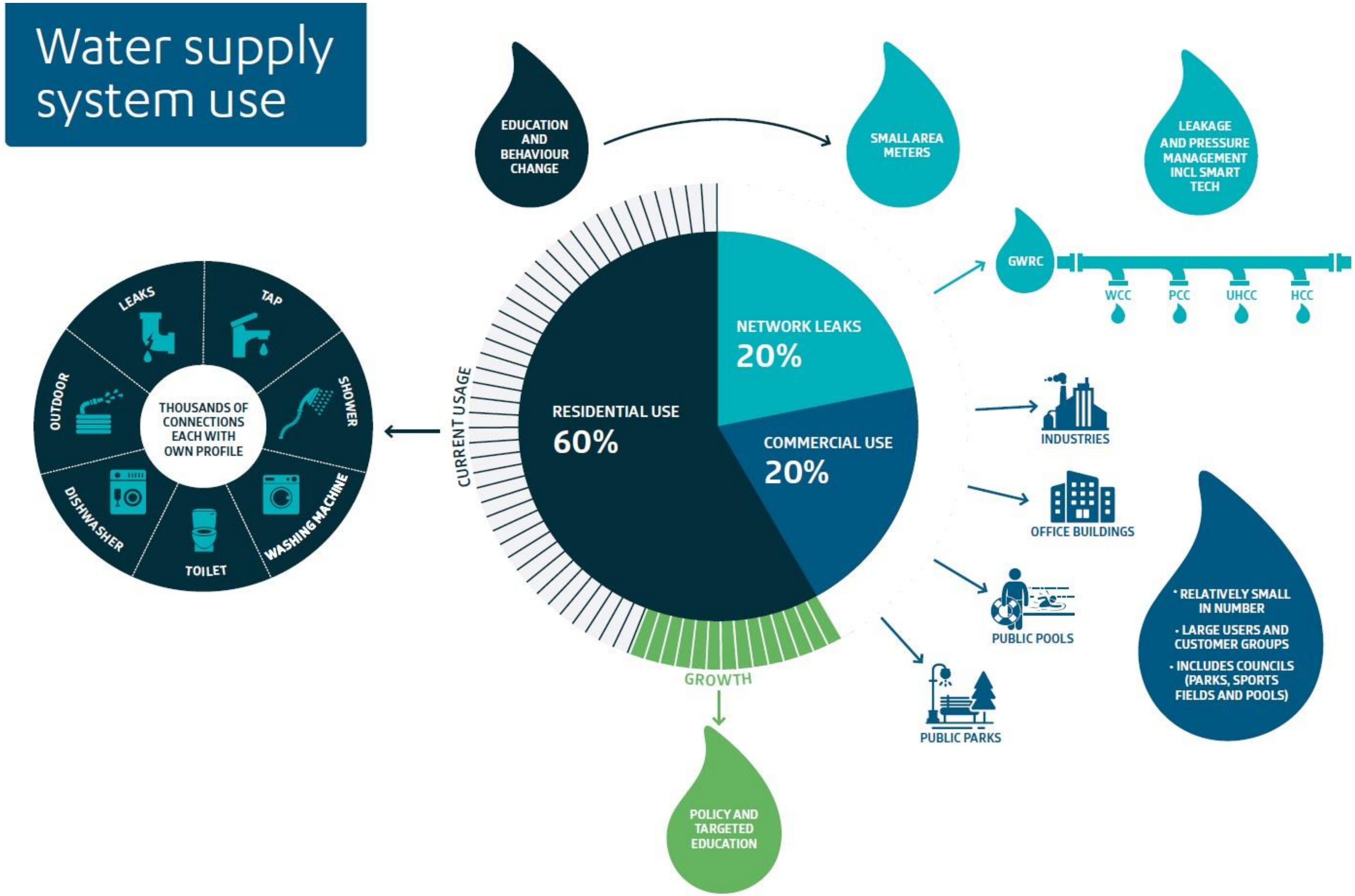


Figure 20 Water demand ‘map’ (note that the figures in this image are based on assumptions and estimates and should not be relied upon)

Six work programmes have been identified to work towards achieving the target gross per capita demand of 320 L/p/d by 2026. These have been presented to client councils and will be considered for funding in the 2021-31 LTP. The work programmes are summarised below, with detailed tasks outlined in **Appendix A**.

Programme 1: A step change improvement in water network management

The amount of water loss on the network is high compared to good practice performance and Wellington Water's approach to water loss and leakage management is relatively immature.

Water loss and leakage is a high priority for water utilities in other parts of the world such as Australia and the UK, meaning that good case studies, references and benchmarks are becoming increasingly available. The adoption of good practice methodologies and technologies, together with improved data on water use and economic intervention levels should mean that a material reduction in leakage can be achieved within the next five years. Savings of more than 10% should be readily achievable if sufficient resources are made available. This will include pipe renewals and upgrades, pressure reductions and new technologies (such as smart metering or leak detection).

Programme 2: Collaborating with Wellington Water's largest commercial and extraordinary users to improve water use efficiency

The challenge is to find a way to 'get in the door' with these customers, align water use to their own values and drivers, and to lead them through the changes in behaviours and technology that will achieve water efficiency. It is likely that sufficient savings are available to contribute to the reduction target, but achieving action will be the greatest challenge. Some of these actions could include audits and accreditation schemes, benchmarking or tariffs.

Programme 3: Minimising the impact of population and new building growth

Growth is the biggest factor that is influencing the demand for water, and the associated risks to supply. However, if all of the new housing was designed to good practice, water efficient standards then the amount of additional water required could be significantly reduced. For example, in the UK, housing legislation requires buildings in water stressed areas to be designed to 110L/p/d, which would halve the forecast requirements and contribute 20% of the total required water saving. Additionally, designing to these standards today will result in long term savings over the life of the building.

If possible, requirements for water efficient design could be adopted into relevant council plans and policies, which will aid in meeting hydraulic neutrality (for stormwater) whilst also reducing the demand on the potable network. Failing that, customers should be visibly 'nudged' in this direction along the entire design-to-build supply chain.

Programme 4: Facilitating more efficient water use by Wellington Water's domestic customers

At around 60% of total demand, domestic consumers make up the greatest share of water demand. However, they are also much more widely distributed and subject to a broad diversity of behaviours and attitudes. In the absence of drought conditions (as in

Australia), volumetric charging (Australia and Auckland) and meters that provide information on consumption (Australia and Auckland) there are limited drivers and tools for behaviour change.

The major water uses in a house are typically (in order) showers, washing machines, toilets, taps and the garden/outdoors, however house-to-house use can vary considerably, making a targeted end-use approach difficult. An overall behavioural change approach may be more successful as it will influence all uses, but the gains are likely to take time and be incremental.

There are other parties with an interest in healthy, efficient and sustainable homes that already have relationships with Wellington Waters customers that Wellington Water can partner with to improve the effectiveness of engagement and implementation.

Universal metering has proven to be effective at reducing domestic water demand through identifying leaks (e.g. Kapiti Coast District Council, Southern Wairarapa District Council). Data from overseas also shows that customers on a metered supply also use less water than unmetered customers, have fewer losses and fewer very high consumption properties (though these outcomes will be influenced to some degree by associated volumetric charging). The business case for universal metering will be developed for consideration by councils. Full deployment of meters is likely to take 2-3 years and may not be achievable prior to 2025.

Other actions to deploy include education programmes on attitudes to water, collaborate with enterprises with aligned objectives (i.e. sustainability trust).

Programme 5: Improving data and understanding

Currently there is an incomplete picture of where water is being used, and this makes it challenging to develop and validate appropriate and effective interventions and to benchmark performance against comparable organisations. Improvements in sensor, communications, and data storage and analytics technology are making it increasingly easy and cost-effective to implement data and analytics capability.

There is a lot of activity in the water efficiency area across the industry and across the world. Wellington Water contacts and relationships should be used to capture relevant case studies and good practice, and to benchmark performance. Some ways to undertake this include smart meters and network meters, updating data and networking management and monitoring systems setting goals of efficiency with key performance indicators.

Programme 6: Monitoring the supply risk

There is relatively little headroom available between existing demand and the capacity of the existing system (see Section 3.2). That headroom could reduce rapidly if growth occurs at the high end of projections or if per capita demand increases. It is important to continue monitoring the supply-demand balance and be prepared to both modify approaches to demand management and commence the process towards the development of a new water storage.

The closer focus on the supply-demand balance is also likely to be required as GWRC considers water allocations in the Whaitua process and as re-consenting of the existing water takes begins in the early 2030's. Some areas of consideration include more monitoring and reporting of supply/demand balance, and scope new water source or storage scheme options.

3.7 Climate change and resilience

Climate change analysis is fully integrated into the current approach to water supply strategic planning. Results from the most recent IPCC 5th assessment show significant variability across scenarios, however the overall expectation is for drier summers and correspondingly wetter winters to occur more frequently and with greater severity over the remainder of the century.

Sea levels are also expected to continue to rise which will increase the risk of aquifer saline intrusion. Table 4 summarises climate change related risks to the water supply network and Wellington Waters approach to adaptation.

Table 4. Climate change risks and approach to adaptation

Risks	Adaptation approach
Sea level rise resulting in increased likelihood of saline intrusion into the Waiwhetu aquifer and reduced sustainable yield.	Reduce aquifer abstraction over the long term to increase the artesian pressures and offset the effect of sea level rise (expected to be a 30% reduction in yield for a 1.5 m rise in sea level, by the end of the century based on the current emissions pathway). Also investigate reconfiguration of the borefield location to reduce risks.
Change in seasonal water source availability resulting in greater demand for seasonal storage and reduced system drought resilience.	Non-asset solutions such as community education and leak reduction, and/or bring forward timing for next major source development.
Increase in rainfall intensity resulting in catchment erosion that degrades water quality or slips that damage infrastructure.	Investment in catchment management and/or potentially significant upgrades to water treatment plants.
Change in catchment biodiversity resulting in an increase in pest animals and/or plants. This could adversely affect water quality and compromise water treatment effectiveness.	Investment in catchment management and/or potentially significant upgrades to water treatment plants.
Increase in likelihood of catchment fires resulting in major source outage.	Investment in catchment management, monitor long term changes and incorporate fire risk management strategies.

High temperatures resulting in an increase in summer water use and a peak demand that exceeds the network capacity.	Non-asset solutions such as community education and leak reduction, watering restrictions in extreme cases and/or increase network capacity if required.

The overall impact of climate change and sea level rise is expected to be an increase in the likelihood of demand shortfall primarily due to reduced seasonal storage.

Resilience to natural hazards is also a key issue for the water supply. The network is particularly vulnerable to major earthquakes. This is because:

- Water sources are remote from the main population centres and are all located on one side of the Wellington Fault.
- Bulk water pipelines cross the Wellington Fault in several locations. Fault rupture would cut off water supply to Upper Hutt, Wellington, Porirua and the western hills of Hutt City. Repair work is expected to take 100 days or more in some areas (particularly Wellington's central, southern and eastern suburbs).
- A significant proportion (over 40%) of all the pipes used for reticulating water within the cities are vulnerable to damage in a seismic event (old cast iron and asbestos cement pipes).

Resilience in the long term will be improved by implementing the *Towards 80:30:80* strategy. This strategy has a goal of providing 80% of customers, within 30 days of a reasonable seismic event, with 80% of their normal water needs. In the short term this includes establishment of an above-ground emergency water supply network through the Community Infrastructure Resilience (CIR) initiative. CIR is currently being implemented and will provide a limited supply of water from day 7 after a major event through to when the reticulated supply is reinstated.

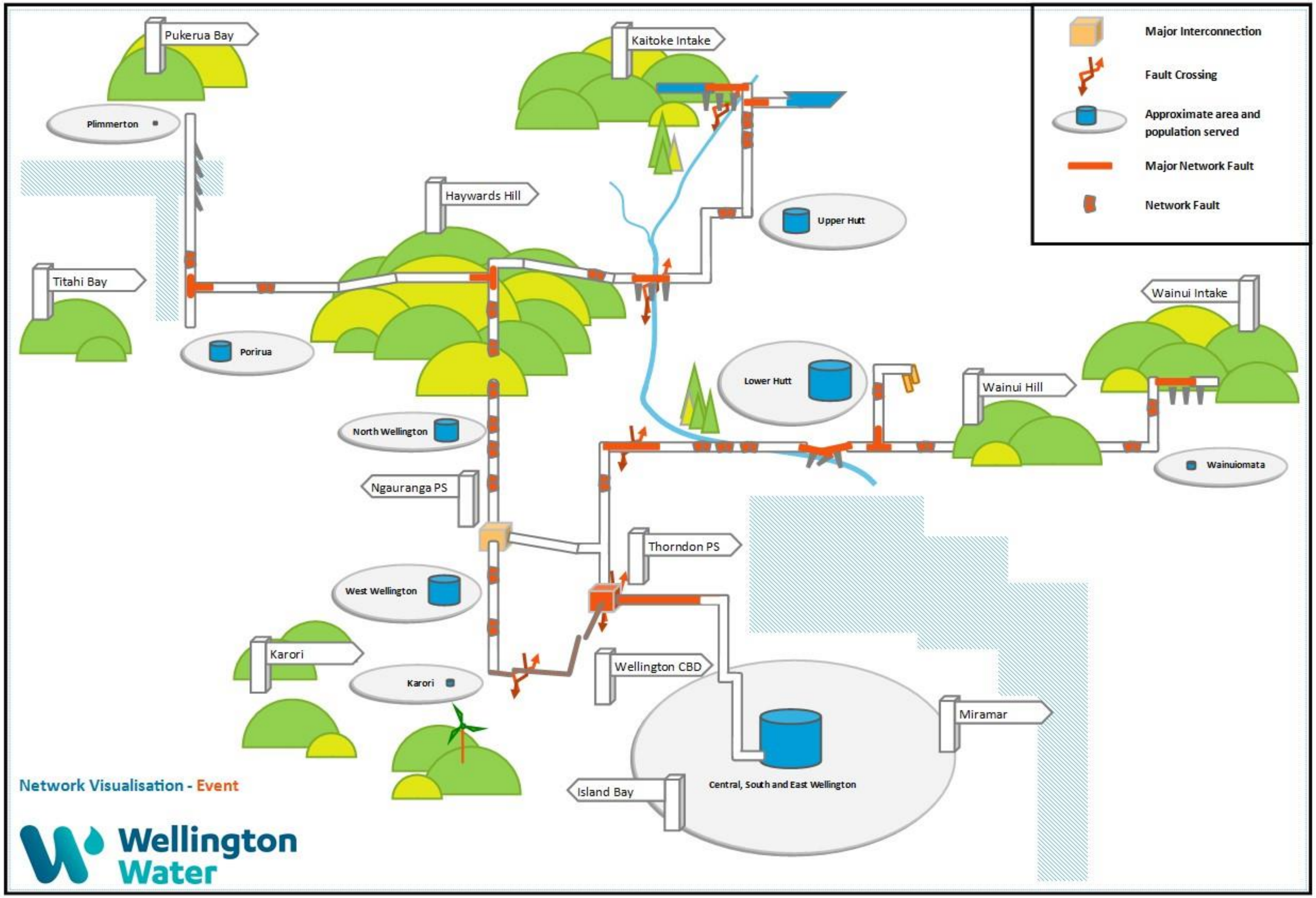


Figure 21 Expected failures in the bulk supply after a Wellington Fault earthquake

4. Flow allocation scenarios

4.1 Background

An expert panel of scientists considered the hydrological and ecological response at seven locations - on the Hutt (five sites) and Wainuiomata Rivers (2 sites) - from scenarios of increased or decreased abstraction for the potable network. The purpose of this exercise was to predict (using the best available data) how river habitat and various ecological metrics would respond to changes in river flows arising from different abstraction rates. The changes were considered in the context of a flow regime that is not modified by any significant abstraction (considered a 'naturalised flow' scenario).

The flow/abstraction scenarios were drafted by GWRC and reviewed by Wellington Water. A hydrological modelling approach (Keenan 2020) was used to assess the changes in river flow as a response to the scenarios, with outputs of this modelling method then run through Indicators of Hydrological Alteration (IHA) software. IHA provides a range of hyro-ecological variables that can help inform changes in river ecology. The results from IHA were then used by the expert panel as part of their decision making process. The range of scenarios considered was broad, with the intent being to provide a sensitivity analysis of ecological response. The feasibility of these scenarios in relation to operational constraints, increasing population and climate change are discussed in the following sections.

4.2 Important assumptions and limitations

Of critical importance is that the modelling approach of Keenan (2020) was for the purposes of an eco-hydrological assessment, and did not utilise Wellington Water's Sustainable Yield Model (SYM) which models the dynamic interaction between the natural and built environment. Subsequently, a core assumption of Keenan (2020) was that any water abstracted could be stored or utilised, and that when water was available from the appropriate source, the full amount of the consent was exercised. In reality, Wellington Water operate the network significantly more conservatively (as described in Table 3), despite having consents to take greater amounts of water. This is primarily done to achieve a low likelihood of network failure consistent with the very high consequence of supply shortfall. In addition, excess water is also returned back into the Hutt River from Macaskill Storage lakes on frequent occasions primarily during winter and spring, which was not incorporated in IHA modelling.

Subsequently, the impacts described in Keenan (2020) and considered by the flow panel are conservative, and the values presented in Table B 1 to Table B 4 should be considered with these assumptions and limitations in mind.

4.3 Scenario effects on meeting demand

The SYM has been used to determine the impact of the allocation scenarios on the drought resilience of the water supply network. The effect of various supply upgrades and reductions in demand per person have also been considered. Figure 22 summarises the results of this work.

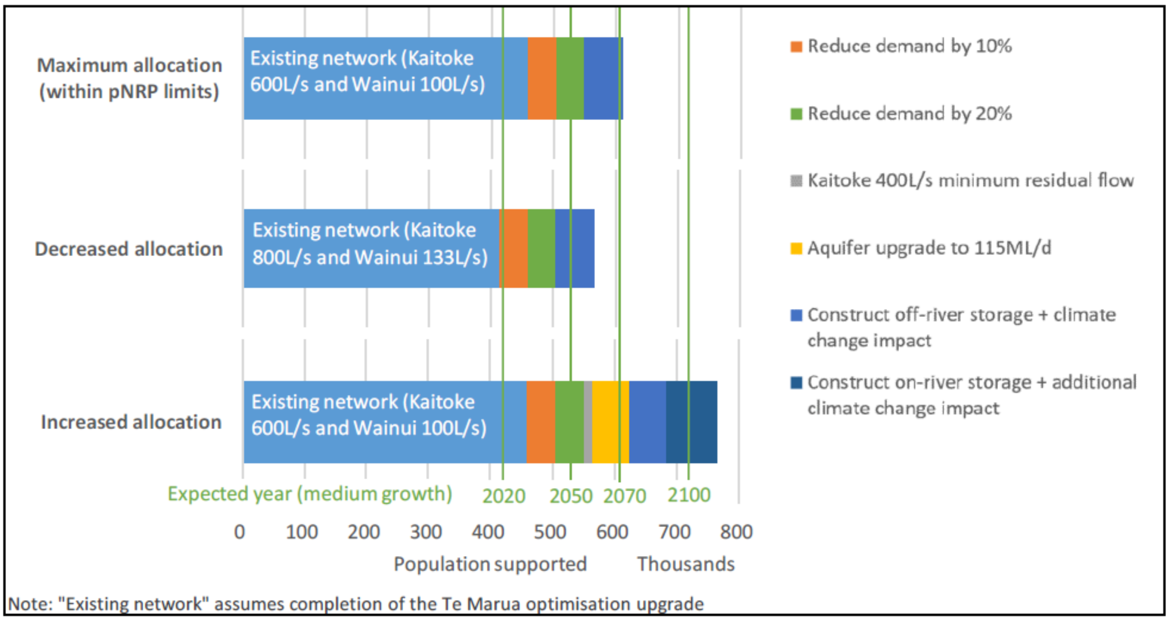


Figure 22 Allocation scenarios and population supported

Key assumptions made in assessing the impact of the allocation scenarios and the expected timing are:

- The current 1 in 50 year drought resilience level of service will remain the same in the long term. This is within the typical range for water utilities, however Watercare have adopted a 1 in 200 year standard and there is a risk this could change for Wellington Water – especially following a significant drought.
- Regional gross per capita demand will not exceed 374 L/p/d in the long term (less for the reduced demand scenarios).
- Demand reductions of 10% and 20% are realistically achievable. However, at this stage the modelled demand reductions are arbitrary, and not supported by evidence confirming the expected costs and benefits.
- Forecast ID growth projections and associated Wellington Water extrapolations provide a reasonable indicator of future population.
- The infrastructure will continue to perform at the current capacity in the long term through effective maintenance and repairs.
- Resource consents will be granted for the proposed long term development options.
- The impact of proposed operational and capital expenditure on rates has not been included in the assessment, on the assumption it would be 'affordable' for the community. This needs further investigation.
- Climate change will not have a significant impact on the drought resilience of the water supply network until beyond 2050.

- The incremental benefit of infrastructure upgrades is transferrable across Whaitua scenarios. As an example, a reduction in consented take at Kaitoke Weir may slightly reduce the effectiveness of constructing additional off-river storage at Macaskill Lakes in Te Marua. It has been assumed that this impact is not significant and the results are fit-for-purpose for a high level assessment.

4.4 Naturalised Flow Scenario

Flow naturalisation was undertaken on the historical river flow record to assess 'natural' low flows of rivers in Whaitua Te Whanganui-a-Tara, prior to abstraction. Naturalised flow was modelled by turning off all abstractions (consented surface and ground water takes). This does not reflect what the 'natural' river flow would be before human development, as it does not take into account the significant changes in landform and hydrology that have occurred as a result of urban development, pastoral and forestry activities, as well as the impact of the 1855 Wairarapa earthquake. These changes have significantly modified river flow dynamics that are not accounted for in the naturalised flow scenario.

The naturalised flow scenario would better reflect what the rivers ecological response may be if all of the potable network abstractions from the Hutt and Waiwhetu aquifer were sourced from a different location. The expert panel considered other sub scenarios (increased allocation, BAU and decreased allocation) against the naturalised flow. The scenario was not intended to consider the removal of supply as a plausible option, however, was intended to provide an understanding of the level of change that could have already occurred from abstraction as part of a sensitivity analysis.

While the likelihood of removing all of Wellington's existing water abstractions is low (to replicate a naturalised flow scenario), if any significant reductions from the current regime are considered then some significant factors would need to be resolved to ensure a long lasting reliable option for future communities while increasing environmental benefits from the current state. This would have to take into account:

1. The current daily water demand varies between 140 and 200 ML/d. Most of this water is supplied from within Te Whanganui-a-Tara, with the Hutt River and Waiwhetu aquifer (which are directly connected) making up ~90% of the supply. Figure 18 shows with population growth, peak daily demand could exceed 350 ML/d within the next 100 years. New supplies would need to cater for this existing and future demand.

2. The location of existing bulk water treatment and distribution infrastructure would likely be inappropriate and need to be reconstructed to suit new or alternative sources. This would also require integration with resilience planning for the maintenance of water supplies during natural events, climate change, droughts, earthquakes, etc.

3. The quality of the water being abstracted from Wellingtons protected catchments and semi-confined aquifer is excellent (see Section 2.2), which reduces the amount of treatment necessary. Alternative supplies under a naturalised flow scenario would require extensive investigation into water quality and source protection (should they be from streams, rivers or aquifers) to understand new treatment requirements and where new treatment plants would be necessary.

4. There are no known alternative sources of fresh water of sufficient quality and quantity in the Wellington area, without considering new run of river storage dams (on the basis that all the existing takes within this Whaitua were ceased in the naturalised flow scenario).

If the objective of a naturalised flow scenario is to enhance the ecological health of the rivers (Hutt and Wainuiomata) and reduce pressure on the Waiwhetu aquifer, then alternative sources would also need to be carefully considered in order not to move the impacts of abstraction elsewhere.

At a high level, consideration of alternative supplies to achieve a naturalised flow could take into account some of the following options. Greater detail on these (and other) options has been provided in Section 5.

1. Seawater desalinisation using reverse osmosis is common in many countries with limited natural freshwater supplies (river and groundwater).

2. New on-river storage dams which could be managed to maintain a minimum environmental flow (but would still result in abstraction and flow-modification in a new river catchment, that would have downstream impacts)

3. Rain water harvesting where appropriate

4. New approaches for harvesting and treatment of stormwater.

New dams or storages in other catchments would result in similar or potentially greater impacts on river habitat and ecological health and would be challenging to consent under the RMA and central governments proposed Action for Healthy Waterways document. Rainwater harvesting could be appropriate in the right setting, however for drought and demand resilience when rainwater is used for all household water use, this often requires large tanks (>20,000 L) which would be severely limited in most of the densely populated urban areas (see Section 5.4). A tank that is too small would mean households could run dry over summer, particularly during droughts, and then require bulk water top ups from the network. Subsequently, this puts more pressure on rivers and aquifers (and the network) already under drought stress. Rainwater tanks for outdoor and greywater use only could be smaller, and can help reduce network demand while promoting water recycling (see Section 5.4). New greenfield sites provide an opportunity to incorporate rainwater harvesting prior to development and investment into significant network infrastructure (which already exists in other urban areas).

Stormwater harvesting for potable supply is a concept that hasn't been explored in detail, however would require the water to be captured, treated and distributed within the existing network. Desalination is a proven technique, although has a significant capital outlay and large power demands.

4.5 Scenario 1 – Maximum Allocation

Scenario 1 (Keenan 2020) considers the utilisation of the maximum available surface and groundwater allocation under GWRC's pNRP within existing low flow restrictions in both the Hutt River, Waiwhetu aquifer and Wainuiomata River. The assumption was that this occurs at the existing take locations (i.e. a new source of supply is not considered in this scenario). Two specific sub-scenarios were also considered for the Hutt Valley, given the more complicated interactions of the Hutt River and Waiwhetu Aquifer when considering surface and groundwater abstractions.

Detailed descriptions of the scenarios, hydrological modelling approach and IHA results can be found in Keenan (2020). A summary of the results of Scenario 1 (and the sub scenarios 1a and 1b for the Hutt Valley) can be found in Keenan (2020) and Appendix B, Table B 1 to Table B 4. Scenario 1 generally showed:

- A reduction in mean annual low flow (MALF) magnitude in the order of 20% in the middle reach (receiving groundwater recharge) and 40% in the upper and lower reaches of the Hutt River, compared to the 'naturalised' regime.

- A reduction in the 7-day MALF of 4% and 17% at Birchville and Avalon when compared to the current abstraction (see Table B 2).

- Low flows are more frequent and longer in duration, and extreme low flows (which are infrequent) experience a high degree of alteration (increased frequency and duration).

- Annual average abstraction from the Hutt River at Kaitoke and the Waiwhetu Aquifer could increase up to 63% and 46% respectively, when compared to current usage (see Table B 2).

- In the Wainuiomata River, annual average abstraction could increase by up to 86% (see Table B 4.

- This is equivalent to an additional 31,887 ML/year (~87 ML/d on average) for the Hutt River if the maximum amounts available under the pNRP are fully utilised (see Section 4.2) and 4,984 ML/year (13.6 ML/d) for the Wainuiomata River.

    - At maximum allocation, Scenario 1 increased the average daily demand from a modelled 173 ML/d (for both the Wainuiomata and Hutt River) to 274 ML/d (calculated from Table B 1).

Assuming Scenario 1 was possible, based on average demand forecasts in Figure 18, this could allow demand to be met until 2085, although there would be similar operational constraints to the current situation during high-stress times with river flows below MALF, meaning greater storage becomes critical.

In reality, Wellington Water cannot operate a consented abstraction at its maximum take all year round. This is because operation without source redundancy would put the community at significant risk of shortfall during planned and unplanned network outages. The SYM has shown that with the planned $15m upgrade at Te Marua WTP the network can sustain a population of 460,000 people consuming on average 172 ML/d (refer Section 3.3). This represents an increase of 21 ML/d above the current 151 ML/d average demand.

Up to 610,000 people could be supplied at an average of 183 ML/d without increasing the consent allocation. This could meet expected population growth through to around 2070, however, would require investment of ~$100 m to reduce demand by 20% and ~$250 m to construct an additional 3,000 ML off-river storage and major treatment/distribution upgrade at Te Marua. At best, the increased demand would utilise around 32 ML/d (or ~30%) of the 101 ML/d “surplus” or “unused” annual allocation identified in this scenario. Improving consent utilisation beyond this would require an increasingly uneconomic level of investment and has not been considered (e.g. storage dam at Wainuiomata).

4.6 Scenario 2 - Increased allocation

Increased allocation considered in this scenario was for the Hutt Valley catchment only, as the Wainuiomata and Orongorongo supplies are generally considered to be unviable for further development. There were five sub-scenarios that were modelled, with the results presented in Keenan (2020) and Appendix B. These scenarios were:

- Scenario 2a – Hutt River at Kaitoke minimum flow reduced from 0.6 m^3/s to 0.4 m^3/s, year-round
- Scenario 2b – Hutt River at Kaitoke minimum flow reduced from 0.6 m^3/s to 0.4 m^3/s, January to March only
- Scenario 2c – increased groundwater abstraction (seasonally variable, peaking at 143 ML/d in January and February)
- Scenario 2d – increased groundwater abstraction (maximum rate achievable while keeping water level at foreshore above 2 m)
- Scenario 2e – combination of Scenarios 2a and 2d, to represent an increase in groundwater abstraction and a decrease in minimum flow in the Hutt River at Kaitoke.

For simplification, this section will refer to Scenario 2e only, which would have the greatest hydrological and environmental changes, while providing the highest volumes of water to meet increasing demand.

A summary of the results of Scenario 2e can be found in Keenan (2020) and Appendix B, Table B 1 to Table B 4. This scenario generally showed:

- a high to very high degree of alteration (using IHA software), with the MALF [10] reducing ~26% in the middle reaches (receiving groundwater recharge) and over 50% in the upper and lower reaches of the Hutt River, when compared to the ‘naturalised’ regime.
- A reduction in the MALF of 12% and 33% at Birchville and Avalon when compared to the current abstraction (see Table B 2).
- Low flows are more frequent and longer in duration, experiencing a high degree of alteration (refer to Keenan 2020) compared to the naturalised flow.
- Annual average abstraction from the Hutt River at Kaitoke and the Waiwhetu Aquifer could increase up to 68% and 79% respectively, when compared to current usage (see Table B 2).

[10] Reference to MALF is considered to be the 7-day mean annual low flow unless stated otherwise..

- This is equivalent to an additional 41,615 ML/year (~114 ML/d on average) for the Hutt River only, if the increased abstraction scenario is implemented, increasing the average daily take from 157 ML/d to 271 ML/d (calculated from Table B 1)

- If Scenario 1 maximum allocation amounts for Wainuiomata River (4,984 ML/year, ~14ML/d described in Section 4.5) were added to Scenario 2e, this would equate to an increase in the average daily demand from a modelled current state of 173 ML/d (for both the Wainuiomata and Hutt River) to ~301 ML/d (calculated from Table B 1).

Table B 1 (and Figure 22) shows that the Scenario 2e lower minimum flow (0.4 m^3/s or 400L/s) does not provide a significant increase in abstracted water when compared to the maximum allocation allowed under the pNRP (scenario 1). The difference between these two scenarios is only 1,459 ML/year (on average), equivalent to ~4 ML/d. However, it should be noted that this water is highly valuable in terms of drought resilience because its availability coincides with the critical summer period.

The greatest increase in Scenario 2e is due to abstraction from the Waiwhetu aquifer, with an additional 19,700 ML/year on average (from the current state), and an extra 8,269 ML/year when compared to Scenario 1, maximum allocation (equivalent to ~22 ML/d).

As detailed in Table 3, the actual average annual take from the Waiwhetu aquifer is currently ~64 ML/d (peaking at 84 ML/d) while Scenario 2e modelled a daily take of ~123 ML/d from the aquifer. The maximum abstraction modelled under Scenario 1a was 100 ML/d (which would meet the peak annual allocation allowed under the pNRP). Scenario 2e groundwater abstraction was simulated through the HAM3 model, and represented the highest feasible abstraction rate (exceeding the pNRP) without breaching saline intrusion trigger rules.

This may suggest there is some additional abstraction potential from the Waiwhetu aquifer than is currently allowed for in the pNRP, although with modelling uncertainties and the need for sustainable abstraction (to prevent salt water intrusion), it would be unlikely that a daily take of ~123ML/d simulated in Scenario 2e would ever occur. The corresponding analysis in the SYM assumed a maximum of 115 ML/d could be abstracted in the driest period without breaching saline intrusion limits. This is not achievable with the current Waterloo borefield configuration, however early indications from HAM3 modelling is that this may be achievable if a proportion of the borefield was moved north into the unconfined zone. This will be the subject of further work through development of HAM5 and the borefield renewal investigation project.

Figure 22 provides an estimate of how far the increased allocation scenario could go in meeting population growth (and increased demand). A range of additional options were considered to demonstrate a pathway to achieving a 100 year vision with current knowledge and technologies. One option included the modelling in SYM of construction of an on-river storage scheme towards the end of the century. The further this option can be deferred the greater the opportunity for technology development to introduce new options for water treatment (e.g. desalination) and/or achieve greater levels of demand reduction.

Figure 22 showed with 20% demand reduction, a 400 L/s minimum flow at Kaitoke and an aquifer upgrade to 115 ML/d, potentially demand could be met to ~2075 under this scenario. This is in contrast to the modelled abstraction by Keenan (2020) of 301.2 ML/d, which could theoretically meet demand to ~2100 (see Figure 18). As detailed in Section 4.5, Wellington Water would not abstract at the maximum consented rate on an annual average basis due to network risks.

4.7 Scenario 3 - Decreased allocation

This scenario examined the effects of decreased abstraction through the increase in minimum flow by 33% in the Hutt and Wainuiomata Rivers. Primarily, this would impact supply over summer only during high stress periods. For the Hutt River there were two additional sub-scenarios:

- Scenario 3a – increased minimum flow at Kaitoke and no change in groundwater abstraction
- Scenario 3b – increased minimum flow at Kaitoke and increased groundwater abstraction as in Scenario 2d (to offset the reduced surface water take at low flows).

The general effects of these scenarios were:

- Reduced abstraction during high stress periods where the river drops below the MALF. This was a 33% reduction in abstraction, equivalent to a reduction from 51 ML/d (current modelled used) to 34 ML/d for the Hutt River.
    - For the Wainuiomata River the effects of a minimum flow change are greater, with the modelled average daily take of 6 ML/d reducing by 53% to 2.8 ML/d (see Table B 3).
- 3% increase in the MALF at Birchville under both scenarios (and in the Wainuiomata River) when compared to current state, however under Scenario 3 b (increased groundwater abstraction to offset), the affects at Avalon are increased from -2% (scenario 3a) to -14% (scenario 3b) (see Table B 2).
- A 14.4% reduction in the MALF at Birchville when compared to the natural regime.

Interestingly, this scenario also showed that while abstraction declines during key periods where the river approaches minimum flow rules, the annual average abstraction (and summer abstraction) is actually higher than the current scenario (see Table B 1). In the Hutt and Wainuiomata Rivers, the annual average abstraction increases by 18,797 ML/d and 4,448 ML/d respectively (equivalent to a combined average daily take of 237 ML/d). The modelled assumptions (Section 4.2) of abstracting at the maximum consented rate show that despite the minimum flow restrictions, there is (at least in theory) capacity within the reduced allocation scenario to abstract a greater quantity of water annually. In practice the key drought resilience limitations occur in summer when rivers recede. This is because of the relatively high reliance on run-of-river supplies and limited volume of constructed storage. Increasing the off-river storage capacity at Macaskill Lakes at Te Marua is feasible (at a nominal cost of $250 m), however options at Wainuiomata are much more limited and likely to come at similar cost with reduced benefit and greater environmental impact.

Under Scenario 3a, a decrease in allocation would result in the population supported by the network reducing from 460,000 people to around 415,000 people (reached in 2018). This effect could be offset by a reduction in demand per person of around 10% or construction of additional off-river storage and associated treatment/distribution upgrades at Te Marua. Demand reduction of 10% may be achievable through the multipronged approach described in Section 3.6. Alternatively, a move to universal metering may be required at an estimated cost of ~$100 m (plus ongoing operational costs for meter reading and replacement). Depending on the preferred approach, options to mitigate the modelled decrease in water allocation would take 5-10 years to implement. It would also bring forward the timing for future source development projects.

5. Future water supply options and uncertainties

Figure 23 shows that if demand per person does not reduce significantly then an increase in supply capacity will need to be in place by 2030 (or as soon as 2026 under a high growth scenario). The graph also shows that the target 10% reduction in gross demand to 320 L/p/d will achieve a supply upgrade deferral of around 10 years. Demand reduction beyond this is expected to be increasingly difficult to achieve without significant investment in interventions like residential metering (estimated at around $100 m + ongoing operating costs).

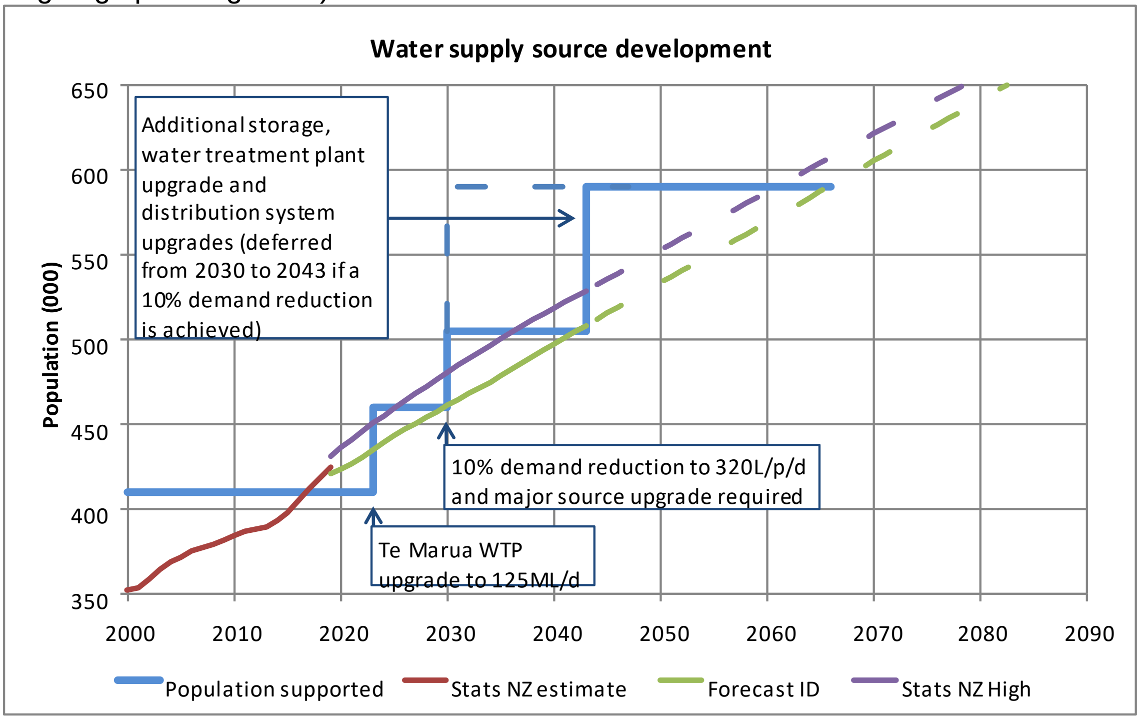


Figure 23 Water supply upgrade options

The following sections provide an overview of some of the approaches that could be undertaken to help meet future demand. This does not consider the flow scenario options described in Section 4.

5.1 Water storage

In the long term the key limitation will be a lack of water storage due to the currently high reliance on run-of-river sources. The Wellington Region is fortunate that it has been able to sustain a significant population for so long with very little constructed storage – enough for around 2-3 months. This is unusual from an international perspective where major urban centres often have storage reservoirs capable of withstanding droughts of 2-3 years or more.

For example, Brisbane's premier water storage is Wivenhoe Dam, capable of storing 3.132 Million ML and servicing a population of ~ 2.6 million people (Seqwater 2020). The volume stored for water supply (with the remainder used for flood protection) is ~348x larger than the Macaskill Lakes (3,350 ML). While the population served is ~6 x greater than the 425,000 people in the Wellington metropolitan region, if the current storage capacity in Wellington was normalised for an equivalent population to Brisbane, this would equate to ~20,500 ML (or only ~1.7% of the Wivenhoe Dam's storage for water supply uses).

As discussed throughout this document (see Figure 16 and Figure 23), greater storage will be necessary at some point in the future to cater for increasing demand and climate change. Auckland City is currently facing a drought that hasn't been experienced for over 25 years, with nine of its water storage dams below 45% of capacity, with the historical average typically 76.5%. In addition to the localised storage dams, Auckland takes a significant volume of water from the Waikato River (outside of its region), up to 150 ML/d, to help meet their cities demands (Watercare 2020). Despite this, Watercare are now imposing water restrictions, including a ban on outdoor water use with the potential to fine individuals up to $20,000 who are caught using water outdoors (i.e. for gardens).

Figure 23 shows that if the people of Wellington can achieve a 10% demand reduction (see Section 5.2), then the construction of a new storage reservoir can be deferred from 2030 to 2043 (23 years away). This reservoir would still require significant investigation, capital raising, consenting, hearings and design prior to construction. New storage would most likely be a third Macaskill lake at Te Marua, filled from the existing Kaitoke consent during winter when there is surplus water available.

The longer the next major storage upgrade can be deferred, the more chance there is for new technologies to be developed that may increase options, reduce costs and/or improve cultural/environmental outcomes. This desire to defer investment would need to be managed within constraints so that the community is not exposed to significant risk. Water storage could come in a variety of forms, including:

1. Additional storage lakes near Macaskill Lakes, for offline storage of abstracted water.

2. New run of river dams (i.e. in the Whakatikei River) that would create a permanent reservoir in the headwaters of a forested catchment

3. New localised reservoirs distributed around the cities to increase storage capacity (i.e. the new 35 ML Omāroro Reservoir in Wellington City). These are however often limited to <3 days of storage capacity to meet local demand.

5.2 Reduced demand

As detailed in Section 3.6 and Appendix A, Wellington Water have developed a number of programmes to help reduce demand. This includes many approaches, such as:

- The adoption of smart metering and network metering across a greater proportion of the network to help reduce demand through better realisation (and education) of water use
- Improved leakage detection using new technologies and better monitoring, which will feed into greater asset renewal and repair through CAPEX and OPEX programmes
- Education campaigns through schools and local councils, to help increase awareness of water use and conservation
- Promoting sustainable water use, including the adoption of water sensitive design, green housing, and/or localised storage and re-use where economically viable and practically suitable.

Even with these programmes being implemented over the next 10 years, and should demand reductions of 10% be achieved, Wellington will still be facing water storage issues in less than 30 years.

5.3 Urban water recycling

A large amount of water could be re-used within the potable network, if it was adequately treated and stored. However, the re-use of water would need to pass cultural and social barriers, particularly where treated wastewater is concerned. In some locations around the country, river water supplies could be considered to already have a proportion of urban 'reused' water, through stormwater runoff and direct wastewater discharges or leakages at upstream locations.

The option of treated wastewater for drinking water has been explored in theory and is being applied in practice in many locations around the world, including Australia. Similar social barriers exist and a number of Australian states have gone down the path of desalination rather than direct wastewater re-use, although some indirect re-use via groundwater recharge or open reservoir top-up is deployed. Perth draws a significant amount of its water supply from groundwater and desalination plants (see Section 5.6), however the groundwater aquifers are recharged (see Section 5.5) through direct injection of wastewater treated to drinking water standards, and act as a natural water storage source (Water Corporation 2020a).

Brisbane has developed a $2.5 billion wastewater recycling scheme (Western Corridor Recycled Water Scheme or WCRWS) for drought resilience. Since construction, the scheme has not been utilised but can be called upon when necessary. Treated wastewater would be pumped to individual recycled treatment plants to produce purified recycled water. Under Australian regulations, recycled water can be used to augment potable supplies only through topping up through a source such as a dam (i.e. no direct connection is allowed to the piped potable network). Subsequently, treated water from the WCRWS (when operating) would be pumped to Wivenhoe Dam for mixing with natural water, and then treated again downstream when abstracted for potable use (Seqwater 2020a).

At a smaller scale, there are opportunities to enhance the re-use of water within residential and commercial properties, particularly for greywater systems. Currently, all water (including that used to flush a toilet) is treated to drinking water standard. As discussed in Section 5.4, rainwater tanks in appropriate locations or in new greenfield developments provide some opportunity to capture water for general household purposes (showering, washing and toilets) or all household use if the tank is large enough. Kapiti Coast District Council (KCDC) has a rainwater and greywater code of practice for residents and the building industry, put together to support the mandatory requirement for all new homes from 2009 to have an alternative non-drinkable water supply (untreated rainwater and/or greywater system) for outdoor, washing machine and toilet flushing use (KCDC 2017).

Stormwater runoff in urban areas can be significant, albeit ‘flashy’. The suitability and viability of capturing this runoff at a larger scale for treatment and potable use has not been explored. This would be separate to rainwater tanks, and may require stormwater storage ponds, which would then need to be pumped to a treatment plant and redistributed through the network.

5.4 Localised collection and storage

Localised collection and storage refers to devices such as rainwater tanks, stormwater harvesting and re-use and small abstractions from bores or streams.

Rainwater/stormwater harvesting on residential properties occurs across most of rural New Zealand where there are limited network supplies. Some of the opportunities and constraints of this option are discussed in Table 5 (noting this may not cover all cultural, ecological and social values of rainwater harvesting).

Table 5. Rainwater harvesting opportunities and constraints

Opportunity	Constraint
Promotes water sensitive housing and resilience, through localised storage at houses that have suitable property area. This could be particularly useful for suburbs that have long wait times following a large earthquake (for example, Miramar could be out of water for up to 100 days).	Large storage tanks are necessary for drought resilience, with tanks >30,000 L common for households with 4 people when they are not connected to the network. Tanks of this size may still need to be topped up by the mains supply over drought periods. In an urban area, tanks of 5-10,000L would be more feasible to install, but provide less storage. This may be suitable for greywater or outdoor water use, while the household is still connected to the network (see KCDC 2017).

Helps mitigate stormwater runoff and promotes hydraulic neutrality. This can benefit the wastewater network as less inflow and infiltration would occur, resulting in less wastewater overflows. NOTE: This benefit is only present when the tank is not full. A full (or near full tank), which is the preference of a home owner using it for potable supply, would have minimal benefit in reducing stormwater runoff.	Water treatment and maintenance of the tanks fall back on private owners. Treatment to same level as the network supply is unlikely, unless filters and UV are incorporated at significant cost to an individual. This could increase health risks and burdens on tax payers.
Would reduce demand across the network meaning less abstraction from rivers and aquifers	Old roofs may have lead nails and lead paint, whereas new properties (or those with new roofs) would have reduced heavy metal risks.
In new greenfield sites, there is opportunity to incorporate rainwater tanks during design phase and promote best practice, while also reducing plumbing costs (compared to a retrofit). May be limited in townhouse developments with small sections.	Difficult to install large tanks in a dense urban area, particularly on sloping sites. Need to be evaluated for earthquake risk should it fail and affect downslope properties and geotechnical requirements for large tanks.
Promotes water education and conservation as owners with rainwater tanks have increasing awareness of their water supply and use, including a desire to undertake leak detection.	Would require plumbing reconfiguration to internal re-use, even if a smaller 10,000 L tank was installed for greywater use. Would then require a joint network + rainwater tank setup, which would be at the cost of the private owner.
	Local councils would need to agree on the promotion and use of rainwater tanks, including passing new rules and objectives in plans where necessary.
	Aging tanks become an environmental legacy issue, where >50 years from present, disposal of thousands of tanks would need to be considered (if they are unsuitable for recycling). Carbon footprint needs to be considered for the creation and installation of a tank against a larger network scheme.

A rainwater tank assessment was conducted by Harrison Grierson Consultants Ltd in 2011 for GWRC, looking at three different roof areas (100, 150 and 200 m^2) and two tank size (5000 and 10,000 L). Some of the key findings of this study are described below (Shaw 2011):

- A 5,000 litre rainwater tank can provide between approximately 65% and 100% of a household's needs for toilet flushing and outdoor use for four to two occupants, respectively, in all but the driest years.
    - the percentage of water required that is provided by the rainwater captured decreases as the roof capture area reduces, occupancy increases, and between average and dry years.
    - two-occupant households would require no top-up, or only a small top-up, from the municipal supply in an average year and slightly more in a dry year
    - three-four occupant households would require a small to large top-up from the municipal supply in an average year and a large to very large top-up in a dry year (substantial top-up with small roof capture area).
- A 10,000 litre rainwater tank captures a larger amount of rainwater, however the difference in rainwater captured between the two tanks in many cases was not substantial.
- A 10,000 litre tank would meet most needs for toilet flushing and outdoor use in an average and a dry year for a two-occupant household. Top-up is still required for three and four-occupant households but a smaller amount than for a 5,000 litre tank.
- A cost benefit assessment was undertaken assuming $7,500 and $10,000 plus GST for a 5,000 and 10,000 L tank, respectively. The annual savings were calculated against volumetric network charges. The assessment showed that, even in the best case scenario at maximum savings, payback for a rainwater tank installation is unlikely to occur within the lifetime of the system, and would be exacerbated if the tank was installed through debt (i.e. borrowing rather than cash purchase).
- The estimated cost for a 5,000 and 10,000 L tank installed on 25% of properties in Wellington, Lower Hutt and Upper Hutt was $231 million and $307 million (in 2011).

In addition to rainwater harvesting, localised storage and abstraction could potentially be undertaken. Wellington Water has explored this through the Community Infrastructure Resilience (CIR) project, which looked into emergency water supplies using local ground and surface water sources. The outcomes of the project are that local sources are available, but they are low yielding (~10% of normal usage) and require onsite treatment. Small streams surrounding wellingtons suburbs are unsuitable for water supply, given their low baseflows and variable hydrological regimes with minimal storage potential over summer. In addition, there is poor water quality from lack of source protection and urban development

5.5 Improved natural storage

Water Sensitive infrastructure has been described in Blyth 2020. It has many benefits, including promoting hydraulic neutrality, similar to a natural flow regime. By enhancing infiltration and detention of stormwater, groundwater levels can increase and baseflow to a river can be sustained over a longer period. Subsequently, abstraction from existing supplies may have a reduced impact on the environment, or potentially could be increased if the effects are minimal.

The Waiwhetu aquifer can make up 80% of the summer water supply when river levels decline, reducing surface water abstraction. As demand increases and sea level rises, abstraction from the aquifer may also decline as water use needs to be managed carefully to reduce the risk of saline intrusion. Subsequently, once the aquifer is fully allocated, the viability of this source during summer periods may be challenged.

Managed aquifer recharge (MAR) maybe a possibility within the Waiwhetu aquifer, where re-injection of water to replenish groundwater levels (and water storage) may help to meet future demand increases and supply constraints (from sea level rise and saline intrusion risks). However, this would require a source of water for re-injection and investigation into suitable locations where this could occur. The source of water could be from stormwater capture (which would be of little benefit over summer or during a drought) or wastewater re-injection, as discussed in Section 5.3, however would require consideration of contamination risks and treatment requirements.

5.6 Desalination (Reverse Osmosis)

Abstraction of ocean water for the potable network is common in many countries with limited natural freshwater supplies (river and groundwater).

Perth (Western Australia) currently abstracts salt water from two desalinations plants, supplying 48% of the city's water supply (with a population of ~2 Million) (Water Corporation 2020). This is undertaken through a process called Reverse Osmosis (RO). The first RO plant was constructed in 2006 at Kwinana and can produce 140 ML/d of potable water. Electricity for the plant is generated from a large wind farm. Perth are currently considering a second RO plant at Kwinana (Perth Seawater Desalination Plant 2, or PSDP2), capable of producing an additional 25 to 50 gigalitres/annum (equivalent to 75 to 150 ML/d of potable water) (Water Corporation 2019).

RO abstracts large quantities of salt water through an ocean intake pipeline, and discharges a concentrated brine back into the ocean. Discharges are often monitored heavily to ensure environmental effects are minimal. PSDP2 would abstract up to 400 ML/d of salt water, and discharge up to 230 ML/d of brine with the residual amount the potable water for network use (Water Corporation 2019).

Power demands from an RO plant are significant, with PSDP2 requiring an estimated 174,000 MWh per annum (Water Corporation 2019) to produce 150 ML/d of drinking water. By comparison, in 2018/19 Wellington used 21,531 MWh of electricity to produce an average of ~151 ML/d of water (including treatment) for the Wellington potable network. The annual power demand for the PSDP2 RO plant is ~8 times greater than the 2018/19 annual power usage for Wellingtons bulk water supply and treatment. As a rough estimate, assuming 0.17 c/KWh, this would increase power costs from ~$3.7 M/annum (based on the 2018/19 power usage) to $29.6 M/annum (assuming an RO plant using the same power equivalent as PSDP2). Other factors such as equipment maintenance and chemical costs would need to be factored in, additional to the initial capital outlay which could exceed $1 Billion.

As technologies improve, the cost of RO will decrease. In addition, the potential to harness power from localised sources (for example tidal or wind) could also be used to offset the large power requirements of RO with 'green' energy. Currently the large capital outlay and annual costs would make RO an expensive option for rate payers in Wellington. However, depending on the public interest in such a project, further investigations could be warranted that may consider a smaller RO plant used in conjunction with current water supplies to improve resilience through droughts, sea level rise and earthquakes.

5.7 Supply diversification

In the long term there are significant resilience advantages to increasing supply diversity. This approach would prioritise initiatives that reduce exposure to single sources that are subject to unpredictable seasonal/decadal changes in water availability. This will be considered in future reviews of the Three Water Strategy and if pursued, could ultimately see the Wellington region supplied by a mixture of river/aquifer sources, RO, winter harvesting, rainwater tanks and urban water recycling. Resilience of our water supplies will also be factored into these decisions in the face of climate change and natural hazard risks.

6. References

Blyth, J. M. 2020. Whaitua te Whanganui-a-Tara - An overview of the Wellington City, Hutt Valley and Wainuiomata Wastewater and Stormwater networks and considerations of scenarios that were assessed to improve water quality. Prepared for Greater Wellington Regional Council Whaitua Committee

DIA. 2020. Three Waters Review. Department of Internal Affairs. Retrieved on 1 April 2020 from https://www.dia.govt.nz/Three-waters-review

GWRC. 2014. Water Supply Annual Report – for the year ended 2014. Greater Wellington Regional Council. http://www.gw.govt.nz/assets/council-publications/WaterSupply-Annual-Report-2013-14-web.pdf

GWRC. 2016. Hutt and Wainuiomata/Orongorongo water collection areas management plan. Prepared by Greater Wellington Regional Council and Wellington Water Limited.

Kāpiti Coast District Council. 2017. Kāpiti Coast Rainwater and Greywater Code of Practice Guidelines. October 2017. https://www.kapiticoast.govt.nz/media/31193/k%C4%81piti-rainwater-and-greywatercop-guidelines-646219.pdf

Keenan, L. 2020. Hydrological impacts of water allocation in major rivers of Whaitua Te Whanganui-a-Tara. Report prepared for Greater Wellington Regional Council.

Seqwater. 2020. Wivenhoe Dam. Retrieved on 12 May 2020 from https://www.seqwater.com.au/dams/wivenhoe

Seqwater. 2020a. Water Treatment – Purified Recycled Water. Retrieved on 1 June 2020 from https://www.seqwater.com.au/water-treatment

Shaw, T. 2011. Household rainwater capture in metropolitan Wellington. Prepared for the Social and Cultural Wellbeing Committee. Greater Wellington Regional Council.

Thompson M, Clapcott J, Holmes R, Franklin P and Heath M. 2020. Flow and Allocation Advisory Panel summary report: Ecological health impacts of different river water abstraction regime scenarios for the Te Awakairangi, Wainuiomata and Orongorongo. Prepared for the Whaitua Te Whanganui-a-Tara. *In Press*.

Watercare. 2020. Drought Response – The impact of Drought and our Planned Response. Retrieved online on 15 May 2020 from https://www.watercare.co.nz/Water-wastewater/Drought-response

Water Corporation. 2019. Perth Seawater Desalination Plant 2 - Environmental Review Document. Retrieved on 21 April 2020 from http://www.epa.wa.gov.au/sites/default/files/Referral_Documentation/2.%20PSDP2_Environmental_Referral_Document_Part%20A.pdf

Water Corporation. 2020. Water Supply – Desalination. Retrieved on 26 April 2020 from https://www.watercorporation.com.au/water-supply/our-water-sources/desalination

Water Corporation. 2020a. Groundwater Replenishment. Retrieved on 5 May 2020 from https://www.watercorporation.com.au/Our-water/Groundwater/Groundwaterreplenishment

Water New Zealand. 2020. National Performance Review. *The New Zealand Water and Wastes Association*. Retrieved on 2nd April 2020 from https://www.waternz.org.nz/NationalPerformanceReview

Wellington Water Limited. 2019. Annual Report 2018-19. Retrieved on 1 May 2020 from https://www.wellingtonwater.co.nz/about-us/purpose/

Wellington Water Limited. 2020. Whaitua te Whanganui-a-Tara Update - Client Councils' Representative Meeting 18 June 2020.

Appendix 1 – Wellington Water Demand reduction programmes

Programme 1: A step change improvement in water network management.

Our actions to improve network management:

- Reducing water loss through adopting good practice operational leakage management (see text box below)
- Optimising existing network pressure management and implementing additional systems where practical and cost effective. Pressure management also increases asset lifetimes and reduces the risk of bursts and leaks, but is challenging to implement in Wellington's topography.
- Deploying smart technologies that support water use efficiency based on successful case studies by other water utilities and our own trials. Possible examples include acoustic leak detection sensors located in the network.
- Pipe renewals programme prioritises leak-susceptible pipes, including consideration of potential approaches for customer water supply pipes
- New and renewed pipes designed to reduce leakage risk (i.e. minimise joints through offsite prefabrication of pipe bends, etc.) and consider within-zone pressure management on new and renewed networks.
- Publicising our leakage performance (number of leaks identified/repaired, time to repair, etc.) to support customer education on the value of water.

Good practice operational leakage management

Good practice for leakage management encompasses a range of activities from leak detection through to repair, with appropriate monitoring, reporting and governance. It is expected to include:

- As the top priority, resourcing up to clear the existing ***leak repair*** backlog (especially below-ground) and then to enable a shorter time between detection and repair, with appropriate performance KPIs
- Increasing ***leak detection*** activities, optimised on risk basis, with rationalised contracts for leak detection services with appropriate KPIs, incentives and reporting protocols
- Establishing a ***water loss champion*** within Wellington Water, reporting on and accountable for performance, with a dedicated team of 2-3 people running the programme and analysing performance
- Expanding the fleet of ***network meters*** and other ***smart technologies*** to enable improved monitoring, reporting and analysis, and ensuring the meters are appropriately maintained.
- Developing and expanding ***data collection and analysis tools****, and* ***analysis capability***.

Programme 2: Collaborating with our largest commercial and extraordinary users to improve water use efficiency

Our actions to improve commercial and extraordinary user water efficiency:

- Working directly with our largest users to identify and implement water efficiency opportunities through approaches such as audits and accreditation schemes, including adopting good practice from overseas
- Client councils adopting and demonstrating water efficient practice across operations (i.e. parks and gardens, pools) and buildings
- Benchmarking and sharing of good practice across motivated customers and customer groups (i.e. craft brewing industry, office buildings)
- Reviewing tariffs for water supply and trade waste.

Programme 3: Minimising the impact of population and new building growth.

Our actions to minimise the impact of population and new building growth:

- Targeted communication and education to encourage water efficient design for new builds and renovations (i.e. in consenting process and in design supply chain). This could potentially be aligned with related programmes such as the Homestar rating system.
- Create regulatory framework for water-efficient practice through review of councils' district plans, bylaws, codes of practice and our regional standards. To include stormwater and potentially grey water use (at a community or individual level), (smart) metering and connection pressures.

Programme 4: Facilitating more efficient water use by our domestic customers.

Our actions to facilitate more efficient water use by our domestic consumers:

- Multi-year behaviour change and education programme to change customer attitude to, and value of water. This will initially be targeted at specific customer groups and communities where impacts can be measured and expanded more widely as appropriate.
- Develop and release new schools education materials, with associated competitions or challenges.
- Identify and collaborate with organisations with aligned objectives (i.e. EECA 'Gen-less' for emissions reduction, Sustainability Trust to add water audit to in-home energy audit, etc.). This includes incorporating water use into councils' actions in response to their climate change emergency declarations, and in any climate change action plans.
- Undertaking more visible enforcement of water use restrictions.
- Work with councils to create incentives for (smart) meter uptake, such as coupon/points schemes, reduced charges for metered customers with usage below target levels, subsidised water efficiency improvements (shower and tap fittings, etc.).
- Work with major landlords (Kainga Ora, WCC, Ngati Toa, etc.) to deploy (smart) meters on all properties.

- Investigate the deployment of subsidised 'leak fix' teams that respond to leaks reported on customer properties (as used in Tauranga).
- Investigate a region-wide "water sensitive gardener" service to help gardeners to adopt water efficient practices (perhaps building on previous KCDC service or through collaborating with partners such as garden centres or landscape gardeners)
- Develop and seek approval for business case for universal (smart) meter deployment to reduce customer-side leakage (and other benefits) with inputs from a sample study (see Programme 5, below)

Programme 5: Improving our data and understanding

Our actions to improve our data and understanding:

- Deployment of small area network meters (SAM) and BRANZ-funded residential smart meters to better understand domestic usage.
- Deployment of SCADA Watch/Info360 to collect and analyse network and commercial customer meters and other relevant time-series data, including establishing in-house analytics capability.
- Deployment of smart meters into representative communities in existing houses and in new developments, to compare performance and the effectiveness of behavioural and educational interventions.
- Establish reporting of key metrics around water use, water use efficiency and leakage, referencing relevant industry benchmarks where possible (i.e. ILI, etc.)
- Participate in industry-wide water efficiency forums (WSAA, Water NZ, IWA, etc.) and seek to share experience with peers (especially Watercare) and sector leaders in Australia, UK and elsewhere.
- Improving our data integrity, including in relation to leaks, bursts and their repair.

Programme 6: Monitoring the supply risk

Our actions to improve our supply risk monitoring:

- Establishing closer monitoring and more frequent reporting of the supplydemand balance (including tracking the effectiveness of the interventions and identifying the trigger point for investment).
- Commence initial preparatory work for a new source or storage, including scoping the requirements and identifying potential options (to commence from around 2021)

Appendix 2 – Scenario demand simulations (Keenan 2020)

Table B 1: Hutt abstraction statistics for the period 2000-2019: actual and synthetic under assessment scenarios 1 to 3

	Actual	Scen 1a	Scen 1b	Scen 2a	Scen 2b	Scen 2c	Scen 2d	Scen 2e	Scen 3a	Scen 3b
Surface take (Hutt at Kaitoke):										
Average annual take (ML/year)	32,448	52,904	52,904	54,363	53,673	n/a	n/a	54,363	51,245	51,245
Average annual daily take (ML/D)	89.0	145.0	145.0	149.0	147.1			149.0	140.5	140.5
Average Jan-Feb take (ML/D)	86.8	127.3	127.3	135.5	135.5			135.5	118.2	118.2
Average daily take during highstress times* (MLD)	51	51	51	68	63			68	34	34
Groundwater take (Waiwhetu aquifer):										
Average annual take (ML/year)	25,093	36,524	36,498	25,093	25,093	38,394	44,793	44,793	25,093	44,793
Average annual daily take (ML/D)	68.7	100.0	99.9	68.7	68.7	105.1	122.6	122.6	68.7	122.6
Average Jan-Feb take (ML/D)	74.3	100.0	129.6	74.3	74.3	140.0	122.7	122.7	74.3	122.7

Notes:

The groundwater use under Scenarios 1b and 2a is deemed not possible, because groundwater level at Petone Foreshore falls below 2 m (hence are shaded orange/pink).
Under Scenarios 2a and 2b, groundwater take is assumed equivalent to current regime – i.e. actual use 2000-2019.
Under Scenario 2e, surface take is equivalent to Scenario 2a and groundwater take equivalent to Scenario 2d.
Under Scenario 3a, groundwater take is assumed equivalent to current regime – i.e. actual use 2000-2019.
Under Scenario 3b, groundwater take is equivalent to Scenario 2d.
*For this analysis, high-stress times are taken to be river flows below MALF at Hutt at Kaitoke; this threshold is used as a threshold to indicate likely warm, dry conditions and therefore high water demand.

Table B 2: Change in abstraction and hydrological indicators (7-day MALF magnitude) in the Hutt River under abstraction scenarios compared to current regime. Positive change indicates increase, negative change indicates decrease.

	Scen 1a	Scen 2a	Scen 2b	Scen 2d	Scen 2e	Scen 3a	Scen 3b
Change in surface take (Hutt at Kaitoke):							
Average annual take	63%	68%	65%		68%	58%	58%
Average Jan-Feb take	47%	56%	56%		56%	36%	36%
Average daily take during high-stress periods	No change	35%	24%		35%	-33%	-33%
Change in groundwater take (Waiwhetu aquifer):							
Average annual take	46%	No change	No change	79%	79%	No change	79%
Average Jan-Feb take	35%	No change	No change	65%	65%	No change	65%
Change in hydrological indicators:							
Birchville 7-day MALF magnitude	-4%	-12%	-9%		-12%	3%	3%
Avalon 7-day MALF magnitude	-17%	-20%	-17%	-24%	-33%	-2%	-14%

Table B 3: Wainuiomata abstraction statistics for the period 2000-2019: actual and synthetic under assessment scenarios 1 and 3

	Actual	Scen 1	Scen 3
Average annual take (ML/year)	5,810	10,794	10,258
Average annual daily take (ML/D)	15.9	29.6	28.2
Average Jan-Feb take (ML/D)	841	1,310	1,178
Average daily take during highstress times* (MLD)	6.0	6.0	2.8

Table B 4: Change in abstraction and hydrological indicators (7-day MALF magnitude) in the Wainuiomata River under abstraction scenarios compared to current regime. Positive change indicates increase, negative change indicates decrease.

	Scen 1	Scen 3a
Change in surface take (Wainuiomata at WTP):		
Average annual take	86%	76%
Average Jan-Feb take	56%	40%
Average daily take during high-stress periods	No change	-53%
Change in hydrological indicators:		
LWP 7-day MALF magnitude	-6%	3%