SAFE AND SUSTAINABLE DRINKING WATER FOR KIRITIMATI ISLAND

Baseline Report

May 2022

1 Contents

2 Acronyms and abbreviations

ACG	Action Coordination Group
CA	Contribution Agreement
d	Day
EU	European Union
EDF	European Development Fund
EUR	Euro
FA	Financing Agreement
FW	Four Wells freshwater lens
GoK	Government of Kiribati
HH	Household
HM	Honourable Minister
L	Litre
L/p/d	Litres per person per day
kL	Kilolitre
km	Kilometre
KWASP	Kiritimati Water and Sanitation Project
MFAT	Ministry of Foreign Affairs and Trade (New Zealand)
MFED	Ministry of Finance and Economic Development
MLPID	Ministry of Line and Phoenix Islands Development
NZ	New Zealand
OPCV	Overseas Project Corporation of Victoria Ltd.
p	Person
PSC	Project Steering Committee
SPC	The Pacific Community
SWMP	Sustainable Water Management Plan
UNICEF	United Nations Children's Fund
WSD	Water and Sanitation Division
NZ	New Zealand
NZD	New Zealand Dollars

3 Introduction

3.1 Context

Kiritimati (pronounced "Christmas") Island, one of three inhabited islands in the Line Islands group of Kiribati, is administered by the Ministry of Line and Phoenix Islands Development (MLPID). Kiritimati is the world's largest low-lying coral atoll comprising mostly lagoon and an approximate land area of 388 km² rising to an average 2 to 2.5 meters above mean sea level. The 2020 population was 7,369 according to the 2020 draft national census, spread among four main areas or groups of villages. Kiritimati had no recorded cases of COVID-19 until May 2022 (contained in quarantine), and the cancellation of the weekly flights to/from Hawaii and Fiji since April 2020 has had a significant impact on the island's typically tourism-dependent economy. The first batch of COVID-19 vaccines for the Line Islands arrived on Kiritimati on 31 August 2021 with the vaccination program rolled-out from September 2021.

The Water and Sanitation Division (WSD), under the Ministry of Line and Phoenix Islands Development (MLPID), manage the island's four main reticulated water supply systems along with water trucking and sanitation services. WSD are challenged with operating and maintaining dated and often dilapidated water infrastructure with little institutional capacity and resources whilst attempting to satisfy growing consumer demand for potable water from the four limited and vulnerable groundwater lenses (Decca, Four Wells, Banana and New Zealand Airfield).

The Government of Kiribati (GoK) has identified Kiritimati as a growth centre, and the 2020 population of 7,369 is expected to increase to double to triple by 2045 with the recent opening of 1,750 new residential land leases in 2017 combined with the construction of a new secondary school, a new multi-purpose port in the pipeline and natural population growth. **There is only sufficient infrastructure in place (groundwater infiltration galleries, pumps, pipelines, distribution networks, etc.) to meet the demand of up to 3,080 people (42 percent of the 2020 population) at 100 litres per person per day (L/p/d), or up to 5,140 people (70 percent of the 2020 population) at 60 L/p/d[1].** The effective water supply reach is in fact less due to high losses and geographic constraints as the four main freshwater lenses are spread across the island. For example, the Decca water supply which services London, Tennessee and South Tabwakea villages underwent a major upgrade from 2014 to 2018 during the SPC implemented, EU-funded (10th European Development Fund – EDF-10), *Improved drinking water for Kiritimati Island project*. As a result, the Decca – London system is presently capable of providing up to 94 L/p/d to all residents of London and Tennessee villages. Whilst further optimisation of the Decca – London system may be required, the condition and supply capacity of the other three water systems are far inferior, with:

- Tabwakea residents with access to less than 20 L/p/d reticulated supply from the Four Wells lens.
    - The water reticulation network extends to 217 customers in Tabwakea. However, more than half of these are disconnected or have other connection and access issues.
- Banana, Bamboo and Main Camp residents with access to less than 16 L/p/d from the Banana lens.
    - Most households in Banana and Main Camp are connected, though not metered. Water is rationed via daily manual operation of valves by a WSD staff member.
    - The reticulation does not extend to Bamboo.

[1] A range of 60 L/p/d to 100 L/p/d has been used to remain consistent with the Kiritimati Sustainable Water Management Plan (SWMP) and WHO guidance on domestic water quantity levels for low-risk health concern. The population carrying capacity figures also assume 10 percent non-residential use and 20 percent losses (actual losses are most likely far greater at present).

- Poland residents with access to no more than 56 L/p/d from the New Zealand Airfield lens.
    - Most households are connected to the reticulated water supply, and metered.

If water supply infrastructure (including reticulation) and management capacity were to improve considerably to abstract water at the maximum sustainable rate from each lens (as per previous hydrogeological survey estimates), with non-residential demand maintained at 10 percent of residential demand and losses controlled at 20 percent or less of total demand, then there would be at least 60 L/p/d of reticulated water available for all villages as per the 2020 census population, and over 60 L/p/d in all villages in 2045.

Figure 2 below compares the 2020 population (yellow) to the 100 L/p/d freshwater lens maximum sustainable carrying capacity (blue and bold; the number of people that can be serviced at that rate, taking into consideration non-residential use and losses) and the 2020 – 2021 average operational pumping carrying capacity (purple with underlined writing). The circle area is proportional to the magnitude of each figure.

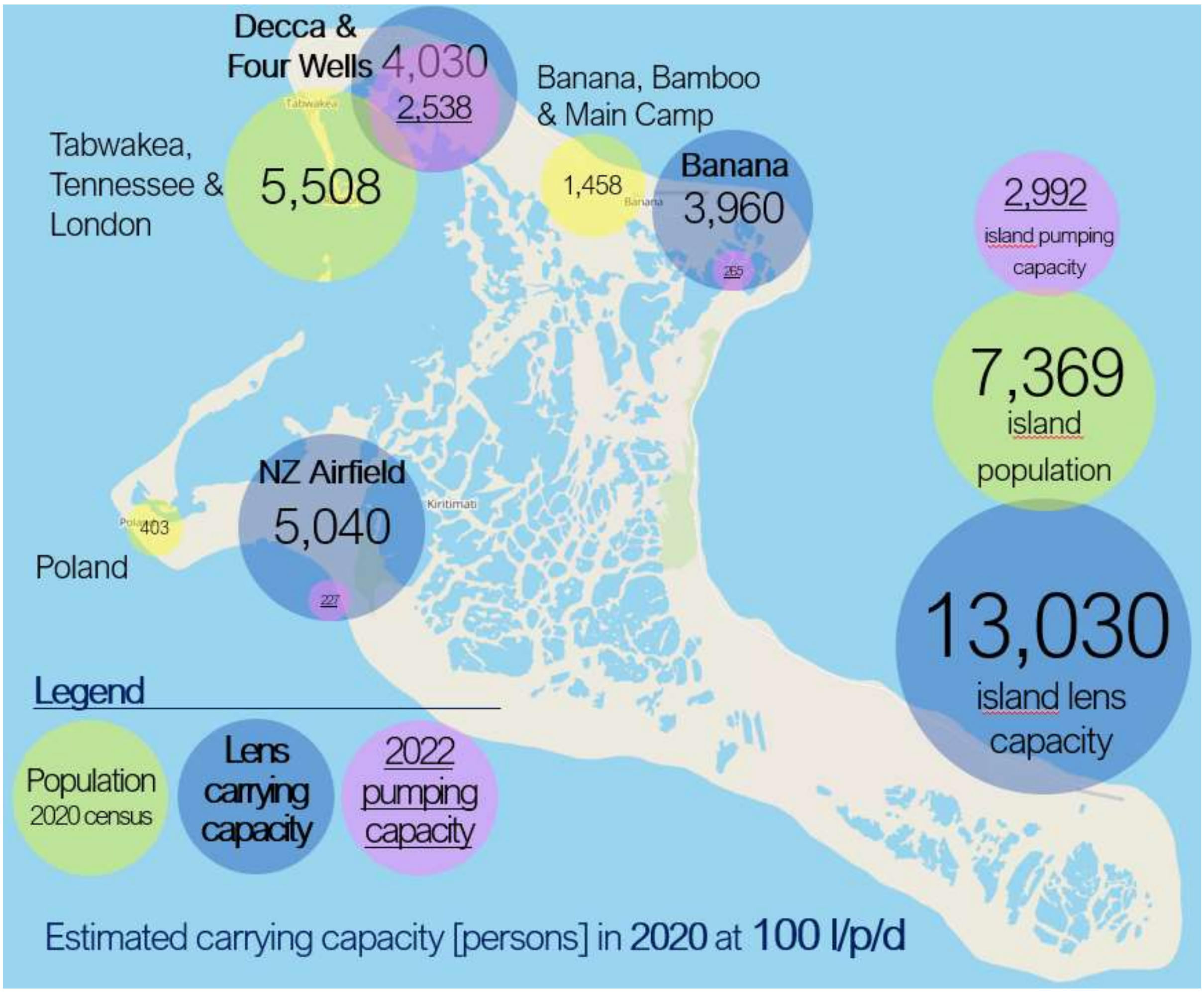


Figure 1. 2020 population (yellow) vs. freshwater lens sustainable carrying capacity (blue) vs. operational pumping carrying capacity at 100 L/p/d

Figure 1 above shows that the freshwater lenses are underutilised and do not meet the needs of the current population. There is plenty of groundwater available in Banana and New Zealand freshwater lenses to satisfy a 100 L/p/d quota for Banana and Main Camp villages and Poland village, respectively. Decca and Four Wells freshwater lenses, dedicated to the north-west villages from Tabwakea to London, are nearing full pumping capacity. Decca has the pumping infrastructure capable of reaching near full sustainable abstraction capacity for the lens (260 – 300 kL/d) when fully operational. Four

Wells lens has installed pumping infrastructure of up to 120 kL/d capacity when fully operational, significantly less than the maximum 300 kL/d lens capacity.

Figure 2 displays the projected 2045 population for each village or group of villages (yellow) and population carrying capacity for each freshwater lens (blue and bold; i.e. the number of people the freshwater lens can provide water for at a given consumption rate – 60 or 100 L/p/d in this case).

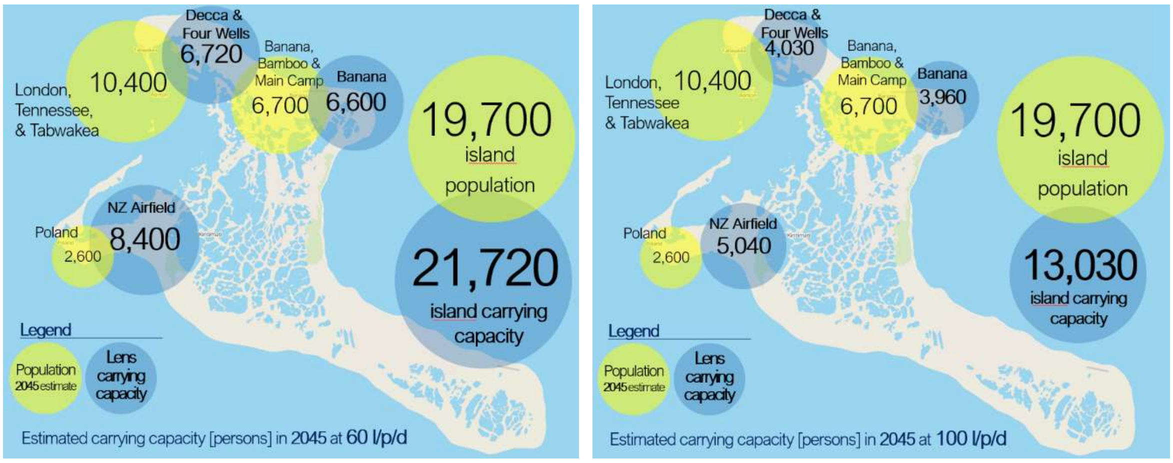


Figure 2. Freshwater lens sustainable population carrying capacity at 60 L/p/d (left) and 100 L/p/d (right) vs. projected 2045 population (yellow)

As can be seen in Figure 2, the total groundwater available is greater than the cumulative island demand for reticulated water at 60 L/p/d (Figure 1). However, the freshwater lens carrying capacity does not align closely with the population size of adjacent villages. This is further evident when looking at the 100 L/p/d scenario (Figure 2), where, with the exception of Poland, the population (yellow circle) is far greater than the lens carrying capacity (blue circles). This suggests that while groundwater is likely to most cost effective and reliable water supply source, alternatives such as desalination will need to come online once the sustainable groundwater abstraction rates are fully utilised.

4 Action description

4.1 Overview of the Action

This Action (project), *Safe and sustainable drinking water for Kiritimati Island*, is funded by the European Union (EU; EUR 6.2M) under the 11th European Development Fund (EDF-11), with an additional NZD 2M (EUR 1.2M) co-financing from New Zealand Ministry of Foreign Affairs (MFAT). The Action is the second of four Components under the broader *EU-Kiribati Partnership for sustainable and inclusive socio-economic development*.

- **Component 1** – Strengthening the economic dialogue and Public Finance Management reforms for inclusive development
    - Implemented through direct Budget Support
- **Component 2** – Safe and sustainable drinking water
    - Implemented by SPC
- **Component 3** – Adequate and equitable sanitation and hygiene
    - Implemented by UNICEF
- **Component 4** – Community and household resilience
    - Implemented by UNICEF

The EU-Kiribati Financing Agreement (FA) came into force on 26 November 2019, followed by a fixed 60-month (5-years; through to November 2024) implementation period. The 52-month implementation period for this Action (Component 2) commenced on 12 July 2020, the date after the final signing of the EU-SPC Contribution Agreement (CA; FED/2020/416-132). The overall management and administration of the project within SPC falls under the Disaster and Climate Resilience Programme, which is part of SPC's Geoscience, Energy and Maritime (GEM) Division (https://gem.spc.int/).

The overall objective of the broader EU-Kiribati Partnership is to support Kiribati in building greater socio-economic and climate resilience. The specific objective is to improve the use of services and goods provided by the public sector with a focus on water and sanitation in the Line Islands. Component 2 – Safe and sustainable drinking water, will focus solely on Kiritimati[2].

SPC are focusing on **knowledge** (understanding water resources and water supply systems), equitable **access** (water supply infrastructure) and **capacity** (management of water systems) for the Action, as per the expected results below.

- Result 1. Improved evidence-based management of water resources and water supply systems (*knowledge*)
- Result 2. Increased access to safe and reliable drinking water supply (*access*)
- Result 3. Strengthened capacity to operate, maintain and manage safe efficient and accountable water supply systems (*capacity*).

The indicative project scope under the above three result areas is summarised in Figure 3.

[2] Water-related capacity building and institutional infrastructure upgrades for Teraina and Tabuaeran (the other two inhabited islands in the Line Island group) are planned under UNICEF-implemented Components 2 and 4.

Result 1. Improved evidence-based management of water resources	**1.1 Strengthened monitoring and assessment**	1.1.1 Establish monitoring program for all groundwater reserves	1.1.2 Build local monitoring capacity	1.1.3 Develop and implement water monitoring plan	
	1.2 Efficient water use	1.2.1 Minimise losses throughout system (including at household level)	1.2.2 Create an incentive scheme for efficient water use	1.2.3 Review island-wide water allocations	
	1.3 Water security	1.3.1 Assess Decca, Four Wells, Banana and NZ Airfield reserves for further development	1.3.2 Plan and prepare for drought response	1.3.3 Investigate options and develop plan to meet long term water demand	
Result 2. Increased access to safe and reliable drinking water supply	**2.1 Increased access for Tabwakea**	2.1.1 Develop and rehabilitate Four Wells groundwater lens (galleries, pumps, pipelines, flowmeters, chlorinator, etc.)	2.1.2 Extend and rehabilitate reticulation in Tabwakea and nearby new leases (piping, meters, etc.)	2.1.3 Provide water truck parts, mini-excavator and trencher	
	2.2 Increased access for Banana and Main Camp	2.2.1 Develop and rehabilitate Banana groundwater lens (pumps, pipelines, flowmeters, chlorinator, etc.)	2.2.2 Rehabilitate reticulation in Banana and Main Camp (piping, meters, etc.)		
	2.3 Increased access for Poland	2.3.1 Develop and rehabilitate NZ Airfield groundwater lens (pumps, pipelines, flowmeters, chlorinator, etc.)	2.3.2 Rehabilitate reticulation in Poland (piping, meters, etc.)		
	2.4 Increased access for London and Tennessee	2.4.1 Reconfigure London village transfer pump operation	2.4.2 Rehabilitate Decca groundwater lens (pumps, chlorinator)		
Result 3. Strengthened capacity to operate, maintain and manage safe, efficient and accountable water supply systems	**3.1 Sustainable management and governance**	3.1.1 Identify institutional (in)efficiencies and opportunities	3.1.2 Water tariff, billing, admin and financial systems review	3.1.3 Facilitate private sector engagement in water system O&M	3.1.4 Support water operations management performance
	3.2 Improved local management capacity	3.2.1 Deploy and train local staff	3.2.2 Design and implement a multi-sector capacity development program for improved on-the-job training		
	3.3 Improved community participation	3.3.1 Improve customer service system	3.3.2 Implement water security and safety awareness and behaviour change program	3.3.3 Incentivise and enforce good household water management	3.3.4 Train community leaders

Figure 3. Action indicative scope (updated May 2022)

The Action will contribute significantly to *Pillar 3 – Infrastructure for Development* of the Kiribati 20-year Vision 2016 - 2036 (KV20) which targets 100 percent of households in Kiribati accessing potable water by 2027. According to UNICEF's multi-indicator cluster survey (MICS), only 52 percent of the Line Islands' population had access to improved and readily available drinking water (less than 30 minutes round trip collection time).

The Action also aligns with Strategic Goal 2 under *Key Policy Area 6: Infrastructure* of the MLPID Ministry Strategic Plan (MSP) 2020 – 2023, which aims to provide "enough and quality water and energy to the public". Applicable key policy indicators under this policy area are:

- New leases connected to quality water and energy
- Percent decrease in number of complaints on water, energy distribution plus housing and internet issues.

5 Previous major water projects on Kiritimati

5.1 Kiritimati Water and Sanitation Project (KWASP) – 1997 to 2002

Water and sanitation infrastructure was installed through an AusAID funded project, Kiritimati Water and Sanitation Project (KWASP), implemented by the Overseas Project Corporation of Victoria Ltd. (OPCV), from 1997 to 2002. The water supply infrastructure installed under KWASP included:

- 15 infiltration galleries with two pumps per gallery (except for one unique 500 metre gallery at Decca with an additional diesel pump)
  - Three galleries at Decca (all equipped with pumps)
  - Three galleries at Four Wells (all equipped with pumps)
  - Eight galleries at Banana (four originally equipped with pumps)
  - One gallery at New Zealand Airfield (equipped with pumps)
- Constructed 10 to 20-metre-high header tanks at Decca, London, Tabwakea, Banana, NZ Airfield and Poland
- Wind and solar pumps at all galleries with additional diesel or petrol pumps at one gallery in Decca and Banana and at the gallery in New Zealand Airfield.
- Village reticulation to small 500 litre household tanks on 2-metre-high concrete stands with metered connections
- A 150 mm PVC transmission pipeline adjacent to the A1 road from Decca to Tabwakea, Tennessee and London
- A 100 mm PVC transmission pipeline from Four Wells adjacent to the A1 road to three low-level 20 kL ferro-cement tanks at Decca
- Solar chlorination units at Decca, Banana and New Zealand Airfield
- Water monitoring boreholes at all freshwater lenses (additional to others installed in a separate project in 1982 – refer to Section 8.6
- Reticulation systems at London, Tabwakea (partial), Main camp and Poland.

5.2 Improved drinking water supply for Kiritimati Island – 2013 to 2018

Major upgrade to the Decca – London/Tennessee water system was the focus of the 2014 – 2018 Improved drinking water supply for Kiritimati Island Project (IDWSKIP) implemented by SPC and jointly funded by New Zealand MFAT and the European Union (EU) under the 10th European Development Fund (EDF-10) mechanism. The EUR 4,941,522 Action involved:

- Drilling of 12 new monitoring boreholes at the Decca and Four Wells freshwater lenses
- Rehabilitation and, in some cases, relocation of wind pumps to better meet demand
- Installation of three new groundwater infiltration galleries at the Decca lens
- Installation of solar pumps at the Decca and Four Wells galleries
- Installation of strainers, flow meters, sampling points and non-return valves at all Decca and Four Wells galleries
- Installation of new solar chlorinators at Decca and Four Wells
- Installation of a new transmission pipeline from the Decca lens to London, isolating the Four Wells – Tabwakea system from the Decca – London/Tennessee system
- Installation of five main (bulk supply) meters
- Rehabilitation and lowering the heights of header tank stands at Tabwakea and London to decrease the pressure in reticulation systems
- Installation of a 250-kL ground-level storage tank and transfer pumps to the header tank at London village
- Rehabilitation of parts of the reticulation infrastructure at London and Tennessee.
- Installation of new flow meters and meter boxes at connections in London and Tennessee.

6 General characteristics of Kiritimati Island

6.1 Kiritimati Island

Kiritimati is one of three inhabited islands in the Line Islands group of Kiribati. Water and sanitation systems are operated and managed by the Water and Sanitation Division (WSD), under the Ministry of Line and Phoenix Islands Development (MLPID) administration. Kiritimati is the largest island in Kiribati and the world's largest low-lying coral atoll comprising mostly lagoon and an approximate land area of 388 km² rising to an average 2 to 2.5 metres above mean sea level. Prior to COVID border closures in April 2020, Fiji Airlines serviced weekly flights to/from Hawaii and Fiji to support the island's tourism-dependent economy – fishing being the main tourist attraction. International ships offload at Kiritimati approximately once every three or four months, and a government-operated ferry services the Line islands (Teraina, Tabuaeran and Kiritimati) at a similar frequency.

6.2 Population

The 2020 census[3] reported a population of 7,369 with 75 percent residing at Tabwakea (3,552 persons; 48 percent), London (known also as Ronton) and Tennessee (1,986 persons combined; 27 percent) villages in the northwest. Banana, Main Camp and Bamboo in the central-North (1,458 persons combined; 20 percent) and Poland in the Southwest (403 persons; 5 percent) make up the balance.

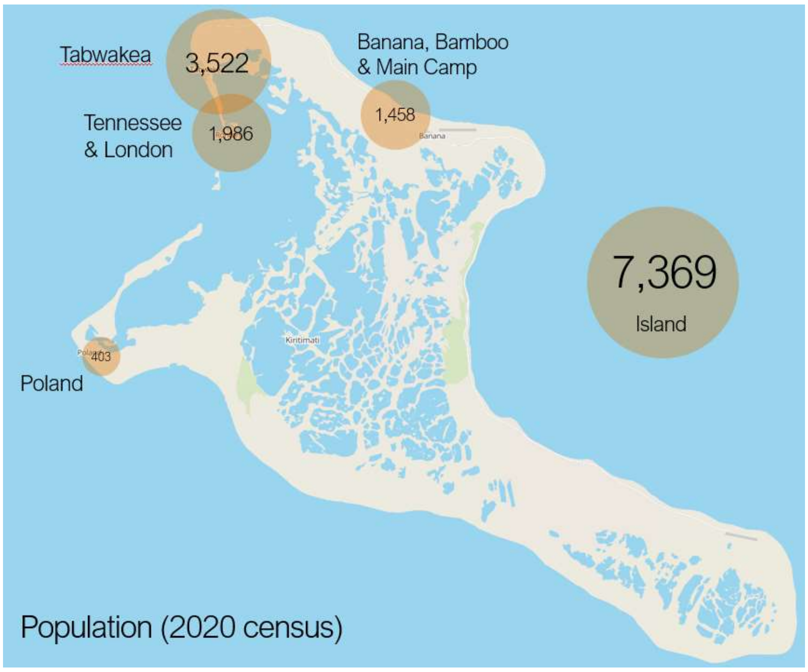
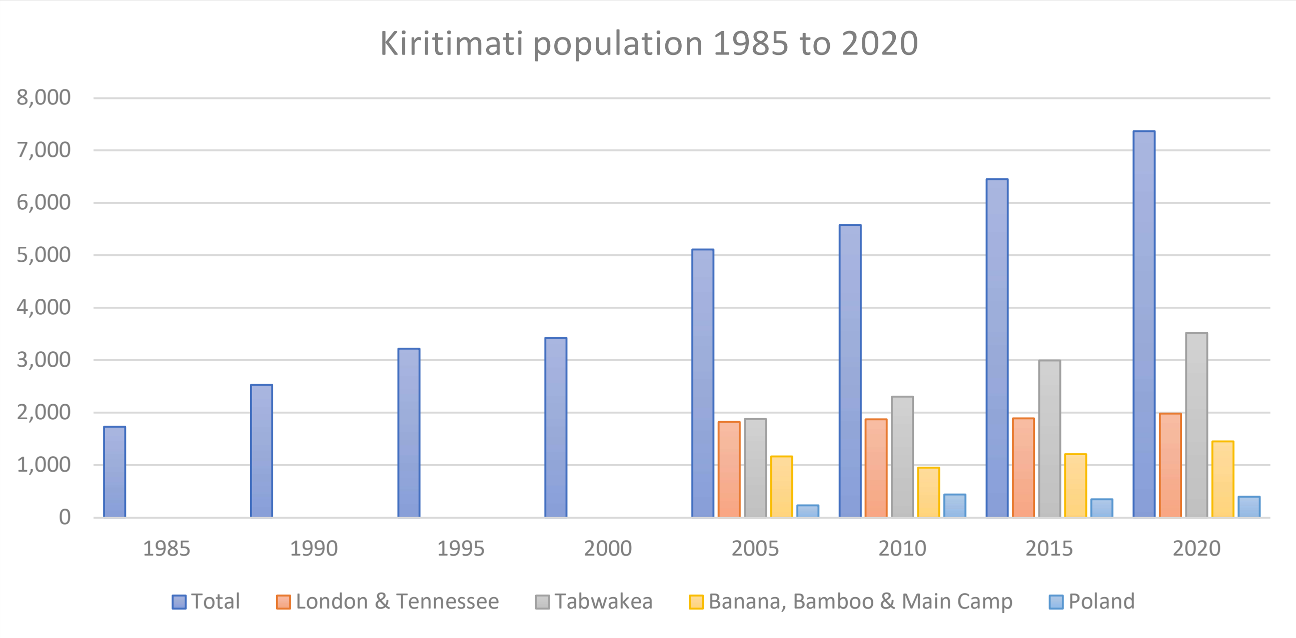


Figure 4. Kiritimati population distribution (as per 2020 census)

Population growth has been variable over the past 40 years with annual growth rates for the island (measured over 5-year census increments) ranging from 1.8 percent from 2005 to 2010 to 8.3 percent from 2000 to 2005. Village level growth rates are also variable, with Tabwakea having an average annual growth rate of 4.3 percent from 2005 to 2020, far exceeding that of London and Tennessee with a combined average annual growth rate of 0.6 percent over the same period. Figure 5 displays

[3] Data from the preliminary draft 2020 national census report, obtained from MFED in August 2021, has been used in this report.

the population increase (and decrease, over some intervals for some villages) for the whole island from 1985, with village/area disaggregation shown from 2005 onward.



Note: national census data used; village level census data only available from 2005 onward.

Figure 5. Kiritimati population 1985 to 2020

GoK has identified Kiritimati as a growth centre. As part of this initiative, nearly 2,000 new land leases were released in 2017, many of which are likely to be occupied by new island residents – particularly people relocating from the highly population-dense urban areas of the island nation's capital, South Tarawa. Table 1 shows a summary of the 2017 lease allocations on Kiritimati, based on MELAD data and development maps.

Table 1. 2017 Kiritimati new lease allocations

Village	Residential lease	Business lease	TOTAL
Tabwakea	486	45	531
Main camp	1,032	50	1,082
Poland	355	30	385
TOTAL	**1,873**	**125**	**1,998**

As an example of how this looks, Figure 6 is a satellite image showing the landscaped demarcation of new lease boundaries near Main Camp prior to occupation and construction activities.

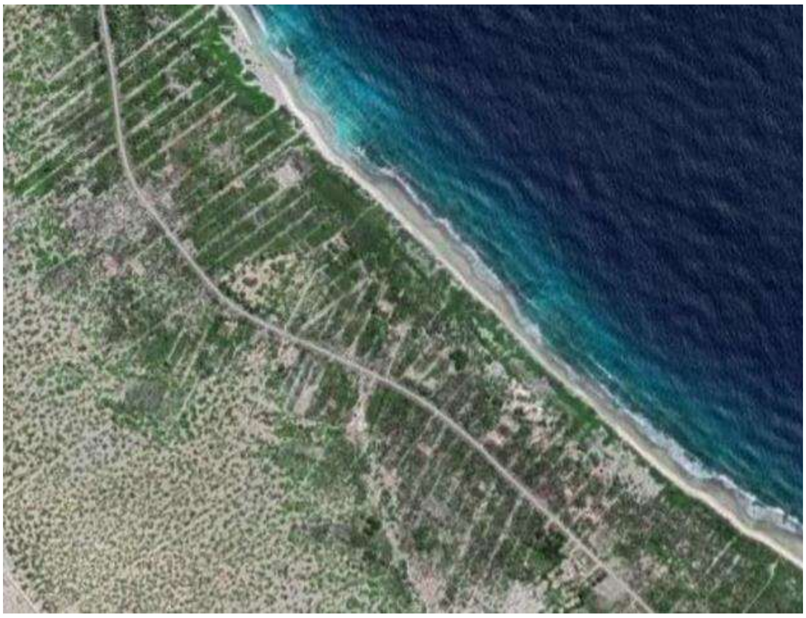


Figure 6. Satellite image of new leases north-west of Main Camp (Google 2021)

The combination of new lease occupation (particularly by new island residents) with natural population growth will result in increasing demand and stress on the island's freshwater resources. The Honourable Minister (HM) MLPID has stated the intention to implement a policy to manage and limit population growth, motivated in part by limited water availability and associated infrastructure and service delivery capacity. For future population estimates as required for design demand calculations, this baseline uses a combination of:

i. Projected village-specific population growth rates through to the year 2045
   - Based on historical trends, land availability and planned land and economic developments
   - 21-years after the new water infrastructure under the Action is planned to be commissioned in 2024, rounded to align with the 5-year census intervals)

ii. Assumed full lease occupancy with an average 6 p/lease
   - For new and old residential, government and freehold leases.

The larger of the above two values for each village has been applied for system design. Given uncertainty of population growth rates (Kiritimati being earmarked as a growth centre for the nation), lease occupancy rates and COVID-relate impacts, this simplified method to determine the ultimate population for the island in 2045 has been applied. Note that is assumes no or negligible new leaseholds will be released and occupied in this period.

Table 2 shows a summary of the 2020 census and 2045 projected population data (by natural growth rate and full lease occupancy, with a 2024 total island population estimate of 17,600 people, 2.4 times the 2020 population.

Table 2. Kiritimati population: 2020 census and 2045 projection

Parameter	London & Tennessee	Tabwakea	Banana, Bamboo & Main Camp	Poland	Total
Population 2020 - census	1,986	3,522	1,458	403	**7,369**
	27%	48%	20%	5%	**100%**
Households in 2020 - census	326	577	239	66	**1,208**
Persons per household – 2020 average	6.1	6.1	6.1	6.1	**6.1**

Parameter	London & Tennessee	Tabwakea	Banana, Bamboo & Main Camp	Poland	Total
Annual natural growth rate - for projections	0.6%	3.4%	3.4%	2.6%	**2.5%**
2045 population - natural growth rate only	2,306	8,125	3,363	766	14,560
	16%	56%	23%	5%	100%
Old leaseholds - residential, freehold & government	203	386	80	73	**742**
New leaseholds - residential & freehold (2017)	0	486	1,032	355	**1,873**
Total leases - residential, freehold & government	203	872	1,112	428	**2,615**
Persons per household – 2045 estimate	6.0	6.0	6.0	6.0	**6.0**
Population 2045 - leases fully occupied @ 6p/lease	1,218	5,232	6,672	2,568	**15,690**
	8%	33%	43%	16%	100%
Ultimate population 2045 - 6p/lease or natural growth rate, whichever is greater *	**2,300**	**8,100**	**6,700**	**2,600**	**19,700**
	12%	41%	34%	13%	100%
Households in 2045 – ultimate population	383	1,433	950	167	**2,933**

** Rounded to the nearest '00*

6.3 Groundwater

The main source of freshwater on Kiritimati is from groundwater lenses formed by rainfall percolating through the highly permeable soils. Rainfall on Kiritimati is highly variable and comparatively low averaging 1,013 mm per year from 1951 to 2020, with an average of only 514 mm per year in the four years from 2017 to 2020. Figure 7 below illustrates the recorded rainfall on Kiritimati since 1951. Note the low rainfall in the years following the 2015/2016 El Nino through to present as Kiritimati continues to experience an extended dry period.

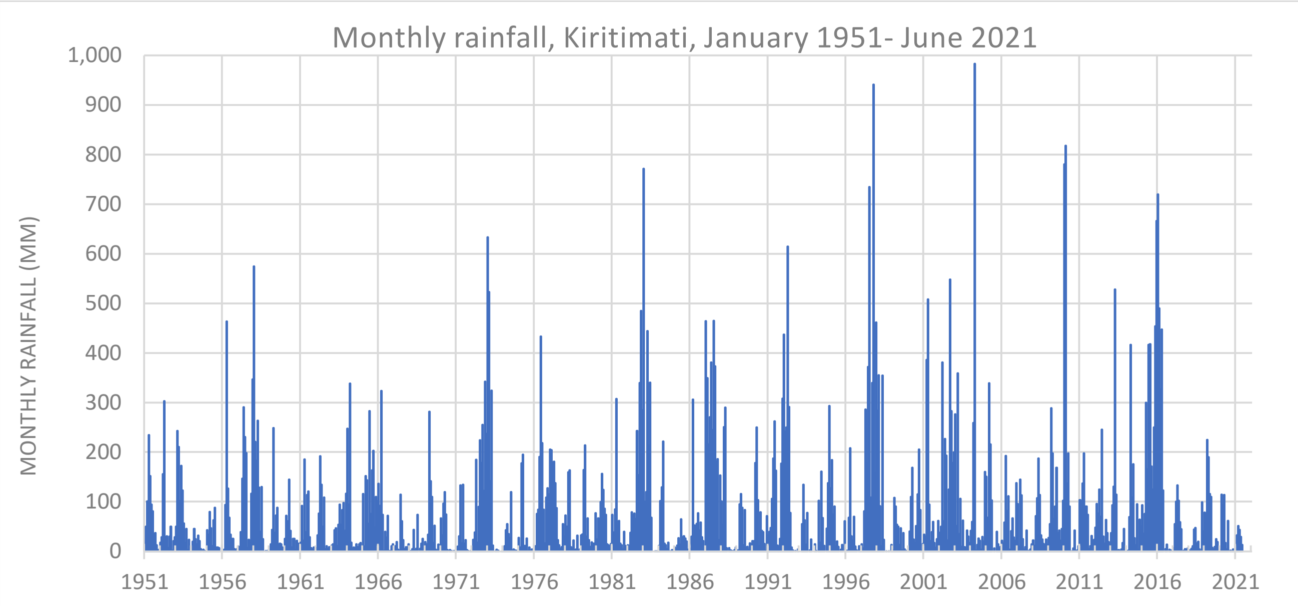


Figure 7. Kiritimati rainfall 1951 to 2020

As a result of the low and variable rainfall, there is limited dependence on rainwater. Desalination is also rarely used (a small unit is at the London Hospital, though out of order, and in early 2022 MLPID were pursuing the procurement of two trial desalination units with capacity of around 500 L/h) due to the high capital and operational costs. Nonetheless, further investigation into the viability of rainwater and desalination to occupy part of Kiritimati's long-term water security plans will be undertaken throughout the Action.

There are four major groundwater lenses on Kiritimati, as shown in Figure 8, each servicing a different village or group of villages.

- The Decca lens supplies London, South Tabwakea and Tennessee villages
- The Four Wells lens supplies part of Tabwakea village
- The Banana lens supplies part of Banana village and most of Main Camp village
- The New Zealand Airfield lens supplies Poland village.

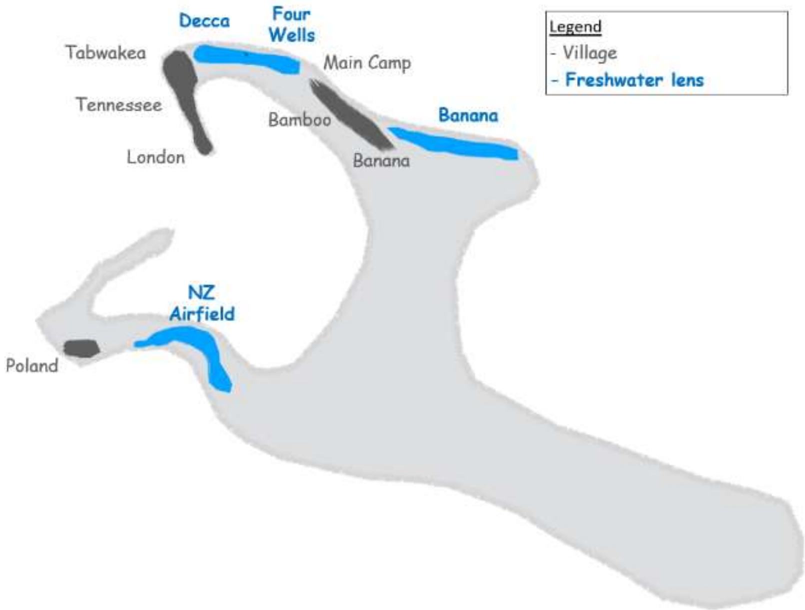


Figure 8. Map of approximate village and freshwater lens locations

The thickness of the freshwater lenses is determined by measuring salinity (electrical conductivity, EC) at different levels of the monitoring boreholes at the water lenses. The standard measure of 0 - 2,500 micro-siemens per centimetre (µS/cm) is used for drinking water, with anything above considered too saline for drinking. The thickness of the freshwater lens varies with pockets that are relatively thicker. Only about 30 percent of the freshwater lens volume is fresh groundwater with 70 percent consisting of sands and gravels. The thickness of the water lens is dependent on recharge from rainfall and abstraction rates. Borehole monitoring data dating back to 1982 (when the first Kiritimati boreholes were drilled) provide a historical record on the status of each freshwater lens.

Figure 9 and Figure 10 illustrate the inverse relationship between rainfall and average freshwater lens thickness at the Decca and Four Wells monitoring boreholes. Figure 11 and Figure 12 show the changes in the salinity near the top of the Decca and Four Wells freshwater lenses, as measured at the base of the gallery pump wells.

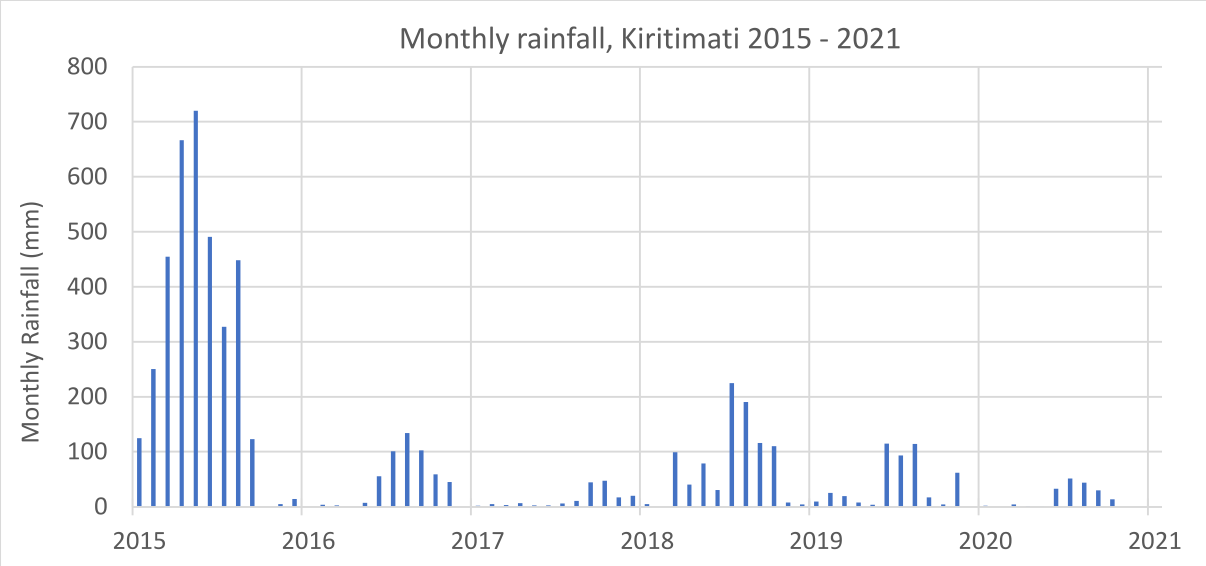


Figure 9. Kiritimati monthly rainfall, Sep 2015 - Jun 2021

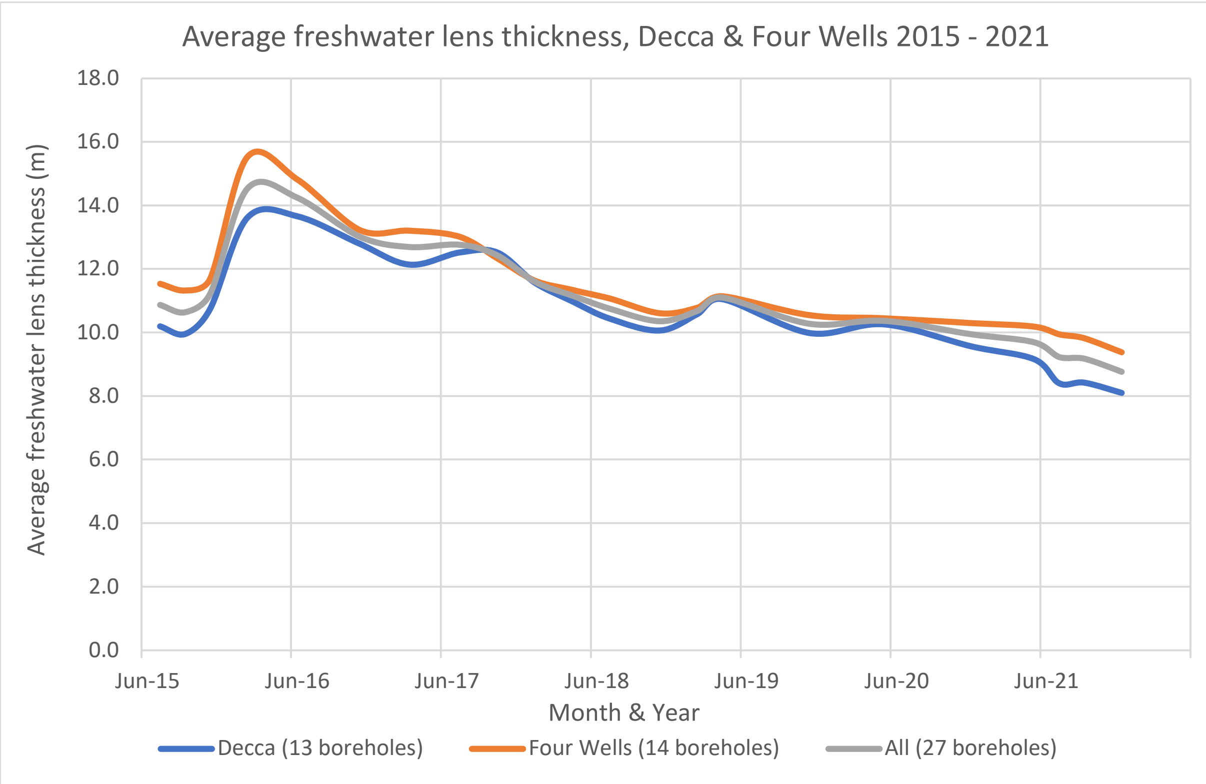


Figure 10. Decca and Four Wells freshwater lens thickness, Jul 2015 – Dec 2021

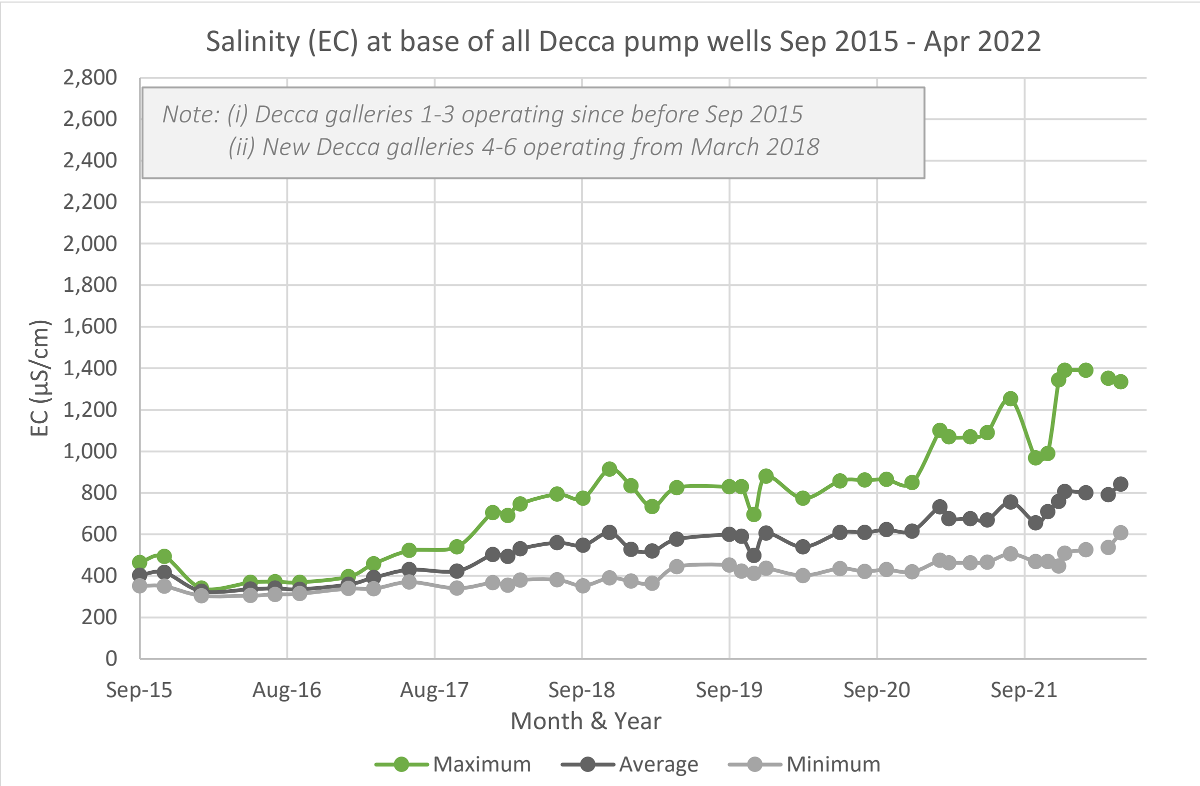


Figure 11. Decca salinity measurements, Sep 2015 – Apr 2022

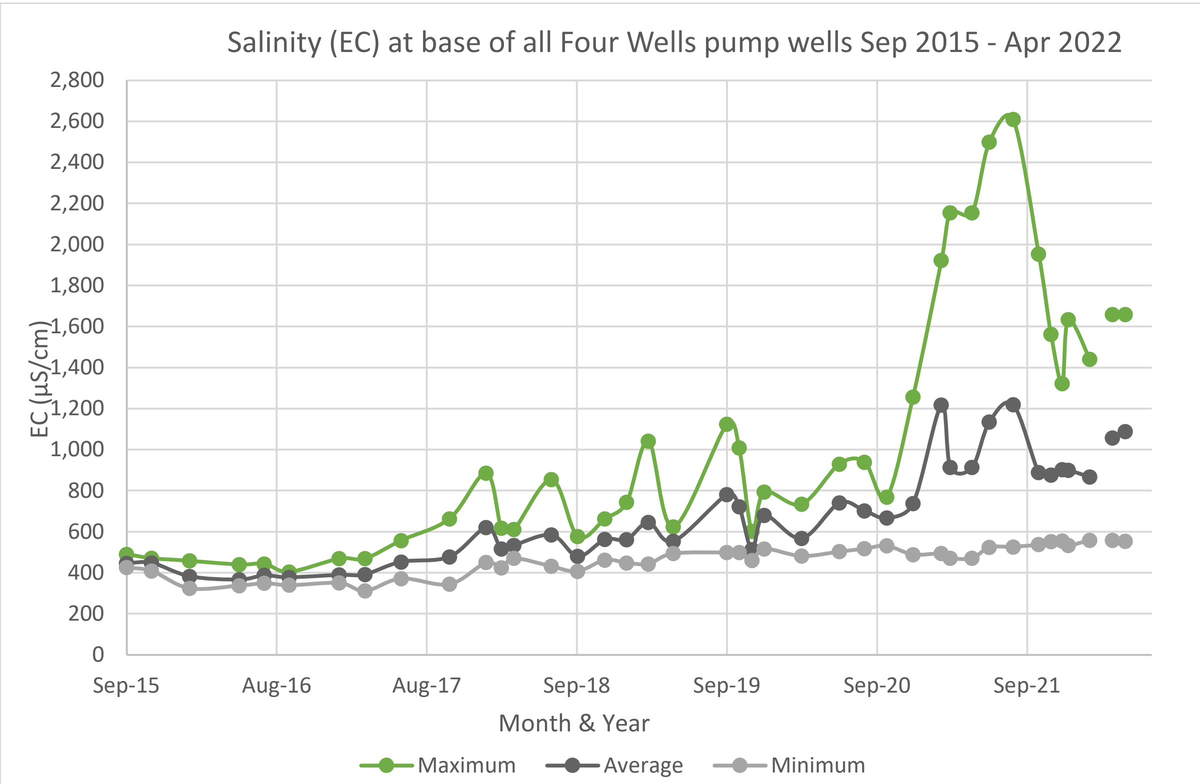


Figure 12. Four Wells freshwater lens salinity, Sep 2015 – Apr 2022

The island's freshwater lenses underwent significant recharge (increase in thickness, decrease in salinity) with the plentiful rainfall during the 2015/2016 El Nino event. However, over six years of relatively low rainfall since this event has seen the gradual increase in salinity (recently exceeding the maximum recommended drinking water threshold of 2,500 µS/cm at some Four Wells pump wells) and decrease in average freshwater lens thickness to below 10 metres which is below the thickness observed immediately prior to the 2015/2016 El Nino event.

The depth of water in the pump wells has also reduced considerably since 2016, with water levels in some pump wells near the minimum to sufficiently cover and cool the submersible pumps. The decline in pump well water levels can be seen in Figure 13, Figure 14 and Figure 15 below.

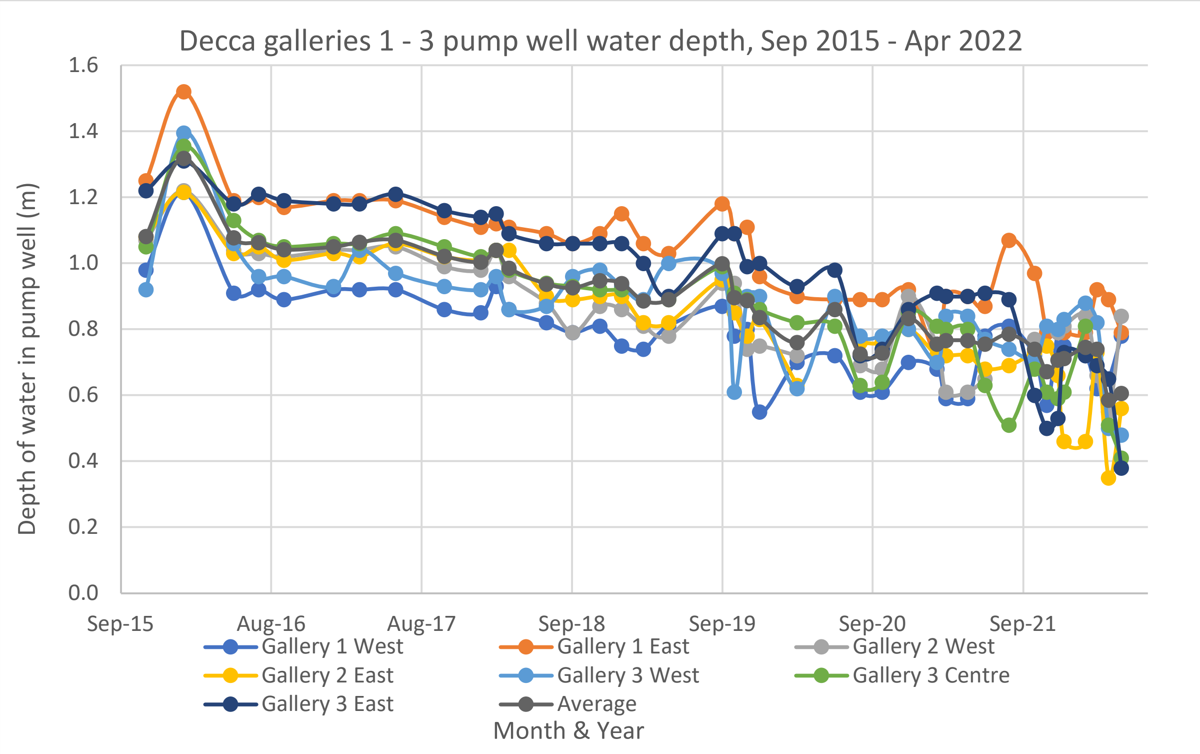


Figure 13. Pump well water depth – Decca galleries 1 – 3, Sep 2015 – Apr 2022

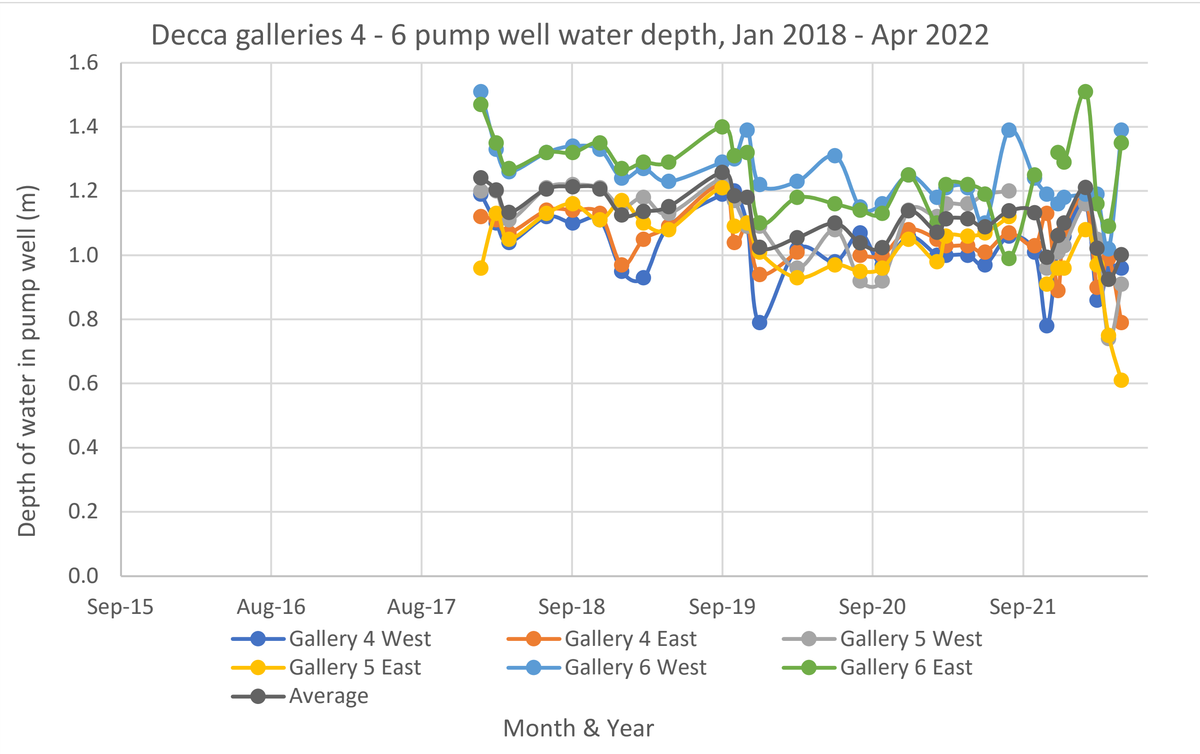


Figure 14. Pump well water depth – Decca galleries 4 – 6, Jan 2018 – Apr 2022

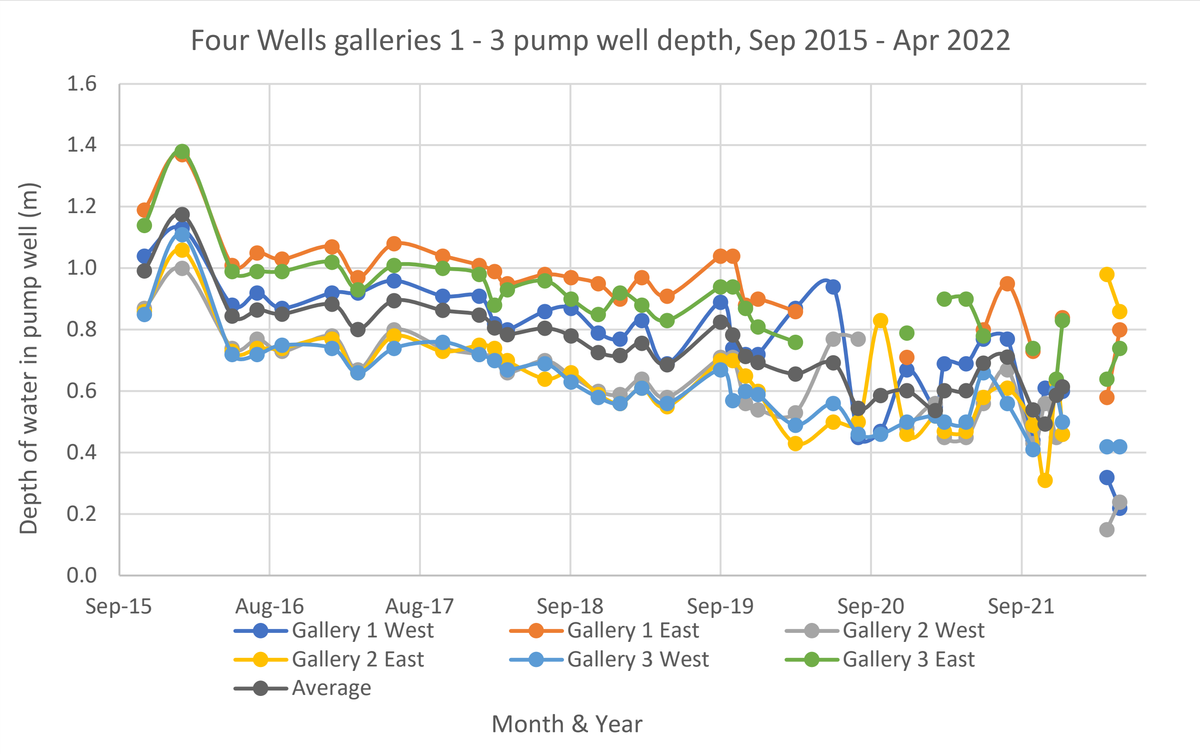


Figure 15. Pump well water depth – Four Wells galleries 1 – 3, Sep 2015 – Apr 2022

7 Kiritimati water availability and demand

Each lens has a maximum estimated sustainable pumping rate as derived from groundwater assessments and calculations, and thus a limited population can be sustainably served solely by groundwater on-island. Table 3 summarises the sustainable pumping rates and carrying capacity (the number of people the freshwater lens can supply) based on average daily reticulated water demand rates of 60 L/p/d (low demand scenario) and 100 L/p/d (high demand scenario)[4]. The table also includes the sustainable pumping capacity based on a maximum 20 kL/day per gallery pump well at each of the lenses using the operational infrastructure in place (i.e., gallery pump wells that are working) as of July 2021.

Table 3. Freshwater lens carrying capacity

Freshwater lens	Decca	Four Wells	Banana	NZ Airfield	TOTAL
Max. sustainable abstraction rate [kL/d]*	260	300	550	700	**1,810**
Pumping capacity of existing functional infrastructure (July 2021) [kL/d]**	240	100	35	40	**415**
Lens carrying capacity @ **60 L/p/d** [persons]***	3,120	3,600	6,600	8,400	**21,720**

[4] Demand rates for reticulated drinking water are as per the 2016 Kiritimati Sustainable Water Management Plan, with 60 L/p/d for households with access to well water, and 100 L/p/d for households without access. 100 L/p/d is also the per capita domestic water consumption service level for "optimal access" and a "very low" health concern, as per WHO Domestic Water Quantity, Service Level and Health guidelines, 2003.

Freshwater lens	Decca	Four Wells	Banana	NZ Airfield	TOTAL
Lens carrying capacity @ **100 L/p/d** [persons]***	1,870	2,160	3,960	5,040	**13,030**
Carrying capacity @ **60 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [persons]***	2,880	1,200	420	480	**4,980**
Carrying capacity @ **60 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [% of **2020 population**]***	145%	34%	29%	119%	**68%**
Carrying capacity @ **60 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [% of projected **2045 population**]***	125%	15%	6%	18%	**25%**
Carrying capacity @ **100 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [persons]***	1,730	720	250	290	**2,990**
Carrying capacity @ **100 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [% of **2020 population**]***	87%	20%	17%	72%	**41%**
Carrying capacity @ **100 L/p/d** @ max. sustainable pumping rates for existing functional infrastructure [% of projected **2045 population**]***	75%	9%	4%	11%	**15%**
Villages served	London & Tennessee	Tabwakea	Banana, Bamboo & Main Camp	Poland	**All villages**
2020 population	1,986	3,522	1,458	403	**7,369**
Projected annual growth rate	0.5%	3.5%	3.5%	2.5%	**2.6%**
2045 projected population	2,300	8,100	6,700	2,600	19,700

** Maximum sustainable abstraction rates may vary depending on rainfall, historical abstraction and further groundwater modelling.*
*** Based on functional pumps in place in late 2021 and assuming all operational pumps abstract at the maximum sustainable rate of 20 kL/d.*
**** Assumes 10% non-residential water use and 20% losses.*

Herein lies a key challenge with this Action: to dedicate financial resources effectively and efficiently to sustainably satisfy the projected growth in reticulated water demand on-island. The challenge is further exacerbated by the 2017 release of nearly 2,000 new leases and the additional water demands and extent of reticulation required. Whilst the cumulative low-end freshwater lens carrying capacity (21,720 persons @ 60 L/p/d) is sufficient to meet the 2045 projected island-wide population, the geographical distance between freshwater lenses and demand centres poses a major challenge.

The variations between available water supply (given by maximum sustainable pumping capacity from infrastructure presently in place, assuming all operational), potential water supply (given by the maximum sustainable abstraction rate for the freshwater lens) and the current and projected (2045) demand, are shown in Figure 16 below.

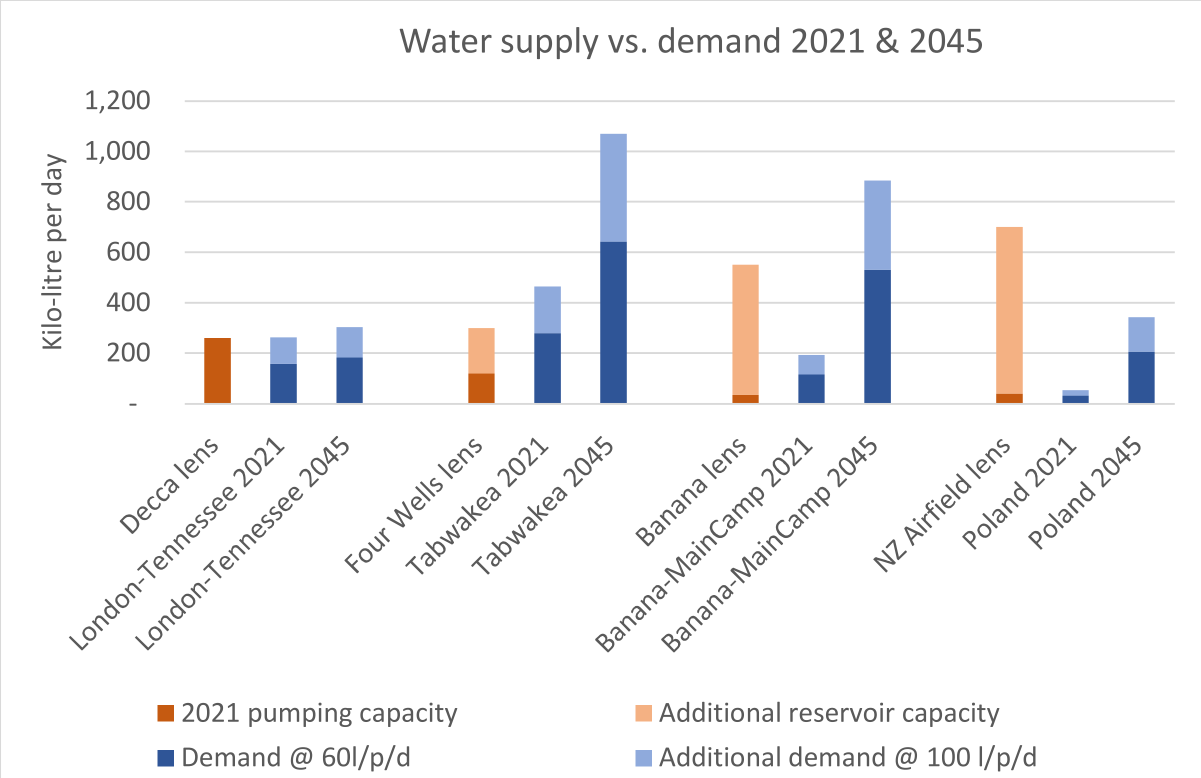


Figure 16. Water supply vs. demand projections, 2021 and 2045

From Figure 16, the present (2021) and projected (2045) water availability for each village is considerably varied. The level of water infrastructure available to satisfy demand also differs significantly, with the Decca galleries able to abstract water at near its theoretical maximum sustainable capacity, and the other lenses with current infrastructure capable of abstracting (at sustainable pumping rates) no more than 40 percent (Four Wells), 15 percent (Banana) and 6 percent (NZ Airfield) of the maximum. Note that the water demand calculations for Figure 16 assume 10 percent non-residential use and 20 percent losses. The actual losses at present are likely far greater for all four main water supply systems on-island.

8 Water supply assets and infrastructure

8.1 Galleries

Each freshwater lens is equipped with one or more infiltration galleries, the majority of which are 400 metres long with two pump wells situated 100 metres from each end. The galleries skim the top fresh layer of the lens and pump it using either a solar, wind or diesel-powered pumps. Water is pumped to chlorinators (all not currently operational), bypassing any header tanks at the freshwater lenses, through transmission pipelines direct to village header tanks or direct to user connections. For London, the water is pumped to an underground tank, then via submersible pumps to a ground level storage tank and then via transfer pumps to a header tank. In total, 18 galleries have been constructed on the island (15 during the 1997 – 2002 Kiribati Water and Sanitation Project (KWASP) and 3 during the 2014 – 2018 Improved Drinking Water Supply for Kiritimati Island Project (IDWSKIP)) of which 13 galleries are presently operational. Figure 17 shows construction of a Decca gallery in 2017.

Figure 17. Gallery construction at the Decca lens during the IDWSKIP project

8.2 Pumps

Table 4 shows a summary of the operational status of pumps at each freshwater lens and infiltration gallery, as per data collected in March 2021 and March 2022. Replacement of some wind and solar pump parts was performed near the end of 2021 (funded by the project), which resulted in improved performance of some of the pumps.

Table 4. Pump performance and operational status, March 2021 and March 2022

Lens	Gallery	Pump well	Pump	Status		Average daily flow rate [kL/d]	
				March 2021	March 2022	March 2021	March 2022
Decca	1	East	Solar pump	Operational	Operational	16.6	20.1
		West	Solar pump	Underperforming	Operational	3.5	24.0
			Wind pump	Operational	Operational	16.8	19.6
	2	East	Solar pump	Not operational	Operational	0.0	17.4
			Wind pump	Disconnected for back-up	Disconnected for back-up	0.0	0.0
		West	Solar pump	Not operational	Not operational	0.0	0.0
			Wind pump	Operational	Operational	16.2	24.6
	3	East	Solar pump	Not operational	Operational	0.0	17.3
			Wind pump	Not operational	Disconnected for back-up	0.0	0.0
		Centre	Solar pump	Operational	Operational	23.4	14.5
			Wind pump	Disconnected for back-up	Disconnected for back-up	0.0	0.0
		West	Diesel pump	Operational	Operational	42.8	20.5
	4	East	Solar pump	Operational	Operational	23.1	22.2
		West	Solar pump	Operational	Operational	29.3	29.1
	5	East	Solar pump	Underperforming	Operational	0.9	30.2
		West	Solar pump	Operational	Operational	22.2	21.6
	6	East	Solar pump	Operational	Operational	23.0	22.3
		West	Solar pump	Operational	Underperforming	21.9	6.0
Four Wells	1	East	Solar pump	Operational	Operational	18.4	19.1
		West	Solar pump	Operational	Operational	21.4	21.8
	2	East	Solar pump	Operational	Operational	18.2	23.2
			Wind pump	Disconnected for back-up	Disconnected for back-up	0.0	0.0
		West	Solar pump	Operational	Operational	16.7	19.7

Lens	Gallery	Pump well	Pump	Status		Average daily flow rate [kL/d]	
				March 2021	March 2022	March 2021	March 2022
	3	East	Solar pump	Operational	Operational	20.7	22.0
		West	Solar pump	Not operational	Operational	0.0	14.4
			Wind pump	Not operational	Disconnected for back-up	0.0	0.0
Banana	1	East	Wind pump	Underperforming	Underperforming	No meter	6.1
		West	Wind pump	Not operational	Not operational	0.0	0.0
	2	East	Solar pump	Not operational	Not operational	0.0	0.0
		West	Solar pump	Operational	Operational	No meter	16.1
	3	East	Solar pump	Not operational	Not operational	0.0	0.0
		West	Wind pump	Not operational	Not operational	0.0	0.0
	4	East	Petrol pump	Operational	Operational	No meter	7.9
		West	No pump	No pump	No pump	0.0	0.0
	5	All	No pumps	Gallery not used	Gallery not used	0.0	0.0
	6	All	No pumps	Gallery not used	Gallery not used	0.0	0.0
	7	All	No pumps	Gallery not used	Gallery not used	0.0	0.0
	8	All	No pumps	Gallery not used	Gallery not used	0.0	0.0
NZ Airfield	1	East	Wind pump	Operational	Operational	No meter	No meter
		West	Solar pump	Not operational	Operational	No meter	No meter
			Petrol pump	Operational	Operational	No meter	~3.0

Each pump well has a maximum sustainable pumping rate of 20 kL/day. As can be seen in

Table 4, some pumps are not pumping at the sustainable pumping rate, and some are not operational at all due to a variety of issues, including faulty controllers and wiring for the solar pumps, and leaking bucket seals for the wind pumps. In March 2021, *no pumping* (or < 1 kL/day) was occurring from four of the 13 pump wells (31 percent) at Decca, one of the six pump wells at Four Wells (17 percent) and five of the eight useable pump wells at Banana (63 percent). Both pump wells at the New Zealand Airfield gallery are in use, though limited performance information is available.

Figure 18. Wind pump rehabilitation (left) and new solar pump (right)

A 2015 study during the early stages of IDWSKIP concluded that solar pumps, equipped with east-west panel orientation to maximise daily pumping duration, were more suitable than wind pumps. Whilst wind pumps have the advantage of pumping 24-hours per day depending on wind speed, the abstraction rates assessed during the study were typically low and variable, particularly during the 2015-16 El Nino period when heavy rain and low average wind speeds were experienced. Conversely, the conditions in Kiritimati are ideal for solar energy with high solar radiation year-round, even during cloudy periods when a sufficient number of well-oriented solar panels will provide the necessary energy for pump operation at desired rates. For this reason, all new pumps installed under IDWSKIP were solar pumps. Wind pumps were rehabilitated and/or relocated and disconnected for backup as needed.

8.3 Disinfection

Water pumped from all four major water sources in Kiritimati is currently not disinfected. Previously installed chlorination units failed shortly after commissioning due to solenoid and inverter issues, system clogging and lack of maintenance. Given that the major freshwater lenses are not "pristine" in terms of biological water quality, disinfection of the groundwater from these sources is essential to ensure it is suitable for drinking. Even though the freshwater lenses and associated galleries do not have human settlements on them (thanks to effective catchment management protocol), there has been some faecal contamination at the galleries. Further, the anticipated increase in exposure to groundwater contamination due to population growth, sea level rise, potential severe weather events and increased groundwater extraction rates, combined with global minimum requirements for water quality, deem an appropriate and effective water disinfection solution as necessary and urgent.

With all four chlorinators out of order, some households practice boiling of water, though this does not appear to be overly common, and may be mainly for babies and the elderly. Few households filter water, and there are few filters available for purchase from private sector on-island. MLPID and Kiribati's Ministry of Health and Medical Services (MHMS) sometimes perform community awareness regarding the importance of household level water disinfection, particularly since the chlorinators have been out of order. The lack of disinfection also results in excessive use of single use bottled water (especially for tourists when international borders are open), a particular concern in such a pristine environment resulting in an unnecessary contribution to Kiritimati's already over-burdened waste management system.

Water supply infrastructure was installed during the KWASP, from 1999 to 2004. KWASP water disinfection involved the installation of three solar-battery powered calcium hypochlorite (tablets/granules) chlorination systems. These were designed and installed by Australian company Wallace and Tiernan (since Hydramet, now Trility) to disinfect groundwater pumped from infiltration galleries constructed during the KWASP. These systems were located:

- At the Decca lens adjacent to the Decca head tank
  - This chlorinator disinfected water from the three groundwater infiltration galleries at Decca, and three galleries at Four Wells
- At the Banana lens adjacent to the southernmost gallery
  - This chlorinator disinfected water from the four Banana galleries
- At the western end of the one New Zealand Airfield gallery.

According to a 2007 ADB Water Supply Working Paper (Falkland and White, 2008: Section 4.7), all three chlorinators were still operational in 2007. However, water quality test results under the same paper suggest the chlorinators were underperforming, with the majority of water quality tests downstream of the chlorinators indicating presence of E.coli (Falkland and White, 2008, Annex B: Sections 4 and 5)).

In 2014, in the early stages of the IDWSKIP, only the NZ Airfield chlorinator was operational (though its effectiveness is questionable, as can be seen in the 2007 water quality test results referenced above). In February 2018, under the IDWSKIP, Hydramet, sub-contracted by Australia-based specialist infrastructure contractor CCB Envico (now Reeves Envico), supplied and installed two replacement solar-battery powered calcium hypochlorite chlorination units housed in separate chlorination sheds (with solar panels secured to the roof) constructed by local contractor TBK Construction. Both chlorinators were installed at the Decca freshwater lens: one disinfecting groundwater from the Decca lens to supply southern Tabwakea, Tennessee and London; and the other disinfecting groundwater pumped from the Four Wells lens to supply part of Tabwakea. Each chlorination system was designed to use calcium hypochlorite in tablet form with capacity for an average daily flow of 240 – 260 kL/day for Decca and 120 kL/d for Four Wells.

All water pumped from the six groundwater galleries at Decca (three constructed during the KWASP and three constructed during the IDWSKIP) flowed through the Decca chlorinator before continuing along the 150mm PVC and 180mm PE pipeline to southern Tabwakea, Tennessee and London. Similarly, all water pumped from the three Four Wells galleries was piped to the Four Wells chlorinator before continuing to Tabwakea via a 100mm PVC pipeline. The chlorination units were programmed to dose chlorine into the main pipelines every 10 litres with chlorine levels to be closely monitored by WSD. CCB Envico provided chlorinator operations and maintenance training to WSD staff in 2018.

Commissioning of the upgraded Decca – London water supply system in 2018 was delayed due to the delay in shipment of calcium hypochlorite tablets to be used for water chlorination. The shipping company (PDL, now NDPL) serving Kiritimati Island could not freight the calcium hypochlorite out of Australia as it was considered highly inflammable. The only ship that agreed to sea freight the cargo was the sailing vessel Kwai that routinely serviced Kiritimati Island from Hawaii. Unfortunately, the Kwai no longer services Kiribati's Line Islands and now operates in the Marshall Islands.

Noteworthy is the availability of Kiritimati's "solar salt", managed and procured under MLPID's Solar Salt division. If the salt if of suitable quality, it could potentially be used to make chlorine via sodium hypochlorite electrolysis.

8.4 Storage

Each water system has at least one header storage tank, though only the London village header tank is used. All header tanks at/near the galleries are either bypassed (Banana and Poland) or available as a surge tank (Decca). A large 250 kL ground-level storage tank and 22.5 kL head tank in London services the Decca – London system. One or two 22.5 kilolitre header tanks service each of Tabwakea (one tank, bypassed), Banana – Main Camp (two tanks at Banana, both bypassed) and NZ Airfield – Poland (two tanks: one at NZ Airfield and the other in Poland, both bypassed). Table 5 provides a summary of water supply storage tanks.

Table 5. Summary of water supply header and ground level storage tanks

System	Decca - London	FW - Tabwakea	Banana - Main Camp	NZ Airfield - Poland
Tanks at freshwater lens	1 x 22.5 kL head tank on 20 m stand; functions as surge tank	No header tank upstream of village	2 x 22.5 kL head tanks on shared 15 m stand (3rd tank missing); all bypassed	1 x 22.5 kL head tank on stand 14 m above ground (TWL @ 16.5 m); bypassed
Tanks at/near village	1 x 10 kL underground tank; 1 x 250 kL ground level storage tank; 1 x 22.5 kL head tank on 6m stand	1 x 22.5 kL tank on 6 m stand; bypassed	1 small head tank at Main Camp operated by Captain Cook Hotel with pump at tank base for service to CCH & surrounding HHs; bypassed	1 x 22.5 kL head tank on stand 10 m above ground (TWL @ 12.5 m); bypassed

Figure 19. London water storage (left) and Decca header tank (right)

Additional to the main water supply storage tanks, many households have small 500 L tanks to store water during times of low pressure and flow rate. Each water supply system is intermittent and predominantly dependent on sun and wind to power the pumps. The float valves in many household tanks have been removed, resulting in significant wastage when tanks overflow.

8.5 Water trucking

WSD have six water tanker trucks: four new Hino tanker trucks provided by Government of Japan in 2021 (2 x 5 kL and 2 x 2 kL); an Isuzu 7 kL tanker; and an Isuzu 3 kL tanker truck. Households and institutions without access to reticulated water in and near Tabwakea, Main Camp, Bamboo and Banana are often dependent on water trucking. Water truck delivery for domestic customers is charged at AU$2.50 per 500 L. Where a household is in arrears and requires tankered water they are required to pay 10 percent of their arrears in addition to the delivery charge of $2.50 per 500 L as a system of encouraging debt repayment.

Shipping vessels and yachts are charged AU$10 per kL for water delivery.

8.6 Monitoring boreholes

Fifty-two multi-level monitoring boreholes have been drilled in the four major lenses on Kiritimati: 14 at the Decca lens (13 currently useable), 15 at the Four Wells lens (14 currently useable), 17 at the Banana lens (four currently useable) and six at New Zealand Airfield lens (four currently useable). In addition to the monitoring boreholes at the four major lenses, five boreholes were drilled and one standpipe was installed (in 1982). Of these, only one borehole (near the Aeon airfield in the southeast part of the island) and the one standpipe (in New Zealand Airfield) are currently useable.

The useable monitoring boreholes at Decca and Four Wells are monitored approximately every three months, whereas the boreholes at Banana and NZ Airfield are rarely monitored. Salinity (EC) is the key parameter tested at each of these boreholes to determine the salinity at each of the tube intervals, from which the thickness of the freshwater lens can be calculated (see Figure 10).

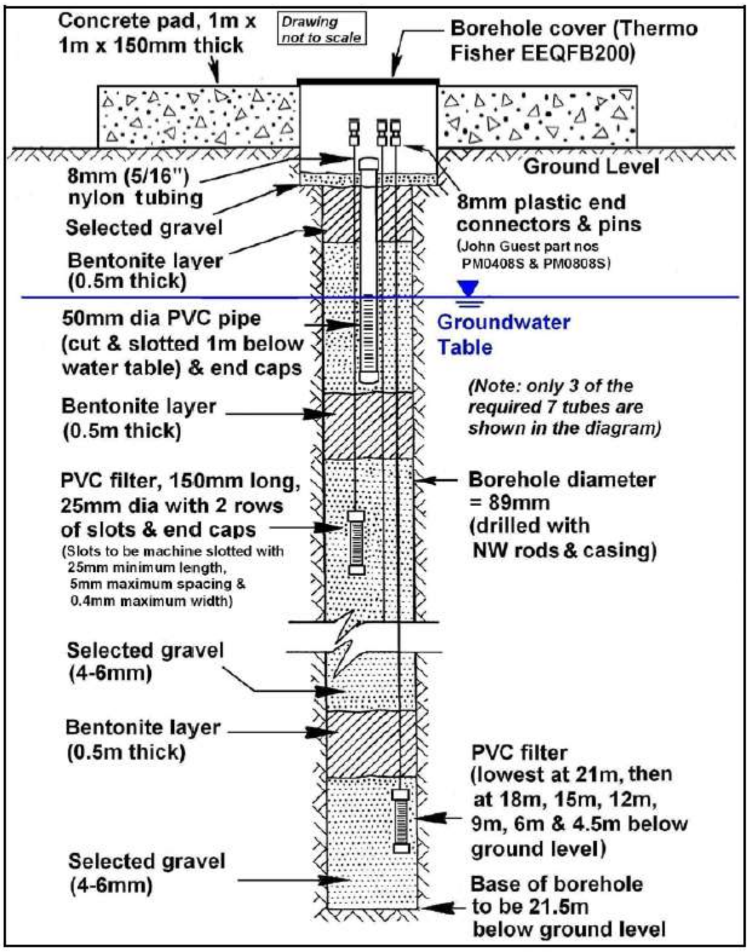


Figure 20. Multi-level monitoring borehole design for Decca and Four Wells

Table 6 provides a summary of the monitoring boreholes and standpipes on Kiritimati.

Table 6. Summary data for Kiritimati Island usable monitoring boreholes and standpipes

Borehole or standpipe (S)	Location	Install date	Tubes	
			No	Depths [to nearest 0.5mbgl]
1. Decca boreholes & standpipes				
DE2	North of main road & northwest of Decca Gallery 3	Jul-82	5	6, 7.5, 9, 12 & 15
DE2(S)	PVC standpipe near borehole DE2	Jul-82		
DE3	Southeast of Decca gallery 1 & southwest of Decca gallery 2	Jul-82	6	6, 7.5, 9, 12, 15 & 23
DE4	South of borehole DE7 (Decca gallery 2)	Aug-82	5	4.5, 8, 9, 12 & 15
DE5	East of Decca gallery 2	Sep-82	6	4.5, 7, 9, 11.5, 14 & 17
DE5(S)	PVC standpipe near borehole DE5	Sep-82		
DE6	Centre of Decca gallery 1	May-98	5	4.5, 6, 9, 12 & 15
DE7	Centre of Decca gallery 2	May-98	5	4.5, 6, 9, 11.5 & 15
DE7(S)	PVC standpipe near borehole DE7	May-98		

Borehole or standpipe (S)	Location	Install date	Tubes	
			No	Depths [to nearest 0.5mbgl]
DE8	Centre of Decca gallery 3	May-98	5	4.5, 6, 9, 12 & 14.5
DE9	South of boreholes DE4 and DE11	Aug-99	7	3.5, 9, 12, 12.5, 18, 21.5 & 26.5
DE10	North of main road to northeast of Decca gallery 3	Aug-99	7	6, 9, 12, 15, 18, 21.5 & 26.5
DE11	South of Decca gallery 2 and borehole DE4	Apr-15	7	4.5, 6, 9, 12, 15, 18 & 21
DE12	Near west end of Decca lens & west of Decca gallery 1	Apr-15	7	4.5, 6, 9, 12, 15, 18 & 21
DE13	East of Decca galleries 2 and 3 & west of borehole DE5	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
DE14	Northeast of borehole DE13 & noth of borehole DE5	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
2. Four Wells boreholes				
FW1	North of Four Wells gallery 3	Aug-82	6	6, 7.5, 12, 14, 21 & 27
FW2	South of main road & east of Four Wells gallery 2	Sep-82	4	6, 12, 15 & 21
FW2(S)	PVC standpipe near borehole FW2	Sep-82		
FW4	South of Four Wells gallery 1	Sep-82	6	4, 7.5, 9, 11.5, 14 & 20
FW4(S)	PVC standpipe near borehole FW4	Sep-82		
FW5	Centre of Four Wells gallery 3	May-98	5	4.5, 6, 9, 12 & 15
FW6	Centre of Four Wells gallery 2	May-98	5	4, 6, 9, 12 & 15
FW7	East end of Four Wells gallery 1	May-98	5	4.5, 6, 9, 12 & 15
FW8	Near west end of Four Wells lens & east of borehole DE14	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW9	East of borehole FW8 & 70m south of main road	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW10	South of Four Wells gallery 1	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW11	South of borehole FW10	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW12	Southwest of Four Wells gallery 1 & north of FW gallery 2	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW13	East of borehole FW12 & west of borehole FW2	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW14	South of borehole FW13 & noth of borehole FW1	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
FW15	Between east end of FW gallery 1 & west end of FW gallery 2	May-15	7	4.5, 6, 9, 12, 15, 18 & 21
3. Banana boreholes				
BA8	Centre of Banana gallery 2	May-98	5	4, 6, 9, 12 & 15
BA15	North & approx. halfway along airport runway	Aug-99	7	6, 9, 12, 15, 18, 22 & 27
BA16	South of east end of airport runway near A1 road	Aug-99	7	5, 9, 12, 15, 18, 22 & 27
BA17	North of east end of airport runway near ocean	Aug-99	7	5.5, 9, 12, 14.5, 18, 22 & 27
4. New Zealand Airfield (NZA) boreholes				
NZ3	Northern part of NZA lens	Aug-82	6	4.5, 6, 7.5, 9, 12, 15
NZ4	Near eastern end of NZA lens	Sep-82	7	4.5, 6, 7.5, 9, 12, 16, 21

Borehole or standpipe (S)	Location	Install date	Tubes	
			No	Depths [to nearest 0.5mbgl]
NZ4 (S)	PVC standpipe near borehole NZ4	Sep-82		
NZ5	Centre of NZA gallery	Aug-99	7	5.5, 9, 12, 15, 18, 22 & 27
NZ6	South of NZA gallery	Aug-99	7	6, 9, 12, 15, 18, 22 & 27
NZ7	North of NZA gallery	Aug-99	7	6, 9, 12, 15, 18, 22 & 27

8.7 Water tariffs, metering and billing

The tariff rates for domestic water usage are summarised in Table 7.

Table 7. Kiritimati water tariff structure (monthly)

Community	London, Tennessee & S. Tabwakea	Tabwakea	Banana, Bamboo & Main Camp	Poland
Residential tariff	Tier 1: AU$1.20 per kilolitre up to 18 kilolitres Tier 2: AU$5.00 per kilolitre over 18 kilolitres			
Commercial tariff	Tier 1: AU$1.50 per kilolitre up to 18 kilolitres Tier 2: AU$5.00 per kilolitre over 18 kilolitres			
Non-metered tariff *	N/A – all connections metered	AU$10.00 per household per month		N/A – all connected households metered
No. metered connections	376	219	18	29
Households connected and metered [%]	100%	38%	8%	~44%

** Applies to households with a water connection but no water meter.*

All households (100 percent) connected to the reticulated Decca supply from South Tabwakea to Tennessee to London are metered and are expected to pay monthly bills. Most households in Poland are also metered. Figure 21 shows a typical house connection meter and meter box as well as one of the bulk supply meters.

Most households in Tabwakea, Banana, Bamboo and Main Camp either have no reticulated water connection or a non-metered connection. Those without access to a water connection are typically reliant on household groundwater wells (most or all of which are exposed to contamination) and the tankered water service provided by WSD. Households with a non-metered connection are charged AU$10 per month. The Kiritimati Sustainable Water Management Plan (SWMP) along with recommendations at the conclusion of the IDWSKIP, suggest the need to review the current tariff structure and rates for the following reasons:

- The current two-tiered structure results in inequity and unaffordable charges for large households and leases with multiple households sharing a single meter. The average willingness to pay for improved water was AU$43 per month (2016 survey), equating to the cost for approximately 6 persons per connection at 100 L/p/d – hence the difficulty for larger households or multi-household leases paying high second tier tariff fees.

- The tariff rates and structure are not understood in relation to operational costs – analysis of the long-term marginal costs of the water supply system is required to understand the cost recovery potential through tariffs.
- Arrears should be (but are rarely) audited in detail to understand the specific circumstances for each customer. In some cases, arrears may result from faulty meter readings or due to high charges from large households or leaseholders sharing a single meter where the second-tier tariff was charged although the per capita consumption may not be excessive.

Support is required to review existing administrative, accounting and financial systems to strengthen the billing and metering system.

Figure 21. Household water meter installation (left) and pump well bulk flowmeter (right)

Whilst revenues in recent months have yet to be assessed in detail, in past years the main source of revenue has been from water truck deliveries.

8.8 Flows

Groundwater abstraction rates vary based on power supply available (solar irradiation, wind speed, diesel availability) and quantity and condition of pumping infrastructure. Bulk flowmeter readings at Decca and Four Wells are normally recorded at roughly the same time each day. Figure 22 shows the average daily flows for Decca and Four Wells combined gallery pumps, January 2015 to March 2022.

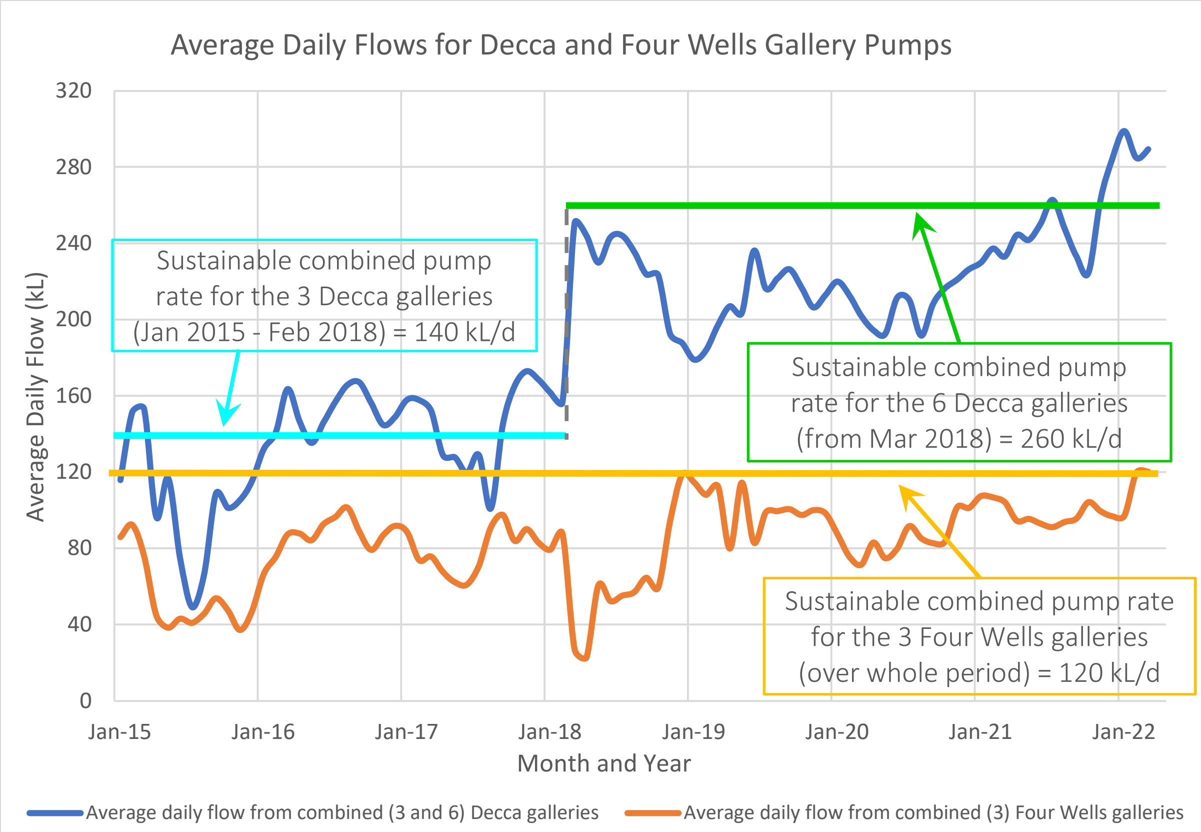


Figure 22. Average daily flows for Decca and Four Wells combined gallery pumps, Jan 2015 to Mar 2022

The combined pump well abstraction rates for Decca (260 kL/d) and Four Wells (120 kL/d) have exceeded the recommended sustainable threshold for some or all months since November 2021.

Bulk flowmeters were installed for each of the operational Banana pump wells in early 2022 (flow rates for March 2022 shown in

Table 4) though the combined abstraction is far below the sustainable combined rate for the installed infrastructure.

The NZ Airfield bulk flowmeter reading has been out of order since early 2021, and no recent flow data is available at the time of writing.

8.9 Losses

Control of water losses is essential to satisfy the increasing water demand across the island. Losses include system leaks (e.g. leaking pipelines) and point of use wastage, including overflow from household storage tanks without a functional float valve. At this stage, it is difficult to measure system losses for the following reasons:

- Potentially inaccurate bulk flowmeter readings
    - The downstream cumulative flow (as per bulk flowmeter readings) sometimes exceeds that of the upstream meters, even when averaged over weeks or months, i.e., meters sometimes suggest more water going out than coming in. This may be partially due to the intermittent system functionality (especially with solar pumps), resulting in negative pressures, air in pipes and backflows
- Illegal water connections where water is used but not measured
- Incorrect household water meter readings

- Lack of household meters, for example in Banana where no houses are metered
- Meter readings occurring at different times on different days, hence historical or real-time snapshots of system performance at a single point in time are not available.

Further investigation is required to identify the major non-revenue water locations and issues.

8.10 Water system operations and management

Kiritimati Island's reticulated water supply systems are managed and operated by the Water and Sanitation Division (WSD) of MLPID. WSD is led by the Water and Sanitation Engineer (WSE), with an organisational structure as shown in Figure 23.

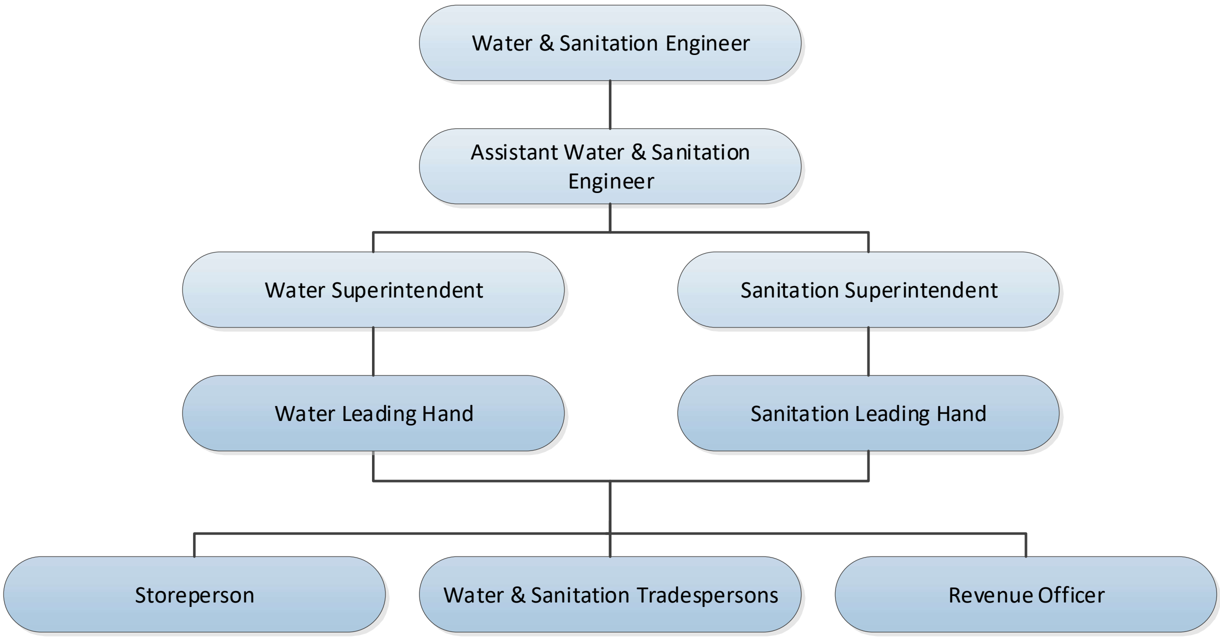


Figure 23. WSD staffing structure

In 2021 and 2022, the Assistant WSE, Water Superintendent and Sanitation Superintendent posts were all funded through the EU-TCF (Technical Cooperation Facility), along with the Water and Sanitation Chief Administrative Officer based under MLPID Administration Division. It is anticipated that these roles (or the capacity to deliver the scope and tasks under these roles) will be absorbed into the MLPID organisational structure by the end of the project.

Each of this Action's result areas (1. Knowledge and understanding; 2. Access; 3. Capacity) will focus on building MLPID institutional capacity to monitor, maintain and sustainably manage the island's water supply systems and water resources. Recommendations at the conclusion of the IDWSKIP stated that "It is critical that the capacity of WSD continues to be strengthened for the long-term sustainability of the water supply infrastructure" and that "WSD management lack the necessary skills to manage the whole water supply system." WSD have since recruited the WSE (in 2019) to facilitate effective management and sustainability of water system infrastructure and water resources.