Te Pātaka o Rākaihautū Banks Peninsula Community Board Information Session/Workshop
AGENDA

Notice of Briefing:

Te Pātaka o Rākaihautū Banks Peninsula Community Board Information Session/Workshop will be held on:

Date:	**Monday 20 May 2024**
Time:	**10.00 am**
Venue:	**Akaroa Boardroom, 78 Rue Lavaud Akaroa**

Membership

Chairperson	Lyn Leslie
Deputy Chairperson	Nigel Harrison
Members	Tyrone Fields
	Jillian Frater
	Asif Hussain
	Cathy Lum-Webb
	Howard Needham
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14 May 2024

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Note: This forum has no decision-making powers and is purely for information sharing.

To watch the meeting live, or a recording after the meeting date, go to:

https://www.youtube.com/channel/UC66K8mOIfQT3I4rOLwGbeug

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4. Duvauchelle & Akaroa Wastewater scheme update 7

The time allocated for this briefing is 40 minutes.

Karakia Whakamutunga

Karakia Tīmatanga

Whakataka te hau ki te uru Whakataka te hau ki te tonga Kia mākinakina ki uta Kia mātaratara ki tai E hī ake ana te atakura He tio, he huka, he hau hū Tihei mauri ora!	*English translation* Cease the winds from the west Cease the winds from the south Let the breeze blow over the land Let the breeze blow over the ocean Let the red-tipped dawn come with a sharpened air. A touch of frost, a promise of a glorious day.

1. Apologies Ngā Whakapāha

At the close of the agenda no apologies had been received.

2. Open Forum

There were no open forum requests at the time the agenda was prepared.

3. Fire and Emergency Update

Reference Te Tohutoro: 24/675513

Presenter(s) Te Kaipāhō : Kerri Pring, Advisor Community Readiness and Recovery

1. Detail Te Whakamahuki

Timing	This information session is expected to last for 20 minutes.
Purpose / Origin of the Information Session	To provide the Board and community members with information about Fire Seasons, impact of wildfires on the land and properties and how community groups can assist with readiness and prevention.
Confidentiality	The workshop and any shared information is not confidential.
Background	Wildfires have plagued the Canterbury District in the 23/24 fire season. Fire and Emergency have been proactive in educating the community regarding the risk of wildfires and their impact on properties.
Key Issues	• How the upcoming fire seasons can impact communities
Next Steps	• Not Applicable.
Useful Links	When Wildfire Threatens | Fire and Emergency New Zealand

Attachments Ngā Tāpirihanga

There are no attachments to this coversheet.

Signatories Ngā Kaiwaitohu

Author	Liz Beaven - Community Board Advisor
Approved By	Penelope Goldstone - Manager Community Governance, Banks Peninsula

Christchurch City Council

Item 4

4. Duvauchelle & Akaroa Wastewater scheme update

Reference Te Tohutoro: 24/487501

Presenter(s) Te Kaipāhō : Thomas Fietzko, Senior Project Manager
Tim Ure, Senior Project Manager
Kylie Hills, Senior Engineer

1. Detail Te Whakamahuki

Timing	This information session is expected to last for 40 minutes.
Purpose / Origin of the Information Session	The presentation for the Duvauchelle and Akaroa will provide an update on both projects' progress and recent changes.
Confidentiality	The workshop and any shared information are not confidential.
Background	The current Duvauchelle wastewater discharge consent will expire in 2031, while the Akaroa consent expires in 2030. In 2020 Council resolved to dispose of the Akaroa treated wastewater to the new irrigation scheme at Hammond Point and Robinsons Bay, while in 2022 Council resolved to pursue irrigation of Duvauchelle treated wastewater to the block of land that includes the Akaroa Golf course, Pony Club and surrounding exotic tree plantations. Assessments made at the time didn't provide compelling reasons to combine the schemes, and the projects progressed in parallel as this was slightly more cost-effective.
Key Issues	**Akaroa** • The relevant consenting authorities are processing the outstanding resource consents for the construction of the Akaroa Treated Wastewater Irrigation Scheme ATWIS project. One of the most significant is the irrigation of the treated wastewater to land, which is being processed by ECAN. ECAN advised us that the consent would be notified, and we accepted it. • Council has tendered the scheme's design. • The land management plan for Robinsons Bay and Hammond Point is nearly complete, and the Council will tender the implementation to start establishing the native trees in the lower areas of Robinsons Bay, along with fencing and track construction. • Survey and geotechnical investigations will commence in May 2024. They will span from the current Akaroa treatment plant to Duvauchelle Show Grounds. We have commenced advertising the need to temporarily shift vessels from the Southeast corner of the boat park to facilitate these investigations. • A detailed design of the scheme will be carried out over the coming year, subject to the acceptance of acceptable resource consent conditions. Construction is expected to commence in early 2026. Construction of the scheme will take two years.

	Duvauchelle • The project team is preparing an application for resource consent to discharge treated wastewater to land. The application will be lodged with ECan by mid-November 2024. • Staff are recommending decommissioning the existing Duvauchelle wastewater treatment plant. The basis for this decision is as follows: ○ It is more cost-effective to operate a single new modern plant. ○ The existing plant will require significant renewals in the future ○ The slope stability risk from the cliff face beside the plant affects its operation. ○ Flow modelling has been completed with the combined scheme of the storage facility at Robinson Bay and three tree trip irrigation areas in the Duvauchelle forest block, Robinsons Bay, and Hammon Point to determine the amount of storage required to manage the expected flows. • An assessment of the proposed spray irrigation at the golf club has identified a number of risks that would need to be addressed in the design and/or managed. The Akaroa Golf Club would need to manage a number of these risks and operate the irrigation within stringent consent conditions. The cost of installing and operating a complaint irrigation system is significantly higher than the approved budget. Council staff are currently assessing options to address these challenges. This information has been presented to the club. • Internal discussions are currently underway to transfer the responsibility of the forest block behind the golf club to from the Parks Unit to Three Waters for the proposed drip irrigation within the forestry block. The majority of existing trees are exotic and have been identified and recommended in a tree assessment report to be removed and replanted due to H&S risk and suitability for the new scheme. The area will be replanted with native trees in a series of staged removal and replanting operations, similar to the other two irrigation schemes.
Next Steps	A report will be presented to the Community Board in due course requesting approval to remove the exotic trees at Duvauchelle Golf Club and replace them with native plants to support the proposed discharge of treated wastewater at this location.
Useful Links	N/A

Attachments Ngā Tāpirihanga

No.	Title	Reference	Page
A ⇩	Akaroa Wastewater Scheme - Design Flow Basis Update Report - 8 April 2024	24/826672	10

Signatories Ngā Kaiwaitohu

Author	Thomas Fietzko - Senior Project Manager
Approved By	Rod Whearty - Team Leader/Programme Manager Wastewater Gavin Hutchison - Acting Head of Three Waters

Christchurch City Council

Beca

Akaroa Wastewater Scheme

Design Flow Basis Update Report

Prepared for Christchurch City Council
Prepared by Beca Limited

8 April 2024

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Appendix A – Akaroa Irrigation Modelling Memo – PDP (2023)

Revision History

Revision Nº	Prepared By	Description	Date
1	Max van den Berg, Logan Thomson	Draft for Council Review (Stage 1)	18/10/2023
2	Max van den Berg, Logan Thomson, Innes Duncan	Draft, updated with Council comments and irrigation results	15/12/2023
3	Max van den Berg, Logan Thomson, Innes Duncan	Draft, updated with further TPS flow commentary	19/12/2023
4	Logan Thomson	Design populations updated and model peer review comments incorporated	14/02/2024
5	Innes Duncan	Updated for final issue to Council	08/04/2024

Document Acceptance

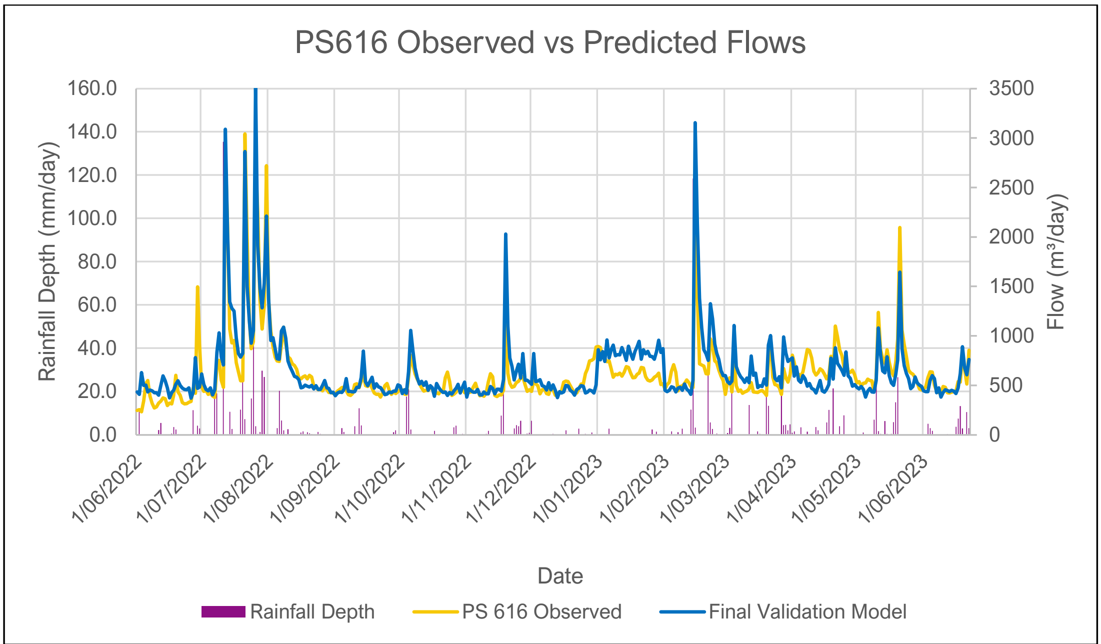
Action	Name	Signed	Date
Prepared by	Max van den Berg, Logan Thomson	P.P	08/04/2024
Reviewed by	Innes Duncan, Angela Dwyer		08/04/2024
Approved by	Amber Murphy		08/04/2024
on behalf of	Beca Limited		

Executive Summary

This report presents a flow design basis and irrigation modelling outputs for the Akaroa Wastewater Scheme. This revision is an update to previous work conducted by Beca in 2020 and utilises updated flow monitoring data and population projections, as well as other revised input factors.

ICM Model Validation

An Infoworks Integrated Catchment Model (ICM) previously developed by Beca has been re-validated for 2 Dry Weather Flow (DWF) events, 5 Wet Weather Flow (WWF) events, and a long time series run using the most recent pump station (PS) flowmeter data, L'Aube Hill WTP flowmeter data, property water meter readings and retentate flow data all provided by Council. Historical flow meter data from the three network pump stations (PS614, PS615 and PS616) has been compared against predicted flow data for validation of the DWF and WWF events. The revised modelled flows and comparison with PS616 observed flows are shown in the figure below.



Wet Weather Validation Period Observed vs Predicted.

The flow graph above shows that the model response is well matched during wet periods in July to September 2022, and May to June 2023. Following an initial dry period in June 2022 the model overpredicts the flow. This is reflected in the assessment of individual wet weather events, where events in winter are generally better validated than those outside of winter.

Updated Network Flows

The upgraded network and reconfigured pump station arrangement has been modelled for a 2, 5 and 10-year ARI, 24-hour duration, RCP 8.5 climate change scenario design storm, with the projected 2053 population. Network upgrades and pump station 616 and 615 duty flows have been sized to prevent network overflows during this event. Council has advised that a 5-year ARI overflow recurrence interval will likely be adopted for the Terminal Pump Station (TPS). The critical 5-year ARI design storm is in winter and has a modelled peak incoming flow of 86L/s into the TPS wet-well. Council has advised the preferred TPS target duty flow is 65L/s. Approximately 330m³ of live storage would need to be provided to buffer the peak instantaneous incoming flow of 86L/s to the 65L/s TPS pump duty for a 5-year ARI design storm event. For comparison, if a pump station design flow of 70L/s was adopted, a storage volume of approximately 210m³ is required. A balance of storage and pump sizing could provide a more cost-effective overall system, allowing for optimised rising main sizing, and more efficient operation.

The modelled required duty flows for the updated network are shown in the table below.

Reconfigured Terminal Pump Station Duty Flows for a 24-hour Peak 2053 Population for various design storm recurrence intervals and seasonal population fluctuations.

Season	2yr ARI peak flow (L/s)	5yr ARI peak flow (L/s)	10yr ARI peak flow (L/s)
Winter (Domestic)	59	86	108
Peak Summer	56	82	105

1: Flow may be buffered to 65L/s by provision of 330m³ of storage in the network

2: Winter scenario assumes 20% initial saturation to reflect more consistent rainfall and reduced evaporation in winter

3: Summer scenarios assume 0% initial saturation to reflect likely drier seasonal conditions

ADWF, PDWF and PWWF have been extracted from the re-validated ICM model for both 2023 and 2053 populations over typical domestic and peak summer periods to determine design flows for the new WWTP treatment train as shown in the table below. In addition, modelled Average Daily Flow (ADF) and Maximum Daily Flow (MDF) which include wet weather flows are included in the table below. Takamatua flows have been estimated based on CCC's Infrastructure Design Standard (IDS) parameters.

Typical Domestic and Peak Summer WWTP Flows for 2023 and 2053 Populations

WWTP Flows	Flow Parameter	Unit	Domestic	Peak Summer
		Period	Feb - December	31st Dec - 6th Jan
Akaroa				
2023	Average Dry Weather Flow (ADWF)[2]	m³/d	439	818
Modelled Population:	Peak Dry Weather Flow (PDWF)[2]	L/s	11.4	22.2
Domestic 777	Average Flow per Capita	m³/d	0.56	0.26
Peak Summer 3,126	Average Daily Flow (ADF)[2,3]	m³/d	605	915
	Maximum Daily Flow (MDF)[3]	m³/d	5,804	
2053	Average Dry Weather Flow (ADWF)[2]	m³/d	462	937
Modelled Population:	Peak Dry Weather Flow (PDWF)[2]	L/s	11.8	24.3
Domestic 882	Average Flow per Capita	m³/d	0.52	0.25
Peak Summer 3,706	Average Daily Flow (ADF)[2,3]	m³/d	626	1012
	Maximum Daily Flow (MDF)[3]	m³/d	5,825	
Takamatua	Average Dry Weather Flow (ADWF)	m³/d	24	96.8
Modelled Population: (2053)	Peak Dry Weather Flow (PDWF)[4]	L/s	0.5	2.0
Domestic 110	Peak Wet Weather Flow (PWWF)[5]	L/s	1.4	5.6
Peak Summer 440	Average Daily Flow (ADF)[6]	m³/d	24	96.8
	Maximum Daily Flow (MDF)[7]	m³/d	36	145.2

1. Dry weather flow includes population derived flow, baseflow, commercial flows and retentate

2. ADF includes all rainfall events throughout the year while ADWF/PDWF excludes all rainfall events

3. Based on 15yr LTS results

4. Based on peak to average ratio of 1.8 as per 6.4.1 of CCC IDS

5. Based on Storm Peak Factor of 2.78 as per 6.4.2 of CCC IDS

6. Assumed same as ADWF

7. Assumed 1.5 factor on ADWF based on pressure sewer reticulation

Allowance has been included for future connection from the Ōnuku Marae into the Akaroa network. No allowance has been made in the above table for the potential future connection of the Duvauchelle Wastewater Scheme.

Updated Irrigation Flows and Modelling

The Akaroa ICM model has been used to run a 15-year long time series with sub-hourly rainfall data from 2008 to 2023. The 15 years of modelled flows have then been extrapolated back using historical daily rainfall data available back to 1972 to produce a 'synthetic' 50-year flow series that has been used to predict long-term irrigation performance. Comparisons have been made of modelled flows against measured flow meter data from 2017-2023 to understand sensitivity in the modelled flows. Wetter winter months are the driver for irrigation performance, and these months appear to over-estimate flows (against measured data) by between 5-13% (averaged monthly across 2017-2023).

To acknowledge the inherent uncertainty in modelled flows, the irrigation models have been run with two sensitivity reductions to the 50-year flow series of 5% and 10%. This approach allows the irrigation performance and overflows to be modelled as an expected range. Other drivers for considering a modelling uncertainty range are that the available data set for model validation is reasonably small, has significant periods influenced by the COVID pandemic, and includes periods prior to significant I&I upgrade work.

We also understand that Council in the last few months of 2023 has made significant adjustments to the operation of the water treatment plant in Akaroa and review of recent flow meter data has shown a significant reduction in ADWF in the order of 20-25%.

The table below summarises the updated irrigation modelling results. Note that 'overflow seasons' are reported below which indicate the number of irrigation seasons (i.e. years) that overflows occur in the model. Whether or not repeat overflows occur within an irrigation season is subject to operational and regulatory aspects not included in the modelling.

Irrigation Scenario Results - Storage Volumes and Overflows

Scenario	Storage Volume (m^3)	Irrigation Area (ha)	Storage Overflow Seasons (over 50-years)
Scenario 1A	20,000	35.7	21
Scenario 1B	20,000	40.7	13
Scenario 2A (incl. Takamatua)	20,000	35.7	24
Scenario 2B (incl. Takamatua)	20,000	40.7	16
Scenario 3 (5% reduction)	20,000	35.7	16
Scenario 4 (10% reduction)	20,000	35.7	11
Scenario 1A (excl. Takamatua)	24,000	35.7	15
Scenario 4 (10% reduction) (excl. Takamatua)	24,000	35.7	7

Key outcomes from the irrigation runs are:

- The expected number of overflow seasons/years across the 50-year modelled period ranges from 11 to 21 taking into account the 10% sensitivity acknowledged in the modelled flows.
- Inclusion of the future Takamatua catchment flows results in 3 additional modelled overflows across the 50-year period.
- Utilising an additional five hectares of irrigable land reduces the number of modelled overflows in the 50-year period by eight (reducing the number overflows by around 35%).

- An increase in storage volume to 24,000m^3 significantly reduces modelled overflow seasons by 30-50%.
- The expected irrigation application limit in winter is 1.68 mm/day, which equates to a winter application of 600m^3 (for the 35.7 ha scenario). Total daily dry weather flow for winter is around 450m^3 and therefore storage is likely to be empty and available at the beginning of a winter rainfall event. Modelled winter overflows are generally from rainfall cut-off events (>50mm/day) that require the entire wet weather wastewater volume to be stored each day.

Data Accuracy and Risk

It should be noted that the flows determined from this modelling exercise are a "best-fit" representation of the expected future performance of the Akaroa wastewater network and that weather and population-driven flow anomalies will occur that this modelling does not account for. An appropriate margin should be considered when sizing the infrastructure for this wastewater scheme. The climate change adjustments factored into the modelling are based on an overall probabilistic assessment and cannot forecast extreme "black swan" rainfall and storm events that are a feature of climate change and that have been observed around New Zealand in recent times.

Council should expect that the design basis settings for the Akaroa Wastewater Scheme will be exceeded on occasions in future due to the variables outlined above. As with any critical Council infrastructure, consideration will be needed as to how the scheme responds to unpredictable 'black swan' events and whether wastewater system responses pose any risks to the assets, the community, or the environment.

1 Introduction

1.1 Background

Christchurch City Council (Council) has been working on upgrades to the Akaroa Wastewater Scheme to remove the existing harbour discharge consent and commission a new land disposal system including associated network and pump station (PS) upgrades and a new wastewater treatment plant (WWTP). The Akaroa wastewater scheme upgrade has been in development since 2013 and involves:

- Infiltration and inflow (I&I) reduction works.
- Reconfiguration of the reticulation and pumping network to reverse the current network arrangement of pumping from north to south, and instead pump south to north.
- New terminal pump station.
- New WWTP including post treatment wetland north of the town.
- New land disposal irrigation system (including buffering storage).

An extensive optioneering exercise has been completed to assess the most suitable disposal system for the scheme with disposal to land being the preferred disposal system (Beca, Akaroa Wastewater Summary of Disposal and Reuse Options, 2020). The proposed land disposal system (at the time of writing this report) comprises the following areas:

- Robinsons Bay Irrigation Site – 31.9 ha dripper irrigation under trees.
- Hammond Point Irrigation Site – 3.8 ha dripper irrigation to pasture.
- Discharge to covered tanks (Robinsons Bay) during wet weather conditions.

The design flow from the catchment is an integral input into every component of the scheme and is difficult to estimate due to the fluctuating population (the area is a holiday destination), high I&I, and relatively limited flow metering records (for model validation). Previous flow estimations have been determined using an Infoworks ICM drainage model of the Akaroa network validated against recorded pump station flows, as well as calibration to flow monitors put out on the gravity side of the network in 2013. Previous flow estimations were made prior to the I&I improvement work being complete and had assumptions factored in for future I&I reduction.

The proposed I&I network improvement work began in 2020 and is now complete. Concept design has been completed for the wastewater scheme and resource consent granted for the terminal PS and WWTP. The resource consent application has recently been lodged (June 2023) for the land disposal system. Council is looking to progress into detailed design in 2024 for the Akaroa wastewater scheme upgrade.

Figure 1-1 shows a schematic of the proposed Akaroa Wastewater Scheme.

Figure 1-1: Overview Schematic of Akaroa Wastewater Scheme Upgrade

1.2 Scope

The purpose of the work is to update the wastewater flow design basis and irrigation modelling for the Akaroa Wastewater Scheme before moving into the design procurement and delivery stage. Previous design flow estimates for the Akaroa Wastewater Scheme have been based on several key assumptions such as future inflow & infiltration (I&I) improvements and population projections. The previous design flows for the Akaroa scheme were determined in 2020. I&I improvement work has since been carried out on the reticulation networks and a longer series of flow meter data is now available. In addition, improvements have been made to the L'Aube Hill Water Treatment Plant (WTP) processes which have reduced the volume of retentate by-wash into the sewer network. During the 2020 flow design basis this was captured as baseflow. A flow meter on the wastewater discharge line from the WTP was installed in 2022 to quantify these flows (note however this meter was only connected to SCADA in mid-2023).

This work has been split into three stages:

Stage 1:

- Review latest flow data, re-validate hydraulic network model and re-produce the design flows and long-time series for the scheme.

Stage 2:

- Re-run the irrigation water balance model with historical daily rainfall data dating back to 1972, to assess the impact the updated network model has on the irrigation storage sizing and overflow performance.

Stage 3:

- Re-run the irrigation models for options of combining the Akaroa and Duvauchelle irrigation systems to determine benefits and feasibility (separate deliverable – not included in this report).

2 Data Analysis

2.1 Model Update and Validation

The updated data for the scheme has been reviewed to understand any changes to prior assumptions around growth, infiltration, and inflow (I&I), retentate and per capita consumption. This initial step allows the key inputs for the model validation to be re-confirmed and agreed with Council.

The network model update and validation process includes:

- Update the network model with any known network upgrades undertaken since the previous model update in 2020, or not captured previously, based on Council Geographical Information System (GIS) data.
- Update the network model with any known operational changes since the previous model update (i.e., pump set points, interlocks etc.)
- Update the model validation to reflect the latest network pump station flow meter data (2020-2023)
- Revise the model to account for the L'Aube Hill WTP retentate discharge into the WW network
- Remove the allowance for further I&I improvements.
- Update current population estimates.
- Update population projections
- Re-validate models based on selected dry and wet weather events.
- Climate change allowance for future design model runs

2.2 Future Population Model Approach

Akaroa typically receives significant visitor numbers in summer and has a much smaller population for the remainder of the year. Therefore, population estimates are divided into periods for 'domestic' (February-December), and peak summer (January). Previous work considered three population estimates: winter (March-November), summer/shoulder (December and February) and peak summer (January). Work undertaken to develop this report found that peak summer population approximately occurs over the week of the 31st December to the 6th January, after which population gradually declines to normal levels over the remainder of January. For this reason, previous work has likely overestimated summer populations from December through to February.

The previous population estimations used Biochemical Oxygen Demand (BOD) in the wastewater to estimate a population equivalent (PE). 2018 winter populations were predicted at 765 PE. To calculate the winter/domestic design population for 2023, Council forecast growth rates from previous work[2] of 0.246% per year were adopted – resulting in a 2023 design winter/domestic population of 777. Peak summer design populations have been revised to be closer to estimates based on more recent summer wastewater flow meter data and have been estimated at 2,349 visitors (total 2023 peak summer population 3,126) – see *section 3.3 DWF validation* for further details.

To project the 2053 population, a 10% domestic growth rate and a 15% visiting growth rate was agreed with Council and applied to the 2023 population figures[1]. To determine future peak summer population, the population increase derived previously was applied to the current peak summer population estimate. The domestic population for Akaroa was assumed to be all residents.

Table 2-1 shows the current and future seasonal population estimates. It is proposed that the Ōnuku Marae will discharge into the south end of the Akaroa network, and that Takamatua will discharge directly to the new WWTP inlet. Both are currently serviced by septic tanks. 2053 projected populations below include an allowance for the Ōnuku Marae.

Table 2-1: Current and Future 2053 Population Estimates

Period	Source	2023 Akaroa	2053[*1] Akaroa	Takamatua (Future)	2053 (incl. Takamatua & Onuku)
Domestic (Feb-Dec)	Domestic	777	882	110	992
Peak Summer (Jan)	Domestic	777	882	110	992
	Visiting	2,349	2,824	330	3,154
	Total	**3,126**	**3,706**	**440**	**4,146**

2.3 Long Time Series Rainfall Data

Historic rainfall data measured in hourly intervals at the Akaroa EWS rain gauge from December 2008 – August 2023 was used to derive a relationship between rainfall derived inflow and infiltration (RDII) and rainfall intensity. This relationship was then extrapolated to predict RDII back to 1972 to develop a synthetic long-time series to model long-term irrigation performance.

Rainfall data used for the 1972 long-time series has been adjusted to consider potential climate change in the future. Guidance from the Ministry for the Environment (MfE, 2018) suggests that while the Canterbury region is expected to experience no change in annual rainfall over the next 80 years, it is expecting seasonal

[1] Meeting minutes between Beca and Council (21/07/2023)

increases and decreases in rainfall as shown below in Table 2-2 (i.e. rainfall events will get larger while longer dry periods are also expected).

Table 2-2: Canterbury Climate Change Seasonal Rainfall (MfE Guidelines 2018)

Season	Precipitation Changes to 2031-2050	Precipitation Changes to 2081-2100
Summer	1%	8%
Autumn	3%	8%
Winter	-4%	-12%
Spring	1%	1%
Annual	0%	0%

A 3-8% increase in autumn rainfall depths may cause the irrigation cut-off trigger level to be reached more frequently and a greater volume of treated effluent needing to be stored (from additional I&I generated wastewater flow). Conversely, a 4-12% decrease in winter rainfall depths should reduce the likelihood of having to cease irrigation and store treated effluent. It is important to understand the impacts of this behaviour.

It should be noted that the climate change adjustments to rainfall were applied to the flow data series post-network model (i.e. the 15-year long time series network model run with hourly rainfall data did not have this rainfall data adjusted for climate change). The 1 in 10-year design event flow to determine network upgrades was adjusted for climate change using RCP8.5 rainfall intensity adjustment.

The precipitation timeseries was adjusted using a linear adjustment, making sure that the 'global' requirement of annual change of 0% and the seasonal requirement (1%, -4% and 3% respectively) are fulfilled. The linear adjustment consists of a slope and intercept which are from an algorithm. The algorithm iteratively draws from the normal distribution (for the slope) and from the intercept range (uniform distribution) until it finds seasonal adjustment parameters for every year that fulfil the seasonal and global requirements.

The climate change adjustments factored into the modelling are based on an overall probabilistic assessment by NIWA. The probabilistic approach cannot forecast extreme individual "black swan" rainfall events (i.e. extreme future rainfall events that are larger than those experienced over the period of the modelling) or the associated network flow response. Recent black swan events include Cyclone Gabrielle and the extreme rainfall event that occurred at Akaroa on 24th of July 2023. Such black swan events are expected to occur with increased frequency and can strike randomly in any location at any time. As the modelling cannot anticipate them, Council should expect that the design basis settings for the Akaroa Wastewater Scheme will be exceeded on occasions in future.

3 ICM Model Re-Validation

3.1 Model Updates

The existing ICM model was reviewed to check whether any new or recently upgraded pipes needed to be added to the model. The Beach Rd, Rue Lavaud, Rue Balguerie and Rue Jolie upgrades installed in 2019 were added to the model during the previous updates in 2020. However, the review found some other pipes upgraded between 2014 and 2023 had not been captured in the model. This includes pipes installed in 2014 by John Filmore Contracting along Aylmers Valley Road, William Street, and Bruce Terrace, Smith Street, Rue Benoit and Rue Balguerie.

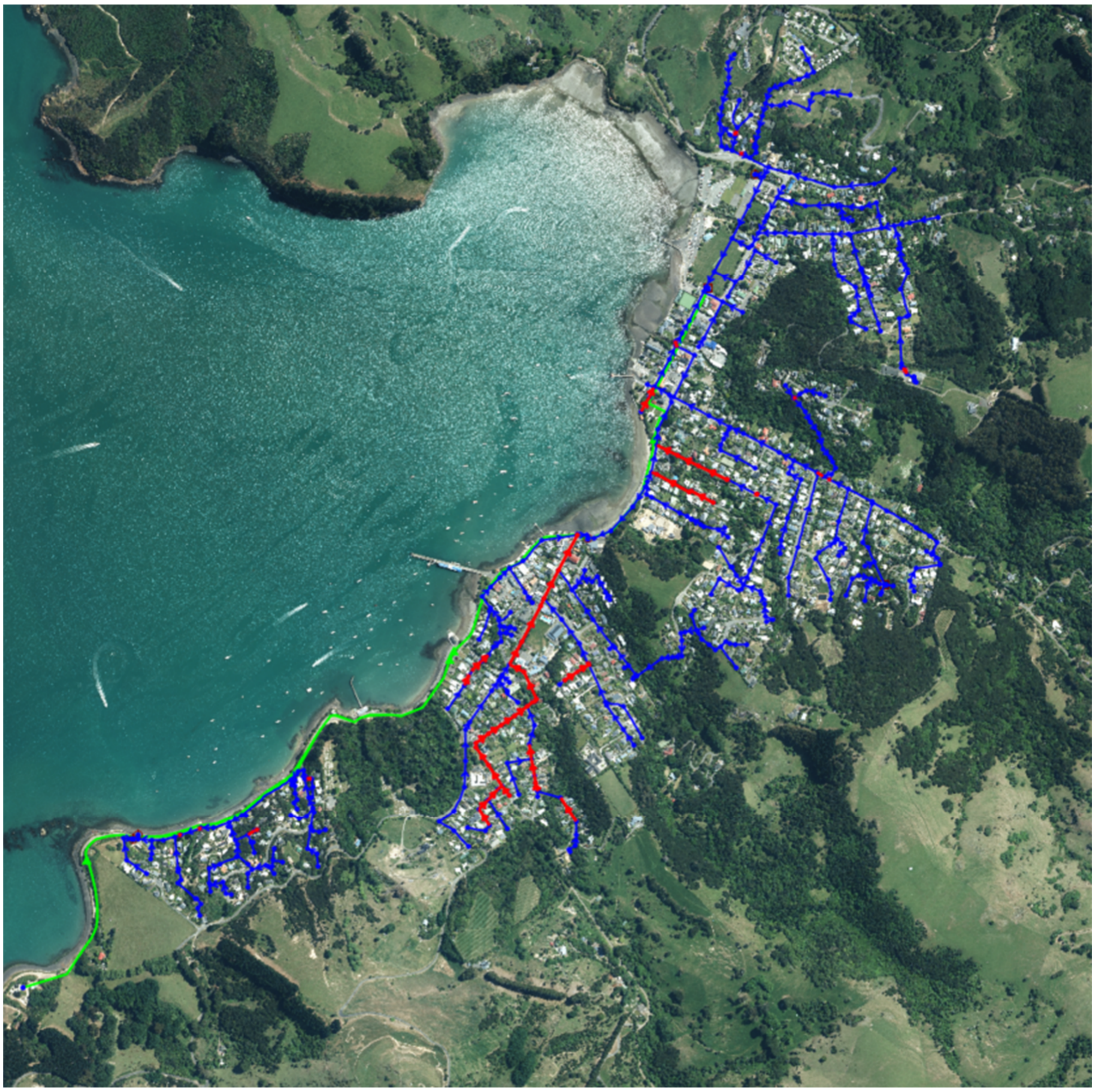


Figure 3-1: Updated GIS Infrastructure Installed from 2014 Onwards (highlighted in red)

Some of the GIS data for the pipes, which needed updating in the model, included missing node elevations, manhole chamber base levels and/or pipe invert levels. These are shown in Figure 3-2.

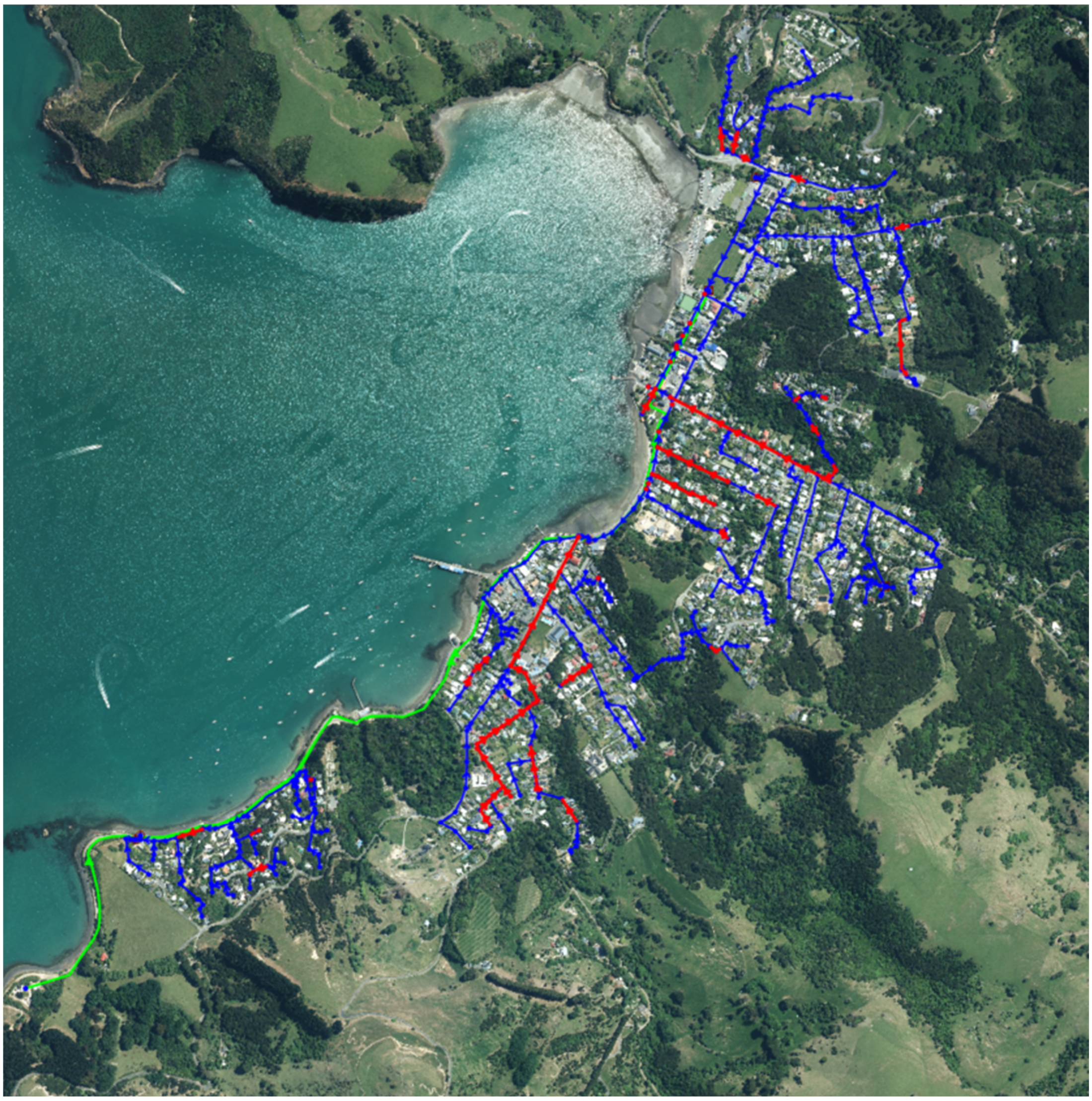


Figure 3-2: Overview of GIS Pipes and Nodes with Missing Parameters (highlighted in red)

Several assumptions were incorporated in updates to the model with the new/missing infrastructure. These updates are summarised in Table 3-1.

Table 3-1: Missing Model Parameters and Model Response

Model Parameter	Model Assumption
Manhole ground level	If a manhole was replaced, its ground level was set to the same value as the previous manhole in the same location. For locations without an adjacent manhole to reference, 1m DEM data was used to derive ground levels in NZVD16, converted to Lyttelton1967 with a 0.365m increase, keeping in mind that this value can vary by ±0.289m. These levels were further adjusted by +9.043m to convert it to Christchurch Drainage Datum (CDD), the vertical datum for the existing model.
Chamber roof level	Established at 0.5m below the manhole ground level.
Chamber base level	Set equal to the lowest known invert level at the manhole. If inlet/outlet inverts were unknown, the base level matched that of adjacent pipe invert levels (if known), or pre-existing manholes (if adjacent pipe invert levels were unknown).
Pipe Invert levels	For 2014 pipes on select streets which lacked invert and chamber level information, a constant gradient assumption was made between two upstream and downstream manholes with known chamber levels. As a result, invert levels could be inferred through gradient, and chamber levels were set to match the lowest invert. In cases where a street had no upstream manhole with a known chamber level, previous pipe gradients (e.g., 0.0147 and 0.01494) were used to back-calculate from the known downstream manhole base layer. This approach improves the completeness and accuracy of the updated GIS infrastructure.

As most pipes are uphill and higher up in the catchments, they are less crucial to the purpose of the model outputs - these being the pump stations and future terminal pump station capacity. Any inaccuracies in invert levels or ground levels shouldn't noticeably affect the pump station results. However, if in future this network model is to be used to make capacity assessments on these pipelines, manhole invert and lid level survey should be undertaken, and the model updated prior to any further analysis being undertaken. It is noted that some manhole surveys were undertaken in Akaroa by Council in 2017, however the surveys did not pick up any of the manholes highlighted in Figure 3-2 above.

3.2 Per Capita Water Consumption Estimate

To determine typical per capita wastewater flows, an assessment of potable water consumption was undertaken. The per capita water demand was determined by using the estimated 2023 winter population of 777 people. The winter period was chosen to exclude any potential impact from gardening activities and tourists who may demonstrate different consumption rates. In winter 2023, Akaroa's water supply delivery was measured at an average of 1,076m³/day. It was determined that 78% of the winter flows were leakage. Of the remaining 22% of legitimate consumption, 69% was residential demand, with 31% commercial demand, based on property boundary meter readings. This resulted in an average residential water supply (WS) demand of 163.7m³/day. This equates to a residential per capita usage of 210.7 litres/person/day.

To make an estimate of per capita wastewater demands, a further 5% leakage was assumed on the private side of the boundary beyond the property connections. This resulted in a per capita wastewater demand of 200 litres/person/day applied to the wastewater model. Tourists' wastewater demand was modelled at 160L/person/day, based on 80% of the residents demand, allowing for reduced domestic use via washing machines and dishwashers etc. It is assumed the per capita wastewater demand is constant all year round.

The water network leakage figure is significant, and it has since been discovered by Council that an incorrect level setting at the Aylmers Reservoir was resulting in continuous overflow.

Potential reductions from reduced retentate discharge into the wastewater network have not been accounted for in this modelling work due to uncertainty of the level of reduction that can be achieved. Going forward, optimising the WTP operation and reducing retentate offers an opportunity for CCC to reduce flows to the wastewater network.

3.3 Model Validation

Dry Weather Flow (DWF) validation events (over a period of a week to capture week and weekend days) and Wet Weather Flow (WWF) validation days were identified from the provided SCADA and Stanley Park rainfall data. For DWF events, periods with a few days of nil or low preceding rainfall were selected, and without other anomalies such as unusually high-water consumption or missing meter data. The purpose of the DWF validation is to establish per capita wastewater demand, trade flows (including retentate from the water treatment plant) and dry weather baseflows from groundwater infiltration prior to updating hydrological parameters during the wet weather validation. For WWF events, large events where wastewater is likely to overflow from the network were avoided.

The proposed model validation approach is as follows:

- The validation period population is estimated from the L'Aube Hill WTP flow meter data during the validation period, and the leakage and water consumption figures derived as described in Section 3.2 above.
- Update the trade flow wastewater demands from the water meter readings at commercial premises. Upon review of these meter readings, the sum of the readings was very similar to the figures already in the model for trade flows. Therefore, no updates to these trade flows were made.
- Apply a point source inflow for the retentate stream from the L'Aube Hill WTP. The readings since the flow meter was connected to the SCADA network between 15/06/2023 – 25/07/2023 were used. These recordings suggest large fluctuations in flow from day to day. Therefore, the average of the SCADA meter readings for this period was used. The estimates provided prior to the meter being connected to SCADA were ignored, as these are generally lower than the meter readings.
- Undertake dry weather period validation using flow meter data from the three network pump station flow meters.
- Undertake wet weather validation to update rain derived inflow and infiltration parameters, based on flow through the three-network pump station flow meters.

DWF Validation

The following two DWF periods were used for dry weather validation as per Table 3-2.

Table 3-2: DWF Event Dates and Populations

Dry Weather	Date	Population Estimate
Winter	5/06/22 – 12/06/22 (7 days)	777
Peak Summer	31/12/22 - 6/01/23 (7 days)	3,126

Peak summer population of 3,126 has been estimated by adopting the domestic and visitor consumption figures and aligning observed flows with measured over this peak period.

Initially population estimates for the summer periods were estimated from the L'Aube Hill WTP flow meter data, with leakage and per capita data derived from the winter period. This resulted in higher populations than presented above, and adopting these populations resulted in a very low per capita demand for summer visitors. It was considered that given the number of variables associated with the summer water usage, namely leakage, potential overflows at Aylmers Reservoir and garden irrigation, this method of population estimate is unreliable.

It should be noted that the originally proposed methodology to estimate leakage, and therefore population based on per capita demand, assumed instantaneous flow data from the Akaroa WTP into the town would be available. This would allow leakage to be determined from night flows and would allow for a more accurate assessment of population for each validation period. However, additional reservoir storage was added downstream of the WTP flow meter. The reservoirs will have the effect of buffering the demands from the network and removes the ability to make population assessments based on leakage determined from night flows.

Retentate flows were averaged from the measured flow meter recording data set for DWF days within the period of 15/06/2023 – 25/07/2023. This was calculated as 127m³/day. Dry weather flows were used as there is a small bunded hardstand catchment at the WTP which drains to the sewer and contributes to the measured flow during wet weather events.

During the validation process, parameters were adjusted so that the total volume modelled over each period at each pump station aligned as closely as possible with the observed flowmeter data from those stations. The aim was for a variance of within +/-10% on pump station volumes during the DWF period, based on Watercare modelling guidelines[2].

Validation of the DWF involved adjusting population and baseflow (i.e. permanent groundwater infiltration) to align daily flow volumes to the pump station flow meters. Retentate in the updated model was applied as a trade flow rather than as a component of baseflow. Previous models inherently allowed for retentate through baseflow based on model calibration.

The baseflow in the Pump Station 614 catchment, where the L'Aube Hill WTP is located, was therefore scaled down to account for the averaged DWF retentate flow of 127m³/day. Baseflows in the PS614 catchment were further reduced to achieve validation. As PS614 pumps into PS615, which then pumps into PS616, reducing the baseflow also reduced volumes in these catchments. In response, further baseflow was added to PS616 to meet validation thresholds.

Table 3-3 and Table 3-4 shows the observed and predicted pump station accumulated flow volumes over the validation periods after validation.

Table 3-3: Winter DWF Observed vs Predicted Pump station Flow Volumes.

Winter DWF (7-day period)			
	PS614	PS615	PS616
Observed (m³)	1633	2659	3206
Predicted (m³)	1968	2617	2870
Difference	17.0%	-1.6%	-11.7%

Table 3-4: Peak Summer DWF Observed vs Predicted Pump Station Flow Volumes.

Peak Summer DWF (7-day period)			
	PS614	PS615	PS616
Observed (m³)	3,347	4,752	5,693
Predicted (m³)	3,647	4,880	5,285
Difference	9.0%	2.7%	-7.1%

The results show that the model is within the specified validation tolerances for all pump stations during the three periods except for PS614 and PS616 catchments during the winter period. The differences could be

[2] WSL Wastewater Network Modelling Specifications, V05, August 2019

due to differences in the retentate flows during the validation period, or differences in population during the validation period.

Note we have provided further analysis in section 3.4 of dry weather periods during the long time series wet weather validation, as this includes groundwater infiltration slow response. These show a better fit within validation tolerances (0.1-5% from observed flows) and provide confidence the final validated model is suitable for the design outputs required.

WWF Validation

Wet weather flow validation was undertaken across the whole period from the 1st June 2022 to the 22nd of June 2023, as well as being assessed against a number of individual periods. The Akaroa network demonstrates a long "tail" of increased flow following rainfall events due to an elevated groundwater table and subsequent increased groundwater infiltration. This effect is pronounced in winter when rainfall is more frequent and the effect of multiple events in succession is cumulative. This period was used for validation as it includes two winter periods, as well as a peak summer period. It is noted that population remains stagnant throughout winter, with scaling factors applied to the accommodation catchments as per Table 3-5. The factors are applied monthly, as this is the smallest resolution able to be applied to replicate seasonal population changes in the model. During this exercise it became apparent that tourist populations outside of the peak January period did not contribute significantly to flows.

Table 3-5: Peak Population Factors Applied to Account for Tourist Populations.

Catchment	Winter Population Factor	Peak Summer Population Factor (Jan)
Accommodation	0	1

The network slow response was validated by:

- Adjusting soil store parameters in the existing sub catchments to represent the initial infiltration response.
- Adding dummy sub catchments upstream of PS614, 615 and 616 to represent the slower infiltration response. These sub-catchments have no population and contribute only slow response infiltration, in addition to the faster infiltration response distributed across the existing catchments, allowing different groundwater infiltration parameters than the other model catchments.

Soil store parameters following validation are presented in Table 3-6.

Table 3-6: Soil and Ground Store Parameters Used to Represent Network Slow Response Following Rainfall Events.

Parameter	Existing Sub Catchments	Dummy Sub Catchments
Soil depth (m)	1.0	1.0
Percolation coefficient (days	0.9	5
Baseflow coefficient (days)	0.01	0.01
Infiltration coefficient (days)	0.2	0.2
Percolation threshold (%)	20	20
Percolation percentage infiltrating (%)	20	80
Porosity of soil (%)	30	30
Porosity of ground (%)	20	20
Baseflow threshold level (m)	-1	-1
Baseflow threshold type	Relative	Relative
Infiltration threshold level (m)	0	0
Infiltration threshold type	Relative	Relative

Ground store (i.e. the "reservoir" below the soil store) parameters were set to effectively turn off ground store infiltration, as this is represented through baseflow.

A plot of the modelled flows versus observed at PS616 is provided in Figure 3-3. Note that the WWTP flow meter was not used as Council advised there were calibration errors with this meter from 2022 onwards. There is little additional catchment contributing between PS616 and the WWTP, namely a landfill leachate drain and a single domestic property.

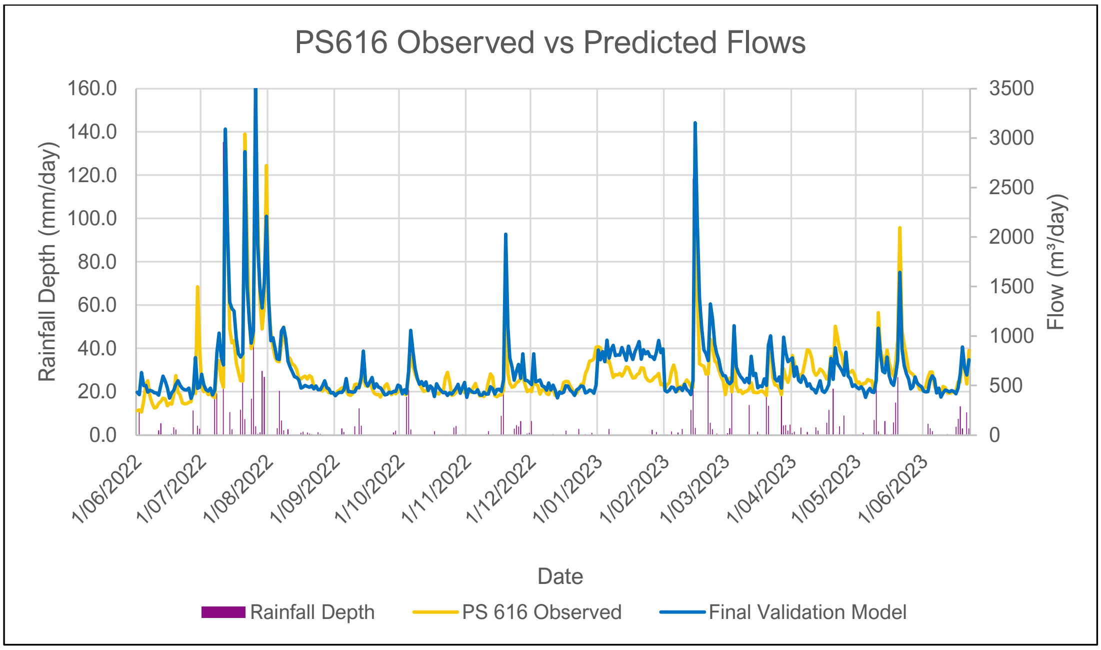


Figure 3-3: Observed vs. Modelled Flows at Pump Station 616 for the Period of 1st June 2022 to 22nd June 2023.

The following observations can be made from Figure 3-3:

- The modelled annual volume over the simulation period is 105% of the observed (flow meter) volume. Note that section 5.2 provides further analysis of monthly and seasonal differences of modelled flows against measured data.
- The slow response tail can be observed following the heavy rainfall period in July 2022 and again in late February 2023. The modelled results show a close fit.
- Some spikes in flows are observed in the metered data that are not observed in the model results. These are typically around public holiday weekends, such as around the 9th of April 2023 (Easter weekend), or are anomalies, such as the 29th June 2022, which does not correspond to a public holiday or substantial rainfall event. The model cannot vary seasonal population fluctuations less than monthly therefore the effect of long weekend population spikes will be missed.
- There is some variability in peak rainfall events between modelled and observed. However, there is no consistent pattern, with some modelled large rainfall events being larger than observed, and some observed events being larger than modelled.

For comparison, the 1 in 5year 24hr climate change adjusted design storm has a total depth of 145mm. The largest single day of rainfall over the validation simulation is 135mm on the 11th July 2022.

Plots of observed vs. predicted flows for PS614 and PS 615 for the Winter 2022 to Winter 2023 period are presented in Figure 3-4 and Figure 3-5.

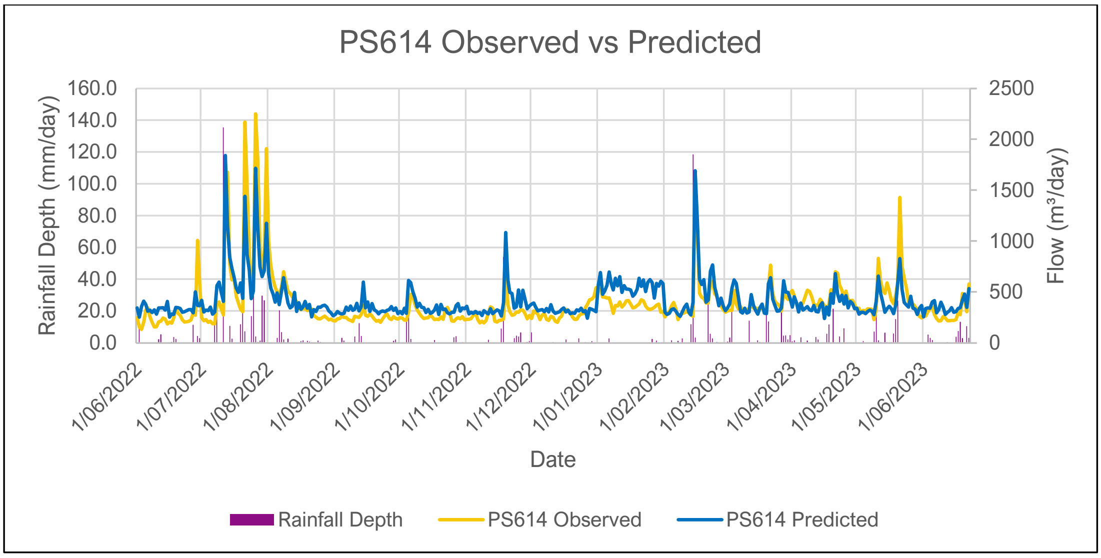


Figure 3-4: Plot of Observed vs. Predicted Flows for PS614

In Figure 3-4 the observed dry weather flows are slightly higher in the model than metered data through spring and early summer 2022. This could be due to differences in the retentate flows, which occur in catchment 614, differences in trade flows from commercial premises, many of which are in this catchment, or differences in population.

Wet weather observed vs modelled flows following a dry period appear to match well. However, as the period of consistently wet weather becomes extended, the latter portion of the wet weather flows tend to be underpredicted.

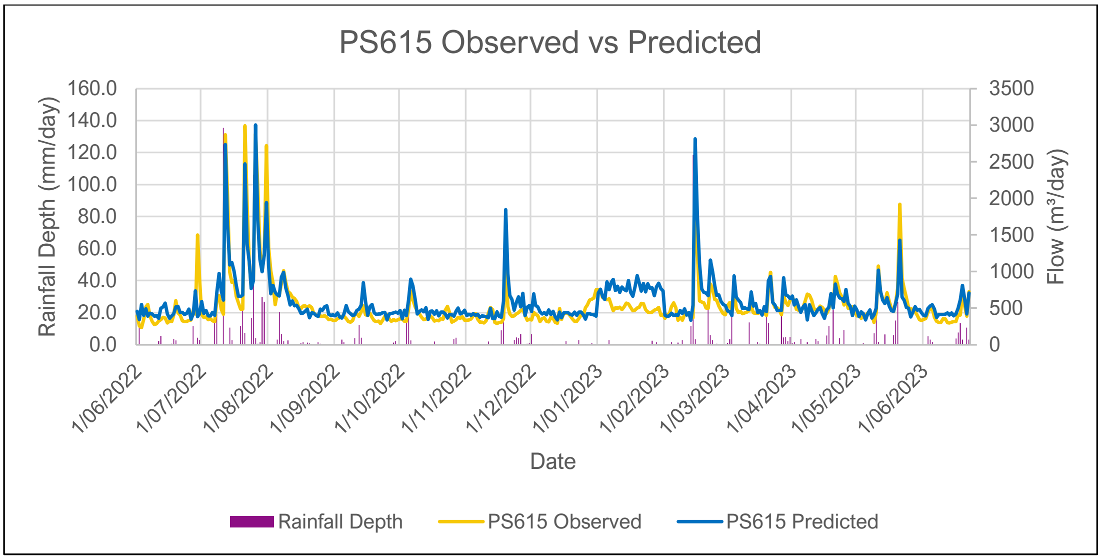


Figure 3-5: Plot of Observed vs. Predicted Flows for PS615

Figure 3-5 shows a similar trend to Figure 3-4 in that the modelled flow is slightly over-represented during dry weather, however this is less pronounced. Wet weather events are also generally a better fit. Validation tolerances adopted were a variance of +20% and -10% volume of flow, as per the Watercare modelling standard. Table 3-7 to Table 3-12 shows the observed and predicted pump station accumulated flow volumes over individual validation events.

Table 3-7: WWF Event Dates and Total Rainfall Depth over Period

Wet Weather	Date	Duration (days)	Rainfall Depth (mm)
Event 1:	19/11/2022	1	54.2
Event 2:	21/04/2023	1	21.8
Event 3:	15/06/2023 - 21/06/2023	6	28.2
Event 4:	22/03/2022	1	49.6
Event 5:	19/07/2022 – 22/07/2022	4	91.3

Table 3-8: WWF 1 Observed vs Predicted Pump Station Flow Volumes.

WWF 1 – 19/11/2022			
	PS614	PS615	PS616
Observed (m^3)	772	1159	1274
Predicted (m^3)	1084	1845	2029
Difference	28.8%	37.2%	37.2%

Table 3-9: WWF 2 Observed vs Predicted Pump Station Flow Volumes.

WWF 2 – 20/04 – 21/04/2023 (2-day period)			
	PS614	PS615	PS616
Observed (m^3)	1123	1436	1744
Predicted (m^3)	1067	1324	1441
Difference	-5.2%	-8.5%	-21%

Table 3-10: WWF 3 Observed vs Predicted Pump Station Flow Volumes.

WWF 3 – 15/06 – 21/06/2023 (7-day period)			
	PS614	PS615	PS616
Observed (m³)	2794	3757	4799
Predicted (m³)	3094	4471	4881
Difference	8.8%	16%	1.7%

Table 3-11: WWF 4 Observed vs Predicted Pump Station Flow Volumes.

WWF 4 – 22/03/2022			
	PS614	PS615	PS616
Observed (m³)	723	1070	1098
Predicted (m³)	1047	1704	1844
Difference	31%	37%	41%

Table 3-12: WWF 5 Observed vs Predicted Pump Station Flow Volumes.

WWF 5 – 19/07 – 22/07/2022 (4-day period)			
	PS614	PS615	PS616
Observed (m³)	5204	6975	7303
Predicted (m³)	4043	6305	7128
Difference	-28.7%	-10.6%	-2.5%

Comparing individual rainstorm modelled results against the network flow meter data shows that generally the winter events (WWF 3 and 5) is within the tolerances stated above, particularly at PS616 at the bottom of the network. Events outside of this period are mostly outside of the tolerances stated above. This is likely due to several factors:

- The updated wet weather validation focused on the long time series data from June 2022 to June 2023 presented in Figure 3-3. This is because it is expected that extended wet weather periods in winter will be the critical design periods determining the irrigation storage volumes, due to lower irrigation rates and treated effluent subsequently backing up in storage.
- Minimum flows from the network tend to drop below the minimum flows in the model following extended dry weather periods which typically occur in summer (although not exclusively – refer to the first month of observed data in Figure 3-3, which shows a low minimum flow in June 2022). The low minimum flows are likely due to lower groundwater levels following dry periods. Lower groundwater results in less infiltration into the network following wet weather events and may also cause exfiltration from the network. No historical groundwater data exists in Akaroa, and fluctuating groundwater levels are not represented in the model.

  The network response following wet weather events in winter typically contains a long slow response for days and even weeks after the event which is not as evident in summer. The validated model captures the typical winter response, rather than the typical summer/dry weather response.
- WWF Event 2 underpredicts the network flows. This is inconsistent with the other events which tend to overpredict and could be due to the fact this period precedes ANZAC Day, therefore the town may have also had higher visitor numbers over that weekend.

3.4 Model Limitations

The updated wet weather model validation includes a simplification through the addition of dummy sub-catchments to model the ground infiltration slow response. These were set up to allow for slower infiltration parameters separate to the faster response groundwater infiltration parameters used in the existing catchments across the network to adequately model the slow response. This may create some limitations in the model:

- The sub-catchments are located just upstream of the pump stations, rather than distributed evenly across the catchment, therefore concentrating flow.
- Sub-catchments provide a long response following rainfall, which continues to contribute flows into dry weather periods.

The effect of the sub-catchments providing flow at a concentrated point in the network is that it potentially doesn't represent conditions further upstream in the network. It is noted that peak flows in the pipes still occur at the peak runoff timestep, rather than at the ground infiltration slow response timestep. For the purposes of this project, which is to size the WWTP, irrigation storage and disposal, network pump stations and some network upgrades just upstream of the pump stations, this approach is considered adequate. If the model is to be used to determine upgrades higher in the catchment, this approach may need to be reconsidered, in conjunction with some targeted flow gauging in the gravity network.

It was noted that the slow response sub-catchments continued to contribute flow during dry periods due to the long tail following rainfall. This was not accounted for in the dry weather validation outlined in Section 3.3, and may lead to an erroneous increase in dry weather flows. Several dry periods from the wet weather validation run from June 2022 – 23 were assessed to quantify the contribution from groundwater infiltration during dry periods. January was excluded from the analysis due to peak population fluctuations resulting in differences between the model and observed. The differences are summarised in Table 3-13.

Table 3-13: Comparison of modelled vs. observed flows at PS616 during dry weather periods over the long time series wet weather validation period.

Period	Modelled (m^3)	Observed (m^3)	Difference (%)	Daily Average Contribution from Soil Store (m^3/d)
28th August to 3rd September 2022	3,167	3,012	4.7	21.4
9th to 15th December 2022	3,047	3,044	0.1	13.2
9th to 15th June 2022	3,789	3,577	5.0	27.0

From these three events the dry weather flows from the validation simulation are at or slightly above the observed flows. In the case of the 1st and 3rd events the soil store contribution is approximately 5% of the total observed daily volume. The 2nd event matches very closely to the observed volume. It is also noted that all events are within the 10% dry weather calibration tolerance outlined above.

In addition, for comparison to the Peak Summer dry weather flow validation results presented in Table 3-4, the modelled volume over the 1st to 6th January is 2.7% higher than observed.

In each case the soil store contribution during dry periods is relatively small in terms of daily volumes. The contribution is within the observed day to day fluctuations of the retentate flows or from population fluctuations. Therefore, extended contribution from the soil store during dry periods will not have a large impact on model results, compared to other variables in the model.

4 Upgraded Network

4.1 Network Upgrades

The upgraded reticulation network with the existing pump stations and rising mains reconfigured to pump from south to north was modelled for a 10-year Average Recurrence Interval (ARI), 24-hour duration, design storm, for the projected 2053 population. (considered to be the "design storm" in future references).

The upgraded network was additionally modelled for 5-year and 2-year ARI, 24-hour design storms to consider alternative design bases for the TPS duty flow. These were modelled for the peak summer and winter periods.

All design storms include allowance for climate change as per scenario RCP 8.5. Derivation of the design storms was documented in our previous modelling report[3].

The validated model was reconfigured to Scenario 4 outlined in the previous modelling report. This consisted of the following network upgrades (and as shown in Figure 4-1, Figure 4-2 and Figure 4-3):

- PS616 reversed to pump into catchment 615 at WWMH 35141.
- PS615 reversed to pump into catchment 614 at WWMH 46821.
- 325m of pipe along Rue Jolie (catchment 615) upgraded to DN225 (WwPipeIDs 89330, 89331, 89332, 89333 and 43829)
- Changes on Beach Rd to remove pipes (WwPipeIDs 43824 and 43825, 48776 shortened).
- Grehan Stream overflow removed. It's assumed this would be replaced by a new overflow at the terminal pump station.
- Upgrade 166m of DN300 pipe to DN375 along Rue Jolie upstream of the Rec Ground (catchment 614).
- Decommission PS614. Install 224m of DN375 gravity main at a slope of 0.25% that bypasses the decommissioned PS614 and conveys flows to the terminal pump station.
- Ōnuku flows have been included in the PS616 catchment for a residential population of 22. The Onuku tourist population was set to 27 in December and February and 75 people in January. Network upgrades required to facilitate this additional demand have not been considered and are modelled as an additional sub catchment.

Pumps and gravity main upgrades were sized such that there were no overflows at manholes or engineered overflows. However, the network was allowed to surcharge to within 0.5m of the manhole lid level.

[3] Akaroa Wastewater Network Modelling Long Time Series and Network Upgrade Scenarios, Beca, February 2021.

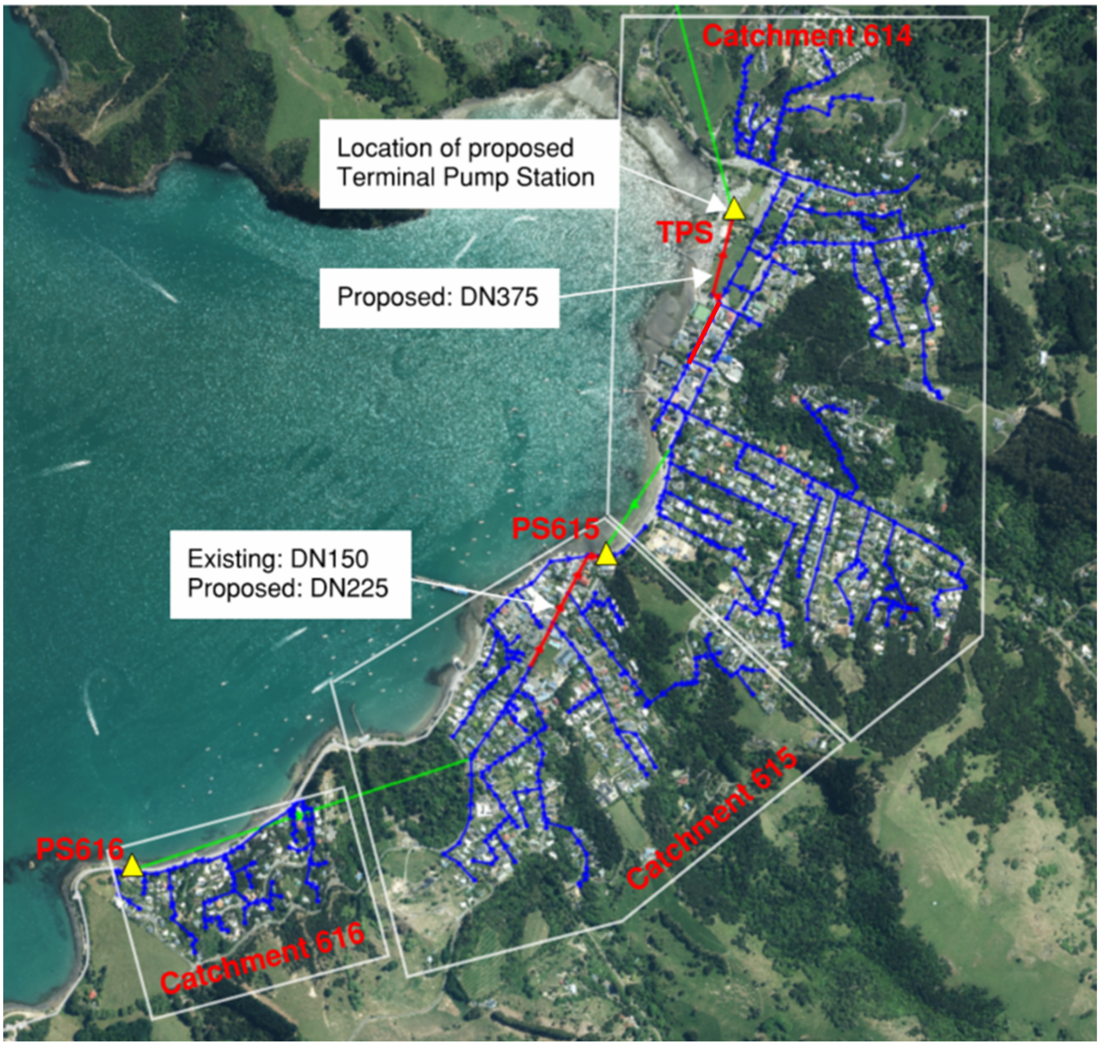


Figure 4-1: Scenario 4 Network Upgrades (in red), with Network Pump Stations Reversed.

Figure 4-2: DN225 Pipe Upgrades (in red) on Rue Jolie.

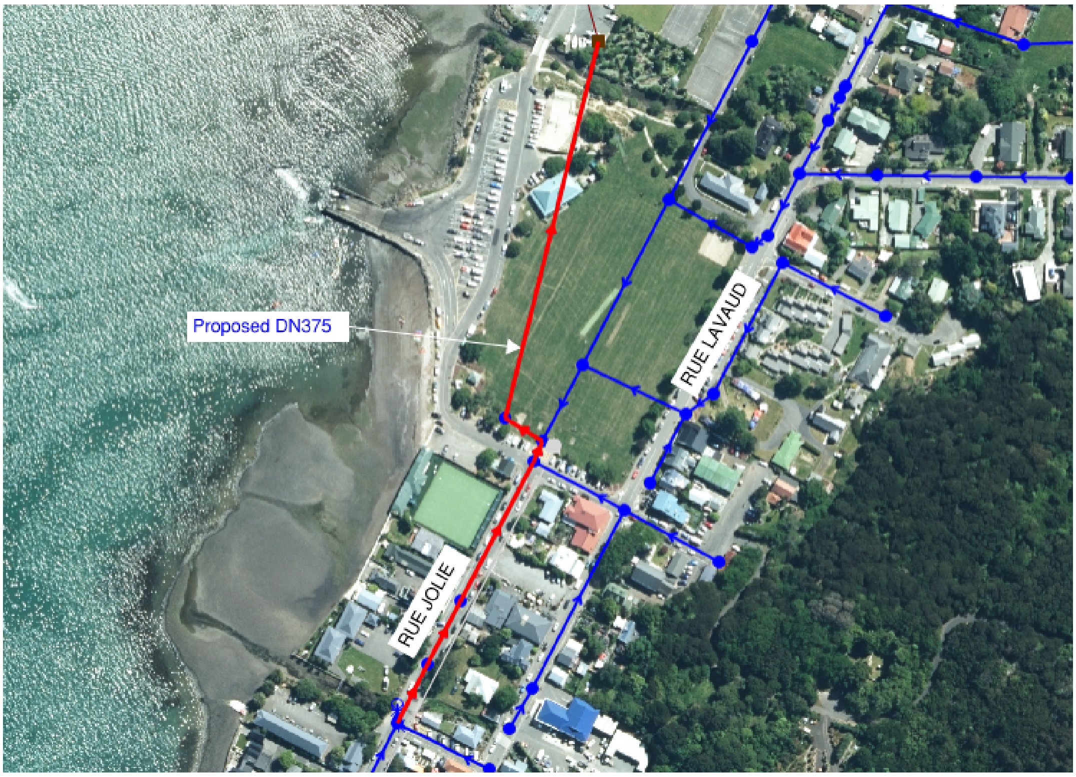


Figure 4-3: DN375 Proposed Pipe (in red) Connecting into the TPS.

For the design storm, the model shows manholes spilling (MH34951 and MH34982). In the current network these would have spilled from the Grehan Stream overflow. This is due to the gravity network being undersized for the peak flows, rather than the size of the upgraded pump stations. Therefore, additional upgrades to the gravity network are proposed (and have been assumed in the model), as shown in Figure 4-4. For modelling purposes, spilling manholes were sealed to make sure all flow is directed to the TPS to help with sizing of the upgraded mains.

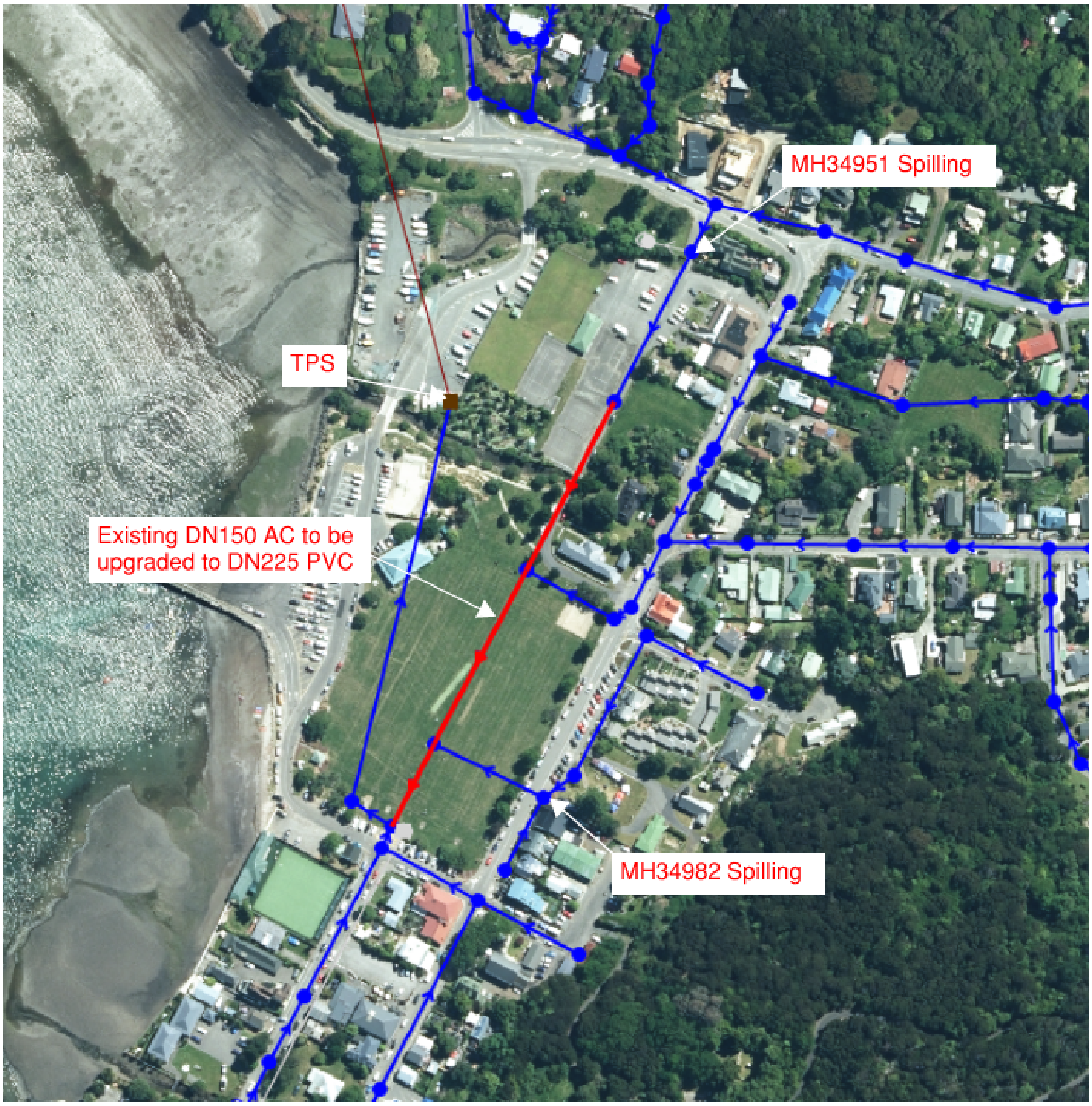


Figure 4-4: Spilling Manholes Without Additional Upgrades Recommended to Avoid Spilling.

Increasing the size of the pipes shown in red from DN150 AC to DN225 PVC is sufficient to prevent spilling and surcharging. An alternative upgrade may be to upsize the second pipe and re-direct and upsize the first pipe west on a more direct route to the Terminal Pump Station – this could be explored at later design stages.

A summary of the gravity network upgrades is provided in Table 4-1

Table 4-1: Summary of Gravity Network Upgrades.

Upgrades from previous 2020 modelling			
Location	**New Pipe Size (mm)**	**Length (m)**	**Details**
Rue Jolie (Catchment 615)	DN225	325	Pipe replacement
Beach road	-	59	Remove pipe
Akaroa recreation ground	DN375	224	New pipe with grade of 0.25%
Additional upgrades identified from 2023 modelling			
Akaroa Recreation Ground	DN225	234	Pipe replacement
Rue Jolie (Catchment 614)	DN375	166	Pipe Replacement

4.2 Upgraded Pump Station Flows

Council may wish to size the new pump stations with reduced duty flows that convey the 2 or 5-year ARI incoming flow and accept overflows beyond these events. Table 4-2 shows the modelled peak inflows into the TPS wet well for different ARI events and periods of the year. The worst-case scenario was winter due to the assumption of a higher initial soil saturation level in winter compared to summer.

Table 4-2 – Modelled incoming peak flow into TPS wet well.

Season	2yr ARI peak flow (L/s)	5yr ARI peak flow (L/s)	10yr ARI peak flow (L/s)
Winter (Domestic)	59	86	108
Peak Summer	56	82	105

Notes:

1. Winter scenario assumes 20% initial saturation to reflect more consistent rainfall and reduced evaporation in winter
2. Summer scenarios assume 0% initial saturation to reflect drier seasonal conditions

The winter hydrograph for the 5-year ARI event at the TPS is shown in Figure 4-5 below.

Table 4-3 and Table 4-4 show the peak flows into PS615 and 616 respectively. Note that for each recurrence interval scenario, the worst-case design flow was selected as the pump duties and left unchanged regardless of the season.

Table 4-3: Modelled incoming peak flow to PS615

Season	2yr ARI peak flow (L/s)	5yr ARI peak flow (L/s)	10yr ARI peak flow (L/s)
Winter (Domestic)	31	47	60
Peak Summer	29.5	45	59.5

Notes:

1. Winter scenario assumes 20% initial saturation to reflect more consistent rainfall and reduced evaporation in winter
2. Summer scenarios assume 0% initial saturation to reflect drier seasonal conditions

Table 4-4: Modelled incoming peak flow to PS616

Season	2yr ARI peak flow (L/s)	5yr ARI peak flow (L/s)	10yr ARI peak flow (L/s)
Winter (Domestic)	5.6	8.2	10.5
Peak Summer	4.9	7.5	9.9

Notes:

1. Winter scenario assumes 20% initial saturation to reflect more consistent rainfall and reduced evaporation in winter
2. Summer scenarios assume 0% initial saturation to reflect drier seasonal conditions

Based on the above peak flow results, Council has advised that a 5-year ARI overflow recurrence interval will likely be adopted for the TPS. The hydrograph into the TPS for the 5-year winter design scenario is presented in Figure 4-5.

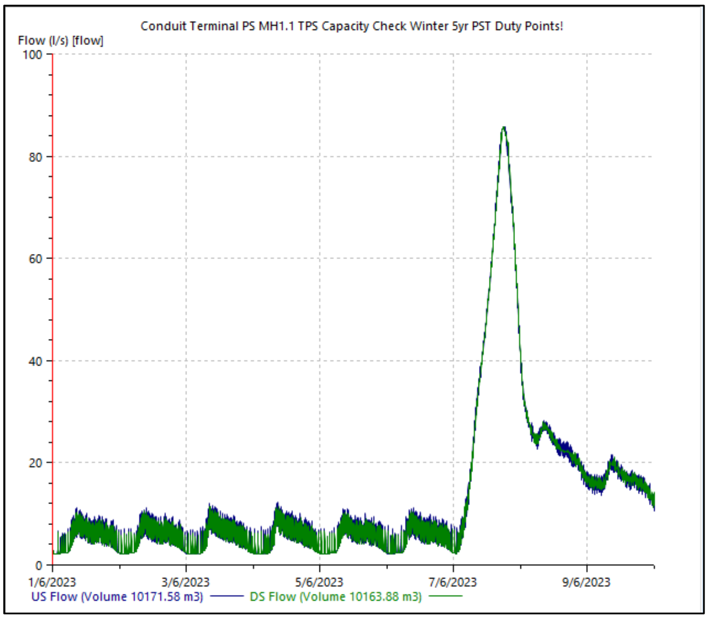


Figure 4-5: Winter 5yr ARI 24hr Design Storm TPS Incoming Flow

The final design may consider buffer storage to reduce the pumping capacity of the TPS and to assist with optimising the TPS operation and cost. Council has advised that the preferred TPS design peak instantaneous flow is 65L/s. A storage volume of approximately 330m^3 would be required to buffer inflow and reduce the instantaneous peak flow from 86L/s to 65L/s for the modelled 5-year ARI event. Note that this volume is estimated from the model results hydrograph. For comparison, if a pump station design flow of 70l/s was adopted, a storage volume of approximately 210m^3 is required.

A balance of storage and pump sizing could provide for a more cost-effective overall system, allowing for optimised rising main sizing, and more efficient operation. Minimum flushing velocities would also be more achievable. Storage could also potentially be staged to spread the capital costs over time. Alternatively, inline storage could be supplied be oversizing the inlet pipe. As the network is already surcharging in this event, there is limited capacity to use the network to provide additional storage.

4.4 Akaroa Wastewater Treatment Plant Flows

Flows have been extracted from the re-validated ICM model for both 2023 and 2053 populations over winter/domestic and peak summer periods to determine design flows for the new WWTP treatment train. Flows for the potential future connection of the Takamatua catchment are also shown. Takamatua flows have been based on IDS per capita flows of 220L/person/day. No allowance has been made in these results for the potential future connection of the Duvauchelle Wastewater Scheme.

Table 4-5: Typical Domestic and Peak Summer WWTP Flows for 2023 and 2053 Populations

WWTP Flows	Flow Parameter	Unit	Domestic	Peak Summer
		Period	Feb – December	31st Dec – 6th Jan
Akaroa				
2023	Average Dry Weather Flow (ADWF)[2]	m^3/d	439	818
Modelled Population:	Peak Dry Weather Flow (PDWF)[2]	L/s	11.4	22.2
Domestic 777	Average Flow per Capita	m^3/d	0.56	0.26
Peak Summer 3,126	Average Daily Flow (ADF)[2,3]	m^3/d	605	915
	Maximum Daily Flow (MDF)[3]	m^3/d	5,804	
2053	Average Dry Weather Flow (ADWF)[2]	m^3/d	462	937
Modelled Population:	Peak Dry Weather Flow (PDWF)[2]	L/s	11.8	24.3
Domestic 882	Average Flow per Capita	m^3/d	0.52	0.25
Peak Summer 3,706	Average Daily Flow (ADF)[2,3]	m^3/d	626	1012
	Maximum Daily Flow (MDF)[3]	m^3/d	5,825	
Takamatua	Average Dry Weather Flow (ADWF)	m^3/d	24	96.8
Modelled Population: (2053)	Peak Dry Weather Flow (PDWF)[4]	L/s	0.5	2.0
Domestic 110	Peak Wet Weather Flow (PWWF)[5]	L/s	1.4	5.6
Peak Summer 440	Average Daily Flow (ADF)[6]	m^3/d	24	96.8
	Maximum Daily Flow (MDF)[7]	m^3/d	36	145.2

1. *Dry weather flow includes population derived flow, baseflow, commercial flows and retentate*
2. *ADF includes all rainfall events throughout the year while ADWF/PDWF excludes all rainfall events*
3. *Based on 15yr LTS (long time-series) results*
4. *Based on peak to average ratio of 1.8 as per 6.4.1 of CCC IDS*
5. *Based on Storm Peak Factor of 2.78 as per 6.4.2 of CCC IDS*
6. *Assumed same as ADWF*
7. *Assumed 1.5 factor on ADWF based on pressure sewer reticulation*

5 Synthetic 50-year Irrigation Flow Series

The Akaroa ICM model has been used to run a 15-year long time series with sub-hourly rainfall data from 2008 to 2023. These 15-years of modelled flows have then been extrapolated back using historical daily rainfall data available back to 1972 to produce a 'synthetic' 50-year flow series that has been used to predict long-term irrigation performance. For further details around how the ICM flows are used to model the synthetic 50-year fit refer to Appendix A.

Table 5-1 shows the 15-year ICM modelled components of annual wastewater flow used to synthesize the 50-year flow series (note that these flows include the future Ōnuku catchment but exclude the future Takamatua catchment).

Table 5-1: Annual wastewater volumes from updated Infoworks model runs. All sources of flow included.

Year	Rainfall (mm)	Total Flow (m^3)	Foul Flow (m^3)	Trade Flow (m^3)	Baseflow (m^3)	RDII (m^3)
2008 (Dec)	31	7,665	2,555	2,478	792	1,840
2009	891	224,872	75,421	69,757	22,237	57,457
2010	1,133	241,532	75,395	69,754	22,237	74,147
2011	820	221,306	75,441	69,734	22,237	53,893
2012	1,192	246,182	75,647	69,935	22,298	78,302
2013	1,190	244,896	75,420	69,757	22,237	77,482
2014	1,209	247,604	75,427	69,757	22,237	80,183
2015	719	213,887	75,422	69,757	22,237	46,471
2016	824	220,836	75,612	69,928	22,298	52,998
2017	1,358	256,685	75,467	69,738	22,237	89,242
2018	1,183	244,190	75,424	69,757	22,237	76,771
2019	987	231,004	75,417	69,757	22,237	63,592
2020	588	205,147	75,606	69,955	22,298	37,288
2021	896	226,836	75,397	69,752	22,237	59,450
2022	978	231,774	75,441	69,734	22,237	64,362
2023 (Aug)	1,002	176,980	51,657	45,300	14,561	65,462
	Total	**3,441,396**	**1,110,749**	**1,024,851**	**326,857**	**978,939**
		100%	32%	30%	9%	28%

Flow volumes measured for parts of 2008 and 2023 result in lower volumes, as they only cover segments of the year.

Table 5-2 shows a statistical summary of the modelled synthetic 50-year irrigation flow series (note that these flows include the future Ōnuku catchment but exclude the future Takamatua catchment).

Table 5-2 – Modelled Synthetic 50-year Flow Statistics (excludes future Takamatua catchment)

Statistic	Modelled 2053 Synthetic Flows
Average (m^3/d)	653
Median (m^3/d)	542
Max (m^3/d)	4817
Min (m^3/d)	435

It is worth highlighting that the maximum daily flow from the synthetic 50-year series is notably less than the ICM modelled maximum flow (presented in the section above). The method used to develop the synthetic 50-year flows focussed on matching volumes across wet weather periods (often multiple days to weeks) rather than on peak day, as the cumulative volume is what is critical for the irrigation performance and sizing.

5.1 Comparisons with Measured Flows

It is acknowledged that the synthetic 50-year irrigation flow series carries uncertainties from the ICM modelled flows, as outlined in Section 3.3, as well as uncertainties from synthesizing the 50-year flows from the 15-year modelled ICM flows. A comparison has been made between the synthetic 50-year irrigation flows and PS616 flow meter measurements from 2017 to 2023 to better understand the differences in the synthesized flows. For comparison purposes, the synthetic flows have been reduced by the 2023-2053 growth portion, exclude future Ōnuku flows and have not been climate change adjusted.

It is also worth noting that the synthetic flows represent the upgraded 10-year ARI capacity network and that flowmeter measurements reflect the current capacity of the existing network. Synthetic flows during larger events are therefore expected to read higher than measured, as current network overflows are not captured in the measured data. However, in the context of long duration irrigation performance this is not expected to have a major impact because network overflows are relatively isolated, and the irrigation storage is more dependent on cumulative daily volumes across weeks and months of wet weather.

Two of the years of flowmeter data are likely affected by the COVID pandemic when Akaroa visitor numbers were reduced. Flowmeter readings are low for periods of these years. While Level 4 lockdown periods are considered to have had a severe impact on wastewater flow readings, baseflows through most of 2020 and 2021 are also lower than the years preceding and following. Conversely, outside of the Level 4 lockdowns, domestic tourism may have been increased in Akaroa for periods, given the lack of international travel at the time.

It is also noted that 2020 was a particularly dry year, with only approximately 60% of the mean annual rainfall. As established in Section 3.3, the Akaroa network appears particularly sensitive to groundwater levels and low flows over this period could also be due to exfiltration. However, there is no historical groundwater data to corroborate this. Therefore, it is difficult to conclusively demonstrate whether the reduced flows during these years is due to reduced population, increased exfiltration, or a combination of both. It is therefore difficult to exclude all of 2020 and 2021 for comparison purposes.

Table 5-3 shows modelled error against measured data for each month across the 2017-2023 period. Note these results exclude the periods considered worst affected by COVID lockdowns: March to July 2020 and August to September 2021.

Table 5-3 – Monthly Averaged Error on Synthetic 50-year Modelled Flows against Measured data (2017-2023)

Month	Average Modelled Flow (m^3)	Average Measured Flow (m^3)	Mean Difference %	Median Difference %
Jan	22,318	19,455	16%	15%
Feb	18,698	16,097	16%	26%
March	17,553	15,179	18%	27%
April	16,766	17,068	1%	6%
May	18,467	19,280	-1%	-12%
June	20,537	18,856	10%	5%
July	30,136	27,196	13%	3%
Aug	16,512	16,079	5%	5%
Sept	17,631	17,123	7%	5%
Oct	17,336	16,532	5%	4%
Nov	17,458	15,983	10%	4%
Dec	17,252	17,515	1%	-12%
		Mean Annual Difference	**8%**	**6%**
		Mean June - September Difference	**9%**	**4%**

The synthetic 50-year modelled flows are considered to fit June to September measured flows reasonably well, with monthly averaged differences across 2017-2023 within 5-13% from measured flows.

Late Summer and early Autumn periods show a more notable over-estimation compared with measured, approximately 16-18% (averaged monthly). Both this and the winter comparison is consistent with the findings comparing individual events in Section 3.3, which found better alignment between predicted and observed flows in winter. Two key contributors to this over-estimation are likely:

- In the ICM model, January (peak-summer) has been modelled with higher population flows to capture peak holiday flows (used as inputs to WWTP design flows). Seasonal population fluctuations can only be applied to the ICM model monthly. Therefore, all of January has elevated population, whereas anecdotally it is considered that the Christmas peak only runs to the 5th of January or thereabouts,
- Similar to above, the modelled results for December are low as the ICM model does not capture the peak population towards the end of December, between Christmas and New Years Eve.
- There are a number of public holidays with associated visitor fluctuations over multiple days during the drier periods of the year which are not captured by the modelled flows.

In addition, the historical flow meter data contains anomalies; examples being:

- April – June 2022 where following Easter peak flows, there is a series of small rainfall events and the flow meter baseline readings drop significantly by up to 50%
- Late April 2019 there is 45mm of rainfall and the flow meter readings show an elevated tail of 750m³/d for the rest of the month. In contrast, after 120mm of rainfall the next month, flow meter readings return to typical base flow (500m³/day) within a week - during which there is subsequent rainfall.

This sort of behaviour is unpredictable and will not be captured within the modelled flows – comparisons of measured and modelled flows during these months will show significant differences and do not necessarily suggest that the modelled flows are inaccurate.

While summer flows are acknowledged to over-estimate against measured, the wetter months average differences are considered within a reasonable tolerance considering the complexity of the catchment and inherent uncertainties and anomalies with measured readings. Noting also that this tighter validated middle portion of the year is where we typically see repetitive wet weather that determines irrigation storage requirements.

Table 5-4 shows the annually averaged modelled differences against measured and shows the modelled volumes are generally close for years outside of 2020 and 2021. Annual differences for 2018 are relatively high however it is worth noting that this was a particularly dry winter and that over-estimations in these drier periods are expected and not considered critical to irrigation sizing as discussed above.

Table 5-4 - Annually Averaged Differences on Synthetic 50-year Modelled Flows against Measured

Year	Annual Rainfall (mm)	June-Sept Rainfall (mm)	% Rainfall occurring June - Sept	Annual Difference
2018	1,220	349	29%	8%
2019	1,023	396	39%	-3%
2020	635	243	38%	*24%*[1]
2021	922	289	31%	*27%*[1]
2022	977	567	58%	1%
2023 (to August)	1,067	572	-	1%[2]

Note 1. Excludes periods considered worst effected by COVID lockdown Mar-July 2020 and Aug-Sept 2021.

Note 2. Annual difference reflects partial year comparison only.

5.2 Modelled Flow Sensitivity

From the above analysis, the modelled flows through the wetter winter months of the year, which are the driver for irrigation performance, appear to over-estimate flows against measured data by around 10%. Noting also that the available data set for model validation is reasonably small and has significant periods influenced by the COVID pandemic (to varying degrees), and earlier 2018 and 2019 data reflects performance prior to significant I&I network upgrade work in later years. Compounding this is the lack of historical groundwater data to confirm trends in wastewater flows relative to groundwater levels and/or population. We also understand that Council over the last few months have made significant adjustments to the operation of their water and wastewater plants in Akaroa and review of recent flow meter data has shown a significant reduction in baseflow in the order of 20-25%.

To acknowledge this uncertainty in the modelled flows, the irrigation models (discussed in the following section) have been run with two sensitivity reductions to the 50-year flow series of 5% and 10%. This approach allows the irrigation performance and overflows to be modelled as an expected upper and lower range.

6 Akaroa Irrigation Modelling

The synthetic 50-year irrigation flow series have been used to re-run the Soil Moisture Balance (SMB) Irrigation model for the Akaroa scheme. Rainfall and modelled treated effluent flows are applied to the proposed irrigation areas at Hammond Point and Robinsons Bay, from which the SMB model determines application capacity to land and alternatively, how much water needs to be stored.

This section presents a summary of the method and results from the updated April 2024 Irrigation Modelling work performed by PDP – see Appendix A for further details.

6.1 Irrigation Parameters

Key modelling parameters for the scheme are summarised in Table 6-1.

Table 6-1 - Irrigation Modelling Parameters

Parameter	Tree Dripper Irrigation
Area	35.7 ha (most suitable area) 40.7 ha (includes 5ha of additional area identified by Council)
Irrigation Season	All year round
Application rate	Summer – 3.08 mm/d Autumn – 2.41 mm/d Winter – 1.68 mm/d Spring – 2.41 mm/d
Irrigation efficiency	100%
Irrigation cut-off trigger	50mm

One of the key parameters for the irrigation modelling is the tree dripper irrigation area, which has been determined using guidance from the USEPA around land treatment of municipal wastewater[4] – key recommendations being:

- Exclude land with slope of greater than 19 degrees unless a site-specific geotechnical assessment confirms land as suitable.
- Exclude land with slope of greater than 15 degrees for land downslope to coastline
- Exclude land with identified instability within or downhill of area
- Exclude land that, if it became unstable, could pose risk to downslope residences and infrastructure.

Assessments of the available irrigable land for the scheme have been made by various geotechnical and irrigation specialists with consideration of the above guidance, however the irrigable areas adopted (Table 6-1) have been taken from the recently lodged resource consent application for the scheme[5].

Based on site conditions (soil type, slope and hill facing direction) a minimum winter application rate of 1.5mm/day (increasing in the shoulder and summer season) was originally adopted as appropriate to not heighten the risk of land instability. As part of the recent resource consent work for the scheme (performed

[4] Process Design Manual for Land Treatment of Municipal Wastewater, USEPA (2011)

[5] Akaroa Treated Wastewater Irrigation Scheme – Application for Resource Consents and Assessment of Environmental Effects (Stantec, May 2023)

by another consultant) it was determined that a 12% increase in these application rates would be appropriate. The modelled applications rates shown above in Table 6-1 reflect this 12% increase.

An irrigation cut-off trigger has been set that if 50mm of rainfall falls during a day the irrigation system turns off and all treated effluent is stored onsite (the system will operate again after the next day with zero rainfall). This trigger level has been set based on the same factors as the application rates (soil type, slope and hill facing direction).

Note that incoming pumped instantaneous flows from the TPS will exceed the treatment train capacity and need to be buffered at the plant prior to treatment. Daily wet weather flows delivered from the TPS will at times exceed the daily treatment train capacity and need on-site buffering prior to treatment. Daily flow buffering has not been reflected in the daily irrigation flows modelled, however this is considered to have a negligible impact as large wet weather events that exceed daily treatment train capacity are likely to trigger the irrigation rainfall limit and therefore flows held to the following day would not have been drip irrigated the day prior in the irrigation model. It is also understood that Council will explore a high flow bypass for the treatment train which will pass higher daily volumes to the irrigation system and storage when required.

6.2 Irrigation Scenarios

Irrigation scenarios have been run to primarily understand the likely overflow recurrence with given on-site (covered) storage volumes. While 35.7 hectares of area has been identified as suitable for tree dripper irrigation, a larger irrigation area of 40.7 hectares has also been assessed, which includes an extra five hectares of area identified as being ‘less desirable’ for treated wastewater application. Note that the same application rates have been applied to this additional area.

Irrigation scenarios have been run that reflect both the inclusion and exclusion of the future Takamatua catchment, as well 5% and 10% reduced flow scenarios to acknowledge the modelling sensitivity discussed above. The irrigation scenarios modelled are:

- **Scenario 1:** Akaroa synthetic 50-year flows (without Takamatua)
  - **Scenario 1A:** 35.7ha of irrigation area
  - **Scenario 1B:** 40.7ha of irrigation area
- **Scenario 2:** Akaroa synthetic 50-year flows (including Takamatua)
  - **Scenario 2A:** 35.7ha of irrigation area
  - **Scenario 2B:** 40.7ha of irrigation area
- **Scenario 3:** Akaroa synthetic 50-year flows with a 5% reduction, 35.7ha (without Takamatua)
- **Scenario 4:** Akaroa synthetic 50-year flows with a 10% reduction, 35.7ha (without Takamatua)

6.3 Irrigation Modelling Results

Table 6-2 summarises the total overflow recurrence reported across the 50-year simulation period for each scenario with 20,000m^3 of storage available. Overflow seasons have also been reported for a larger 24,000m^3 storage facility for the base Scenario 1A and the 10% reduction Scenario 4.

Note that ‘overflow seasons’ are reported below which indicate the number of irrigation seasons (i.e. years) that overflows occur in the model. Whether or not repeat overflows occur within an irrigation season is subject to a number of operational and regulatory aspects such as;

- how overflows will be managed (whether storage will be further drawn-down to provide capacity following an overflow) – how much and at what rate? etc.

- What will define an overflow 'event' – i.e. how many days between storage spilling defines a new event?

The irrigation modelling undertaken does not capture the above resolution and therefore 'overflow seasons' have been reported and are discussed further below.

Table 6-2 Irrigation Scenario Results - Storage volumes and overflows (extract from Appendix A)

Scenario	Storage Volume (m^3)	Irrigation Area (ha)	Storage Overflow Seasons (over 50-years)
Scenario 1A (excl. Takamatua)	20,000	35.7	21
Scenario 1B (excl. Takamatua)	20,000	40.7	13
Scenario 2A (incl. Takamatua)	20,000	35.7	24
Scenario 2B (incl. Takamatua)	20,000	40.7	16
Scenario 3 (5% reduction) (excl. Takamatua)	20,000	35.7	16
Scenario 4 (10% reduction) (excl. Takamatua)	20,000	35.7	11
Scenario 1A (excl. Takamatua)	24,000	35.7	15
Scenario 4 (10% reduction) (excl. Takamatua)	24,000	35.7	7

Key outcomes from the irrigation runs are:

- The expected number of overflow seasons/years across the 50-year modelled period ranges from 11-21 considering the 10% sensitivity acknowledged in the modelled flows (at 35.7 hectares).
- Inclusion of the future Takamatua catchment flows results in 3 additional modelled overflows across the 50-year period.
- Utilising an additional five hectares of irrigable land reduces the number of modelled overflows in the 50-year period by eight (reducing the number overflows by around 35%).
- An increase in storage volume to 24,000m^3 significantly reduces modelled overflow seasons by 30-50%.
- The irrigation application limit in winter is 1.68mm/day, which equates to a winter application of 600m^3 (for the 35.7ha scenario). Total dry weather flow for winter is around 450m^3 and therefore storage is likely to be empty and available at the beginning of a winter rainfall event. Modelled winter overflows are generally from rainfall cut-off events (>50mm/day) that require the entire wet weather wastewater volume to be stored each day.

Further operational and planning considerations are needed to determine a management approach for overflows in terms of storage drawdowns, discharge rates, how overflows will be reported and discharge locations etc.

6.4 Irrigation Performance with Measured Flows

Similar to the modelled flow comparisons with measured flows (Section 5.1), modelled irrigation performance has been compared with irrigation performance using measured flow meter data (i.e. how we would expect the irrigation storage to have been utilised with flows measured over the last seven years). Figure 6-1 shows modelled irrigation storage usage when measured flow meter data (2017-2023) is input as the incoming flow into the SMB irrigation model. For comparison, modelled flow storage usage - Scenario 1a (base model) and Scenario 4 (-10%) are shown. Note that modelled flow results exclude Takamatua flows, however, include 2023-2053 population growth and climate change allowance.

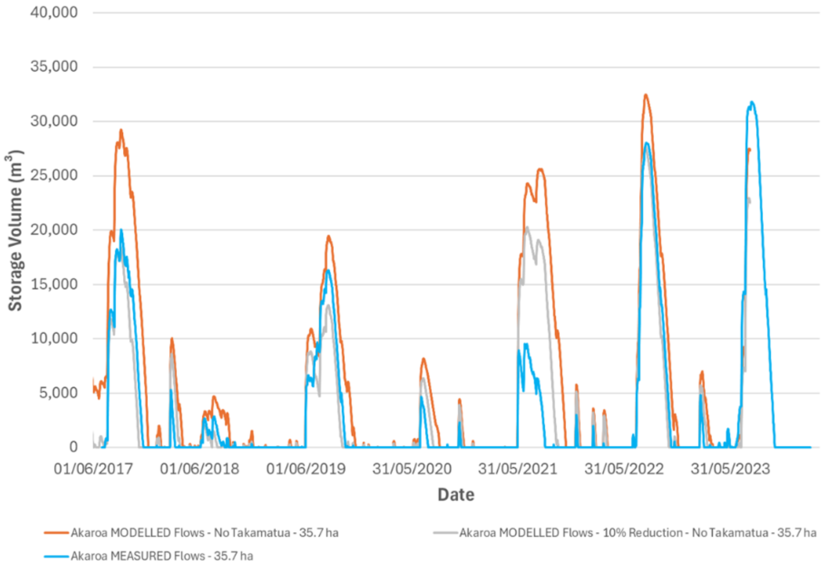


Figure 6-1: Comparison of Irrigation Performance with Modelled and Measured Flows *(PDP – Appendix A)*

Modelled storage usage with measured flows values generally sit between the base model (Scenario 1a) and the -10% reduction model (Scenario 4). The 2020 and 2021 winter comparisons show storage usage with measured flows is significantly less than modelled flows, however as discussed above in Section 5.1, this is potentially impacted by COVID and other factors.

Whilst the modelled flows include population growth allowance to 2053, this is a relatively small volumetric portion (~10m^3/day or ~900-1200m^3 during the above storage utilisation periods). Climate change allowance applies a reduction to winter rainfall depths and volumes (Section 2.3), which reduces modelled storage usage. Typical rainfall during the storage utilisation (winter) period is around 400-500mm, which once reduced by the projected 4% climate reduction in winter rainfall, would indicate a reduction in I&I wet weather volume in the order of 300-500m^3 (using the rainfall - I&I relationship developed in Appendix A). Modelled storage usage is therefore expected to read ~500-1000m^3 greater than measured, as a result of population growth (additional) and climate change (reduction) allowance. The modelling is therefore conservative for the early development of the scheme prior to growth eventuating. This is somewhat highlighted above by the storage usage exceeding the proposed 20,000m^3 volume more often for the base model (which includes growth), than the measured flow model.

Acknowledging some variation (both negative and positive), and input differences (growth, climate change etc.), this comparison suggests that the modelled flows provide a fair representation of how the proposed irrigation system is expected to perform. The variation in flows shown with this comparison also helps illustrate the rationale behind adopting a performance 'range' for considering irrigation performance, overflows, and sizing infrastructure.

7 Data Accuracy and Risk

7.1 Data Accuracy

The model has been previously calibrated to wastewater network monitors installed in the network in 2013, and twice validated to flow meter data from the pump station flow meters in 2018 and 2023 (which is described in this report). This validation is based on several sources of data including:

- Flow meter data from the network wastewater pump stations
- L'Aube Hill WTP data
- Water meter consumption data
- WTP retentate recorded flow data.

Uncertainty exists around several inputs to the model validation exercise, in particular:

- Assumed winter population used to derive the per capita demand figures, which are in turn used to derive population estimates for the dry weather validation period.
- Population estimates on the day or week of the validation period.
- Population growth assumptions to 2053
- Retentate volumes on the day or week of the validation period, if outside of the metered period.

As per capita demands are to be derived from meter readings over the winter period, even with an assumed population, the total volume will match recorded figures (at least for the winter period).

Peak seasonal populations are more difficult to predict, and there will be differences from year to year and over long weekends that cannot be captured by the model. This will not have a great impact on the network capacity, as it is designed for a 1 in 10-year rainfall event, and wet weather flows from rainfall are multiples of the peak day population flow.

7.2 Extreme Events

It should be noted that the flows determined from this modelling exercise are a "best-fit" representation of the expected future performance of the Akaroa wastewater network and that weather and usage anomalies will occur that this modelling does not account for. An appropriate margin should be considered when sizing the infrastructure for this wastewater scheme.

The climate change adjustments factored into the modelling are based on an overall probabilistic assessment. The probabilistic approach cannot forecast extreme individual "black swan" rainfall and storm events that are a feature of climate change and that have been observed around New Zealand in recent times. Recent black swan events include Cyclone Gabrielle and the extreme rainfall event that occurred at Akaroa on 24th of July 2023. Such black swan events are expected to occur with increased frequency and can strike randomly in any location at any time. As the modelling cannot predict them, Council should expect that the design basis settings for the Akaroa Wastewater Scheme will be exceeded on occasions in future.

As with any critical Council infrastructure, consideration will be needed as to what happens during extreme 'black swan' events and whether wastewater system responses pose any risks to the assets, the community or the environment.

8 Summary

Network and pump station design storm flows, treatment train average dry weather flows, and long-time series irrigation flows for the future 2053 Akaroa Wastewater Scheme performance have been modelled using Infoworks ICM software. The previous design flows for the Akaroa scheme were determined in 2020[6], however I&I improvement work has since been carried out on the reticulation network, a longer period of flow meter data is now available, and the retentate flow, which discharges to the wastewater network from the L'Aube Hill Water Treatment Plant (WTP) has been metered for a short period.

ICM Model Validation

An ICM network model previously developed by Beca has been re-validated for 3 Dry Weather Flow (DWF) events, 5 Wet Weather Flow (WWF) events and a long time series run using the most recent pump station (PS) flowmeter data, recent L'Aube Hill WTP flowmeter data, property water meter readings and retentate flow data all provided by Christchurch City Council (Council). Historical flow meter data from the three network pump stations (PS614, PS615 and PS616) has been compared against predicted flow data for validation of the DWF and WWF events. Model parameters such as baseflow and population scaling have been adjusted with an aim to align with the validation target of +/-10% cumulative pump volume (Watercare, 2019) for each DWF period.

WWF events were validated mainly through modifying groundwater infiltration parameters. The Akaroa network has a long response following wet weather events, particularly during winter, due to elevated groundwater levels. The model wet weather response was updated to the period between June 2022 to June 2023 to capture winter, back to back wet weather conditions and the resulting slow response. Following an initial dry period in June 2022 the model overpredicts the flow. This is reflected in the assessment of individual wet weather events, where events in winter are generally better calibrated than those outside of winter. Validation of the winter periods following wet weather is considered more appropriate to the outcomes of this project, where winter storms are likely to be the crucial period for determining irrigation storage sizing.

Updated Network Flows

The upgraded network and reconfigured pump station arrangement has been modelled for a 2, 5 and 10-year ARI, 24-hour duration, RCP 8.5 climate change scenario design storm, with a projected 2053 population. Network upgrades and pump station 616 and 615 duty flows have been sized to prevent network overflows during this event. Council have advised that a 5-year ARI overflow recurrence interval will likely be adopted for the Terminal Pump Station (TPS). The critical 5-year ARI design storm is in winter and has a modelled peak incoming flow of 86L/s into the TPS wet well.

A live storage volume of approximately 330m^3 would be required to buffer inflow and reduce the instantaneous peak flow from 86L/s to 65L/s for the modelled 5-year ARI event. A balance of storage and pump sizing could provide a more cost-effective overall system, allowing for optimised rising main sizing, and more efficient operation. Minimum flushing velocities would also be more achievable. Storage could also potentially be staged to spread the capital costs over time.

Flows have been extracted from the re-validated ICM model for both 2023 and 2053 populations over winter/domestic and peak summer periods to determine design flows for the new WWTP treatment train. 2053 modelled ADF for winter and peak summer are 626 and 1,012m^3/day respectively. These flows include an

[6] Akaroa Wastewater Network Modelling Long Time Series and Network Upgrade Scenarios, Beca, February 2021.

allowance for the future connection from the Ōnuku Marae into the south end of the Akaroa network but exclude the potential future connection from the Takamatua and Duvauchelle catchments.

Updated Irrigation Modelling

The Akaroa ICM model has been used to run a 15-year long time series with sub-hourly rainfall data from 2008 to 2023. These 15-years of modelled flows have then been extrapolated back using historical daily rainfall data available back to 1972 to produce a 'synthetic' 50-year flow series that has been used to predict expected long-term irrigation performance (factoring in assumed population growth and climate change impacts). Comparisons have been made of modelled flows against measured flow meter data from 2017-2023 to understand and acknowledge sensitivity in the modelled flows. Modelled flows through the wetter winter months of the year, which are the driver for irrigation performance, appear to over-estimate flows against measured data by around 5-13%.

To acknowledge this inherent uncertainty in modelled flows, the irrigation models have been run with two sensitivity reductions to the 50-year flow series of 5% and 10%. This approach allows the irrigation performance and overflows to be modelled as an expected range. Other drivers for considering a modelling uncertainty range are that the available data set for model validation is reasonably small, has significant periods influenced by the COVID pandemic, includes periods prior to significant I&I network upgrade work. We also understand that Council over the last few months have made significant adjustments to the operation of their water and wastewater plants in Akaroa and review of recent flow meter data has shown a significant reduction in baseflow in the order of 20-25%.

Key outcomes from the updated irrigation runs are:

- The expected number of overflow seasons/years across the 50-year modelled period ranges from 11-21 considering the 10% sensitivity acknowledged in the modelled flows (at 35.7 hectares).
- Inclusion of the future Takamatua catchment flows results in 3 additional modelled overflows across the 50-year period.
- Utilising an additional five hectares of irrigable land reduces the number of modelled overflows (at 20,000m^3 storage) in the 50-year period by eight (reducing the number overflows by around 35%).
- An increase in storage volume to 24,000m^3 significantly reduces modelled overflow seasons by 30-50%.

It should be noted that the flows determined from this modelling exercise are a "best-fit" representation of the expected future performance of the Akaroa wastewater network and that weather and usage anomalies will occur that this modelling does not account for. An appropriate margin should be considered when sizing the infrastructure for this wastewater scheme. The climate change adjustments factored into the modelling are based on an overall probabilistic assessment and cannot forecast extreme individual "black swan" rainfall and storm events that are a feature of climate change and that have been observed around New Zealand in recent times. Council should expect that the design basis settings for the Akaroa Wastewater Scheme will be exceeded on occasions in future. As with any critical Council infrastructure, consideration will be needed as to what happens during extreme 'black swan' events and whether wastewater system responses pose any risks to the assets, the community, or the environment.

Christchurch City Council

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Appendix A – Akaroa Irrigation Modelling Memo – PDP (April 2024)

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5 April 2024

Innes Duncan
Senior Civil Engineer
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CHRISTCHURCH 8141

Dear Innes,

AKAROA RECYCLED WATER SCHEME - IRRIGATION MODEL RESULTS FOR RECYCLED WATER DISPOSAL AT ROBINSONS BAY WITH SUPPLEMENTARY WETLAND

1.0 Introduction

Christchurch City Council (CCC) is investigating options to irrigate recycled water from a proposed wastewater treatment plant (WWTP) servicing the Akaroa township. Pattle Delamore Partners Ltd (PDP) have been engaged by Beca Ltd to prepare a soil moisture balance (SMB) assessment so that an appropriate storage volume can be estimated for the irrigation scheme.

This letter has been prepared to present the recycled water storage requirements of the irrigation scheme using an updated long-term recycled water flow series derived from the Beca integrated catchment model (ICM). Irrigation of recycled water to trees planted at the 'Head of the Bays' sites was modelled using this long-term recycled water flow series for the following scenarios:

- Scenario 1: Irrigation of recycled flows from Akaroa only, over an area of:
  - 35.7 ha, or
  - 40.7 ha.
- Scenario 2: Irrigation of recycled flows from Akaroa and Takamatua catchments, over an area of:
  - 35.7 ha, or
  - 40.7 ha.
- Scenario 3: Irrigation of recycled flows from Akaroa only (with a 5% reduction applied), over an area of 35.7 ha.
- Scenario 4: Irrigation of recycled flows from Akaroa only (with a 10% reduction applied), over an area of 35.7 ha.

All scenarios include a WWTP with a wetland that can be used for additional storage. The output for this modelling is the number of storage overflow events associated with a covered storage volume of 20,000 m³ over the 51-year climate dataset.

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2.0 Model Method and Inputs

2.1 Recycled Akaroa Water Flow Estimate

2.1.1 Measured Flows

Beca has developed an Integrated Catchment Model (ICM) based on the measured flow data recorded at the Akaroa WWTP and wastewater pump stations. The ICM includes proposed updates to the network as well as factors to account for future population growth and climate changes. The PDP modelling is based on a synthetic flow series developed using the Beca ICM model.

2.1.2 Synthetic Flow Series

The Soil Moisture Balance (SMB) model uses a synthetic flow series developed from modelling the wastewater network's response of flow to rainfall and applying this relationship to historic rainfall data. This approach captures the effects of wet and dry years and reduces bias associated with relying on a smaller dataset of actual measured wastewater flows. Details of how this synthetic long-term flow series was developed are described below.

PDP developed a synthetic long-term recycled water flow series for the Akaroa WWTP spanning the period 1 January 1972 to 7 August 2023. This was developed by applying the relationship between flow and rainfall from Beca's Integrated Catchment Model (ICM) of the Akaroa township wastewater network to historic climate data. The ICM estimates wastewater water flows generated within the catchment servicing the WWTP from 19 Dec 2008 to 27 August 2023. The ICM outputs the recycled water flow broken down into the following constituents:

- Baseflow (permanent groundwater infiltration into the network)
- Trade flow (composed of commercial flows and retentate from the L'aube Hill WTP)
- Rainfall derived inflow and infiltration (RDII),
- Soil Storage derived inflow and infiltration (soil store), and
- Foul flow (composed of residential wastewater flow and portions from accommodation catchments).

The ICM is the foundation for developing the long-term recycled water flow series. The dry weather flow (all flow components except for RDII and soil store) have been taken as a monthly average from the ICM. It is assumed that all flows that reach the WWTP are treated and conveyed to storage/irrigation on the same day.

2.1.3 Baseflow, Trade Flow and Foul Flow:

It is noted that while the baseflow and trade flow have been assumed to be a constant daily rate based on the ICM results, the foul flow varies daily, with trends apparent on a monthly scale. Table 1 shows the components of the dry weather flows broken down monthly.

Table 1: Monthly breakdown of flows.

Parameter	Baseflow (m^3/day)	Trade Flow (m^3/day)	Foul Flow (m^3/day)
January	61	191	444
February	61	191	189
March	61	191	183
April	61	191	183
May	61	191	183
June	61	191	183
July	61	191	183
August	61	191	183
September	61	191	183
October	61	191	184
November	61	191	183
December	61	191	192

These values are used to create the long-term recycled water flow series by taking the sum on flows each day and adding additional flow from RDII, soil store, and Takamatua catchment flows (described in section 2.1.2).

2.1.4 Rainfall Derived Inflow and Infiltration (RDII):

The Beca ICM model uses sub-hourly rainfall intensity to estimate RDII and soil store parameters. There is limited rainfall data to this resolution over the long-term model period. Therefore, the RDII in the long-term recycled water flow series is estimated based on the relationship seen between RDII and event rainfall (summed on a daily timestep) from the ICM.

Figure 1 shows the RDII response in the wastewater network corresponding to rainfall events. A rainfall event is considered independent if there have been two or more consecutive days without rainfall. The RDII is summed on a rainfall event basis.

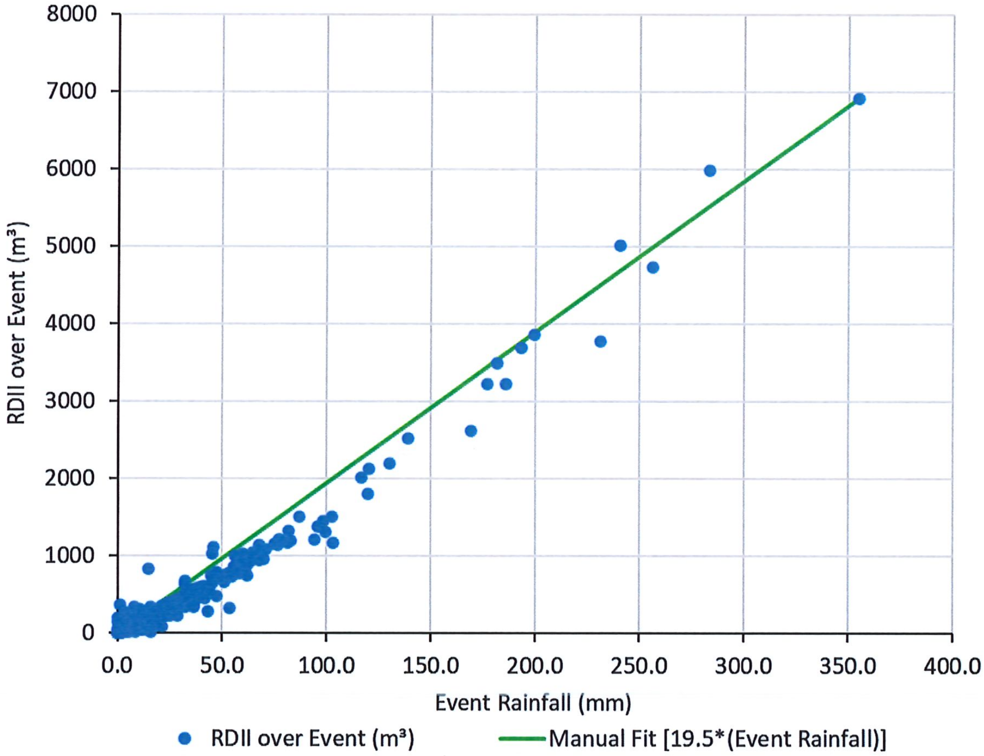


Figure 1: Relationship between VCSN Rainfall Events and the RDII response from the Beca ICM.

A manual trendline has been selected to estimate the relationship between RDII and a rainfall event. The manual trendline is tailored to fit the larger rainfall events (> 100 mm rainfall events). It is noted that, although non-linear trendlines may provide a better overall fit to the data, the purpose of the long-term recycled water flow series is to provide an estimate of the peak recycled water storage volume required over the modelling period. Therefore, the trendline is chosen to favour larger rainfall (resulting in larger RDII) events.

2.1.5 Soil Store Flow

After a rainfall event, a portion of the rainfall depth is considered to be held within the soil where it slowly enters the wastewater network via inflow and infiltration. This is observed as a tail to the immediate RDII response in the ICM. As with the RDII, a relationship was developed to estimate soil storage over the long-term flow series (Equation 1). The magnitude of the soil store contribution is estimated as a proportion of the RDII following a rainfall event which then decays over time. Following a rainfall event, the contribution is 'topped up' by adding to the previous day's soil store value.

$$\boldsymbol{soil\ store\ flow = RDII \times 0.54 \times exp^{-0.25*days}}$$

Equation 1: Soil Store (applied the day after a given rainfall day)

This relationship was then applied to historic long-term rainfall data (adjusted for climate change by Beca) to produce the RDII and soil store components of the long-term recycled water flow series. The Akaroa electronic weather station (EWS) was determined to be the most appropriate station to use for this series as this was the closest station to the Akaroa network. However, the Akaroa EWS only had data available from mid-December 2008 to the present day. Rainfall from the NIWA Virtual Climate Station Network (VCSN) 20249 was therefore selected to complete the extended rainfall series[1].

A comparison between VCSN 20249 and Akaroa EWS indicates that on average there is a difference in annual rainfall totals of approximately 1%. The timing of measured rainfall events is similar for the two-rainfall series, providing confidence in using the VCSN 20249 dataset to estimate RDII.

2.2 Comparison to ICM Output

The long-term recycled water flow series is compared to the ICM in Figure 2. In general, the long-term recycled water flow series underestimates the peak recycled water flows on large RDII days. However, the purpose of the model is to understand the storage requirements of the system. These requirements are driven by the volume of recycled water in wet winter months. Table 2 shows the difference between the PDP long-term flow volumes and the ICM flow volumes from June to September (inclusive) each year.

The difference between the peak recycled water flows modelled in the ICM and the long-term flow series is the timing of the soil store. It is acknowledged that there is a difference in timing of up to 24-hours on daily peaks. Adjusting the soil store to contribute on the same day as the rainfall would result in a general over-estimation of the peak recycled water flows on a larger RDII day. As the volume of the flows over multiple days to weeks influences the peak storage, the impact of these timings is within the uncertainties of the model. As shown in Table 2, the PDP model provides a good fit over the winter months to the ICM model.

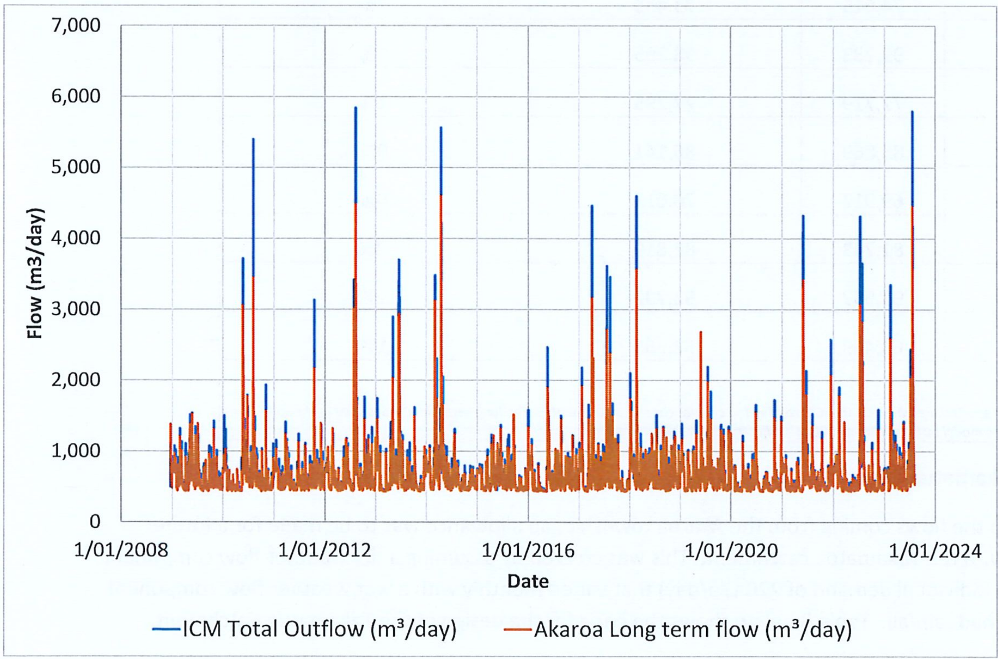


Figure 2: Long-term recycled water flow series compared to the ICM.

[1] The VCSN stations are generated on a 5 km grid and provide estimates of daily rainfall based on the spatial interpolation of actual data observations made at climate stations located around the country. VCSN 20249 is located approximately 4 km north of the Akaroa township and provides rainfall from 1 January 1972 to the present day.

It should be noted that the daily volume of recycled water generated from the network has not been limited. All flows generated are assumed to be captured and delivered to the WWTP and available for irrigation.

Table 2: Comparison of Long term flow volumes to the ICM.

June – September Year	Beca ICM	PDP Long term Flow	Difference
2009	73,995	72,646	2%
2010	96,243	94,973	1%
2011	70,691	69,120	2%
2012	101,566	99,627	2%
2013	94,824	92,887	2%
2014	71,903	70,615	2%
2015	81,083	80,151	1%
2016	74,615	73,435	2%
2017	99,283	98,295	1%
2018	77,719	77,295	1%
2019	85,869	86,141	0%
2020	69,912	70,013	0%
2021	81,743	82,810	-1%
2022	93,557	92,732	1%
2023	63,469	62,865	1%

Notes:
1. *Values reported are based on the ICM rainfall (no climate change adjustments). The long-term flow series used in the soil moisture model includes climate change adjustments provided by Beca.*

2.3 Takamatua Flow

In addition to the flows coming from the Akaroa township, an allowance was to be made for a future connection with the Takamatua catchment. This was created by assuming a dry weather flow component (based on an individual demand of 220 L/p/day) that varied monthly with a wet weather flow component on days that had rainfall. Table 3 below shows the basis for the design of the Takamatua Catchment.

Table 3: Takamatua Flow Basis

Months	Takamatua Population[1]	Individual Demand	Takamatua Flow Contribution (m³/day)
Mar-Nov	110	220 L/p/day	24
Dec, Feb	220		48
Jan	440		97

Notes:
1. *Populations as provided by Beca*

Wet weather flows were assumed to contribute an additional 50% of dry weather flows on days with rainfall greater than 2 mm/day. This was applied as a flat rate for all days with rainfall greater than 2 mm/day.

It is noted that due to the RDII assumptions made for Akaroa and Takamatua above, RDII and annual volumes are likely biased towards overestimating the flows.

2.4 Irrigation Assumptions

The proposed method of irrigation at Robinsons Bay modelled in this assessment is irrigation to native trees. For irrigation to native trees, drip irrigation is assumed with the recycled water applied to the land irrespective of soil moisture conditions. Table 4 lists the key assumptions that have been made:

Table 4: SMB Model Assumptions

Parameter	Drip Irrigation – 100% Efficiency
Recycled Water Flow	Long-term recycled water flow series (Akaroa dry weather flows + Akaroa wet weather flows + Takamatua flows)
Rainfall[1]	1972 to 2008: NIWA VCSN 20249 2008 to 2023: Akaroa EWS
Rainfall Cut-off	If rainfall > 50mm/day then irrigation ceases until next dry day
Potential Evapotranspiration (PET)	NIWA VCSN 20249
Irrigation Season	All year round
Irrigation Area	35.7 ha or 40.7 ha
Maximum Irrigation Application Rate[2] (mm/day)	Summer – 3.08 Autumn – 2.41 Winter – 1.68 Spring – 2.41
Soil Profile Available Water	Irrigation regardless of PAW

Notes:
1. *The combined rainfall series has been adjusted for climate change impacts by Beca. This is the same series used for estimating the long-term RDII component of flows, as described above.*
2. *Rates displayed are maximum depths that can be irrigated provided there is adequate flow/stored volume available.*

The maximum irrigation application per day is less than the long-term acceptance rate of the soils and is selected to avoid surface ponding when the PAW is at field capacity.

2.5 Wetland Operation Rules

A sub-surface wetland is proposed, which will be filled with granular media and planted with wetland species. An additional freeboard is included to extend the potential depth of the wetland above the surface of the media. The wetland is treated as open storage within the model and sees increases in the volume stored during rainfall as a result. The stored volume will decrease with evapotranspiration. Due to a minimum water level being required in the wetland to maintain plant growth, the model diverts recycled water from the WWTP to the wetland each day to replace evapotranspiration losses where necessary. Aside from small flows to maintain plant health, the wetland only receives additional recycled water when the covered storage is 100% full.

Previous modelling has included a controlled wetland discharge to the harbour, set at a constant rate of 2 L/s. This has not been included in this modelling. It was specified by CCC that stored water within the wetland can only be removed via evapotranspiration or drawdown for irrigation. If the wetland freeboard is exceeded, the volume of water above the freeboard will overflow into the harbour at an unrestricted rate. This is what is referred to as an "overflow event" in the results.

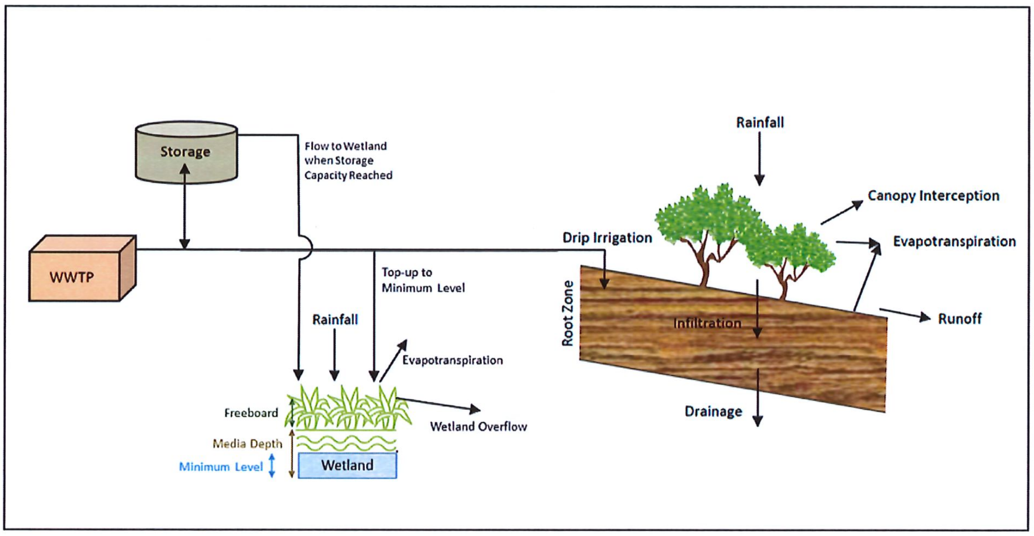
<u>Wetland Model Summary</u>

Wetland Surface Area:	3,200 m^2
Wetland Media Depth:	0.3 m
Wetland Media Porosity:	30%
Wetland Freeboard Depth:	0.9 m
Wetland Minimum Level:	100 mm

The above parameters result in a total volume of water in the wetland (including freeboard) of 2,208 m^3.

2.6 Model Schematic

Figure 3 below shows a graphical representation of soil moisture balance model.



Extended Soil Moisture Balance Concept Incorporating Wetland

Figure 3: Schematic showing the soil moisture balance.

3.0 Updated Model Results

3.1 Model Inputs

The following scenarios are evaluated in this letter:

- Scenario 1: Irrigation of recycled flows from Akaroa only, over an area of:
  - 35.7 ha, or
  - 40.7 ha.
- Scenario 2: Irrigation of recycled flows from Akaroa and Takamatua catchments, over an area of:
  - 35.7 ha, or
  - 40.7 ha.
- Scenario 3: Irrigation of recycled flows from Akaroa only (with a 5% reduction applied), over an area of 35.7 ha.
- Scenario 4: Irrigation of recycled flows from Akaroa only (with a 10% reduction applied), over an area of 35.7 ha.

Each scenario uses the updated long-term recycled water flow series (discussed in section 2.1 above), with the irrigation parameters detailed in Table 4, and the wetland as described above.

As a basis for comparison, the model was run using measured flow data recorded from July 2017 – February 2024 with no maximum storage volume. This measured flow scenario did not include any additional climate adjustments or future growth factors.

3.2 Model Results

3.2.1 Flow Estimate Model Results vs Available Flow Data Results

Figure 4 shows the modelled storage assuming there are no storage limits. The scenarios shown are: Scenario 1 (the PDP modelled Akaroa flows over 35.7 ha of area), Scenario 4 (the PDP modelled Akaora flows with a 10% reduction over 35.7 ha of area), and the measured flow.

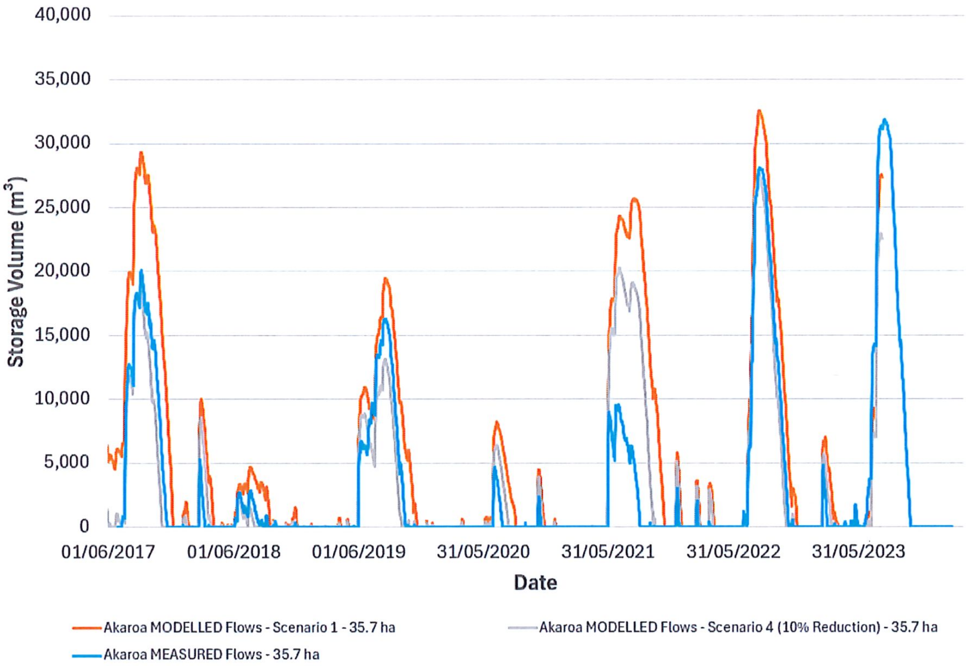


Figure 4: Comparison of flow estimate model results with measured flow data model results.

Modelling the current measured flow data provides smaller storage requirements in many cases when compared to the allowance for population growth and climate change. Some large rainfall events in 2022 and 2023 yield storage requirements that are comparable to the model runs assuming climate change and population growth. As both estimated flow and available flow data results are of similar magnitude and pattern, confidence is taken that the results of this modelling are suitable for use in decision-making steps in future.

3.2.2 Overflows by Scenario

Each scenario was run within the SMB model to model the number of overflow events for each 51-year flow series. The results of this modelling are shown in Table 5 below.

Table 5: Model Results for Irrigation to Native Trees - By Scenario

Scenario	Area Irrigated	Storage[1]	Number of Years with Overflows
001	35.7 ha	20,000	21
	40.7 ha	20,000	13
002	35.7 ha	20,000	24
	40.7 ha	20,000	16
003	35.7 ha	20,000	16
004	35.7 ha	20,000	11
001	35.7 ha	24,000	15
004	35.7 ha	24,000	7

Notes:
1. *The volumes shown are for the covered storage. There is also an additional 2,208 m^3 of wetland storage volume on top of these volumes*

3.2.3 Causes of Overflow Events within the Model

Overflows within the model are typically seen during winter months, however, overflows can also occur during other times of the year. An example is provided in Figure 5 and discussed below. It should be noted that this example covers the largest wet-weather period in the synthetic long-term flow series.

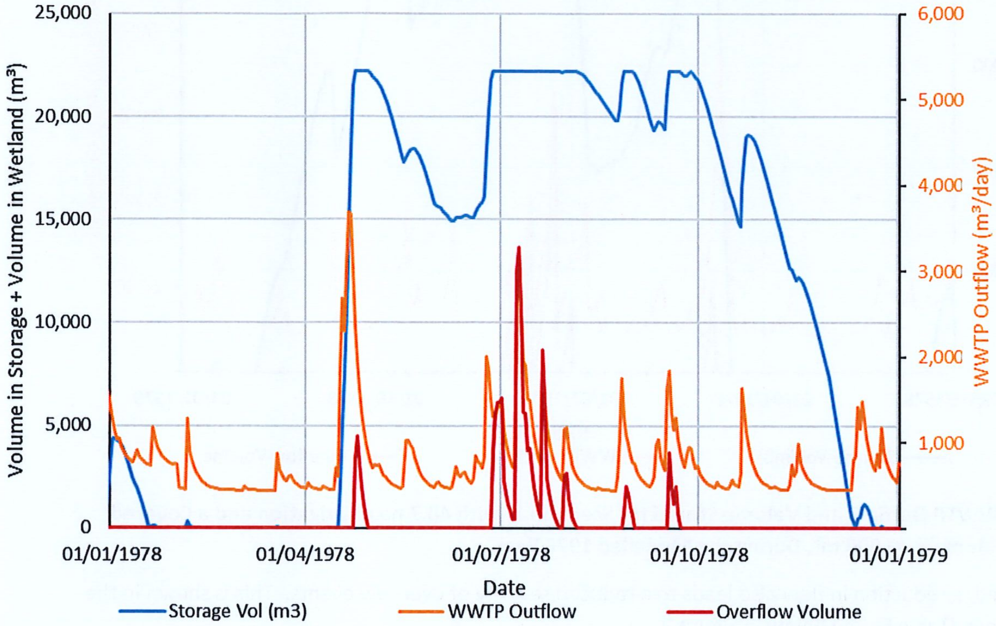


Figure 5: WWTP Outflow and Volume Stored for Scenario 1, with 35.7 ha of Irrigation and a Covered Storage Volume = 20,000 m³, During the Modelled 1978 Year.

As shown above, a large rain event (in this case 378 mm of rainfall over one week) causes the recycled water flow to spike. The rainfall event triggered the 50 mm rainfall cutoff value for irrigation. This combination leads to all recycled water accumulating until the storage capacity is reached. Note that within this figure the storage capacity is 22,208 m³ (20,000 m³ of covered storage with 2,208 m³ storage within the wetland).

Following the initial spike, the higher irrigation rates during the shoulder season allow for the volume within storage to be drawn down. However, multiple rain events during winter months cause the storage to once again reach capacity within a short period of time. A reduced irrigation rate in winter then prevents any significant further drawdown.

During spring, the increased irrigation rates once again allow for some drawdown, however, repeated rainfall does result in some overflows still occurring. Eventually, the higher irrigation rates overcome the additional flows due to rainfall and the volume of recycled water within storage drops to zero.

Storage during summer each year drops to a zero value in all scenarios modelled for at least one day.

The inclusion of a wetland does help the resilience of the system to overflows as it allows more buffer capacity within the system. However, within this model the wetland is only acting as additional storage.

Increasing the area available to irrigate allows stored volume to be drawn down at a steeper rate, thereby providing the system with greater resilience to sequential rainfall events. This is shown the results above (Table 5) and below in Figure 6.

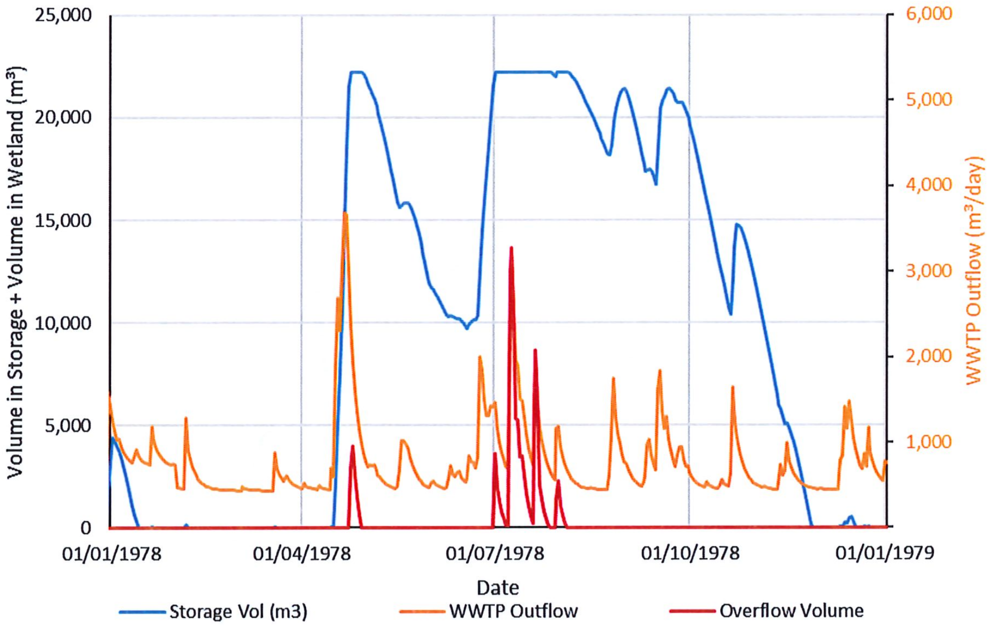


Figure 6: WWTP Outflow and Volume Stored for Scenario 1, with 40.7 ha of Irrigation and a Covered Storage Volume = 20,000 m³, During the Modelled 1978 Year.

As expected, a reduction in flow also leads to a reduced severity of overflow events. This is shown in the results above (Table 5) and below in Figure 7.

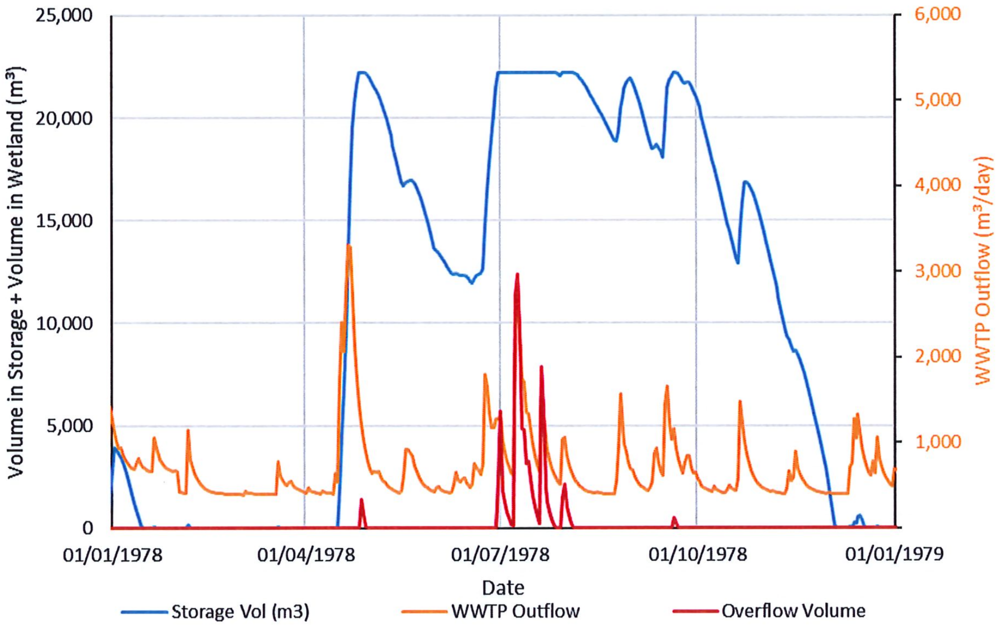


Figure 7: WWTP Outflow and Volume Stored for Scenario 4, with 35.7 ha of Irrigation and a Covered Storage Volume = 20,000 m³, During the Modelled 1978 Year.

4.0 Conclusion

This letter was prepared to update the results of the Akaroa recycled water scheme SMB model. The update was made to reflect the changes made to both the Beca ICM and new irrigation/storage assumptions made by PDP, Beca and CCC.

The results of the modelling indicate the following:

- All modelled scenarios see years with overflows given a covered storage volume of 20,000 m³.
- The number of years with overflows range by scenario (11-24 overflow years within those modelled).
- Limited irrigation ability in winter combined with increased and more frequent rainfall is a major cause of overflows.

5.0 Limitations

This model has been prepared for the purpose of estimating the peak treated recycled water storage requirements for the Akaroa wastewater disposal scheme. The assumptions surrounding the development of the long-term flow record reflect this purpose and may not be suitable for assessments of the typical operating conditions.

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of recycled water flows provided by Beca and Christchurch City Council and the analysis of future flows carried out by Beca. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Beca for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Yours sincerely

PATTLE DELAMORE PARTNERS LIMITED

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Karakia Whakamutunga

Closing Prayer

Unuhia, unuhia Unuhia ki te uru tapu nui Kia wātea, kia māmā, te ngākau, Te tinana te wairua i te ara takatā Koia rā e Rongo, whakairia ake ki runga Kia tina! TINA! Hui e! TĀIKI E!	Draw on, draw on, Draw on the supreme sacredness To clear, to free the heart, the body and the spirit of mankind Rongo, suspended high above us (i.e. in 'heaven') Draw together! Affirm!