LEVERAGING DATA TO IMPROVE WATER NETWORK OPERATIONS

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ABSTRACT

Population growth and climate change have significantly increased the pressure on water bodies, and water management needs to become more efficient to meet these challenges. Water network managers must work to create a water supply system that is highly resilient, efficient, and sustainable to protect water sources and their intrinsic values as well as respond to increased customer expectations. Through optimising the water network, significant amounts of energy, treatment and pumping costs, and treatment resources can be saved.

Hamilton City Council has a strategy to create water supply zones to better manage its water network and control water losses. The Council is working to hydraulically separate the entire city network into water supply zones with district metered areas (DMAs). Strategic flow metering will enable understanding of water consumption and water losses without residential metering.

A mass balance approach is used to understand water consumption, plus the location and volume of water losses. The flow composition looks at getting an estimation of the net water consumption and how much is lost through the distribution. The effectiveness of this system depends highly on the densification, accuracy, and continuity of the metering system. Flow records are captured every five minutes, seven days a week, in more than seventy locations within the network.

To transform this large volume of flow data into insightful outputs has required the joint effort of multiple disciplines. Leveraging Hamilton City Council's knowledge of the network, plus the data management experience that Mott MacDonald offers has allowed the development of custom tools to enable data-based decision making. Graphic representations of the water network, DMAs, meter locations, plus charts of water consumption and pressure have provided a clear picture of the current state of the network and tools to support further optimisation.

This paper will provide examples of data visualisation and how this has been used to improve day to day operations of the water network in Hamilton City. Some lessons learnt along the way will be shared so that others may learn from Hamilton's experiences.

Hamilton City Council's experience has shown that efficient data management is essential to understand, control, and optimise its water network. Being able to visualise the data has helped to understand the status of the network and the challenges for each DMA. Sharing experiences and working collaboratively across

councils and consultants will enable the New Zealand water industry to respond and facilitate the changes driven by population growth and climate change.

KEYWORDS

Drinking Water Network, Data Management, Network Operation, Water Management, Operational Improvement

PRESENTER PROFILE

Heather Kikkert is a chartered engineer with over 14 years of experience with water and wastewater networks in three countries – New Zealand, Scotland and Hong Kong. Currently Heather works for the Hamilton City Council working to improve the operational efficiency of Hamilton's three-water networks and closed landfill sites.

Diana Galindo is a civil engineer with a master's degree in Resources Hydraulic Engineering. She has worked on three-waters infrastructural projects for public and private companies in New Zealand, Australia, Indonesia, and South America over the last 11 years. Her current role involves leveraging her engineering background and computational programming skills to develop digital solutions to support water management decision-making.

INTRODUCTION

Hamilton City is located near the centre of the North Island of New Zealand. This paper describes the water network in Hamilton City and how it is monitored.

Water Network Overview

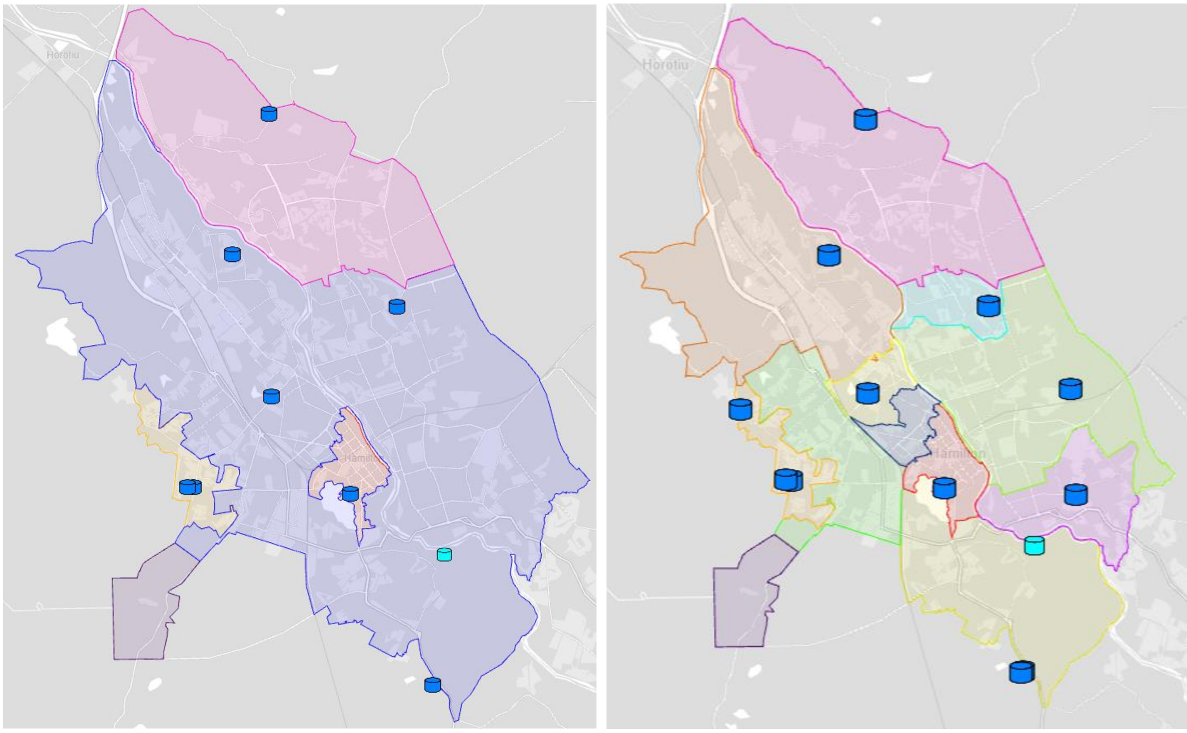
Hamilton City is located near the centre of the North Island of New Zealand. Hamilton has one water treatment plant in the south of the city that takes water from the Waikato River as it winds its way north towards Port Waikato near Auckland. The treatment plant distributes water via a bulk water main to nine water storage reservoirs as well as directly to the reticulation. There are more than 1250 kilometres of water mains and over 59,000 service connections, most of which are residential. The 53,000 residential connections are not metered in Hamilton, though industrial and commercial connections are metered, as are points where water is supplied to the surrounding Waikato District.

A bulk water main circles the city, with pipes from the treatment plant crossing the Waikato River to feed water north along both the east and west sides of the city. This bulk ring main joins the east and west sides of the city in the north, near Pukete. The Pukete Reservoir can help to push water from west to east along the bulk main ring in emergencies.

The city is split into six water supply zones, plus the 'Blue Zone' that comprises the rest of the network. Each water supply zone is fed by a single reservoir, though the Blue Zone is fed from the remaining four reservoirs and directly from the bulk water main supplied by the treatment plant.

Hamilton City Council is working towards creating nine water supply zones, each with it's own reservoir. This will decouple the treatment plant from network demand and allow greater network resilience and optimised energy use. It will also help to simplify operations and minimise water losses through improved ability to monitor district metered areas (DMAs). Part of these improvement works include increased monitoring of network flow and pressure.

Figure 1: Hamilton Water Network Supply Zones in 2020 (left) and the Future (right)



WATER NETWORK OPERATION AND MONITORING

Currently the Hamilton City Council Plant Operations Team operate the water network and hence monitoring is largely focused on reservoir operation, citywide consumption and maintaining levels of service with regards to minimum pressures. At the treatment plant, flow and pressure are measured feeding to the east and west sides of the bulk ring main. Flow into and out of reservoirs is measured, as is the flow through the furthest point of the bulk ring main near Pukete. There are also pressure gauges at critical, high elevations to inform the pressure control points for reservoir pumps. These critical pressure gauges ensure that Hamilton customers are being supplied pressure that is within the Hamilton City Water Supply Bylaw 2013 (Hamilton City Council, 2013), with the minimum pressure at point of supply being 10 metres head (100 kPa). Normal operating pressure is noted as 20-30 m head (200-300 kPa) in the Bylaw and the Regional Infrastructure Technical Specifications (RITS) (Waikato Local Authority Shared Services, 2018) set a target minimum pressure of 20 m head.

Starting around 2013, Hamilton City Council started installing meters on all mains that feed off the bulk water main, then moved to a more strategic approach aiming to measure flow into District Metered Areas (DMAs) and zones. Eventually, when all the water supply zones are created, the bulk water main will only feed reservoirs and the meters at offtakes will become obsolete. There are also pressure gauges, some in the same location as the DMA flow meters and some at critical high and low elevations. These reticulation meters and pressure gauges are monitored by our Reticulation Operations Team to assist with response to customers and network issues.

HAMILTON CITY'S WATER NETWORK CHALLENGES

Hamilton is one of the fastest growing cities in New Zealand, with the population predicted to increase from 200,755 in 2018 to 230,000 in 2061 (Mott MacDonald, 2020). Along with other enabling infrastructure, the water network is expanding to meet this demand with 1.8 kilometres of new water mains installed by Hamilton City Council in the 2019-20 year (Hamilton City Council, 2021), with more vested to Council by developers.

As mentioned in the section above, only commercial and industrial customers are metered in Hamilton. This means a high proportion of water consumed in the city is not metered, making water mass balance calculations challenging. Without knowledge of customer consumption, assumptions must be made on the level of water losses.

Climate change impacts, such as the recent hot, dry summers, put strain on the water supply network to meet customer expectations of levels of service. Hamilton City Council experience suggests that customers in newly built houses desire to maintain their new lawns and gardens to a high standard even during near drought conditions. In general, outdoor water use can double water demand in residential areas, even with water restrictions of 4 hours maximum outdoor sprinkler use.

The Waikato River is an important water source for many towns and businesses (such as farms). In order to protect the mana of the awa (river), it is important for Hamilton City Council to consider ways to reduce water losses.

These challenges help to drive Hamilton City Council towards further improvements in network resilience, efficiency, and minimisation of water losses. Network monitoring provides data to inform improvement decisions based on where water is going.

WATER NETWORK MONITORING

The locations of the zone and DMA boundaries were determined by the size of the reservoir and population able to be served and the requirements for emergency storage. Large zones were split into smaller DMAs, while smaller zones are their own DMA. These boundaries determined the location of flow monitoring to measure demand.

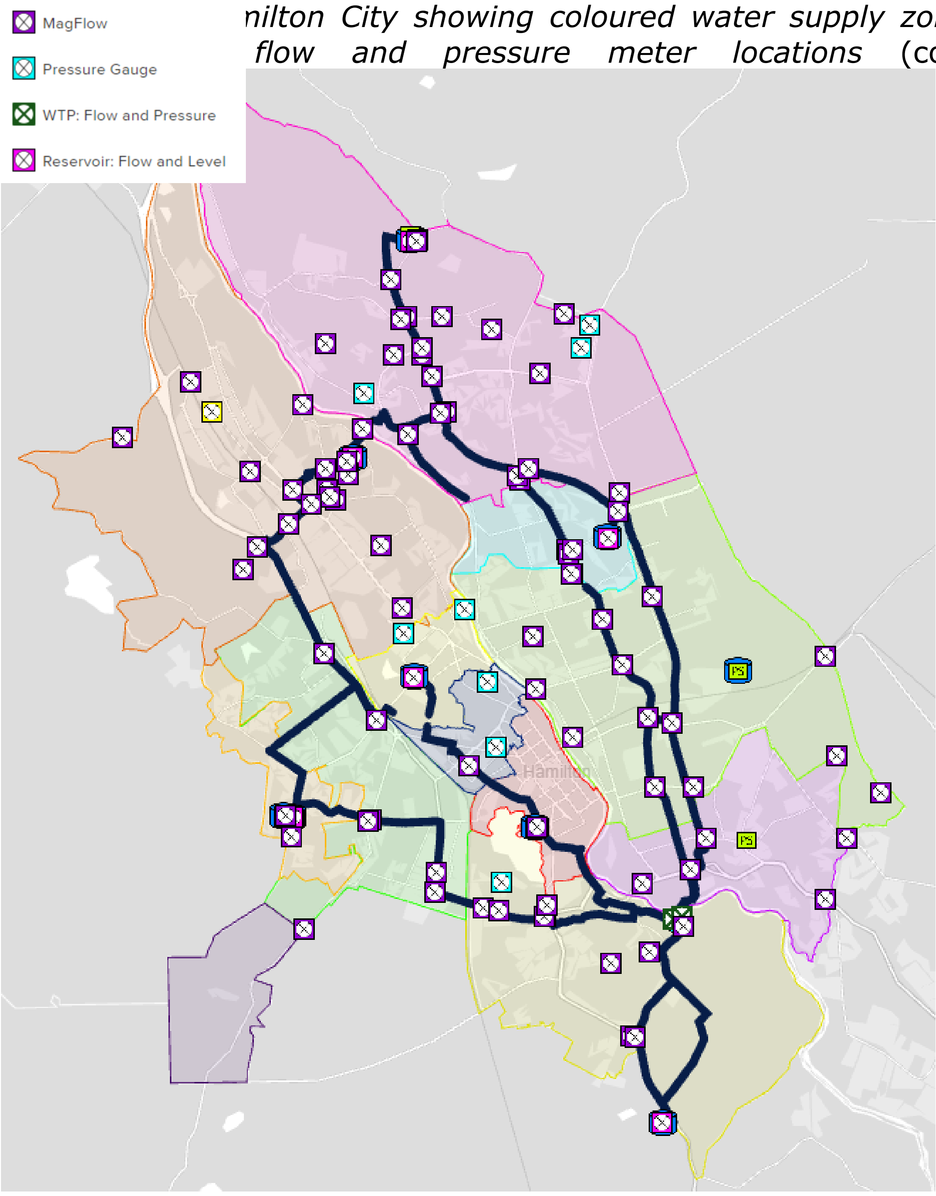
The majority of Hamilton's water network flow meters were installed as part of DMA enabling works from 2013 to present. These enabling works included installing road crossings and valves to reduce dead ends and allow water to loop when boundary valves were closed. In some locations, flow meters were installed as the DMA boundary rather than creating a hard boundary of closed valves.

DATA COLLECTION

Large sets of data are daily recorded to support the operation of the Hamilton water network. The Supervisory Control and Data Acquisition (SCADA) system enable HCC to view real-time flow, pressure and level measurements, and facilitate the network performance by remotely operating network elements such as pumps and valves, mainly part of the bulk system.

Flow, pressure, and level measurements are collected from two sources. One dataset is collected by Hamilton City Council and stored in what is called the Historian System; a second dataset is collected by Mott MacDonald. Both datasets are displayed in the Mott MacDonald web platform, Moata. Most of the data is collected every five minutes, seven days a week, 356 days a year.

The location of flow and pressure meters are represented spatially in a map along with the zone boundaries, the water reticulation, and the modelling results as shown Figure 1 below. The union of all information in just one place provides a holistic overview of the network.



nilton City showing coloured water supply zones (future), bulk flow and pressure meter locations (coloured squares)

DATA VISUALISATION

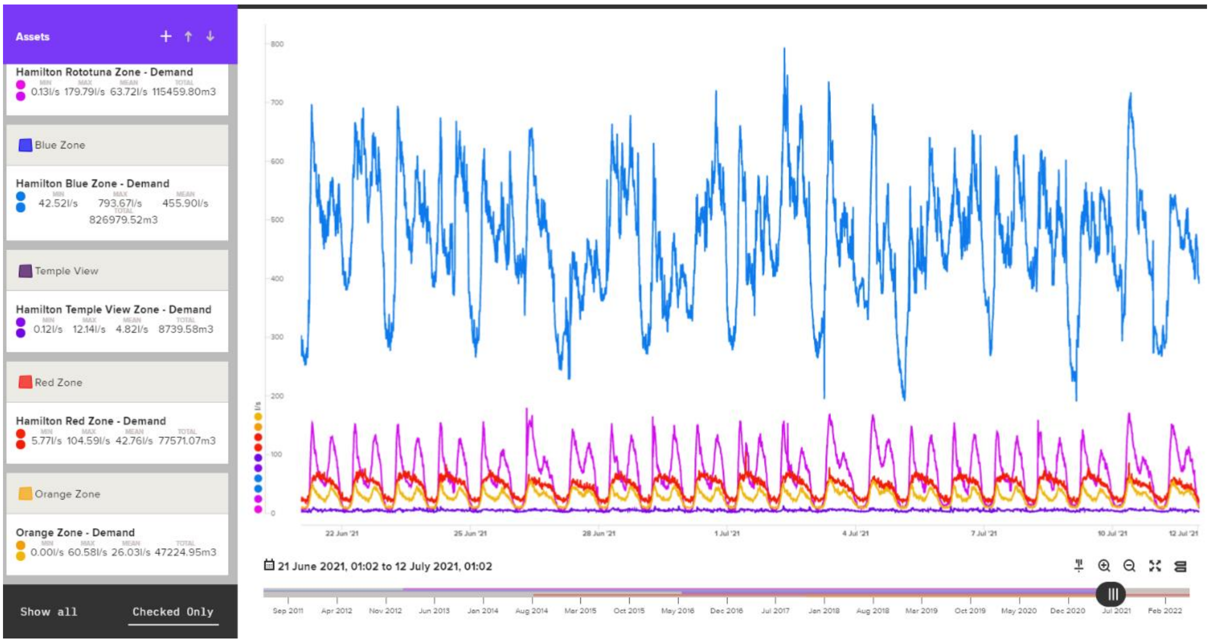
Hamilton City Council have achieved that the amounts of information collected every day are safety stored in local servers and in the cloud. Data collection and data storage is not as challenging as it used to be in the past for any organisation. Every time there are more tools available to facilitate data exploration, having to spend less time manipulating data and more in make it a proper use. The challenges then become in using the information and engineering knowledge to optimise the system as fast as it requires.

There are multiple challenges when working with real-time data. Network analysts often have access to more data than can be easily processed or data with incorrect readings, time-scale errors, or missing values. Fortunately, multiple scripts are embedded in the Moata platform to compile, organise, and display the information.

The data collected is used by multiple teams at Hamilton City Council for viewing operational data and hydraulic modelling results. These teams rely on the available data to update the Hamilton hydraulic model which support Hamilton Strategy Planning.

As mentioned in section above, meters are installed at the boundaries of each DMA. The data collected from approximately 67 locations allow the mass balance per DMA. The net flow supplied to each area is calculated as the sum of all flows coming into each zone (inflows) minus all the flows leaving the zone (outflows), as shown in **Error! Reference source not found.** and Figure 6.

Figure 2: Mass Balance per Zone



Although the information can be displayed in detail and layered from the map view, a dashboard was developed in 2021 to consolidate this information and to support the Reticulation Operations Team with daily insights about the performance of the water network.

The dashboards were designed to display the current water consumption in each zone and whether the results from the mass balance in each DMA show the system behaving as expected. A screenshot of the dashboard overview page is shown in Every day *at 6 am, the dashboard (see Figure 3, below) is automatically updated with the demand calculation of the day-before for each Zone and DMA. These demands are compared with pre-defined "lower" and "upper" thresholds to evaluate if the reported demands are within the expected range. Warning icons are displayed along the values (see yellow "!" in Figure 3) to suggest an action by the reticulation operations team.*

Figure 3.

Every day at 6 am, the dashboard (see Figure 3, below) is automatically updated with the demand calculation of the day-before for each Zone and DMA. These demands are compared with pre-defined "lower" and "upper" thresholds to evaluate if the reported demands are within the expected range. Warning icons are displayed along the values (see yellow "!" in Figure 3) to suggest an action by the reticulation operations team.

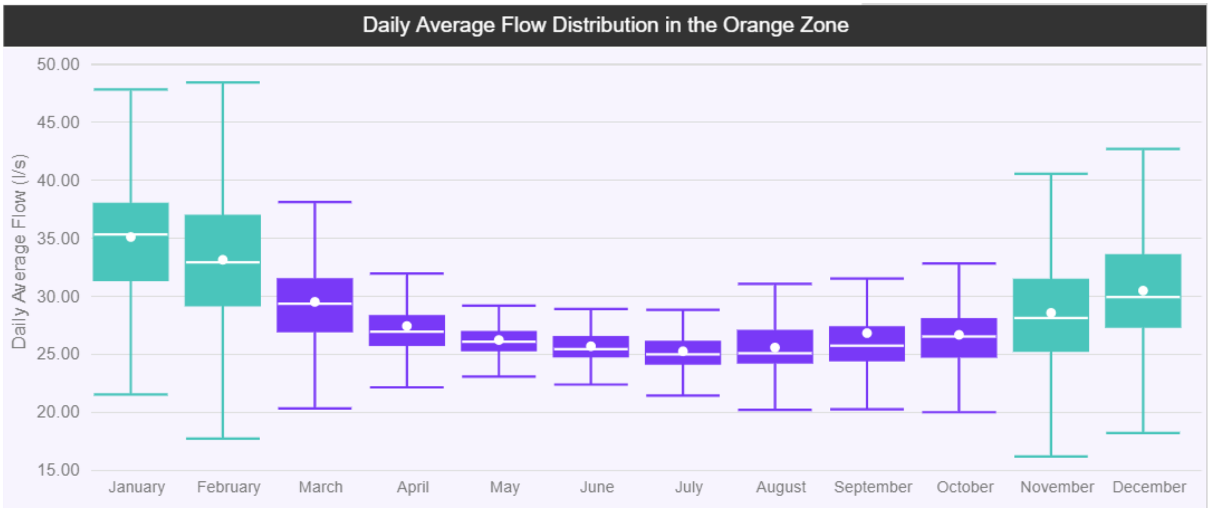
Figure 3*: Daily flow per Zone*

Daily Average Demand (l/s) - Zones

Real Time Data	Zone Name	Current Minimum Flow (l/s)	Current Average Flow (l/s)		Current Maximum Flow (l/s)	Expected Average Flow Range (l/s)	Last Updated	Consumption per Capita (l/h/day)
	Blue Zone	257.8	472.6	!	717.7	(357 - 451)	10/07/2021	334.2
	Orange Zone	9.2	28.1	!	60.6	(25 - 27)	10/07/2021	247.0
	Red Zone	16.0	39.9	!	86.3	(41 - 88)	10/07/2021	858.9
	Rototuna Zone	8.7	67.0	✓	170.1	(59 - 68)	10/07/2021	187.8
	Temple View DMA	2.4	5.1	✓	9.7	(5 - 6)	10/07/2021	335.9

Thresholds are updated every day based on a statistical analysis of the records from the last three months. As a general guideline, the lower thresholds correspond to the lowest percentile 25 (lower quartile) and the highest upper threshold of the percentile 75 (upper quartile) of daily average demands.

Figure 4*: Annual Flow Distribution*



When a yellow sign is triggered for any of the Zones/DMAs, further investigation of the differences can be made using the historical records presented in the report. Charts and tables are used to allow comparison in multiple periods of time, such as the example in

Figure 5 and Figure 6.

Figure 5 Daily Average Flow - Annual Comparison

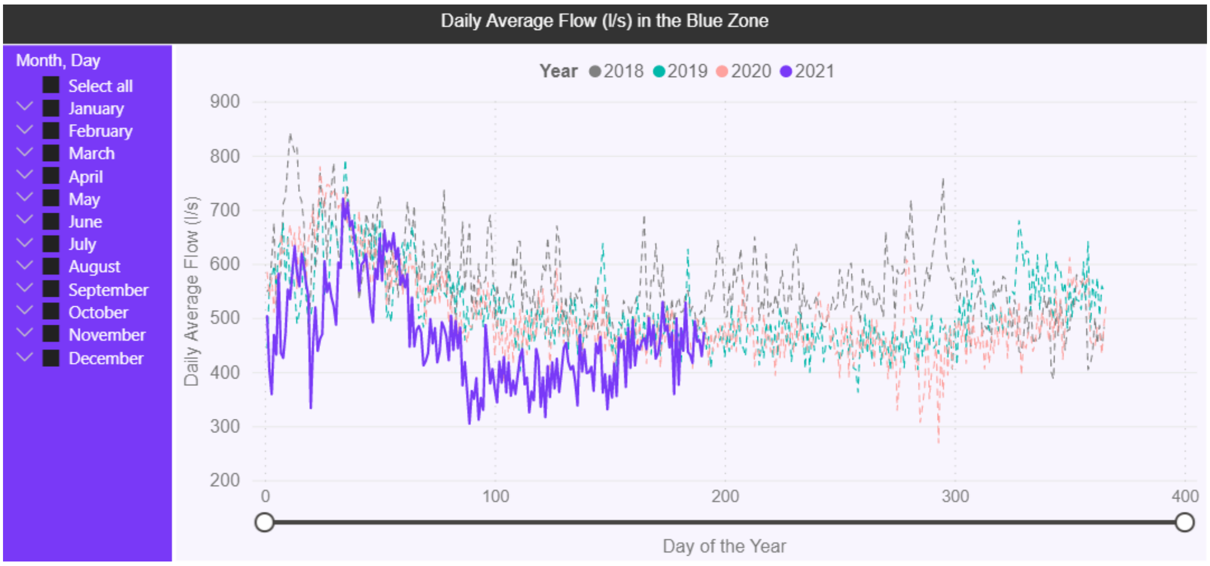
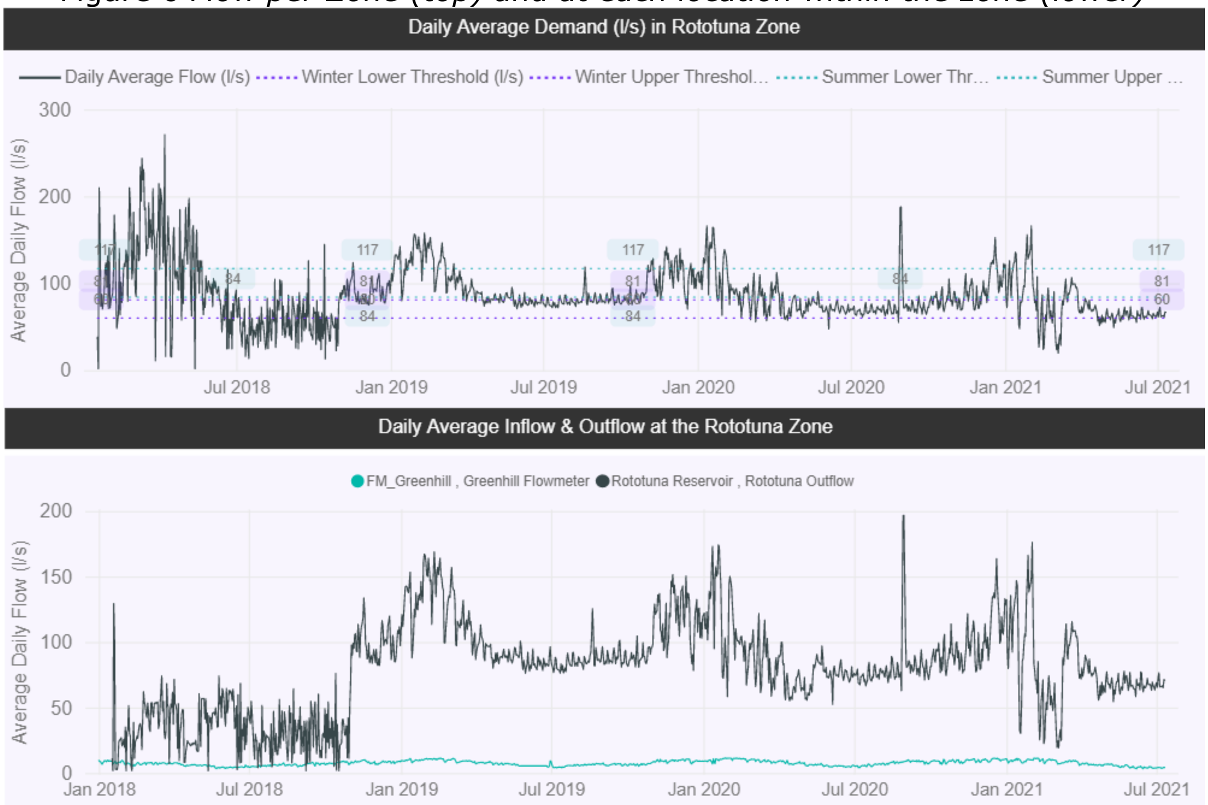


Figure 6 *Flow per Zone (top) and at each location within the zone (lower)*



The consumption for Hamilton City is also calculated and presented in the dashboard. This is calculated by adding the demand of each of the six zones. Records from 2018 to yesterday are delivered using a line chart and a table to highlight when one of the alert levels established by HCC has been reached. As shown in

Figure 7: Dashboard table of city level consumption with colours indicating alert levels on higher days, coding colours indicate when an alert level has been exceeded.

Figure 7: Dashboard table of city level consumption with colours indicating alert levels on higher days

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2018																															
January	54.2	54.6	59.8	65.6	51.7	55.8	57.8	69.9	71.2	76.1	81.5	79.3	77.0	78.5	71.2	70.0	69.6	57.1	66.0	67.3	74.3	64.6	66.3	80.1	74.1	79.4	69.4	73.7	82.4	81.4	76.9
February	66.3	65.9	64.5	73.2	81.3	81.3	76.4	71.7	63.6	52.7	60.7	71.0	72.9	74.6	67.1	75.3	69.7	78.3	80.7	78.6	70.0	67.0	64.5	80.3	74.4	73.3	62.8	70.2			
March	71.0	75.5	76.8	72.2	78.0	82.5	67.5	69.7	77.0	79.5	74.5	71.7	73.0	77.6	78.5	72.4	67.2	76.2	87.9	67.7	78.7	66.0	67.8	66.4	68.7	70.2	67.0	65.5	73.9	78.7	69.0
April	66.0	68.3	76.4	71.6	66.8	69.2	87.8	67.9	70.2	62.0	71.1	64.8	63.4	54.0	55.0	56.2	69.0	74.3	65.7	71.4	71.6	59.9	65.7	61.4	69.5	61.2	59.8	59.9	59.5	65.5	
May	71.1	73.6	75.1	69.1	68.2	71.2	77.6	70.1	58.6	63.9	67.8	54.1	53.6	62.3	68.3	63.1	65.7	60.1	61.3	56.3	59.7	55.0	55.1	62.8	53.3	57.6	56.8	60.1	62.9	58.2	58.0
June	54.9	54.4	49.1	56.0	61.0	60.8	60.2	57.9	59.8	59.8	60.6	60.4	66.3	70.7	59.1	52.9	60.9	63.6	70.0	58.9	63.6	61.0	54.3	54.6	53.9	55.3	56.2	57.1	60.3	57.9	
July	58.3	59.4	59.7	58.1	58.0	54.9	50.6	52.0	55.9	53.9	60.7	55.8	55.5	57.3	57.5	63.3	66.3	63.0	53.8	55.2	57.6	53.3	61.9	58.9	62.4	65.5	55.2	54.4	58.2	58.7	62.5
August	67.4	63.1	53.2	55.2	52.3	62.3	57.2	54.2	55.2	59.9	54.4	57.7	63.3	57.0	53.9	64.0	54.9	63.7	68.0	65.3	53.6	64.3	58.9	61.7	54.2	57.4	56.7	56.8	54.3	54.6	52.5
September	55.3	53.0	55.7	56.4	54.2	59.3	64.3	55.7	56.0	56.1	62.9	65.3	53.2	59.2	57.4	53.7	60.4	59.9	59.6	59.8	61.2	55.2	59.5	58.9	62.5	54.0	68.4	62.1	61.0	60.7	
October	56.1	63.2	62.4	59.5	64.6	66.8	67.8	72.2	66.6	57.7	57.4	53.6	55.4	67.7	59.5	60.7	64.2	62.1	68.4	69.1	68.6	78.4	67.1	63.3	61.1	60.5	61.3	54.1	57.3	57.9	65.9
November	63.2	58.2	51.3	57.1	60.5	62.4	64.1	54.7	56.2	57.6	57.0	53.1	64.8	62.9	64.5	64.1	68.0	66.2	60.1	59.3	53.9	60.1	59.7	50.3	50.6	54.3	58.3	54.5	61.6	52.9	
December	52.7	53.0	53.5	56.4	60.7	57.7	61.0	49.8	49.6	60.9	54.8	61.2	58.3	53.2	55.5	57.4	63.1	61.9	65.6	63.0	62.9	63.6	60.0	47.8	47.9	50.8	58.0	54.4	56.9	53.4	55.9
2019																															
January	53.3	64.7	65.4	68.7	65.9	73.5	75.1	78.3	68.1	75.5	67.0	72.3	64.1	56.0	58.5	63.0	71.9	64.6	63.1	62.5	65.7	73.6	76.0	80.6	80.2	65.1	66.1	71.0	81.8	80.1	79.4
February	74.7	73.4	84.0	90.0	82.9	75.3	67.1	78.5	74.2	73.6	80.0	71.0	79.4	78.1	77.7	72.2	79.5	71.9	80.0	71.4	73.9	58.4	59.1	58.0	66.3	67.4	71.4	72.8			
March	74.1	70.1	76.6	73.1	77.8	74.4	70.3	58.1	57.9	57.7	65.2	64.0	65.6	63.9	68.9	65.3	66.8	64.0	62.8	63.1	68.0	63.5	65.8	61.1	67.4	63.9	65.3	54.0	60.1	56.5	56.7
April	58.2	59.4	58.8	62.5	57.2	62.2	59.2	61.8	64.8	63.5	55.8	60.8	55.6	57.7	60.5	61.1	60.3	62.3	53.0	55.5	48.2	51.8	56.4	58.5	52.4	58.3	53.6	54.5	59.8	56.3	
May	59.7	54.5	57.8	53.3	57.3	53.5	60.8	55.0	59.6	53.8	58.2	51.7	60.6	58.2	60.4	51.8	57.9	52.7	55.7	56.7	58.8	60.0	59.6	57.2	65.2	64.5	69.3	62.3	54.9	57.7	50.7
June	53.3	48.8	57.0	55.8	57.9	53.9	56.9	52.1	58.7	53.8	60.9	54.9	53.3	57.0	51.0	55.2	50.4	57.5	52.8	57.1	49.9	53.6	53.6	58.4	52.9	53.3	55.9	52.7	54.3	49.3	
July	54.7	56.8	67.1	55.4	55.7	53.1	52.4	54.7	54.1	56.4	51.1	52.8	48.1	50.9	53.4	54.3	52.4	54.9	49.4	53.7	51.3	58.9	52.2	54.0	56.5	51.6	52.3	50.7	55.7	54.9	55.6

Daily minimum, maximum, and average pressure is summarised in the dashboard for each site and for each Zone (see Figure 8.). Additionally, daily pressure changes are calculated and highlighted with a coloured flag when they are above 5m and 10m head. Figure 9 shows several sites where large pressure fluctuations were recorded. These differences represent operational issues or exercises (such as hydrant flushing), or stolen water or leakage that the network analyst can inspect and identify. A link to the 5 minutes-profile can be accessed directly from the dashboard Figure 9for data verification, as shown in *Figure 10*.

Figure 8: All *Pressure Sites in Rototuna Zone*

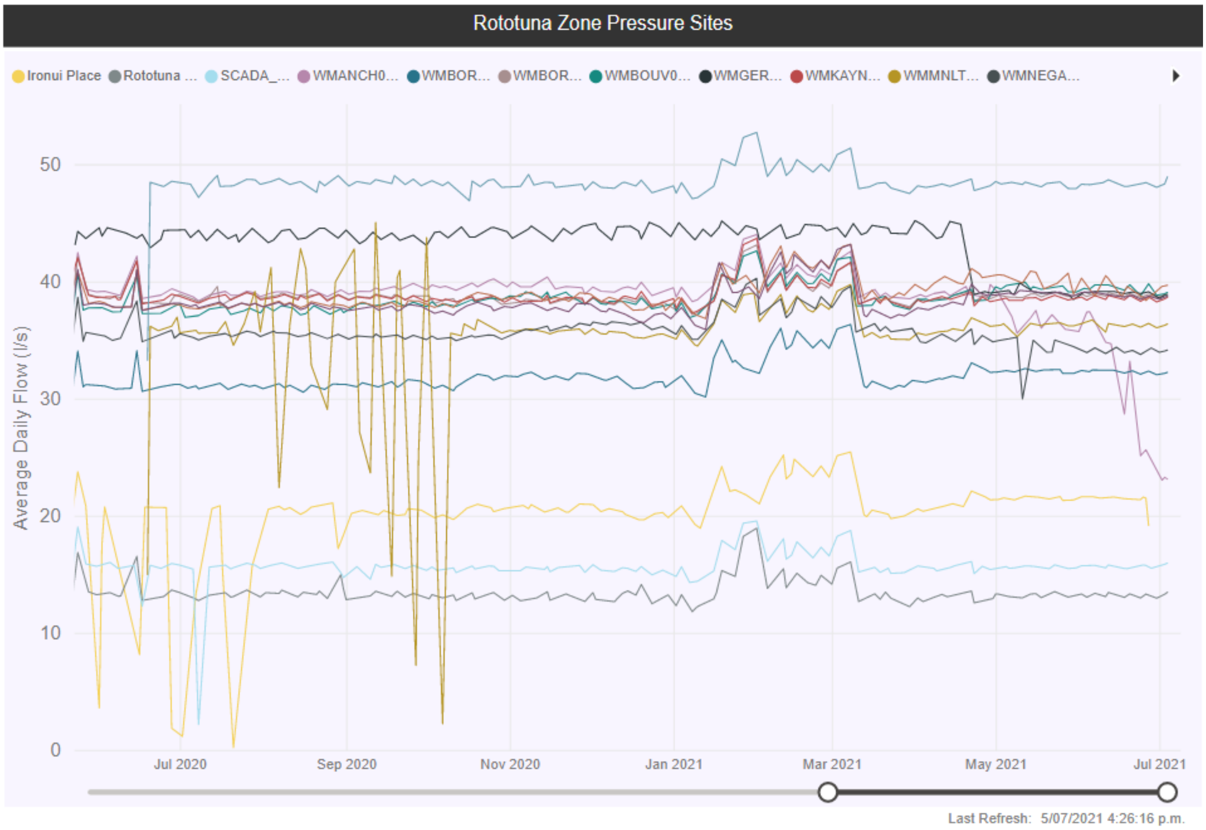


Figure 9: *Pressure Sites Summary Dashboard*

URL	Zone Name	Site Name	Trace Name	Source	Daily Minimum Pressure (m)	Daily Average Pressure (m)	Pressure Drop (m)	Expected Average Pressure Range (m)	Last Updated
	Blue Zone	Seddon Rd	Seddon_Road_Pressure_Sensor	SCADA	-24.9	8.5	33.4	(4.2 - 35.3)	10/07/2021
	Rototuna Zone	Somerton Booster Inlet	WaioraReservoirSomerset_PumpInletPressure	SCADA	175.0	205.8	30.8	(196.7 - 207.1)	10/07/2021
	Blue Zone	WMPUKT0111	Pressure	Mott MacDonald	35.6	42.2	6.6	(40.4 - 42.9)	10/07/2021
	Blue Zone	Ann St	Ann_Street_Pressure_Sensor	SCADA	52.7	58.9	6.2	(56.5 - 59.5)	10/07/2021
	Blue Zone	WMTEWEMNGA-F	Pressure	Mott MacDonald	37.3	43.3	6.0	(41.8 - 44.1)	10/07/2021
	Blue Zone	Alison St	Alison_Street_Pressure	SCADA	20.4	26.2	5.8	(26.4 - 27.8)	10/07/2021
	Blue Zone	WMDALG0042	Pressure	Mott MacDonald	32.9	38.6	5.7	(36.5 - 38.6)	10/07/2021
	Blue Zone	WMRUFF0084-F	Pressure	Mott MacDonald	39.6	45.2	5.6	(44 - 46.6)	10/07/2021
	Blue Zone	WMBREK0001-OPP	Pressure	Mott MacDonald	33.9	39.0	5.1	(38.3 - 39.8)	10/07/2021
	Blue Zone	WMELLI0002B	Pressure	Mott MacDonald	35.6	40.3	4.7	(40.1 - 41.6)	10/07/2021
	Blue Zone	WMDEY0418-OPP	Pressure	Mott MacDonald	30.9	35.5	4.6	(34.9 - 36.6)	10/07/2021
	Blue Zone	WMGRAM0002	Pressure	Mott MacDonald	36.6	41.2	4.6	(41.6 - 44.4)	10/07/2021
	Blue Zone	WMTUHI0004-OPP	Pressure	Mott MacDonald	33.1	37.6	4.5	(36.3 - 38.9)	10/07/2021
	Blue Zone	WMQUEN0002-2	Pressure	Mott MacDonald	33.3	37.6	4.3	(37.9 - 39.4)	10/07/2021
	Blue Zone	WMCOMM0108	Pressure	Mott MacDonald	33.9	38.2	4.3	(38.1 - 39.7)	10/07/2021
	Blue Zone	WMDUKE0067-3	Pressure	Mott MacDonald	27.7	31.8	4.1	(32.2 - 33.6)	10/07/2021
	Blue Zone	Edgecumbe St	WaioraReservoir_Edgecumbe_Water_Pressure	SCADA	51.6	55.2	3.6	(54.9 - 56.6)	10/07/2021

Last Refresh: 7/11/2021 6:01:30 AM

Figure 10: Example of pressure dropping below the (dotted line) threshold, which would trigger an alarm

Real time alarms are set for flow and pressure sites when the instantaneous value is above or below the thresholds presented in their relevative dashboard pages. These alarms are reported in a MS Team Channel for the Reticulation Operations Team to manage.

REAL-TIME ALARMING

With information being reported every five minutes, there is great potential value that can be extracted from it. Moata Map view provides an overview of how the system is currently organised and how it is planned to be with regards to water supply zones. Data can be found easily as everything is centralised.

The dashboards have added consolidated data of the information in daily metrics that help the operation's analyst to quickly have an idea of where there are issues at DMA level and respond to questions around unusual consumption behaviour and spot where large instantaneous flows have been taken (potentially illegally).

Although these tools provide a system overview for the previous day, Hamilton City Council desired a real-time alarming module to proactively respond to issues as they happen. The data is being collected every 5 minutes and, alarms have been set up to automatically send an email and MS Teams notification when instantaneous flow and pressure is out of an expected range.

Currently, this initiative is being tested. The Operations Reticulation Team is building knowledge of the network and what is normal and expected and what is not. The alarms prompt the team where to look, saving review of every monitoring site independently.

THE VALUE OF THE DATA

Development of the Moata Dashboards has allowed for more of the Reticulation Operations Team to increase their involvement in monitoring the water network. This is a shift from the Plant Operations Team monitoring the water network with a reservoir operation focus. Developing skills of the Reticulation Operations Engineers helps to move the team towards the Hamilton City Council goal of being data lead.

The Reticulation Operations Team are responsible for customer complaints around the water network, such as low water pressure, colour, and odour, plus has oversight of water shutdowns for renewals and repairs. Having the tools that process the data is helping the team to build knowledge of what is normal in the water network so that changes in the flow and pressure trends can be spotted and investigated. While the alarms system is still under development, this will eventually help the team respond to issues before customers call them.

The following section describe examples of how data has supported the operation of the Hamilton Water Network.

CREATION OF WATER SUPPLY ZONES

Hamilton City is in the process of creating water supply zones around each of the city's reservoirs. In May 2021, the Operations Teams decided to create Ruakura Zone around the new Ruakura Reservoir in the east of the city. This reservoir increases the city's resilience by providing more water storage on the eastern side of the city. The zone would allow better control of pressure in this area as well as measuring flow to 9,127 customer connections. The zone is planned to be split further into six DMAs.

Creating the zone involved closing twelve valves ranging in size from 50mm to 620mm. Traffic management requirements meant that the large valves would be closed around 04:00, with the remainder being closed in succession after the morning peak had passed. The Reticulation Operations Team were monitoring the impact of the changes, looking for pressure and flow changes and anything that might cause customer complaints. Potential complaints can come from flows changing direction as this can cause sediments and fine biofilm layers in pipes to be suspended into the flow, causing discolouration of the water. The Reticulation Operations Team were also monitoring customer complaints in the area recorded by the call centre. The data from monitoring in the office was fed out to the team in the field, who in turn fed them information on when major valves were closed.

It was expected that the pressure would drop when the three largest valves ranging from 300mm to 620mm were closed, as these were major flow paths from the bulk water main. Instead, observation of pressure gauges within the new zone showed that pressure rose by 1 m head across the zone. As the remainder of the zone valves were closed, the pressure remained steady and the reservoir pump output did not increase, indicating that the zone was not closed. It was not immediately obvious to the team why the zone was not closed.

The following day, the Plant Operations Team noticed issues filling reservoirs and it was discovered that the bulk ring main had been erroneously closed rather than the major feed off of it. The close proximity of the valves (and perhaps the very early time they were closed) had led to this error. Emergency traffic management and confined space entry rectified the error, and the changes were immediately evident in the data. Network pressures dropped around 10 m head with the zone closed, from 40 to 30 m head, and the reservoir pumps started feeding the zone (refer to Figure 10Figure 11Figure 11 below).

Figure 11: Representative pressure change within *Ruakura Zone before and after the zone creation on 21 May 2021*

MINIMISING WATER LOSSES

In the future as zones and DMAs are created, flow balancing will inform about water demand and help target water saving messaging to areas that are using more water than others in the city. This will enhance the current messaging that occurs during summer months.

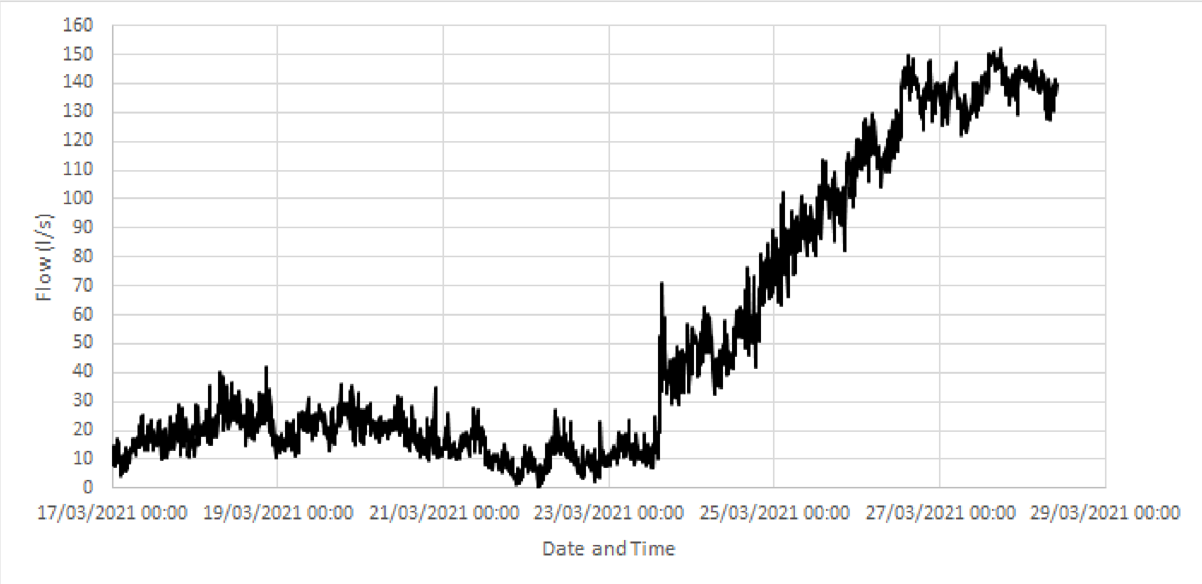
Water losses will also be monitored through tracking night flows, with increased night flow indicating leakage. This can trigger network investigations to detect leaks in a proactive way and repair them promptly.

RECORDING WATER LEAKS

Prior to enabling alarm thresholds, casual meter checks picked up on the flow trend shown below in *Figure 12*. This meter records flow from the bulk water main into a 250mm asbestos cement pipe laid in the 1960s that feeds along Tuhikaramea Road in the southwest of the city. The huge flow increase indicated a major leak along this pipeline.

This flow trend was spotted on the 7th of April 2021, after the flow meter had stopped sending data back on the 29th of March. It appeared that there had been a major burst on 23rd March when the flow jumped from 20 l/s to around 45 l/s and then continued to climb up to around 140 l/s. The flow had sat at around 140 l/s for around two days until the telemetry failed.

Figure 12: Flow increase recorded at feed into Tuhikaramea Road suggesting a major water leak



Inspection of customer leak reports found that a large leak had been reported that morning at 11:30, saying water was coming from the pavement in two places and pouring over the road. A work order had been created, and a repair team was on site. The work site was 500 metres downstream from the flow meter site. When the worksite was visited, and it was discovered that an old 20mm tapping band had failed (see *Figure 13: The source of the water leak on Tuhikaramea Road, a 20mm hole where a tapping band had failed*


). Inspection of the broken band suggested that it may have suddenly failed on one side, then the water pressure forced the band further off, creating a larger hole over time. The repair crew reported that there was a lot of water, but nowhere near 100 l/s that had shown on the data.

It was concluded that the flow jump on 23rd March did reflect the initial failure of the tapping band but that the following increase in flow was not representative and reflected an issue with the flow meter. It was noted that the pressure did not change over this period at all, highlighting the importance of alarms on the rate of change of flow to track leaks.

This example also shows a real challenge of network monitoring and the importance of maintaining continuity in the data, as the telemetry failure meant it was not possible to review the immediate impact of the repair.

Figure 13: The source of the water leak on Tuhikaramea Road, a 20mm hole where a tapping band had failed

LOCATING FLOW RESTRICTIONS

Typically, temporary pressure loggers that can be connected to hydrants are used to locate network issues, such as flow restrictions. Following an incident of poor flow feeding to a zone boundary pressure sustaining valve (PSV) on Hukanui Road in May 2021, an investigation was undertaken to locate the source of the flow restriction. As part of the investigation, a permanent pressure logger was installed into a nearby site on Wairere Drive (375m away). This is the location of a DMA flow meter and hence could make use of the existing telemetry to feed the data back to Moata in near-real-time (approximately 8-15 minute delay).

The use of near-real-time logging allows for quick feedback on trials and changes in the network to determine their success. In this case, *Figure 14: GIS map of water network showing two meters (circled) with* an *elevation difference of 2 metres, yet 5 metres difference in head*

showed a five-metre head pressure difference, although the elevation difference was only 2 metres. This suggests a flow restriction causing around 3 metres of head loss. At the time of writing, investigations continue.

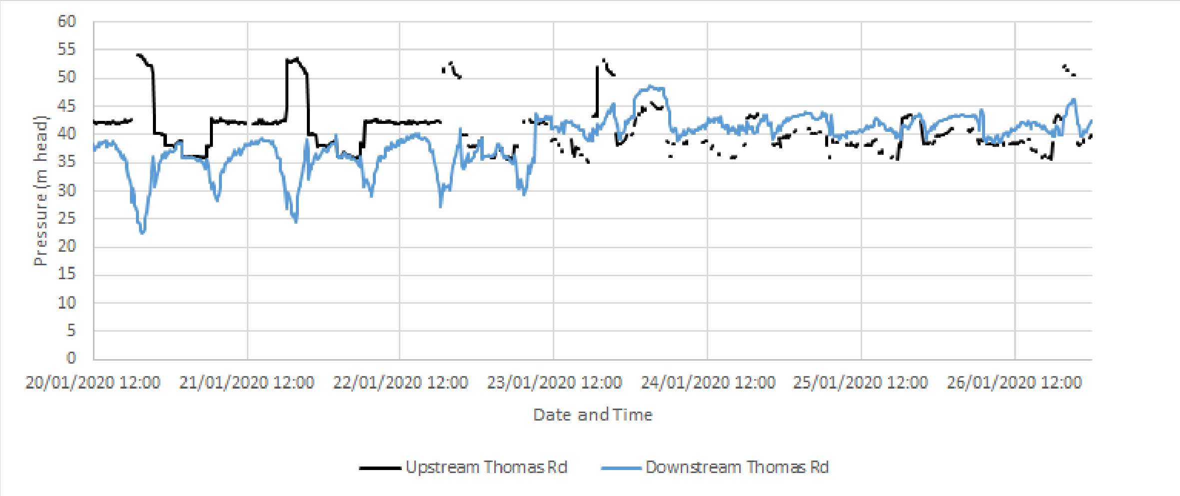
Figure 14: GIS map of water network showing two meters (circled) with an elevation difference of 2 metres, yet 5 metres difference in head

Another example of the permanent pressure loggers enabling location of a network issue occurred on Thomas Road in early 2019. At Thomas Road, two permanent pressure loggers showed a different pressure pattern despite being on the same 300mm diameter pipeline 1.7km apart (refer to

Figure 15). Further investigation using temporary pressure loggers between these locations was able to pinpoint the location of a closed valve. After the valve was opened on 21st February 2019, the pressure patterns matched, and the minimum pressure improved by more than 10 m head. This pressure improvement was critical during the high demand of the dry summer period.

This investigation at Thomas Road is a good example of how permanent data loggers can be used in combination with temporary loggers to track down and resolve network issues. The information from the permanent sites helped to advise where to start looking and gave prompt feedback on the resolution.

Figure 15: The upstream and downstream pressure pattern matched after the valve was found and opened



CONCLUSIONS

Hamilton is one of the fastest growing cities in New Zealand and a high proportion of water consumed in the city is not metered, making water mass balance calculations challenging. These challenges help to drive Hamilton City Council towards further improvements in network resilience, efficiency, and minimisation of water losses. Network monitoring provides data to inform improvement decisions based on where water is going.

The majority of Hamilton's water network flow meters were installed as part of DMA enabling works from 2013 to present. Large sets of data are recorded daily to support operation of the Hamilton water network. Hamilton City Council ensure that the large volume of information collected every day are safe safely stored in local servers and in the cloud. Data collection and data storage is not as challenging as it used to be in the past for any organisation. The challenges then become how to best use the information and engineering knowledge to optimise the system as fast as it requires.

The information collected is displayed in detail and layered from the map view, and a dashboard is used to consolidate this information. The dashboards have added consolidated data of the information in daily metrics that help the operation's analyst to quickly have an idea of where there are issues at DMA level and respond to questions around unusual consumption behaviour and spot where large instantaneous flows have been taken (potentially illegally). Although these tools provide a system overview for the previous day, Hamilton City Council desired a real-time alarming module to proactively respond to issues as they happen.

Data is now commonly recognised as the most valuable asset in infrastructure. Without efficient data governance, organisations would not have the information to effectively understand, control and optimise their systems. Hamilton City Council's experience has shown that efficient data management is essential to understand, control, and optimise its water network. Being able to visualise the data has helped to understand the status of the network, make informed decisions and resolve issues in the DMAs. Sharing experiences via this paper and working collaboratively across councils and consultants will enable the New Zealand water industry to respond and facilitate the changes driven by population growth and climate change.

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