MASTER PLAN IMPLEMENTATION: CHALLENGES AND LESSONS LEARNT

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ABSTRACT (500 WORDS MAXIMUM)

The rapid growth of Hamilton has brought with it significant challenges, including maintaining suitable clean water services in the future. Seven years ago, Hamilton City Council (HCC) and Mott MacDonald embarked on a joint journey to develop a comprehensive water strategy addressing current system performance issues and future shortfalls. This resulted in the development of a 30-year Master Plan recommending network upgrades to address current and forecast system performance issues identified using a detailed water supply hydraulic model.

As options started to be implemented, multiple challenges arose:

- From a planning and modelling perspective, the model's limitations were highlighted during the early phase of options implementation. The model includes a single set of controls and was based on peak day conditions whereas operations and demands vary daily. Despite being calibrated the model still depicts a "flawless" image of the network. However, due to incorrect valve status in the network, multiple operational issues occurred during the upgrades implementation. This experience affected the trust that the project team had in the model and in the proposed solution. Another challenge identified during the implementation of upgrades was the modellers limited involvement past the planning phase, which resulted in design issues and postponing the original program of work.

- From an operational perspective, multiple challenges had to be overcome as the zones were being implemented. An erroneously closed valve resulted in part of the network to run out of water during the implementation of a new water supply zone, while zone boundary valves were found to be passing. A valve check including specialised acoustic equipment had to be carried out to identify the passing valves. A pump station was installed, this was initially intended to (and designed for) solely pumping into a reservoir but it was found that this pump is also used to service customers demand, far from its designed duty point and flow range. In a different zone, booster pumps were not adequately designed, resulting in postponing the zone closure. No bypass was included in the design of a new reservoir, which reinforced the resistance to implementing the zone closure.

These challenges are being addressed to ensure a smoother implementation in the future:

- From a planning perspective, the GIS and population data are being updated and the model recalibrated. An automated model validation tool is being developed to model any demand and control scenario based on real time data. The modellers are now working with the design team to ensure assumptions and recommendations are well understood.

- From an operational perspective, lessons learnt are collected from early implementation work. Boundary valves are planned to be verified for passing water as

they are being closed. A valve check was carried out inside the boundary of a new zone to prevent areas running out of water due to erroneously closed valve. 20% of the valves on major pipes were found to be closed in this zone, confirming the need for a comprehensive valve check prior any zone closure.

KEYWORDS

Water supply, asset management, hydraulic modelling, long term plan

NOMENCLATURE

HCC: Hamilton City Council

WTP: Water Treatment Plant

LOS: Levels of Service

DMA: District Metered Area

PRESENTER PROFILE

Julie is a Chartered Professional Engineer with seven years' experience as a water resources engineer and modeller. During this time Julie has developed a robust set of modelling skills by undertaking several model build and calibration projects and has managed multiple field test campaigns. Julie has also acquired global experience working on UK and Australian based projects.

Evan Vaughters received a Bachelor of Science on Sustainable Resource Science from the University of Washington (USA). He has worked for the last 12+ years in the New Zealand water industry in both the private and public sector throughout the Upper North Island.

Nasrine is a Chartered Professional Engineer with ten years' experience in water resources engineering. She is currently leading Mott MacDonald's digital delivery team. During her career Nasrine has successfully delivered over 20 water supply models across New Zealand and Australia. She has been involved in all the different phases of modelling project and, over the last couple of years, has developed long term water strategies across New Zealand.

1 INTRODUCTION

With a population of 165,500 inhabitants, Hamilton is the fourth largest city in New Zealand. Located one-hour drive south of Auckland in New Zealand, it is split in two by the Waikato River, which provides water to the town via a single water treatment plant in the south end of the city. The treatment plant, which was built in 1971 off Waiora Terrace, has a maximum capacity of 106 ML/day. The current water system has over 1,200 km of reticulation pipe work, with pipe sizes varying from 40mm to 750mm in diameter. The bulk ring main servicing Hamilton City is approximately 54km long.

With 2.6% growth per annum over the last 6 years, Hamilton is amongst the fastest growing cities in New Zealand. The rapid growth of Hamilton has brought with it significant challenges, including maintaining suitable clean water services in the future. Seven years ago, Hamilton City Council (HCC) and Mott MacDonald embarked on a joint journey to develop a comprehensive water strategy addressing current system performance issues and future shortfalls. This resulted in the development of a 30-year Master Plan recommending network upgrades to address current and forecast system performance issues identified using a detailed water supply hydraulic model.

The Master Plan implementation started with the Orange Zone extension in 2016, followed by the Rototuna Zone closure originally planned for mid-2017. Another 7 zones are planned to be implemented in the next three years resulting in significant operational and infrastructure changes. With the implementation of new water supply zones, multiple challenges arose and solutions had to be found to progress with the Master Plan implementation. The challenges and lessons learnt are summarised in this paper.

2 WHY A MASTER PLAN

2.1 ORIGINAL SYSTEM OPERATION

The Hamilton network was originally subdivided into three pressures zones, two small zones (Red and Orange) and one large zone (Blue zone), as shown on Figure 1:

- The Blue zone, which includes over 90% of the demand, consists of 5 reservoirs and associated pump stations. Several (27) supply points service local reticulation and fill the 5 reservoirs from a ring main that originates from the WTP. The ring main is supplied from both the eastern and western direction with two separate pump sets at the WTP. Operations change daily to maintain satisfactory turnover in the reservoirs and meet demand requirements.

- The Red and Orange zones are isolated from the bulk ring main and the reticulation for each zone is serviced by a single reservoir and pump station.

This approach means that the water treatment plant must be operated to match the immediate demands of water customers due to limited clear water tank storage at the treatment plant site. This creates a complex system which makes it hard to identify and resolve potential problems as well as providing a consistent level of service across the city. This manual operation also makes monitoring, modelling and understanding system performance in unseen scenarios difficult.

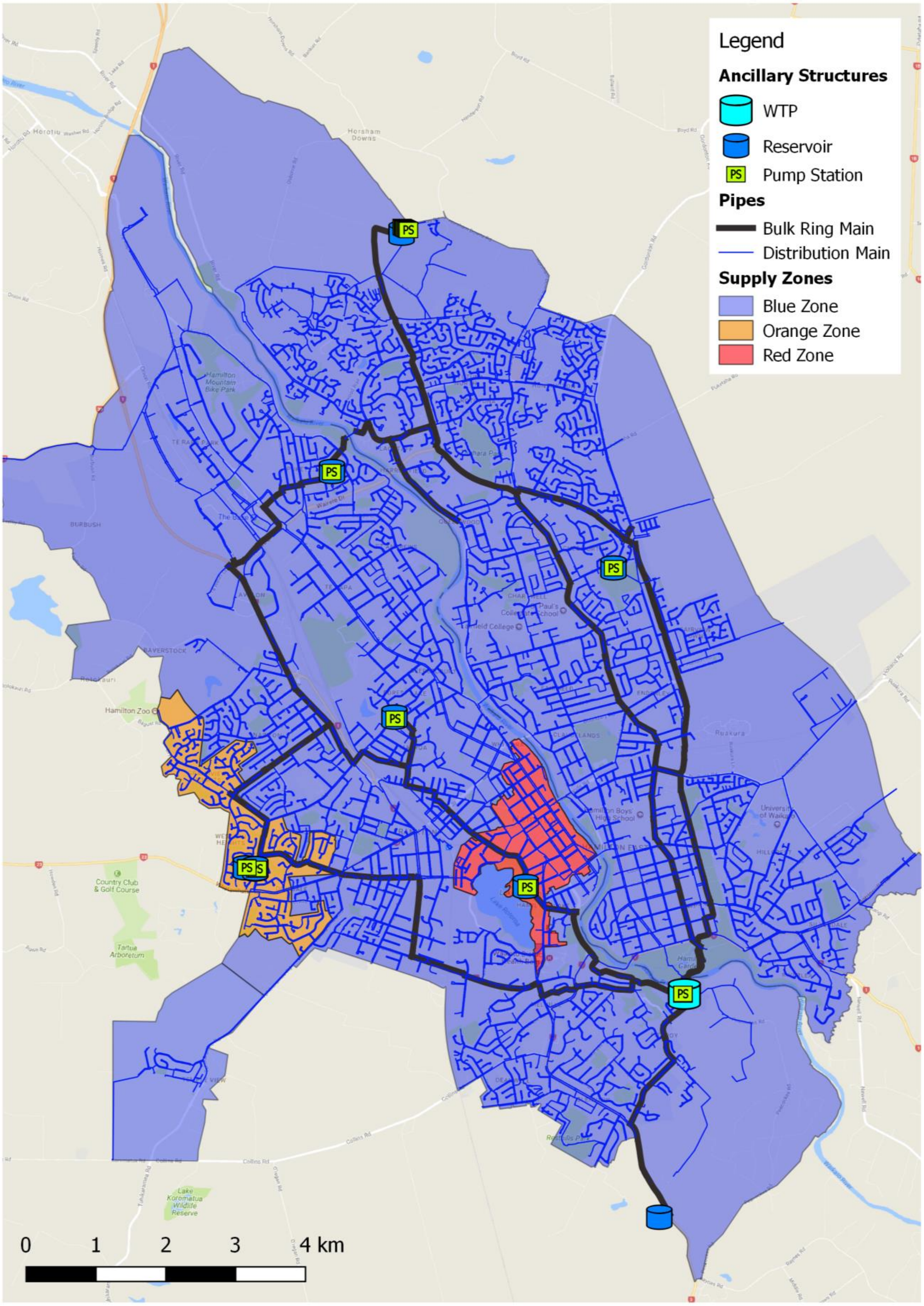

Figure 1: Current System Operations

2.2 PREDICTED GROWTH

The population in Hamilton is predicted to increase by 40% in the next 44 years, which is just under 1% growth per year in average. Population increase is predicted to be the greatest between 2017 and 2031, with an average annual growth of approximately 1.4% per year.

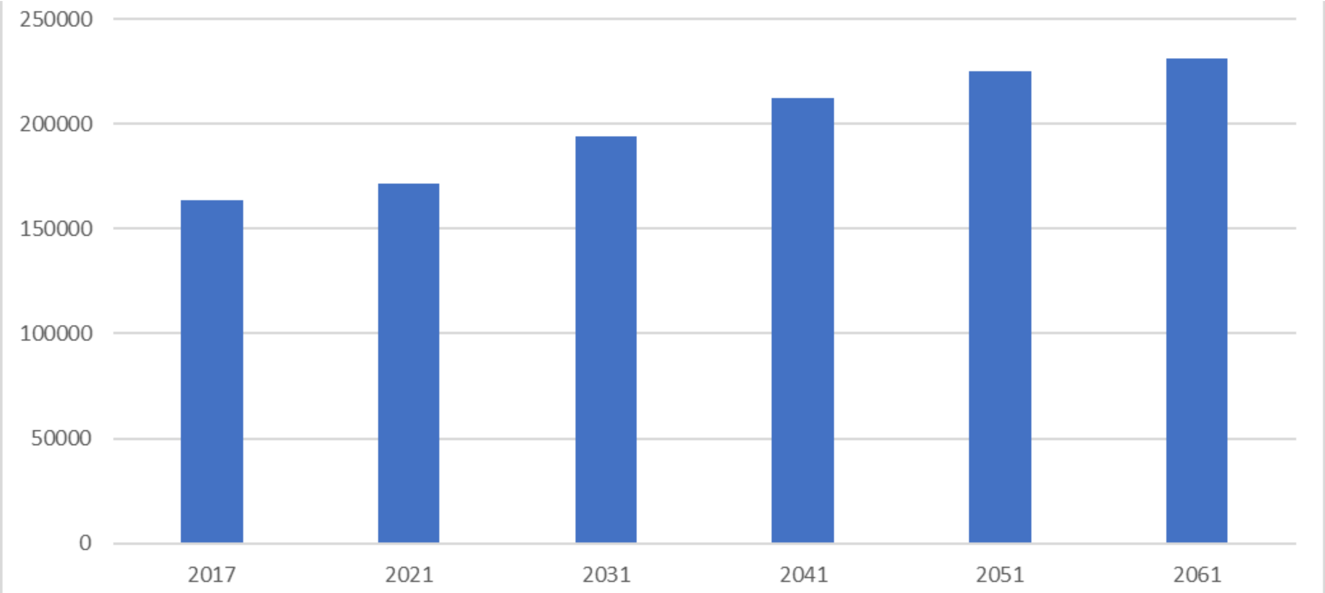

Figure 2: Predicted Population Increase

Without upgrading the current network and operational framework, the system performance in the city was predicted to deteriorate significantly due to the expected growth, not meeting the required minimum levels of service set by Hamilton. To unlock growth, it was identified that significant upgrades needed to be completed by 2021.

2.3 MASTER PLAN GOALS AND APPROACH

The Master Plan goals were to simplify operations, increase network resilience, optimise energy use, ensure water quality and minimise water losses across the network for current and future demand conditions. The Master Plan provided a framework to:

- maintain system performance in the future,
- optimise the use of existing infrastructure,
- Decouple the water treatment plant from day to day network operations to improve network resilience and simplify operations,
- Integrate with a DMA implementation strategy to help reducing water loss.

Separating (decoupling) the water treatment plant from day to day network operations by isolating the reservoirs and pump stations was found to be the best way to achieve the Master Plan's mission statement.

Decoupling is done by splitting the blue zone reservoirs and associated pump stations into discrete supply zones with a dedicated bulk main filling the reservoirs in each zone. Isolating each reservoir will provide ultimate control of each zone and help identify where water loss is happening.

Figure 3 below shows the proposed zones associated to reservoirs (two new reservoirs are planned to be constructed to palliate the lack of storage on the eastern side of the river).

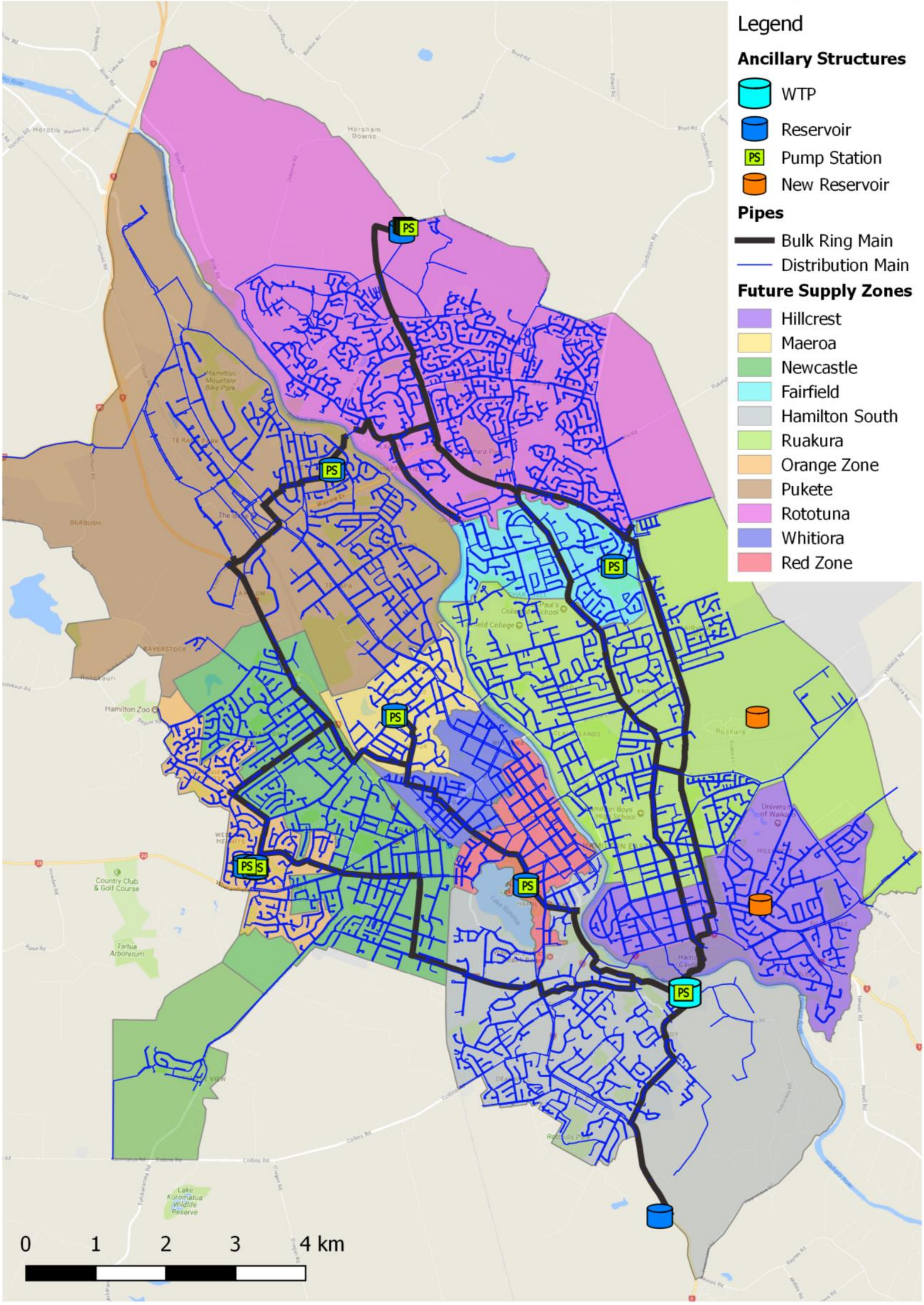

Figure 3: Master Plan Approach

3 CHALLENGES: WHAT CAN GO WRONG DURING THE IMPLEMENTATION OF THE PLAN?

3.1 IMPLEMENTING THE PLAN

Two iterations of the Hamilton Water Master Plan were produced over a 6-year period.

The first iteration consisted in a high-level options study comparing solutions to resolve current and forecasted system performance issues. As part of this exercise the project team established a network strategy and an operational philosophy setting out the basis of the Hamilton water Master Plan. The proposed strategy was discussed and refined with Hamilton's various stakeholder to ensure buy in from the wider water team.

The second iteration of the Master Plan went into more details in a view to provide a base document for budgeting and implementation purpose. The second version of the Master Plan refined the high-level findings of the first Mater Plan and established a staged timeline for the implementation and prioritisation of upgrades.

The zone implementation started one year after approval of the Master Plan 2, with the aim to get all zones completed by 2021. With such an aggressive timeline, it is critical to draw lessons learnt from previous years for successful implementation of the plan.

The following sections reflects on the lessons learnt during the first year of the Master Plan implementation.

3.2 PLANNING LIMITATIONS

The Hamilton water supply Master Plan was based on a detailed hydraulic model built and calibrated between 2011 and 2013. This model included a single set of controls and was developed for peak day conditions using the first GIS version of the Hamilton water network (digitised from paper plans in 2011). Future model scenarios were created using population predictions derived in 2013.

The following limitations were identified during the implementation of the Master Plan:

- The GIS dataset used to develop the detailed model of Hamilton's water supply network was the first digitised version of the water network. During the model calibration process, a number of connectivity issues were identified and resolved. Since this first iteration, the GIS has been updated to include missing assets and to correct connectivity based on operators' feedback. However, the network connectivity represented in the original hydraulic model may not represent actual network configuration. This is a significant limitation for the implementation of the Hamilton Master Plan that requires valves to be closed to isolate new supply zones. The closure of the Rototuna zone in May 2018 provides an illustration of this limitation. The zone newly implemented was found to be leaking despite all the identified zone valves being closed. Potential interconnections not represented in the GIS are suspected and currently being investigated.

- The sizing of the proposed infrastructure detailed in the Master Plan was based on future model scenario results. These scenarios were developed based on Hamilton's 2013 population forecast, using current demand distribution as a base assumption to quantify future flows throughout the network. Different population predictions have been developed since 2013 which may impact the size of the planned infrastructure. Additionally, very few connections are metered in Hamilton therefore the current demand was distributed based on the number of properties serviced in each supply zone which may not be representative of actual water use. While the upgrades proposed in the Master Plan were developed to provide operational flexibility, this may not be the case for the infrastructure actually designed. For example, lower flows than expected could represent an issue for some pump stations. This would need to be addressed following the implementation of each zone, once more details are available regarding actual demands in each zone.

- The Hamilton Water Master Plan focused on peak demand conditions in a view to size and estimate costs for the proposed infrastructure adequately. However, this was found to be a limitation during the design and implementation phases of the plan. From a water quality perspective, maintaining good reservoir turnover is critical. Reservoir turnover is worse during low demand periods and represent a daily challenge for Hamilton's operators. To get the buy-in from the operation team, further modelling had to be undertaken for average and low demand conditions to advise on reservoirs operations and prove that turnover would be satisfactory throughout the year. Modelling peak conditions was also found to be insufficient during design phases. While pipes and reservoirs are sized for peak demand, pumps for example need to be capable of providing the whole demand range, including the lowest flows. In multiple occasions further modelling was requested to provide the design team with suitable information to undertake the pumps design.

- Despite going through a detailed calibration process, models generally depict a flawless image of the network where every piece of infrastructure is working as intended. However, as detailed in the next section, the implementation of the plan has shown that the reality may differ from this. It is not unusual to find unexpected closed or partially closed valves within the zone, passing zone valves have also been an issue and pump stations are not necessarily working in their designed operational range or following theoretical pump curves.

3.3 DESIGN CHALLENGES

An important part of the implementation process is the design and construction of the proposed infrastructure. This phase involves subdividing the Master Plan proposed solutions into discrete work packages supervised by different project managers in Hamilton City Council and delivered by various consultants and contractors.

One of the main challenges that has been highlighted as part of this process was the ability to understand the impact of design decisions on the overall Master Plan strategy. It was found that some minor changes in design at a project scale could have significant implications on the operational philosophy established as part of the Master Plan. An example of this is the design of the pipework arrangement around the new Rototuna reservoir. One of the emergency procedure developed as part of the Master Plan was to provide the ability to bypass all reservoirs and to connect reservoir filling mains directly to downstream pump stations to maintain levels of service if/when reservoirs need to be kept offline. No bypass was included around the Rototuna reservoir which means that the zone will need to be operated as a much lower level of service in case of planned or unplanned reservoir maintenance.

In multiple instances the infrastructure implemented varies slightly from the option recommended in the Master Plan. Most of the time these differences are justified by project feasibility, building practicability and impact on project costs. The examples below illustrate some of the changes that were made during the design phase of work:

- In the Master Plan, the Hamilton South dedicated filling line was initially proposed to be a 520mm (internal diameter) pipeline. However, due to constructability issues (namely crossing gullies), the selected pipe was reduced to a 476mm (internal diameter), one size down the initially selected pipe size. This design decision had to be made to maintain project costs to an appropriate level despite its impact on operational flexibility, and the uncertainty around future demands.

- The Rototuna reservoir filling line was also downsized when compared to the Master Plan proposed solution. The decision was made to reduce the pipe size filling the Rototuna reservoir but to provide provision to install a booster pump station in the future to overcome increased head losses through this line.

Another challenge faced during the design phase of work was found to be the budget allocated for each project. As part of the Master plan, a program and associated cost estimates were provided for the proposed upgrades. While the Master Plan costs included high contingencies, some projects were found to present constructability challenges resulting in significant increase in cost. This was the case for the Pukete reservoir filling line, the cost for the 60m pipe installed between the bulk main and the reservoir was multiplied by 10 when compared to the original budget due to unseen difficulties in the reservoir layout and existing services in the vicinity. The budget allocated by Hamilton City Council dictates the implementation timeline and the completion of the Master Plan upgrades. It is a critical aspect of the Master Plan implementation.

3.4 OPERATIONAL CHALLENGES

This section focuses on the challenges faced by the operation team in charge of implementing and commissioning the proposed Master Plan upgrades.

3.4.1 MAINTAINING LEVELS OF SERVICE

One of the challenges faced by the operation team during the implementation of the Hamilton water strategy was to maintain satisfactory levels of service throughout the water network. While every effort was made to stage the installation and commissioning of each project to minimise the impact on customers, a number of unforeseen complications occurred resulting in performance issues. A few examples are discussed below:

- Prior to the implementation of water supply zones, the Hamilton water supply distribution system was very open which implied a great redundancy in the network. This was highlighted during the extension of the Orange water supply zone where an unexpected closed valve resulted in part of the network to run out of water. Figure 4 below shows the location of the closed valve and the area affected.

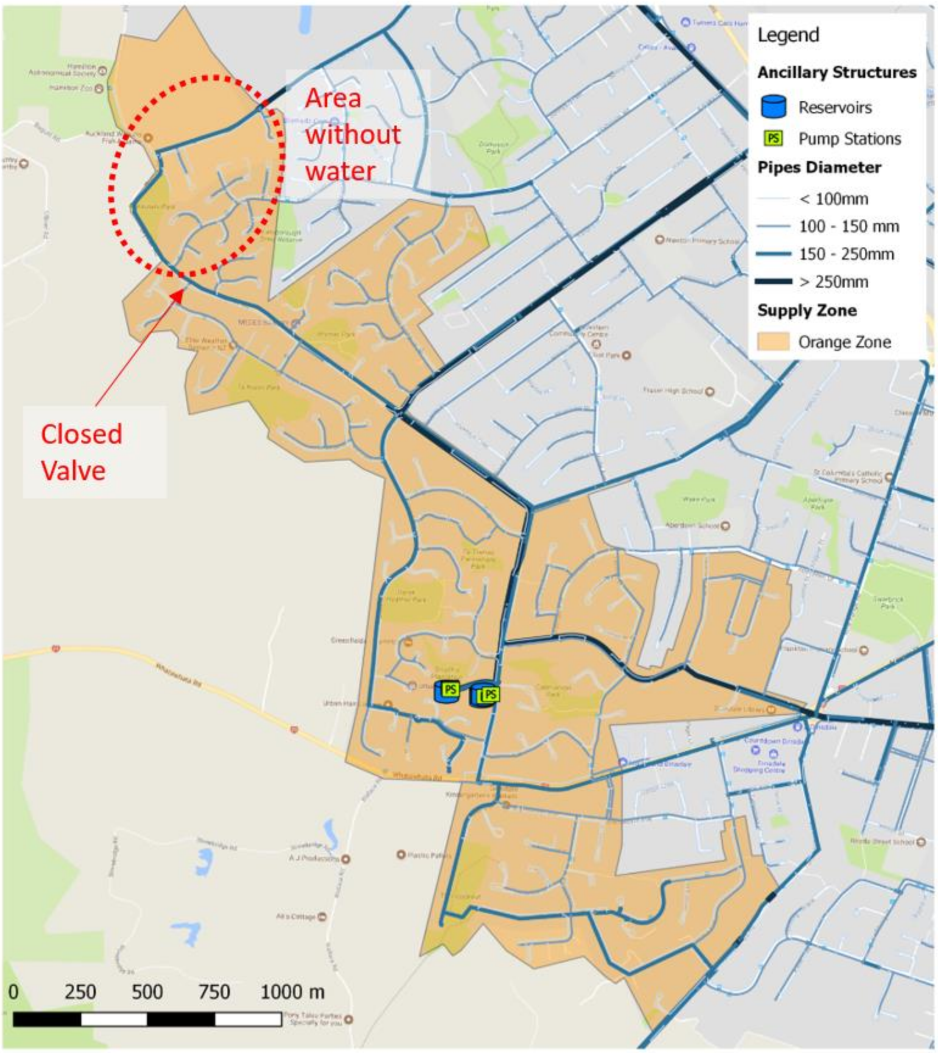

Figure 4: Loss of LOS due to a closed valve

- Following the construction of the Rototuna reservoir, several commissioning snags were identified. As a result, the closure of the water supply zone due to be serviced from this reservoir was delayed by several months.

3.4.2 NETWORK OPERATION

During the Master Plan implementation some issues were identified around the importance of network controls and how these can affect the performance of upgrades. This is illustrated in the examples below.

The Newcastle pump station was originally designed to fill the Dinsdale Reservoir from the Newcastle Reservoir. However, the Newcastle reservoir currently struggles to drain as it is the only reservoir in the Blue Zone not equipped with a booster pump station and it is competing with the pressure serviced from the WTP. The WTP and other reservoirs' pump stations are pumping to demand and the Newcastle reservoir head is not enough to drain against the resulting head. As part of an upgrade to establish a dedicated filling line connecting the Newcastle reservoir to the Dinsdale Reservoir an emergency pipeline (supposed to be closed under normal operation conditions) was installed to enable pumping from the Newcastle reservoir into the Blue Zone. Because the Newcastle Reservoir turnover was not optimal, this pipeline was left open to be used to pump into the Blue Zone and to increase the outflow from this reservoir. With the extension of the Dinsdale Zone (Orange Zone) this pump station does not have enough capacity to supply increased Dinsdale flows as well as pumping into the Blue zone.

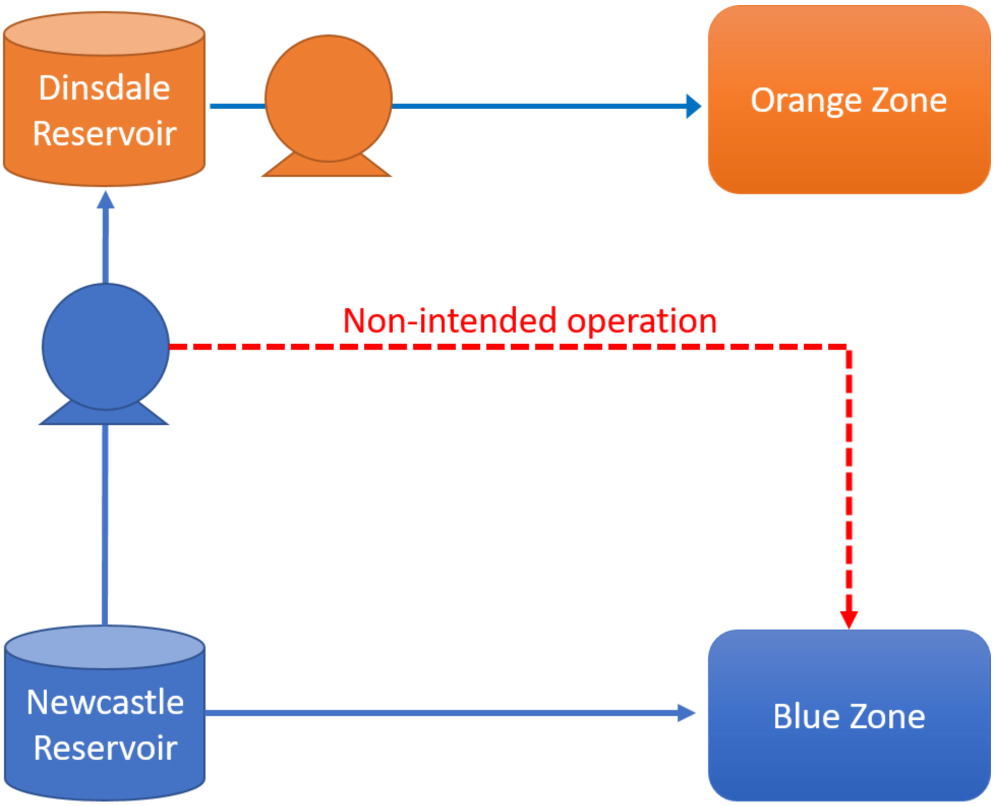

Figure 5: Non-intended operation of the Dinsdale pump station

The recent closure of the Rototuna zone, also highlighted some issues around intended asset operations. The Rototuna reservoir and pump station operations were not changed following the closure of the water supply zone. The reservoir is currently set to fill overnight while the booster pump station is operating during daytime, whereas the zone was intended to be serviced from the booster pump station at all times while the reservoir would be filled at a constant flowrate throughout a 24hour period of time. This issue results in low pressure performance and is currently being resolved by the Hamilton operational team.

3.4.3 ENSURING ZONE INTEGRITY

As part of the Hamilton Master Plan, multiple water supply zones will be closed. Ensuring the zone integrity during its implementation is critical to ensure the network operates as intended. This aspect has also a noticeable impact on the operational range of the pump stations servicing each zone and on the prioritisation of leak detection.

Prior to its extension, the Orange Zone was found to have high night flows (representing approximately 50% of the zone average demand) and therefore an investigation was carried out. The following was found:

- One zone valve (painted red) was found open on a 250mm pipeline.
- In 9 locations the valve lid and/or the kerb marking were either blue (suggesting an open valve) or the kerb was not marked.
- The network GIS was found to be erroneous in one location.

After closure of the valve, the night flow was reduced by half, as shown on the figure below.

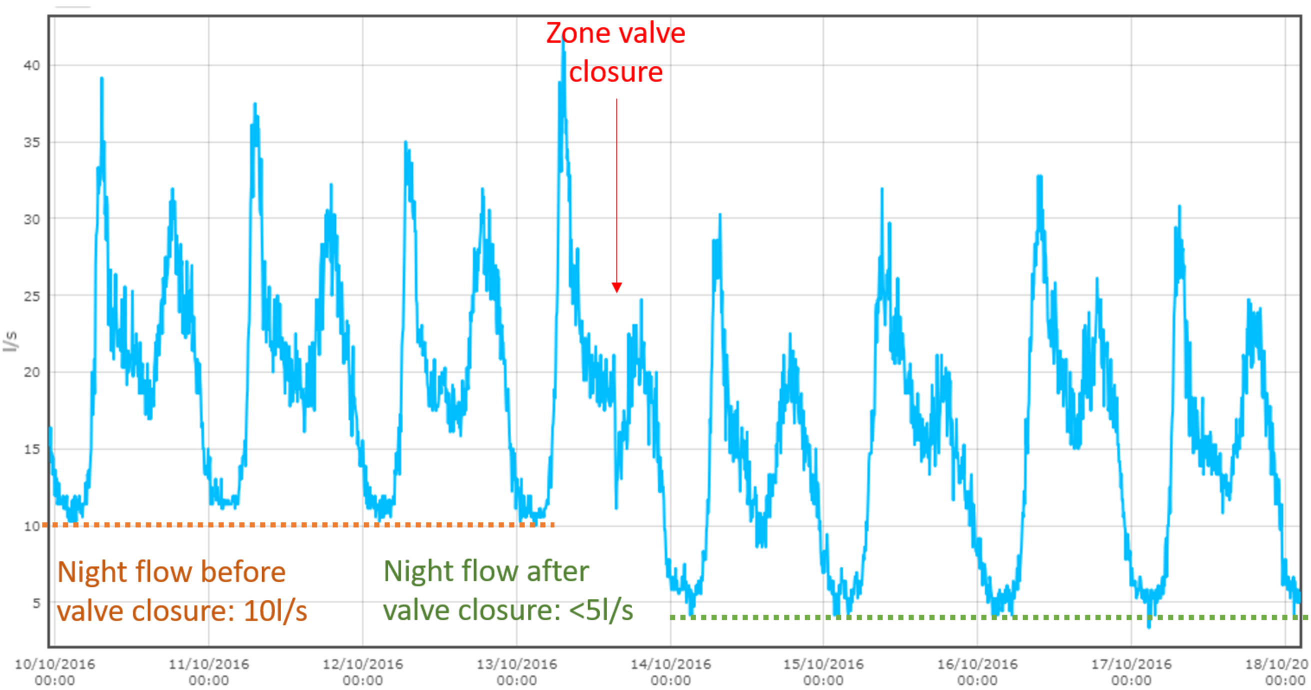

Figure 6: Night flow reduction after valve closure

Following the extension of the Orange Zone, the night flow increased again to unexpectedly high values (20l/s). After further investigation, it was found that two zone valves were partially closed, passing water. The figure below shows the flow into the zone, before and after the passing valves were found and closed. Once again, the night flow was reduced by half after zone closure.

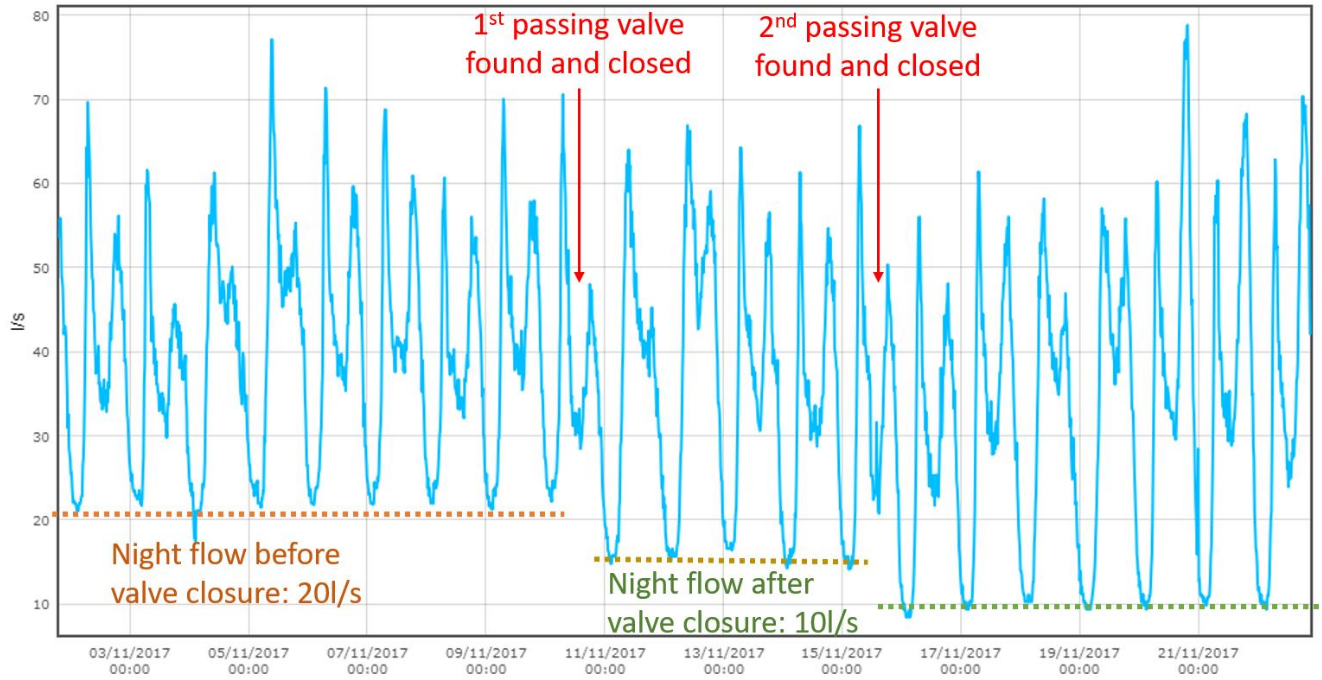

Figure 7: Night flow reduction after multiple valves closure

4 SOME SOLUTIONS: HOW TO ENSURE A SUCCESFUL IMPLEMENTATION OF PLANNED OPTIONS?

Based on the above findings the project team responsible for the implementation of the Master Plan proposed options has established the following requirements.

4.1 PLANNING TOOLS OPERATIONALISATION

Planning tools such as hydraulic models have proved to be critical to develop and implement the options proposed as part of the water Master Plan. Beyond their role to better prepare for the implementation of upgrades, they have been crucial to identify and resolve unexpected issues.

However, as mentioned above, these tools have their limitations. They only offer a snapshot of the network for specific conditions, based on the knowledge gathered at the time of the model development. To address some of these concerns, the need to operationalise models to capture real-time operations and updated information datasets has been identified. Hamilton decided to invest in further hydraulic modelling and monitoring in a view to get a more detailed understanding of the network operations during the Master Plan implementation. The following steps were taken on the road to live modelling:

- Hamilton's water model and GIS database were synchronised as part of a recent model update process. Hamilton's GIS was updated to capture model build requirements in terms of connectivity and representation of critical assets. This process was undertaken in a view to automate the identification and quantification of GIS updates and to fast track any future geospatial update of the model.

- The distribution of current and future demands was automated based on Hamilton's population model and flow monitored through the SCADA system. This enables the model demand to be automatically updated for any specific historical day and simplifies the update of future scenarios when the population forecast model is modified.

- An automated validation tool was developed to use permanent loggers as the source of the hydraulic model controls. This tool enables the model to be run for any historical condition. Permanent loggers were also installed as part of this initiative to capture network performance at critical network locations (for pressure and flow). This offers a base monitoring network that can be used to track actual system performance and to ensure model results can be continually validated against logging data.

- A detailed calibration exercise was undertaken during summer 2018, to refine model findings, identify potential network anomalies and ensure the model can be used to define future control settings in more details.

4.2 WORKING AS A TEAM

Communication needs to be maintained between the different teams involved throughout the Master Plan implementation process. Planning, operation, design and maintenance teams need to remain involved throughout the entire project lifecycle to avoid any loss of information. These teams should work as a single team to successfully deliver the Master Plan.

For example, the planning team should work alongside project designers to ensure assumptions and recommendations are well understood during the design process. The planning team needs to understand the limitation of the options originally proposed and should advise on the impact of the design decisions that are taken. Operations and maintenance should also be considered throughout the design process, to ensure the system designed provides flexible operation and maintenance.

4.3 PREPARING FOR THE IMPLEMENTATION OF UPGRADES

The commissioning and implementation of upgrades needs to be prepared attentively. An implementation team including all relevant stakeholders should be identified to reduce any potential risk and quickly identify and resolve unforeseen issues occurring during the implementation process. For example, the following strategy has been identified to isolate future water supply zones in Hamilton:

- Planning representative: Confirm valves to close to isolate the zone, confirm intended zone operation once the zone is closed, verify that all permanent and temporary loggers are up and running to identify any system performance issue, be ready to use model to help identify and resolve any unforeseen issues.

- Design representative: Confirm operation of designed assets is understood, be ready to help identify and resolve any unforeseen issues occurring with designed assets (pump station, pipeline, etc).

- Operation representative: Confirm operation of isolated zone is understood, modify operations of network following zone closure, monitor system performance changes throughout the network, help identify and resolve any unforeseen issues.

- Maintenance representative: Undertake an extensive valve check before zone closure (the Rototuna valve check found approximately 20% of closed valves confirming the need for a comprehensive valve check prior any zone closure), verify that valves to be closed can be operated, are tight when closed and are in satisfactory condition. Be ready to assist with the resolution of any unforeseen issues.

- Leak detection contractor: Help identify any passing valve, or unrecorded connection point.

Implementation plans at the pressure zone level are currently being developed. The relationship between the zones is captured to ensure assumptions in terms of programme and operations are well understood. Those plans are being developed with operator staff inputs and in conjunction with the design team to include the information required for design purposes. They are planned to be used as mini zone management plans to be read by any team member starting work in the service area, to ensure everyone is familiar with the zone operation and assumptions for the proposed upgrades.

5 CONCLUSIONS

The rapid growth of Hamilton has brought with it significant challenges, including maintaining suitable clean water services in the future. Seven years ago, HCC and Mott MacDonald started developing a comprehensive water strategy addressing current system performance issues and future shortfalls, which resulted in the development of a 30-year Master Plan recommending upgrades to address system performance issues identified using a detailed water supply hydraulic model.

As options started to be implemented, multiple challenges arose, mainly related to the following:

- Model limitations:
    - Reliance on accuracy of GIS, model assumptions, population predictions
    - Reliance on accuracy of network configuration and operator feedback
    - Additional complexity in pipes and pumps sizing to meet operational resilience, redundancy and flexibility.

- Design challenges
    - Constraints in project management and budgeting on isolated packages of work
    - Impact of timing and constraints on the proposed programme.

- Operational challenges
    - Maintaining LOS
    - Unexpected network operations
    - Maintaining zone integrity.

These challenges are being addressed to ensure a successful implementation in the future, with the following solutions currently being implemented:

- Operational planning tools:
    - Updating the model with latest GIS and population and developing tools to automate the process
    - Developing an automated validation tool
    - Maintaining the monitoring data stream

- Working as a team: ownership of the project is critical, with a pilot team including a person from each team (planning/strategy, modelling, operation, design, maintenance) that will be leading the zones implementation.

- Right preparation to limit issues and act fast in case of issue.

Learning from previous challenges and reflecting on the journey to identify how to continually improve, the team delivering the master plan is working on ensuring a smoother implementation of the planned options in the future.