WATER SUPPLY NETWORK MASTER PLAN

PREPARED FOR NAPIER CITY COUNCIL

November 2019

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Executive Summary

Objectives

Napier City Council (NCC) has engaged Stantec to develop a master plan identifying investigations and capital upgrades required for the water supply network to meet the Level of Service now and in the future.

This report summarises the key drivers for the Napier water supply, the work done to date and the recommended way forward.

Drivers

The over-arching vision is that of a modern water system that can reliably supply safe water to customers, now and in the future.

The drivers are:

- **Safe** water is distributed to customers.
- **Clean** water is distributed to customers.
- Water is distributed with sufficient **pressure**.
- The network is **resilient** to shocks and stresses.

Master Plan

A series of capital works will be required to achieve the performance objectives of these drivers. Some of these works are not scoped accurately at this stage and will require preliminary investigations.

The master plan includes works and investigations already in progress as well as future stages. The master plan is presented in nine work packages, some of which may be undertaken in parallel.

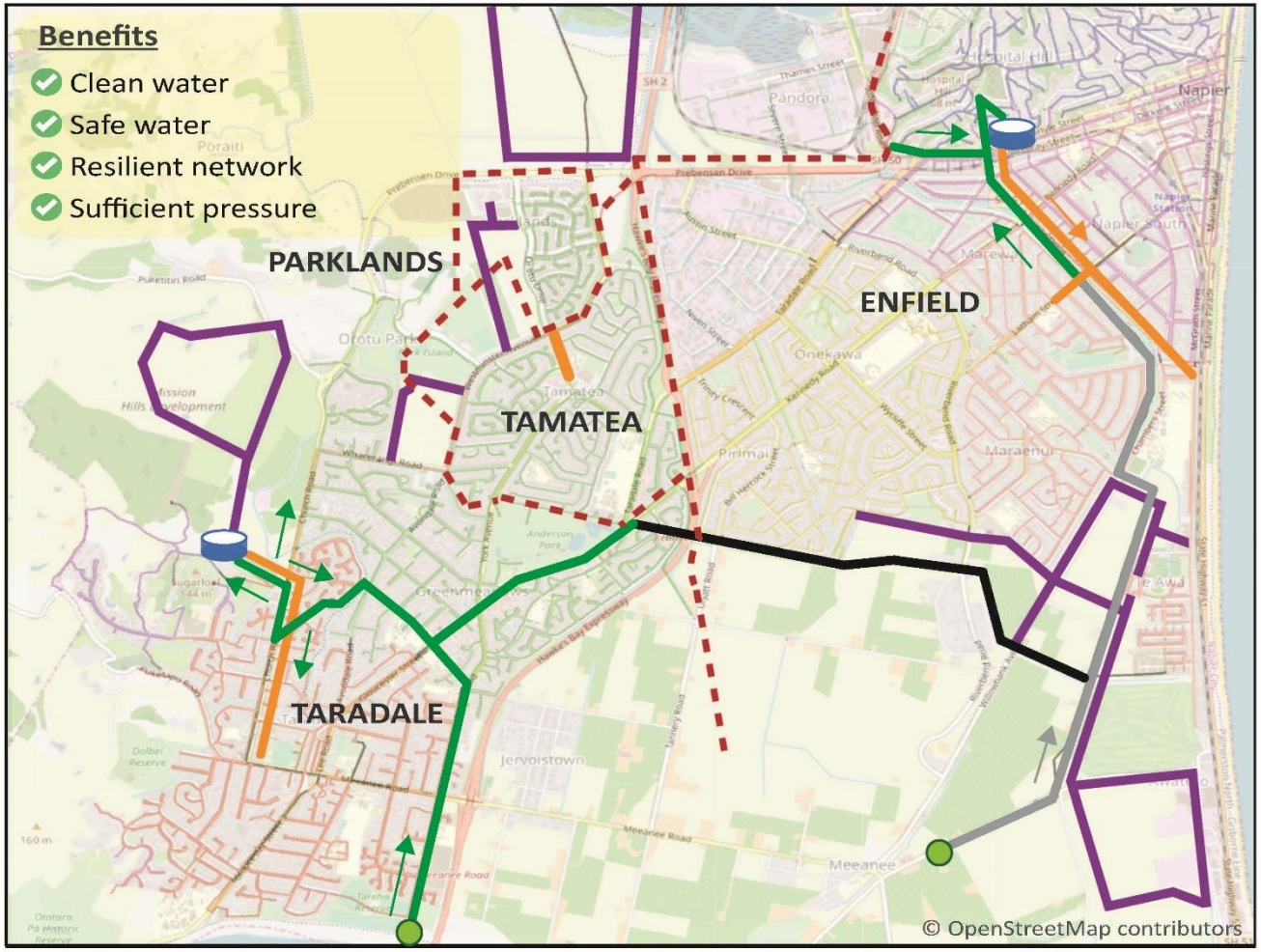
Table 0: Master Plan Summary

Package	Driver	Cost	Risks, opportunities	Status
1: Reduce the manganese load	Safe Clean	$2.7M	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	In progress. **High priority** as it enables several other tasks to proceed.
2: Delineate Taradale / Enfield	Safe Clean	$0.1M	Marginal performance in Tamatea	Can be started any time
3: Dedicate Taradale	Safe Clean	$10.6M	Cost estimate may change depending on Package 1.	Requires some of Package 1
4: Dedicate Enfield	Safe Clean Pressure Resilient	$11.6M	High uncertainty regarding cost for Enfield Reservoir	In progress. **High priority** as it enables several other tasks to proceed.
5: Manage demand	Resilient	$6.6M	Includes OPEX for leak detection and repair	Can be started any time
6: Connect Awatoto to Taradale	Resilient	$2.1M	Cost estimate may change depending on Package 3.	Requires Package 3
7: Rationalise Thompson Reservoir pipework	Resilient	$0.3M	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	Can be started any time
8: Ensure FW2 Fire Flow Availability	Pressure	$4.0M		Can be started any time
9: Enable growth	Pressure	$3.5M	Cost estimate of greenfield developments not included, assumed paid by developer.	

The key features of the proposed system are:

- The water sources should be separated from the distribution; customers are less at risk of contamination than currently.
- The hydraulic and chemical conditions in the distribution network should be less conducive to discoloration events.
- Key pipe upgrades should be implemented, mainly in Taradale; the level of service for minimum pressure and fire fighting capacity is met.
- Water demand should be managed efficiently; population growth is supported.
- The network should be able to operate with either bore field taken out of service for a certain period of time.

Napier Water Supply Master Plan



Legend (only key elements shown)

- Greenfield developments
- Proposed distribution main
- Proposed dedicated rising main
- Existing pipe, can be used as rising main
- Existing rising main
- Reservoir
- Proposed new pressure zone delineation
- Bore field, potentially new location for pipe extentions and treatment

Level of Service: Sufficient capacity to achieve 20m minimum pressure and FW2 fire protection under future demand.

Operation: N/A

Cost Estimate: $40.6M

Napier City Council

Water Supply Network Master Plan

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1.1 Objectives

Napier City Council (NCC) has engaged Stantec to develop a master plan identifying investigations and capital upgrades required for the water supply network to meet the Level of Service now and in the future.

This report summarises the key drivers for the Napier water supply, the work done to date and the recommended way forward.

1.2 Previous Work

Stantec prepared an initial assessment of the water network performance ("Napier Water Supply Model Development", 2017). This was based on an un-calibrated hydraulic model, which was sufficient to broadly outline the future of the network, but still required validation ("Napier Interim Master Plan", 2018).

The main difficulty for the hydraulic model calibration was the lack of flow metering equipment throughout the water network. NCC and Stantec undertook a significant amount of work throughout 2019 to plan, deploy and test temporary flow meters, intended to collect sufficient data to enable model calibration ("NCC Water Supply Model Calibration", 2019).

1.3 Updated Master Plan

This calibrated model was used to develop a series of scenarios, representing the envisioned evolution of the water supply network, assessing its hydraulic performance and identifying required capital works.

The key drivers have changed slightly between the interim master plan and this 2019 update, and this is reflected in the recommended work programme.

2. Network Overview

2.1 General

This section provides a brief overview of the water supply network. For a more in-depth description of the network, please refer to the "Napier Water Supply Model Development" report (Stantec, 2017).

2.2 Topography

Most of the city is located at the north end of the Heretaunga Plain and therefore at low elevation. Napier Hill near the city centre represents a key exception as it rises up to elevations close to 100m above sea level. The Western Hills also harbour residential properties, albeit sparser.

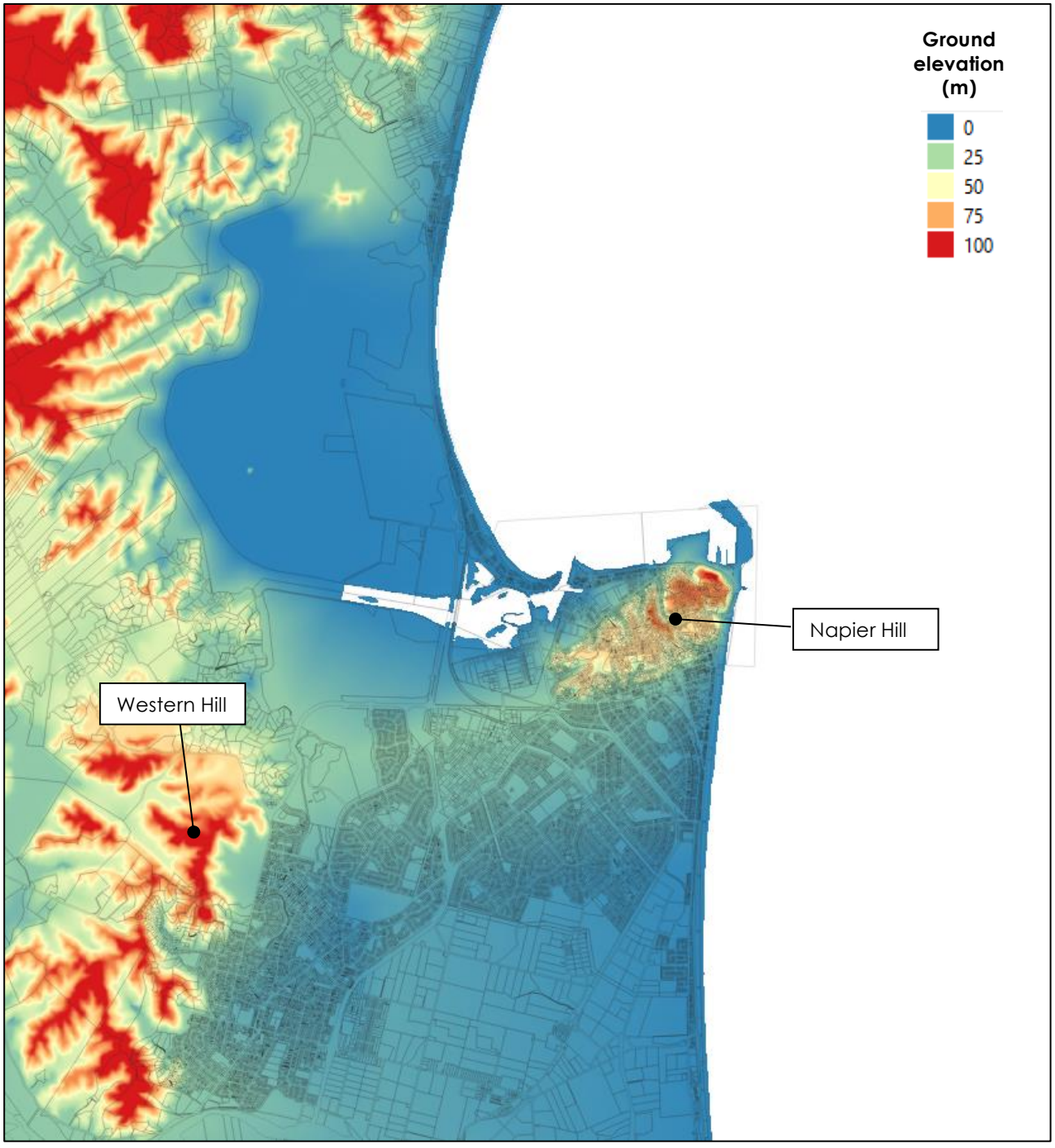


Figure 2-1: Topography

2.3 Water Source

Napier's water supply is sourced from the Heretaunga Plain aquifer, which is shared with Hastings.

Water is pumped from the aquifer into the network by a series of bores, shown in Figure 2-2.

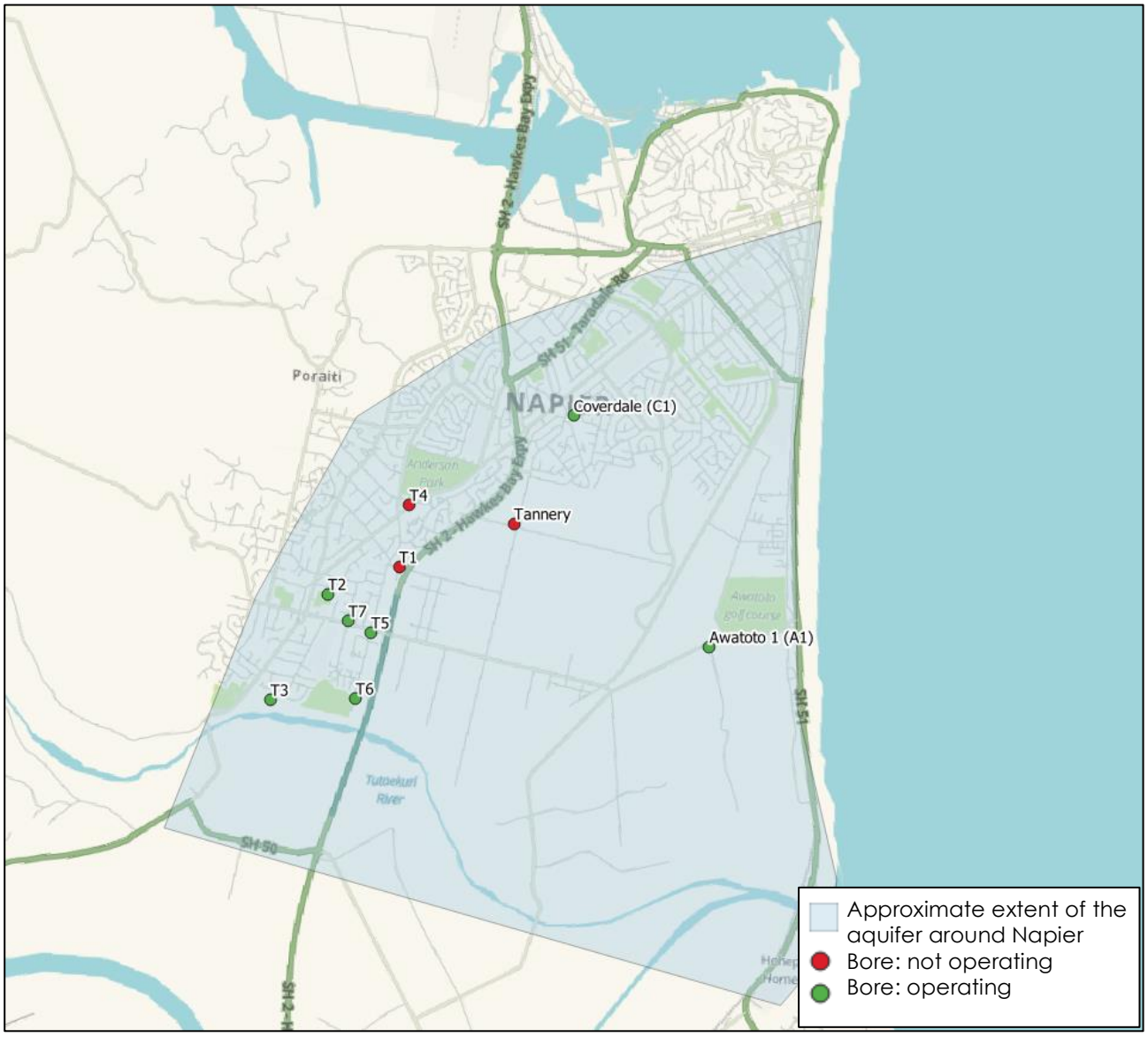


Figure 2-2: Approximate Extent of the Heretaunga Plain Aquifer around Napier [based on NCC AMP]

The resource consent conditions dated 1 March 2010 indicate that:

- The maximum rate of taking and maximum 7-day volume for each well shall not exceed set values for each bore (refer to the "Model Development" report for details on each bore set value).
- The instant cumulative rate of take from all wells shall not exceed 784 l/s.
- The cumulative 7-day volume take from all wells shall not exceed 387,744 m^3 (equivalent to 55,392m^3/day).

2.4 Water Network

From the bores, water is pumped directly into a 480km distribution network. The main feature of the system is the large Taradale / Enfield zone, which contains the majority of the customers and infrastructure. Several small pressure zones are located in high elevation areas, and constitute District Metered Areas (DMAs). Figure 2-3 provides an overview of the pressure zones.

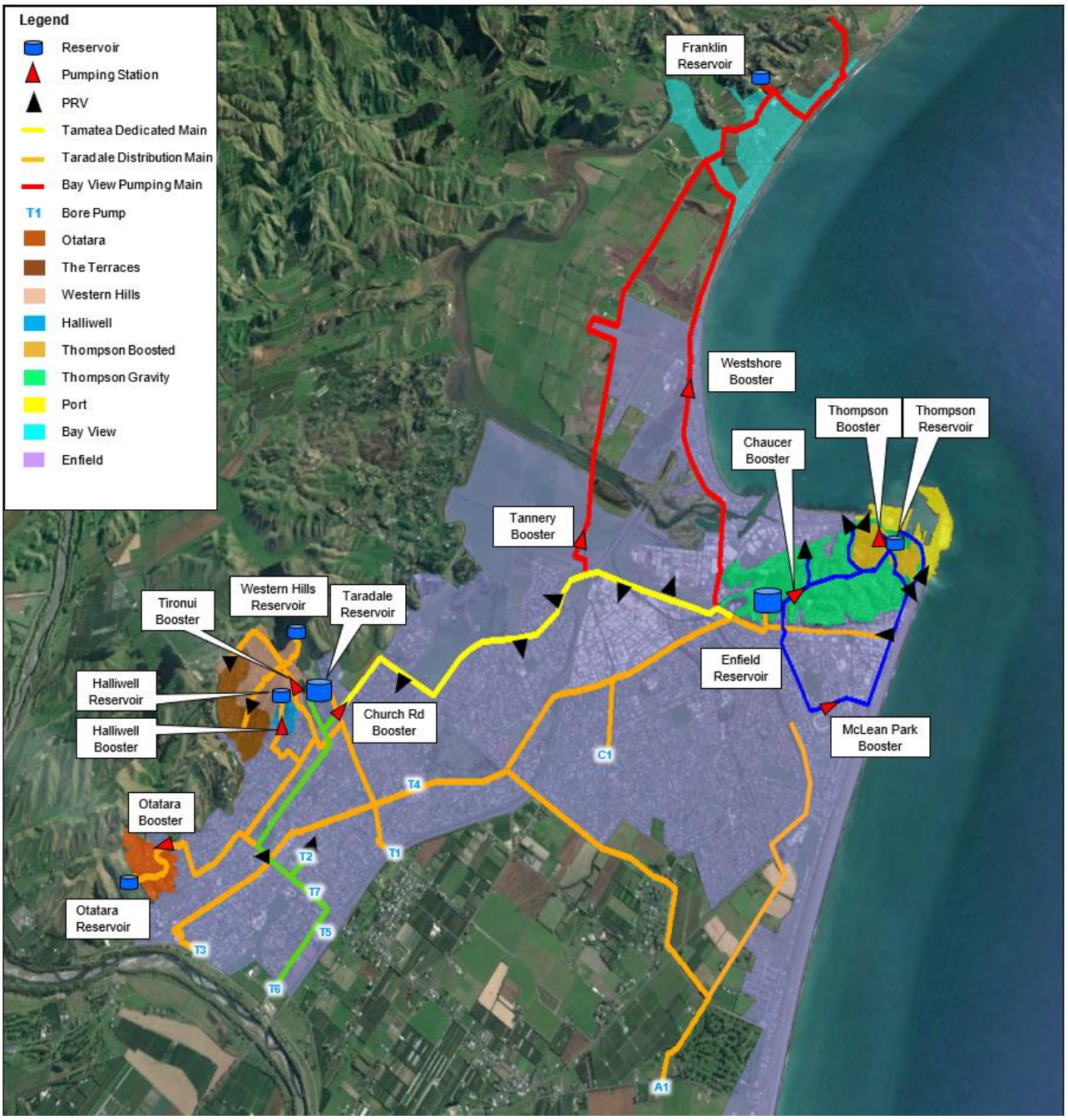


Figure 2-3: Network Schematic

The Enfield (11ML) and Taradale (9ML) reservoirs constitute the main storage in the city. Both reservoirs have a top water level of 61.5m and supply low level customers down to sea level.

A second Taradale Reservoir (also 9ML) is built but not commissioned at the time of writing.

The Enfield Reservoir has known structural issues and requires repair or upgrade, either at its current site or in another site.

Six other reservoirs provide storage for the high elevation areas; the highest property serviced by the network is located at approximately 105m.

- The Thompson Reservoir (109m elevation) is located on Bluff Hill; it comprises of three storage tanks connected by a complicated set of pipes. The fact that these are not well located or understood and are very hard to access presents a risk to the continuity of supply.
- The Church Road booster pump station is located near the Taradale reservoir; it is used to push water from the bores to the Enfield Reservoir, which is located hydraulically further than the Taradale Reservoir.
- The Westshore and Tannery booster pump stations convey water from the Enfield system to the Bay View area.
- The other booster pump stations serve local high elevation areas.

Current best practice consists in separating water sources from the network distribution. This facilitates water treatment and reduces risk of contamination to customers. While the city has made efforts in the past to combine all the sources into dedicated rising mains, this is not completed yet. There are several pathways from the bores directly to distribution, either through direct connections, pressure reducing valves or via the Church Road Booster.

2.5 Water Usage

The water network supplies approximately 60,000 people through 26,117 connections, the vast majority of them being un-metered residential. The existing water network is essentially one very large zone with multiple boundary points such as PRVs, bores and pump stations. The complex nature of the zone and the lack of adequate flow metering equipment has made accurate demand analysis difficult.

NCC has commissioned Thomas Consultants to undertake a water balance every year ("NCC Water Balance Brief report 2019"). The key findings for Napier are as follows:

- A high level of authorised unbilled demand, through parks and sports fields.
- A relatively high level of leakage, around 25% across the city.
- A yearly usage of approximately 11,000 ML/year.
- A peak day usage of approximately 42ML/day.

The demand analysis work undertaken during the hydraulic model calibration has confirmed this estimated level of leakage.

The water demand used for the master plan represents the average day of peak week (ADPW) for two planning horizons:

- Current (2017)
- Future (ultimate development based on the Heretaunga Plains Urban Development Strategy including intensification and greenfield growth, both residential and non-residential).

Future per-capita demand was conservatively assumed to remain as per the existing value. Residential intensification often leads to a reduction of per-capita demand. This was not considered as part of this work but NCC may wish to investigate how this may affect future water needs.

The demand for both planning horizons is presented in Table 2-1.

Table 2-1: Assumed Water Demand by Type

Type	Current PDD (m^3/day)	Future PDD (m^3/day)
Residential	30,935	41,388
Non-Residential	6,273	6,731
Leakage	5,238	5,711
Total	42,446	53,830

More detail on the demand calculations and allocation are provided in "NCC Water Supply Model Calibration".

3. Drivers and Strategies

3.1 General

NCC have identified a number of drivers to guide the development of the water supply network. These are presented in this section. The over-arching vision is that of a modern water infrastructure that can reliably supply safe water to customers, now and in the future.

The drivers are:

- **Safe** water is distributed to customers.
- **Clean** water is distributed to customers.
- Water is distributed with sufficient **pressure**.
- The network is **resilient** to shocks and stresses.

3.2 Safe Water is Distributed to Customers

3.2.1 Where We Are

Until 2017, the water from the aquifer was distributed without treatment. Following the Havelock North contamination and the detection of very small amounts of *E. coli* in the Napier reservoirs, NCC decided to exercise caution and undertook a review of the contamination risk of its water bores.

A number of bores were found to present particular risk, for example being relatively close to sewer pipes, and were taken out of service. In-line chlorination (sodium hypochlorite) was implemented just downstream of the remaining bores to provide a disinfectant residual within the distribution network.

The current best practice for water safety consists in creating multiple barriers of protection. The confining geological layers of the aquifer and the aquifer material itself form the first barrier. Disinfection forms a second one and chlorine residual in the distribution network forms a third one. Napier is currently investigating alternatives to retaining a chlorine residual in the distribution.

Changes to the Drinking Water Standards and requirements on water utilities are expected to be implemented in the near future, although the details are not clear at present.

3.2.2 Where We Want To Be

NCC wants to continue meeting the Drinking Water Standards' requirements.

Currently water is pumped directly from the aquifer to the network, which is not desirable. Pumping water through a dedicated supply main to the reservoir before distribution would give Operations more time to react to an emergency, dilute a potential contamination and provide an additional point for emergency treatment.

3.2.3 How We Get There

To achieve this goal, NCC has set out the following measurable objectives:

- Abandon bores deemed unsafe from a micro-biological point of view.
- Treat water supplied by the remaining bores. As the targets and principles pertaining to disinfection and chlorine residual are not defined, this aspect is not included in this master plan.
- Separate the supply (from the bores) and the distribution network (from the reservoirs).

3.3 Clean Water is Distributed to Customers

3.3.1 Where We Are

The introduction of chlorination led to a large number of customer complaints because of dirty or discolored water coming out of the tap.

After two years, discoloration issues still occur and cause extreme public discontent.

Most of the issues have been recorded around the centre of the city, broadly at the interface between the Taradale and Enfield zones.

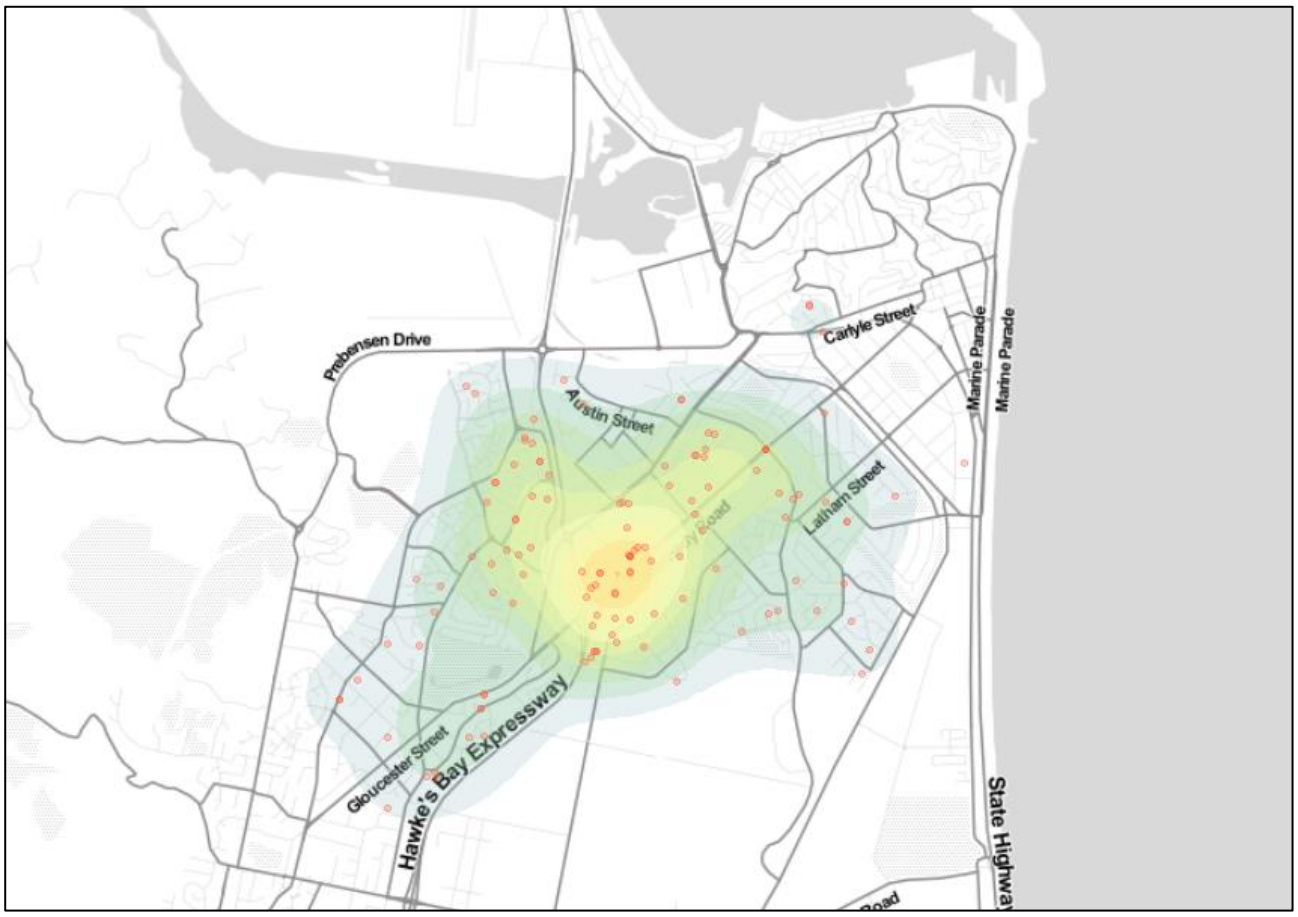


Figure 3-1: Water Clarity Complaints (October 2018, varies in location and intensity over time)

The current understanding of the issue can be broadly presented as follows:

- Over the years, manganese present in dissolved form in the aquifer water has accumulated in the biofilm inside the distribution pipes.
- The pH and oxido-reduction potential (ORP) conditions of the water contributed to manganese remaining mostly in dissolved form, thus invisible.
- The introduction of sodium hypochlorite has caused the biofilm to either degrade and be dislodged or to release manganese compounds into the water.
- The chlorine has also changed the ORP, making the water more prone to the presence of manganese in oxidised form (black deposits) rather than dissolved (invisible).
- Manganese in oxidised form tend to deposit in thin layers on the pipe surface, but can be dislodged easily if the flow in the pipe reverses.

3.3.2 Where We Want To Be

NCC's goal is to return the number of water aesthetics complaints to pre-chlorination levels.

3.3.3 How We Get There

To achieve this goal, NCC has a broad strategy consisting in:

- Understanding the issue better.
    - Undertaking sample analysis at various points of the system.
    - Recording complaints effectively.
    - Linking discoloration episodes to hydraulics using the model.

- Reducing the manganese loading in the system.
    - Considering alternative sources containing less manganese.
    - Considering treatment to remove manganese.
- Removing manganese and biofilm deposits.
    - Active pigging and flushing programme.
- Avoiding conditions prone to oxidation of manganese.
    - Considering replacing chlorination by other treatment systems, thereby restoring pre-chlorination ORP and making the water less prone to manganese in oxidised form (black deposits).
    - Avoiding flow reversals in the network by:
        - Not using A1 bore, McLean Park Pump Station, Chaucer Booster Pump Station until they can be isolated from the distribution, so they don't disturb the local distribution hydraulics.
        - Closing connections between the supply from the bores and the distribution network.
        - Delineating the Taradale and Enfield supply zones.

3.4 Water is Distributed with Sufficient Pressure

3.4.1 Where We Are

The hydraulic model was used to simulate current and future peak day demand, along with hydrant fire demand, in order to identify constraints in the network and areas where this level of service cannot be met.

No major issue was found with the current network operating in its current configuration with current peak demand. However, new pipes are required to retain the current Level of Service after the separation of the supply from the distribution ("Safe water" and "Clean water" drivers), the delineation of Taradale from Enfield ("Clean water" driver), the creation of metered areas ("Resilient network" driver) and the increased demand from future growth ("Resilient network" driver).

3.4.2 Where We Want To Be

NCC has the following measurable objectives:

- Normal Conditions: The system pressure should ideally remain between 40m and 60m at the point of supply. The minimum and maximum target pressures are 20m and 80m respectively.
- Asset Outage: The system pressure should remain above 10m at all customer supply points, in the event of a pipe or pump outage.
- Fire-Fighting Demand**:** NCC's target is to provide 25 l/s at 10m residual pressure within 270m of the hazard, following the road[1]. This is equivalent to class FW2 as per the Fire Code.

3.4.3 How We Get There

To achieve these objectives, it is recommended that:

- NCC investigates, locates and eliminates the suspected network restrictions identified during the calibration of the hydraulic model. These represent inexpensive quick wins to slightly improve the network performance.
- NCC undertakes the pipe upgrades and extensions listed in the various work packages presented in Section 4.

It is important to note that several pipe upgrades are contingent on decisions being taken on the location of potential future bore sites and the location and elevation of a potential new Enfield Reservoir.

[1] SNZ PAS 4509:2008 (the Fire Code) indicates that half this flow must be available within 135m of the hazard. This was assessed using the hydraulic model under peak demand, with fire flow simulated at a time where the demand is equivalent to 2/3 of daily peak demand.

3.5 The Network is Resilient to Shocks and Stresses

3.5.1 Where We Are

3.5.1.1 Supply / Demand Balance

Sections 2.3 and 2.5 indicate that the current peak day demand usage is around 43MLD, and is expected to increase to 52MLD in the future. This is not far from the current maximum 7 day extraction consent of 55MLD, and the future adequacy of supply is therefore sensitive to assumptions made around the future number of users, the future water consumption per user and the future leakage volume.

We understand that NCC has not set a target for leakage and has not completed an Economic Level of Leakage assessment.

3.5.1.2 Source Redundancy

Napier currently uses two main areas for extracting ground water: the Taradale/Coverdale area to the west and the Awatoto area to the east. While it is possible to operate the network without Awatoto, it is not currently possible to do the same without the Taradale/Coverale bores.

3.5.1.3 Enfield Reservoir Condition

There are known concerns with the structure of the Enfield Reservoir, and it is due for replacement between 2022 and 2025.

Replacing the reservoir in its existing location will not be possible without taking the reservoir out of commission for a long period of time. This is undesirable because the reservoir is needed to maintain the Level of Service in the eastern part of the city.

Replacing it at the same elevation in another part of Napier Hill may be difficult because of the scarcity of flat sites and the difficulty in acquiring already-developed land.

Replacing it at a higher elevation has hydraulic consequences, both positive and negative which will be discussed in a separate document.

In all cases, changing the location of the reservoir would require expensive pipe extensions.

3.5.1.4 Enfield Reservoir Water Level

Most of the water bores are located close to the Taradale Reservoir, while the water demand is distributed between both the Taradale and Enfield reservoirs. During periods of high demand, Operations sometimes have difficulty replenishing all reservoirs overnight. Enfield Reservoir is generally the most problematic. It is therefore essential that the balance between supply and demand is maintained, now and in the future, under normal conditions and during the outage of any network component.

3.5.1.5 Thompson Reservoir Pipework

The pipework in/out and between the Thompson reservoirs has developed organically over the years and is now complex and hard to access and operate. It leaves NCC vulnerable to a failure that would result in a costly, long and complicated shut-down and emergency repair.

3.5.2 Where We Want To Be

NCC wishes to address all these issues to reduce the risk of loss of supply to customers.

To assess the hydraulic performance of the network we have assumed that the leakage volume would not increase in the future, but ideally it would reduce to provide more buffer in the supply/demand balance.

3.5.3 How We Get There

To improve the resilience of the network, NCC has the following objectives:

- Manage Supply
    - While considering alternative bore locations for water quality reasons, ensure that Council retains the ability to draw about 55MLD from the aquifer in average over 7 days.
- Manage Demand (this is in line with the "Pressure" driver)
    - Understand leakage and genuine water use better by installing flow meters and setting up metered zones that can be monitored effectively.
    - Actively search for leaks and repair leaky assets.
    - Consider other active demand management actions.
- Upgrade the Enfield Reservoir

    - Confirm preferred location for the proposed Enfield Reservoir.
    - Procure the new reservoir.
- Improve supply to the Enfield Reservoir
    - Construct the dedicated rising main required for the "Safe water" driver.
- Consider infrastructure needed to supply the system only from the Awatoto bores, at least temporarily.
- Rationalise the Thompson reservoirs pipework.

4. Master Plan

4.1 Overview

A series of capital works will be required to achieve the performance objectives of the various drivers listed in Section 3. Some of these works are not scoped accurately at this stage and will require preliminary investigations.

The master plan includes works and investigations already in progress as well as future stages. It is presented in nine work packages, some of which may be undertaken in parallel.

Costing assumptions are presented in Appendix A. Table 4-1 presents a summary of the works proposed. Details of the tasks within each package are set out in sections 4.2 to 4.10, and are presented in tabular form in Appendix E.

Table 4-1 Master Plan Summary

Package	Driver	Cost	Risks, opportunities	Status
1: Reduce the manganese load	Safe Clean	$2.7M	Cost estimate is a place holder only. This task needs to be scoped in more detail.	In progress. **High priority** as it enables several other tasks to proceed.
2: Delineate Taradale / Enfield	Safe Clean	$0.1M	Marginal performance in Tamatea	Can be started any time
3: Dedicate Taradale	Safe Clean	$10.6M	Cost estimate may change depending on Package 1.	Requires some of Package 1
4: Dedicate Enfield	Safe Clean Pressure Resilient	$11.6M	High uncertainty regarding cost for Enfield Reservoir	In progress. **High priority** as it enables several other tasks to proceed.
5: Manage demand	Resilient	$6.6M	Includes OPEX for leak detection and repair	Can be started any time
6: Connect Awatoto to Taradale	Resilient	$2.1M	Cost estimate may change depending on Package 3.	Requires Package 3
7: Rationalise Thompson Reservoir pipework	Resilient	$0.3M	Cost estimate is a place holder only. This task needs to be scoped in more detail.	Can be started any time
8: Ensure FW2 Fire Flow Availability	Pressure	$4.0M		Can be started any time
9: Enable growth	Pressure	$3.5M	Cost estimate of greenfield developments not included, assumed paid by developer.	

4.2 Package 1: Reduce Manganese Load

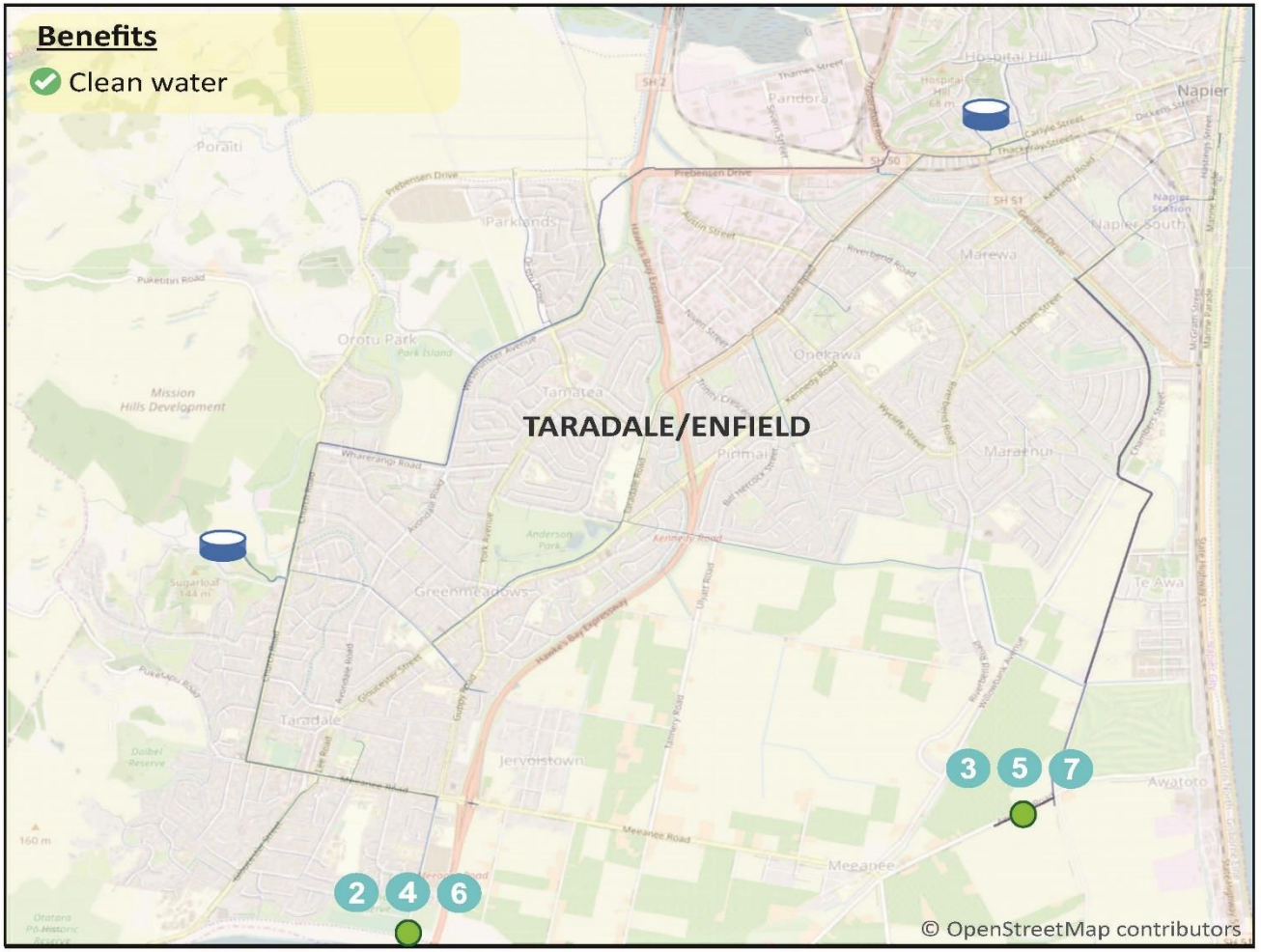
This work package is aligned with the "Safe water" and "Clean water" drivers. It essentially implements the strategy presented in Section 3.

It consists in reducing the frequency of discoloration episodes by:

- **Task 1-1**: Understanding the issue better.
    - Recording complaints effectively (already in place).
    - Undertaking sample analysis at various points of the system (already under-way but may be improved).
    - Link discoloration episodes to hydraulics using the model.
- Reducing the manganese loading in the system.
    - **Tasks 1-2 to 1-5**: Considering alternative sources containing less manganese (investigations currently under-way).
    - **Tasks 1-6 and 1-7**: Considering treatment to remove manganese.
- Removing manganese and biofilm deposits.
    - Active pigging and flushing programme (already in place).
- Avoiding conditions prone to oxidation of manganese.
    - **Part of Tasks 1-6 and 1-7**: Considering replacing chlorination by other treatment systems, making the water less prone to manganese in oxidised form (black deposits).

Because of the numerous unknowns regarding the nature if the issue, the ground water quality and the treatment options, no reliable cost estimate can be proposed for this work package at this point. Nominal allowances for the various tasks totalling $2.6M were included in the work programme as place holders, but this is not based on any substantial knowledge at this stage.

Package 1: Reduce Manganese Load



1. Investigate discolouration issues further (chemical and hydraulic)
2. Seek alternative bore locations with less manganese (Taradale)
3. Seek alternative bore locations with less manganese (Enfield)
4. Potentially create new bore sites (Taradale)
5. Potentially create new bore sites (Enfield)
6. Potentially install manganese treatment (Taradale)
7. Potentially install manganese treatment (Enfield)

Legend

- Existing water pipe
- Reservoir
- Existing bore field

Level of Service: Sufficient capacity to achieve 20m minimum pressure under current demand.

Operation: Sources pumped into distribution.

Cost Estimate: Cannot be estimated accurately at this point. $2.6M included in master plan as place-holder.

4.3 Package 2: Delineate Taradale / Enfield

This work package is aligned with the "Safe water" and "Clean water" drivers: it creates additional safety barriers and reduces the flow reversals which are likely to contribute to the discoloration problem. It forms part of the "Safe water" strategy outlined in Section 3.2.3.

Task 2-1 consists in closing all valves between the Enfield and Taradale systems. A potential contamination in the Enfield system will be physically isolated from the Taradale system. This constitutes an improvement from the current situation.

At this stage, the Enfield system will be reliant on the Awatoto and Coverdale bore for normal operation, with the Church Road Booster Pump Station assisting for high demand periods; the water sources will still be connected to the distribution in this part of the network. The Coverdale and Awatoto bores supply about 200 l/s combined, so under peak summer demand it is necessary to run the Church Road Booster Pump Station approximately 6 hours a day to maintain the water level at the Enfield Reservoir.

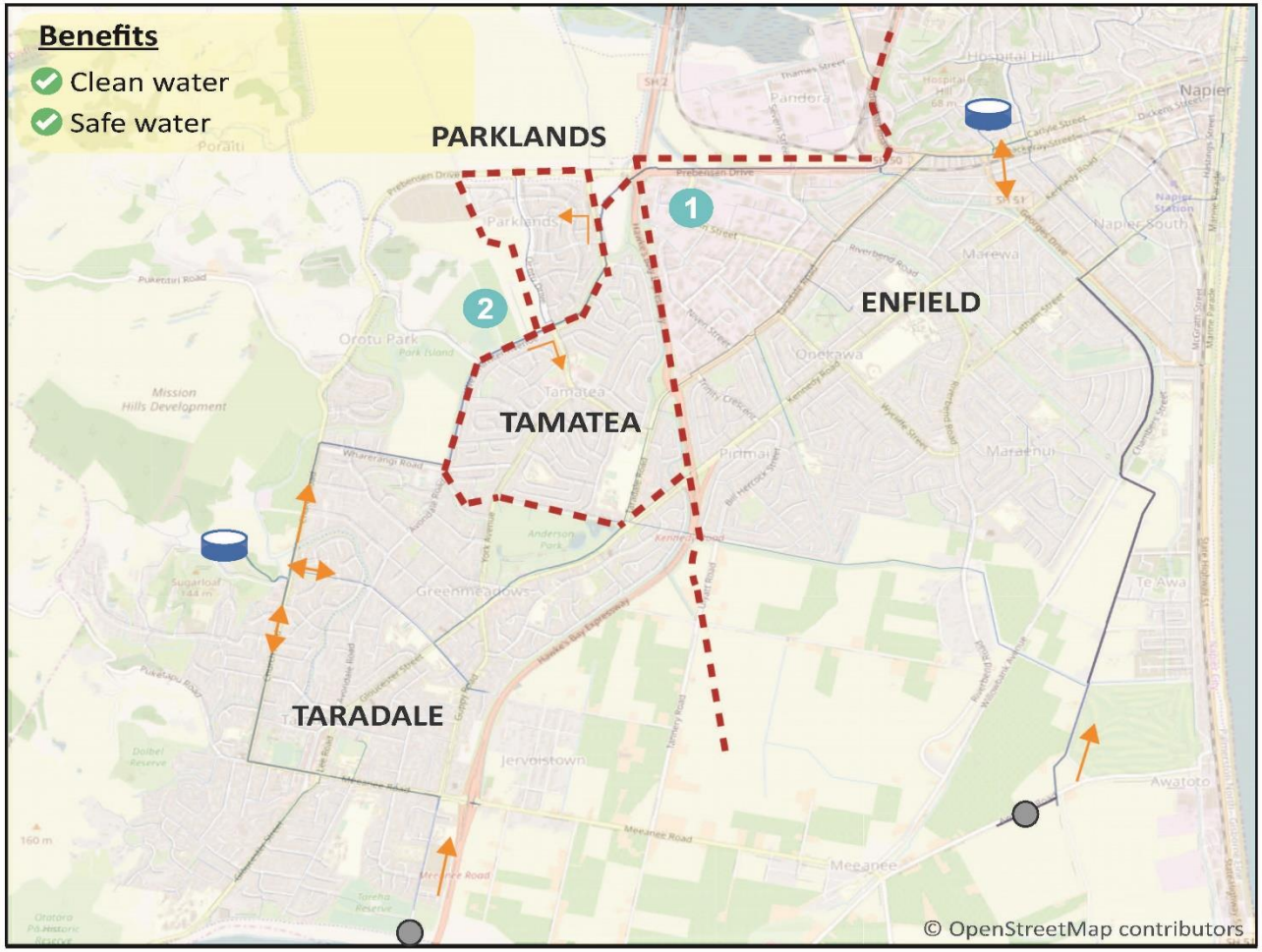
Task 2-2 consists in closing additional valves around the Tamatea area, so it is single-fed from Durham PRV. This in turn will naturally create a single-fed 'Parklands' zone supplied from the Pacific PRV.

This is intended to avoid flow reversals in Tamatea and Parklands and therefore reduce the frequency of discoloration episodes.

This does significantly increase the velocity (2.5m/s) and head losses through the existing pipe downstream of the Durham PRV during peak demand. This may result in shearing of biofilm and result in new discoloration complaints, although this may be manageable through preventive pigging. A FW2 fire flow availability will be only marginally achieved at the extremity of the proposed pressure zone. This performance is improved by Task 3-5.

Consideration should be given to modifying the connectivity of the Tannery booster pump station at the same time. Currently the booster is drawing water from downstream of the Pacific PRV, while it may be more efficient to draw water from upstream of the PRV. This is likely to require only minor works.

Package 2: Delineate Taradale/Enfield



1. Close all valves between Taradale and Enfield
2. Close all boundary valves around Tamatea and Parklands

Legend

- Existing water pipe
- Proposed dedicated rising main
- Proposed distribution main
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under current demand.

Operation: Church Road booster pumps into the Enfield distribution. Marginal pressure in Tamatea.

Cost Estimate: $0.1M

4.4 Package 3: Dedicate Taradale

This work package is aligned with the "Safe water" and "Clean water" drivers: it creates additional safety barriers and reduces the flow reversals which are likely to contribute to the discoloration problem. It forms part of the "Safe water" strategy outlined in Section 3.2.3.

Separating the supply and distribution in Taradale means that all the water in the Taradale system will be first pumped to the Taradale reservoirs, then will gravitate to the distribution. The instant peak flow through the inlet and outlet of the reservoirs will be significantly increased. This therefore requires additional capacity for both the inlet and outlet pipes.

Task 3-1: An additional 450mmØ dedicated rising main (4km in length) is required from the Taradale bores to the Taradale Reservoir. It is recommended that, instead of building parallel to the existing Meeanee Road rising main, the new pipe should be laid along Osier Road. This will reduce the risk of both pipes being damaged by a single event and also make it easier to connect to the Awatoto bore field (Package 5).

Before this can be designed, it is necessary to confirm the preferred location of the future Taradale bores (Package 1).

For the purpose of this work programme we have included a new parallel pipe for the rising main and a combination of additional pipe and pipe upgrade for the distribution. This level of detail is sufficient to estimate the extent and the cost of the works required, but the detail of the preferred layout need to be confirmed during the design stage.

The cost estimate captured in this document assumes that the Taradale bores will remain approximately in their current location. If this is not the case, this would increase the length of the required rising main.

There are three main pathways for the water distributed from the Taradale reservoirs:

- South towards Puketapu along Church Road.
- East towards Greenmeadows under existing properties.
- North into Tamatea via the Durham PRV.

While there are capacity constraints through all three, only the southern route is proposed for upgrade: the northern route is less stressed and upgrading the existing 375mm pipe east towards Greenmeadows was considered too challenging.

Task 3-2: Construct a new 600mmØ outlet pipe from the Taradale Reservoir down to Church Road. Additionally, upgrade the existing 150mmØ south along Church Road to 375/450mmØ down to Puketapu Road.

It may be possible to repurpose the existing rising main along Church Road as a distribution main. This may reduce or eliminate the need for the Church Road 375/450mmØ upgrade, but would require an increase in the size of the proposed rising main in Task 3-1. This option should be investigated.

Task 3-3: To retain FW2 fire flow availability it will be necessary to:

- Upgrade existing 150mm 1973 AC pipe along Waterhouse Street to 200mm, from Puketapu Road to O'Dowd Road (640m in length).
- Upgrade existing 200mm 1972 AC pipe along Puketapu Road to 300mm, from Church Road to Gloucester Street (400m in length).
- Upgrade existing 100mm cross-connection at the intersection of Howard Road and Frickleton Street to 150mm (50m in length).
- Upgrade existing 100mm cross-connection at the intersection of Gloucester Road and Roskilda Crescent to 150mm (50m in length).
- Upgrade existing 100mm 1972 AC pipe along Elliott Street and Murphy Road to 150mm, from Howard Road to Frickleton Street (520m in length).

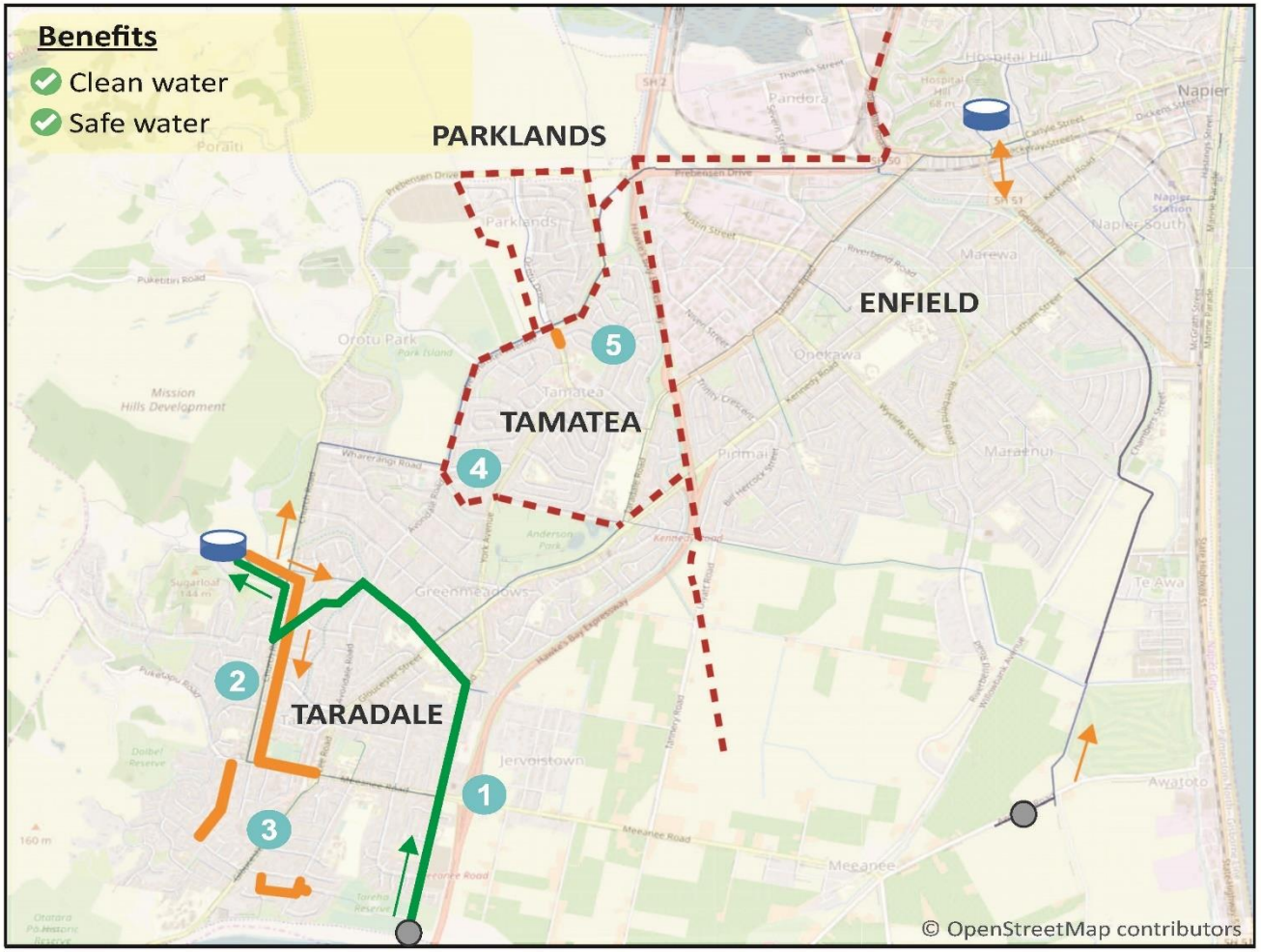
Some of these upgrades may not be required if NCC retains the Lee Road PRV as emergency-only, so it would only operate during fire flow demand.

Task 3-4: It is necessary to set all Taradale PRVs to only operate during emergencies, except for Durham PRV.

Task 3-5: To alleviate the marginal performance caused by the isolation of the Tamatea zone in Package 2, it is necessary to upgrade the existing 200mm/150mmØ pipe along Durham Avenue to 300mm/250mmØ, from Westminster Avenue to Southwark Avenue (110m in length).

This was not included in Package 2 to make it clear that the isolation of Tamatea and Parklands is recommended, at least as a trial, without the need for pipe upgrades.

Package 3: Dedicate Taradale



1. Construct new 450mmØ dedicated rising main to Taradale Reservoir
2. Construct new 600mmØ outlet pipe and upsize existing pipe along Church Road.
3. Upsize existing pipes along Waterhouse Street, Elliott Street and Puketapu Road. Upgrade cross connection at Frickleton Street.
4. Set all Taradale PRVs to not operate under normal peak demand, except for Durham PRV
5. Upsize existing pipe along Durham Avenue

Legend

- Existing water pipe
- Proposed dedicated rising main
- Proposed distribution main
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under current demand.

Operation: Church Road booster pumps into the Enfield distribution.

Cost Estimate: $10.6M assumes current T6 bore location is retained.

4.5 Package 4: Dedicate Enfield

This work package is aligned with all "Safe water", "Clean water", "Sufficient pressure" and "Resilient network" drivers.

Task 4-1: First it is necessary to confirm a preferred location for the Enfield Reservoir. Investigations are already under-way to identify candidates, to confirm the selection methodology and list possible risks and opportunities.

Task 4-2: NCC will then be able to proceed with land acquisition, if required, and then to construction.

Based on the relatively recent Taradale reservoir 2 construction, NCC estimates that the cost for this task is in the order of $7M including investigations/planning, land acquisition, earthworks and construction. We have added $1M to renew the pipework to and from the reservoir.

This will make the network more resilient by eliminating the risk associated with the poor condition of the Enfield Reservoir.

Task 4-3: Once a preferred location for the Enfield Reservoir is identified, it will be possible to finalise the Awatoto rising main, probably to the foot of the hill under the Enfield Reservoir.

Task 4-4: Extend the rising main from the Church Road Booster Pump Station up to the Awatoto rising main, probably at the foot of the hill under the Enfield Reservoir.

The cost estimates included in the work programme for Task 4-3 and 4-4 are based on the current location for the Enfield Reservoir: if the reservoir is relocated, this will lead to longer pipes and higher costs.

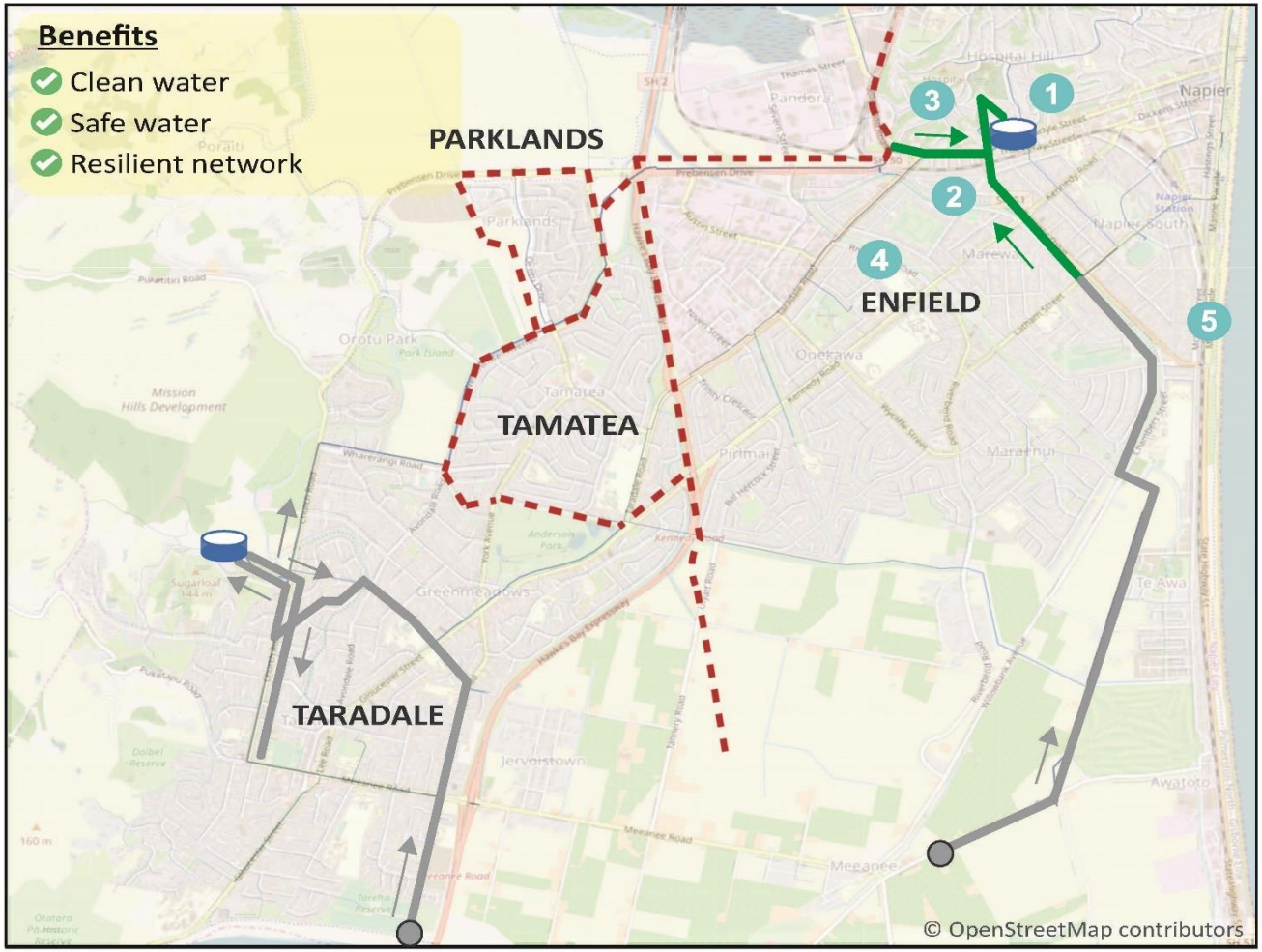
Task 4-5: To maintain sufficient pressure in the distribution network, the network restrictions identified during Calibration will need to be confirmed, located and eliminated. This is unlikely to require significant expense as they are likely to be a small number of closed valves or pipes being physically disconnected without this being captured in GIS. A series of field checks have been identified to try and identify these restrictions; these are presented in Appendix B.

Task 4-6: At this stage, NCC will be able to set all PRVs on the Enfield side and the McLean Pump Station to only operate during emergencies. However, as the Chaucer Booster would need to operate longer hours to compensate for McLean Park Pump Station (about 20 hours per day under PDD), NCC may wish to consider upgrading the Chaucer Pump Station. The Chaucer Pump Station would also need to take water from the Enfield Reservoir directly and not from the distribution. These were not included in this work programme.

This Work Package will complete the "Safe water" strategy of separating the water sources from the distribution.

It is important to note that the elevation of the new Enfield Reservoir is likely to have an impact on the upgrades required on the distribution. A higher reservoir is likely to reduce the need for pipe upgrades, while creating new costs and risks. This will be investigated as part of Task 3-1.

Package 4: Dedicate Enfield



1. Identify site and build new Enfield Reservoir
2. Complete Awatoto rising main
3. Upgrade pipe from Hyderabad Road to Awatoto rising main
4. Investigate and eliminate network restrictions found during calibration
5. Set all Enfield PRVs and McLean Pump Station to not operate under normal peak demand

Legend

- Existing water pipe
- Proposed dedicated rising main
- Proposed distribution main
- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under current demand.

Operation: N/A

Cost Estimate: $11.5M high uncertainty regarding Enfield Reservoir cost

4.6 Package 5: Manage Demand

This work package is aligned with the "Resilient network" driver: by reducing the water demand NCC will reduce the risk of exceeding the extraction limits from the aquifer, reduce the effect of a pipe or pump failure and increase the length of time the stored water volume can last in an emergency. It will also generate financial savings and demonstrate good stewardship of a natural asset.

Task 5-1: Undertake active leakage management by systematically looking for leaks. This can be done using different techniques such as acoustic detection, thermal imagery or hydrophones.

The cost for Task 5-1 cannot be estimated accurately as neither the goal, the techniques or the providers are known at present. A nominal allowance of $100,000 per year was included in the work programme as a place holder, but it is not based on any substantial knowledge at this stage.

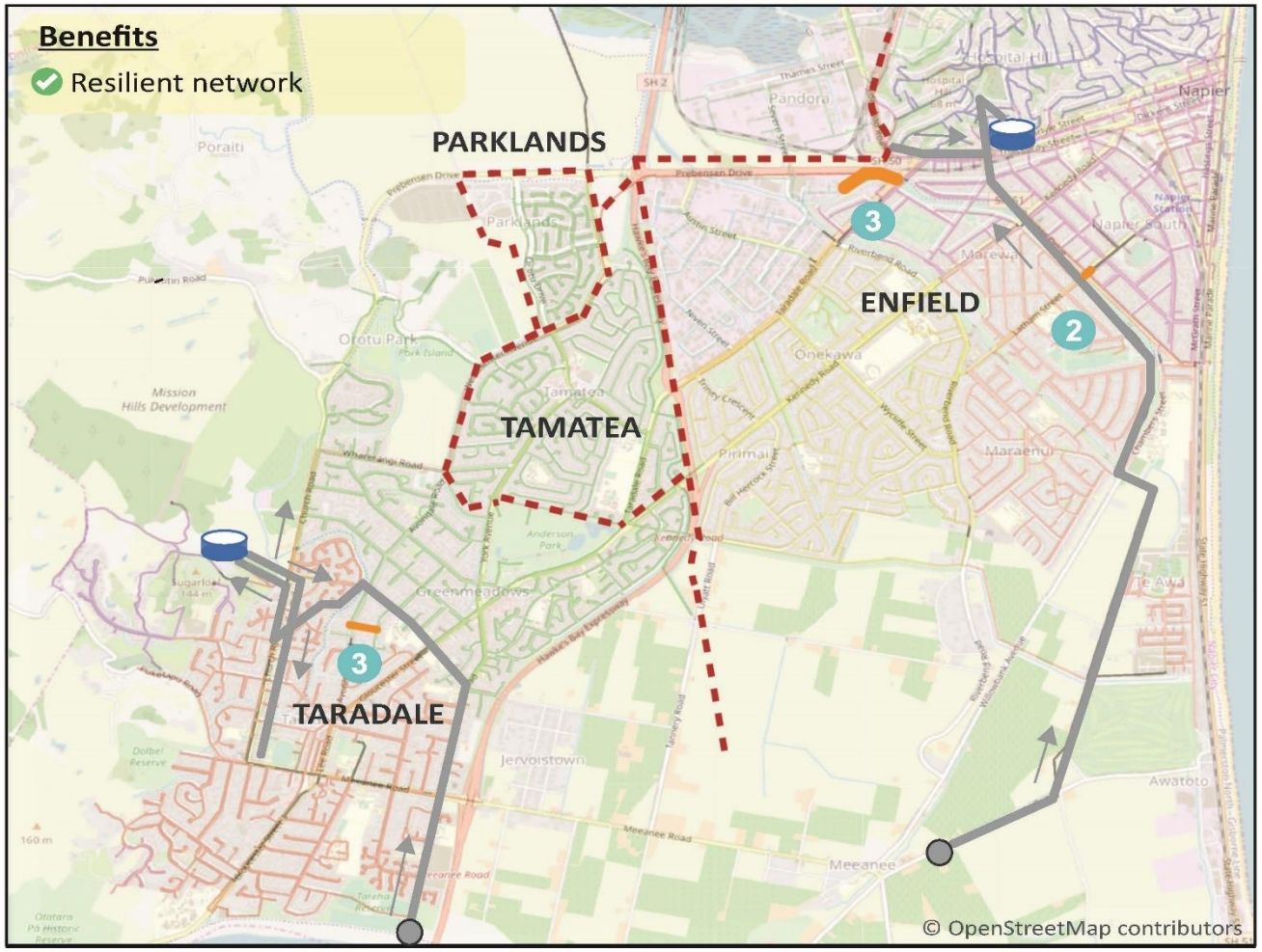
Tasks 5-2: To enable the subsequent setup of DMAs and maintain 20m pressure under peak demand, it is necessary to install a new cross connection between the 150mm and 500mmØ pipes at the intersection of Latham Street and SH51.

Task 5-3: It is recommended that the DMA layout identified in previous work by both Thomas Consultant (2017) and Stantec (2018) be implemented. This will require installing approximately 22 flow meters, detailed in Appendix C. To retain FW2 fire flow availability it will be necessary to:

- Upgrade existing 100mm 1975 AC pipe along Blenheim Street, to 150mm (170m in length).
- Upgrade existing 100mm 1950 CI pipe laid along the Ford Street accessway, to 150mm between Taradale Road and No60 / Superfly amusement Park (330m in length).

This will enable NCC to better monitor water usage, night flow and leakage, thus speeding up leak detection and repair. It will also provide better information to support decisions and consultation pertaining to customer usage.

Package 5: Manage Demand



1. Undertake active leakage detection and repair
2. Construct 300mØ cross-connection between 150mmØ and 500mmØ existing mains on Latham Street
3. Form DMAs (closed valves and flow meters) and upsize existing pipes along Blenheim Street and Ford Street

Legend

- CBD
- Enfield Centre 1
- Enfield Centre 2
- Greenmeadows
- Onekawa Industrial
- Otatara
- Pandora
- Taradale
- Thompson Boosted
- Thomspon Gravity
- Western Hills
- Proposed distribution main
- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under current demand.

Operation: N/A

Cost Estimate: 6.6M assumes current Enfield Reservoir location and ongoing active leakage management OPEX.

4.7 Package 6: Connect Awatoto Bores to Taradale

This work package is aligned with the "Resilient network" driver: by providing a dedicated pipe between the Awatoto bores and the Taradale system, it enables the water supply to operate for a period of time if the Taradale bores are out of operation.

As the future location and capacity of the Awatoto bores is still the subject of investigations (Package 1), it is not yet possible to confirm how long the network could operate solely with an Awatoto supply. For the purpose of this work, we assumed that the Awatoto bore field can produce 500 l/s and that the Taradale bore field is not operational.

Water will normally be pumped from the Awatoto bore field into the dedicated rising main finalised in Work Package 4. Work Package 6 consists in using the existing 300mmØ branch going west from Eriksen Road along Harold Holt Avenue up to Taradale Road. This pipe is currently shut but from Work Package 3 onwards it is expected to be part of the distribution network and to remain open. However, it may be used in emergency situations to convey water from the Awatoto bores to the Taradale rising main if:

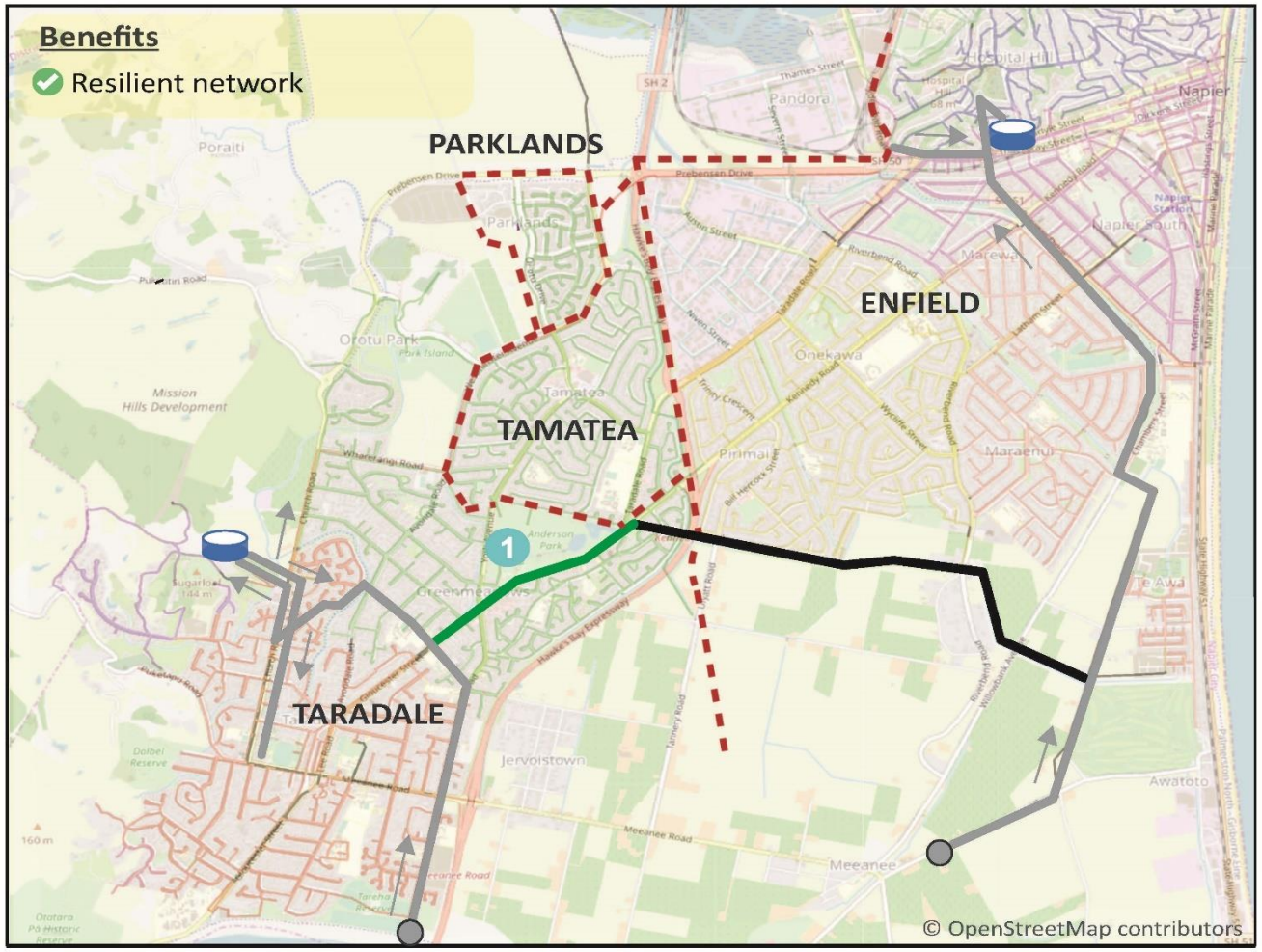
- Operations close existing valves to isolate the pipe from the distribution.
- The pipe is extended to connect to the Taradale rising main.

Task 6-1: Extend the existing 300mmØ pipe from the intersection of Kennedy Road and Taradale Road, along Kennedy Road to the proposed rising main from the Taradale bores (Work Package 3). This requires constructing 1.6km of 350mmØ pipe.

The hydraulic model suggests that, with this upgrade and 500 l/s pumping capacity at the Awatoto bores, the supply can be maintained for approximately 30 hours under current peak demand. After that time, the Taradale reservoirs drain entirely and the supply will be interrupted in the Taradale zone unless NCC modifies the network configuration. For example the delineation valves between Taradale and Enfield could be temporarily re-opened.

It should be noted that the current system can already operate if the Awatoto bores are out of service, essentially because the Church Road Booster Pump Station can transfer water from Taradale to Enfield.

Package 6: Connect Awatoto to Taradale



1 Construct 350mmØ rising main along Kennedy Road

Legend

- Existing pipe, can be used as rising main
- Proposed dedicated rising main
- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under future demand.

Operation: Approximately 24 hours of operation under peak demand before Taradale Reservoir drains, depending on the Awatoto bore capacity

Cost Estimate: $2.1M

4.8 Package 7: Rationalise the Thompson Reservoir Pipework

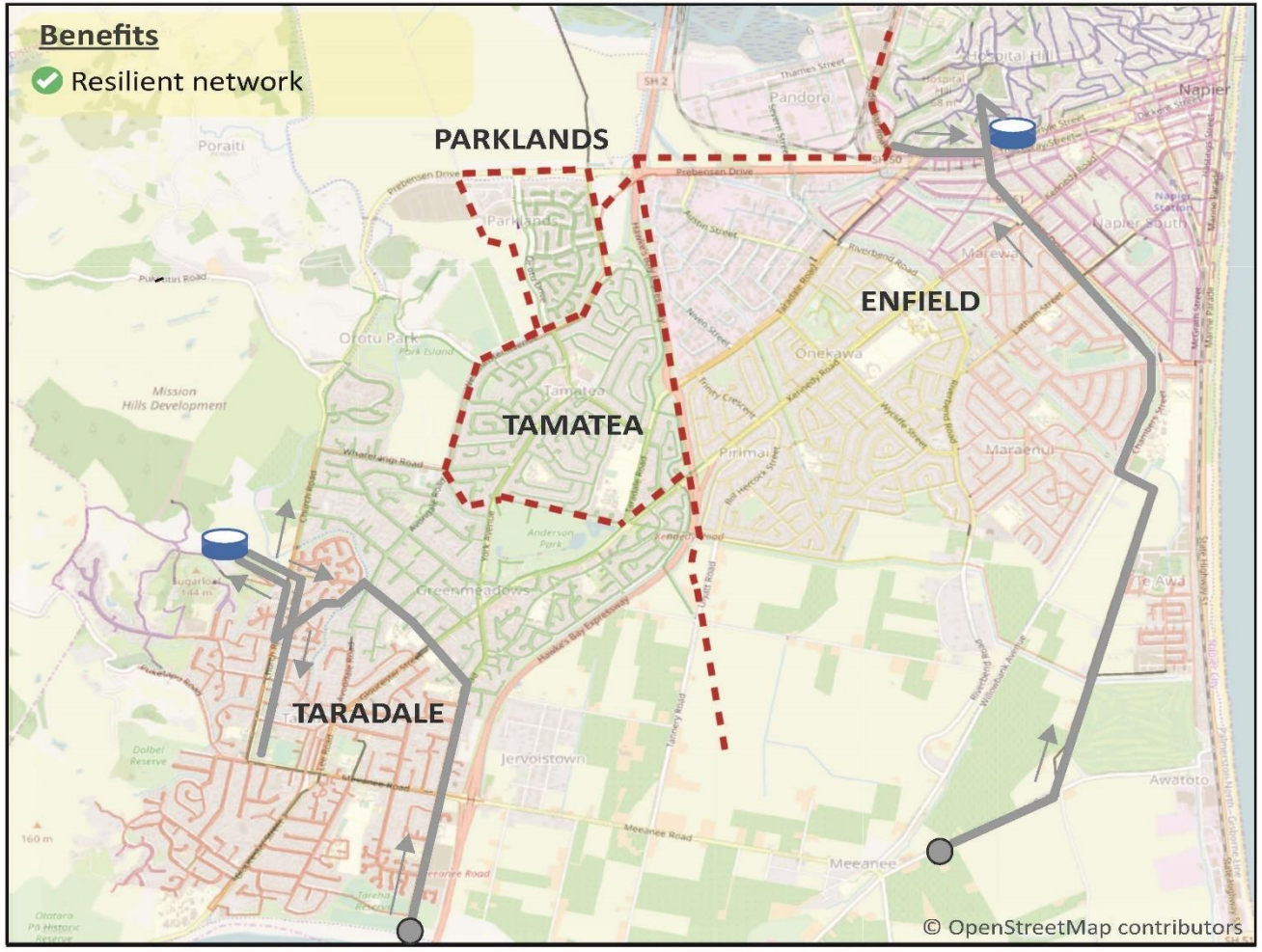
This work package is aligned with the "Resilient network" driver: by simplifying the pipework around the Thompson Reservoir, NCC will reduce the time and complexity of a possible emergency pipe repair near the reservoir.

Task 7-1 is only loosely defined, and is expected to include:

- An investigation phase with an excavation of existing pipes, some of which are known to be as deep as 4-5m.
- A planning phase to confirm the preferred arrangement with the three existing tanks in the future.
- A design phase to confirm the preferred pipework layout.
- A construction and commissioning phase.

The cost for this cannot be estimated accurately at this point. A nominal allowance of $300,000 has been included in the work programme but this needs to be confirmed once the preferred layout is identified and pipe marking/localisation has been completed.

Package 7: Rationalise Thompson Reservoir Pipework



1 Investigate and upgrade existing pipework at Thompson reservoirs (outside map)

Legend

- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure under future demand.

Operation: N/A

Cost Estimate: Cannot be estimated accurately at this point. $0.3M included in master plan as place-holder.

4.9 Package 8: Ensure FW2 Fire Flow Availability

This work package is aligned with the "Pressure" driver. Pipe upgrades are required in several parts of the existing network to ensure FW2 fire flow availability.

Existing fire deficiencies which are eliminated by upgrades captured in previous work packages are not addressed in this section. Fire deficiencies which are created by previous work packages are addressed by upgrades included in the relevant work package.

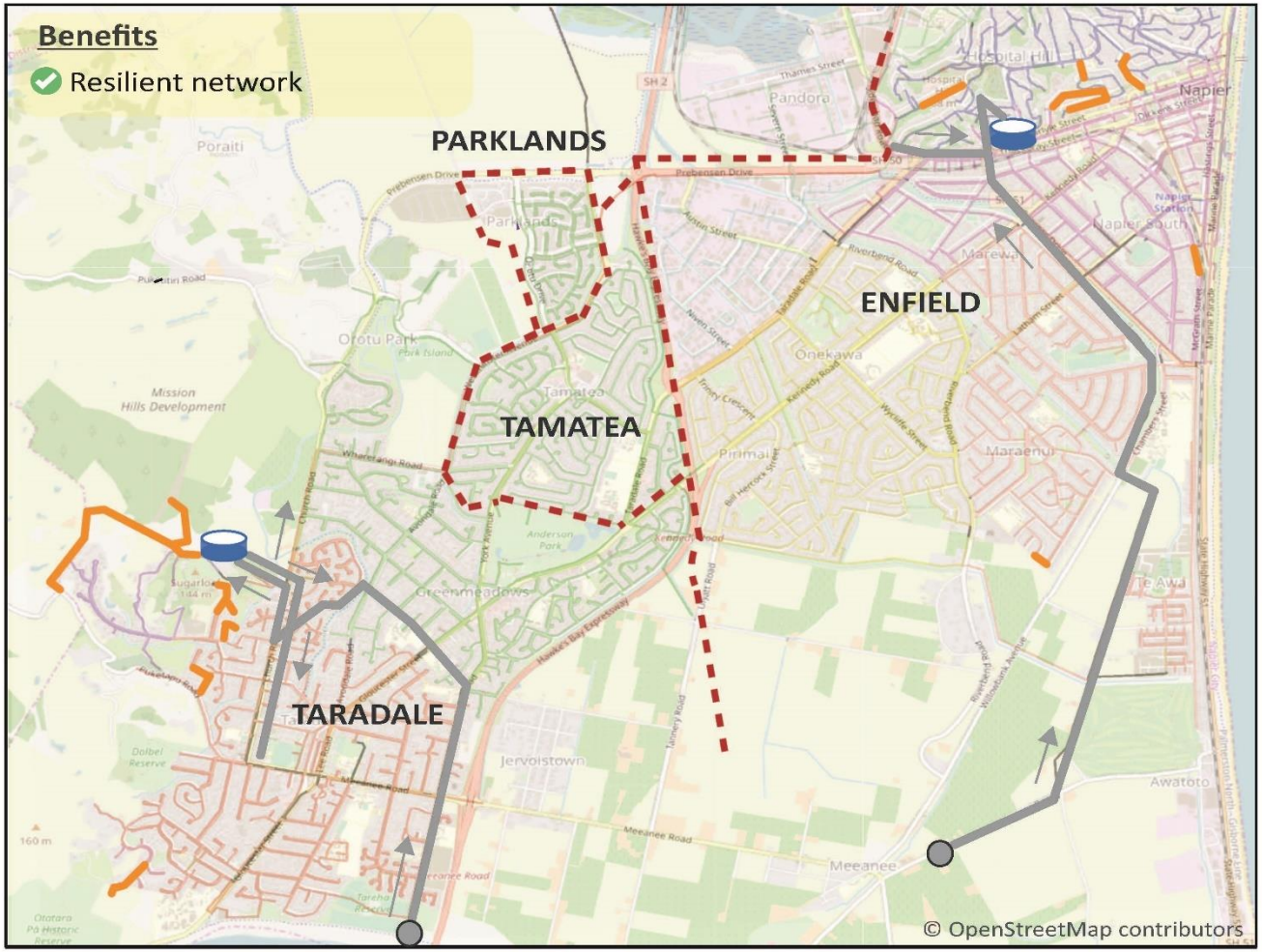
Existing upgrades which are not eliminated by previous work packages require a series of 16 pipe upgrades, listed in Appendix D and shown in the plan below.

Table 4-2: Fire Upgrades

8-1: Upgrade existing 150mmØ pipe along Franklin Road/Le-Quesne Road to 200mmØ, between Main North Road and No. 48 Le-Quesne Road (1700m in length).
8-2: Upgrade existing 100mmØ pipe along Onehunga Road to 150mmØ, between No. 190 and No. 262 Onehunga Road (790m in length).
8-3: Upgrade existing 150mmØ pipe along Hill Road to 200mmØ, between Terrace Road and Petane Road (130m in length). Additionally, construct a new 150mmØ cross-connection between the existing 150mmØ pipe at the proposed 200mmØ pipe at the intersection of Main North Road and Hill Road (near node Asset ID XXXX000002, 50m in length). Additionally, upgrade existing 100mmØ pipe along Hill road to 150mmØ, between Franklin Road and Terrace Road (350m in length) and between Petane Road and No. 80 Hill Road, excluding the existing section of 150mmØ pipe in between (430m in length).
8-4: Upgrade existing 100mmØ crossing the property at No. 54 The Esplanade to 150mmØ (90m in length). Additionally, upgrade existing 50mmØ/75mmØ pipe along The Esplanade to 150mmØ, between No. 54 and 99 The Esplanade (680m in length)
8-5: Upgrade existing 150mmØ along Kipling Avenue to 200mmØ, between Napier Terrace and Hooker Avenue (170m in length). Additionally, upgrade existing 75mmØ along Faraday Street to 150mmØ, between Hooker Avenue and Smale Terrace (410m in length). Move the boundary valve to south of the hydrant at the intersection of Smale Terrace and Faraday Avenue. Additionally, upgrade existing 100mmØ along May Avenue to 150mmØ, between Hooker Avenue and No. 23 May Avenue (180m in length).
8-6: Extend existing 100mmØ pipe at No. 4 Guys Hill Road and connect to the existing 75mmØ pipe along Chaucer Road South (50m in length). Additionally, upgrade existing 75mmØ/100mmØ main at the intersection of Chaucer Road South and Guys Hill Road to 150mmØ (10m in length), and create a 150mmØ cross-connection between existing 350mmØ rising main and proposed upgraded pipe (10m in length).
8-7: Create a new 100mmØ cross connection between the existing 75mmØ and 100mmØ pipes at the intersection of George Street and Bracken Street.
8-8: Upgrade existing 100/50mmØ pipe along Main Street to 150mmØ, between Spencer Road and No. 25 Main Street (260m in length).
8-9 Upgrade existing 75mmØ pipe along Milton Road to 150mmØ, between Cameron Road and No. 6 Milton Road (230m in length).
8-10: Upgrade existing 100mmØ pipe along Tironui Drive/Puketapu Road to 150mmØ, between No. 62 Tironui Drive and No. 255 Puketapu Road, excluding the existing section of 150mmØ pipe in between (1700m in length). Additionally, upgrade existing 150mmØ pipe outlet from Western Hill Reservoir to No. 82 Tironui Drive to 200mmØ (460m in length).

8-11: Construct a new 100mmØ pipe between existing 100mmØ pipe at Masefield Avenue and existing 100mmØ pipe at Mason Avenue (130m in length).
8-12: Upgrade existing 100mmØ pipe along Birdwood Street/Harpham Street to 150mmØ, between Nicholas Street and No. 12 Birdwood Street (220m in length).
8-13: Upgrade existing 100mmØ pipe along Ewan Place/Kent Terrace to 150mmØ, between Nicholas Street and No. 9 Ewan Place (130m in length).
8-14: Upgrade existing 100mmØ pipe to 150mmØ from Halliwell Reservoir to Cumberland Rise Extension (210m in length).
8-15: Upgrade existing 100mmØ pipe to 150mmØ from Otatara Reservoir to Poaka Place (340m in length).
8-16: Upgrade existing 75mmØ pipe along Wellesley Road to 100mmØ, between Todd Street and No. 26 Wellesley Road (270m in length).

Package 8: Ensure FW2 Fire Flow Availability



1 Multiple pipe upsize through-out network

Legend

- Proposed distribution main
- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure and FW2 fire protection under current demand.

Operation: N/A

Cost Estimate: $4M

4.10 Package 9: Enable Growth

This work package is aligned with the "Pressure" driver: urban intensification and greenfield expansion will add more demand onto the system, leading to higher velocity in pipes and less pressure for customers. To retain the Level of Service, several pipe upgrades will be required.

The works presented in this section assume that all pipe upgrades included in other work packages have been completed. It also requires knowing the preferred location of the Enfield Reservoir (Task 4-1).

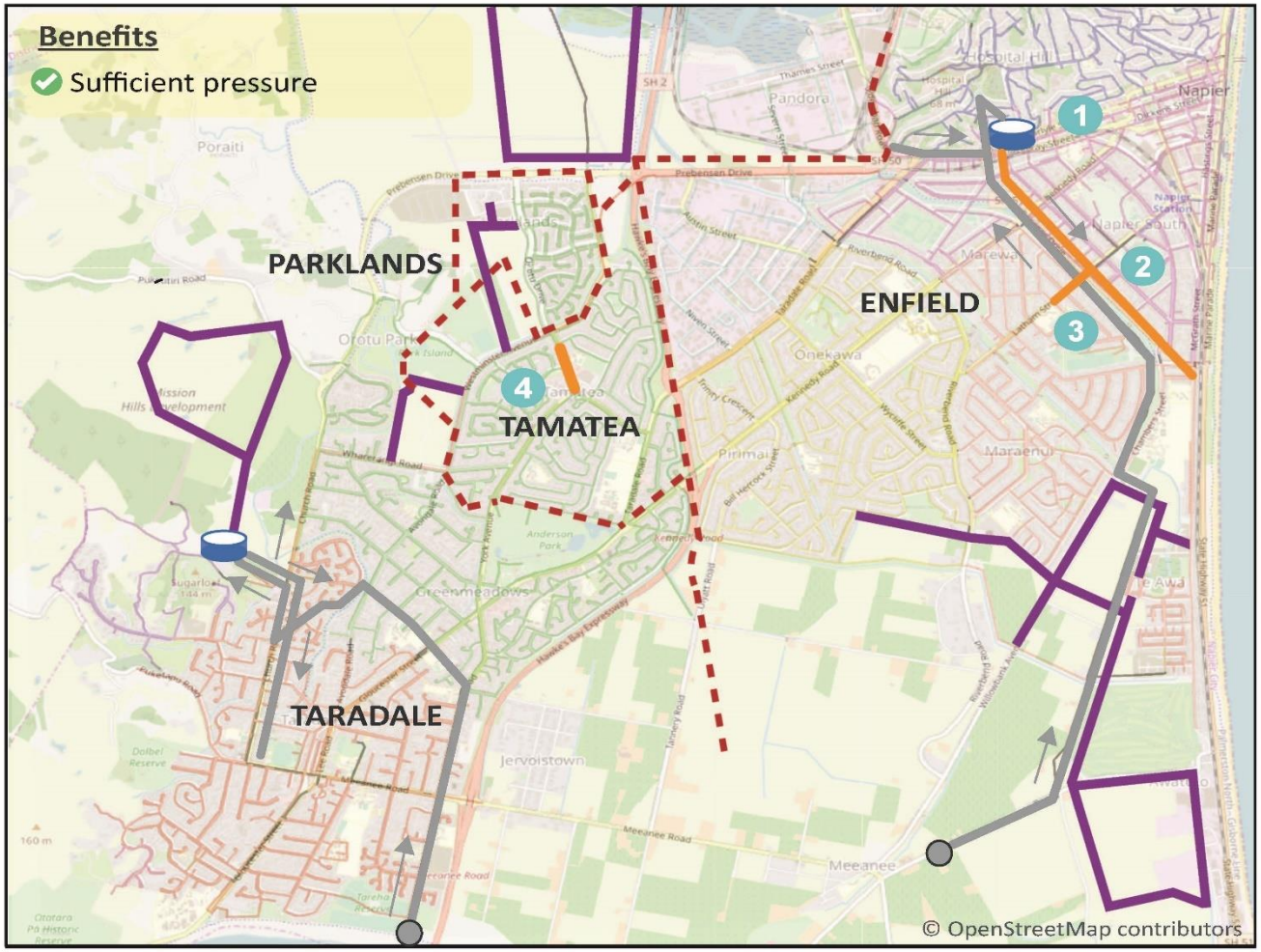
Task 9-1 consists in providing distribution network extensions to reach and supply greenfield developments. These extensions have been estimated based on the zones drawn in the HPUDS, but they will need to be revised as more details become available regarding the greenfield developments. As these are expected to be paid for by developers, no cost estimate was included in the work programme.

It will also be necessary to increase the capacity between the Enfield Reservoir and the south-eastern part of the city. In particular this includes:

- **Task 9-2:** Construct a new 375mmØ distribution main from the Enfield Reservoir, down to Thackeray Street. Additionally, upgrade the existing 100mmØ pipe along SH51 from Thackeray Street to Te Awa Avenue (2,170m in length).
- **Task 9-3**: Construct a new 300mmØ main along Latham Street from Douglas McLean Avenue to Barker Road (230m in length).
- **Task 9-4**: Upgrade existing 150mmØ 1970 AC pipe along Durham Avenue to 200mmØ, from Southwark Avenue to York Avenue (110m in length).

It is important to note that the elevation of the new Enfield Reservoir is likely to have an impact on the upgrades required on the distribution. A higher reservoir is likely to reduce the need for pipe upgrades, while creating new costs and risks. This will be investigated as part of Task 4-1.

Package 9: Enable Growth



1. Extend distribution as part of greenfield developments
2. Construct new 375 mmØ outlet from Enfield Reservoir and upsize existing pipe along Georges Drive
3. Upsize existing pipe along Latham Street
4. Upsize existing pipe along Durham Avenue

Legend

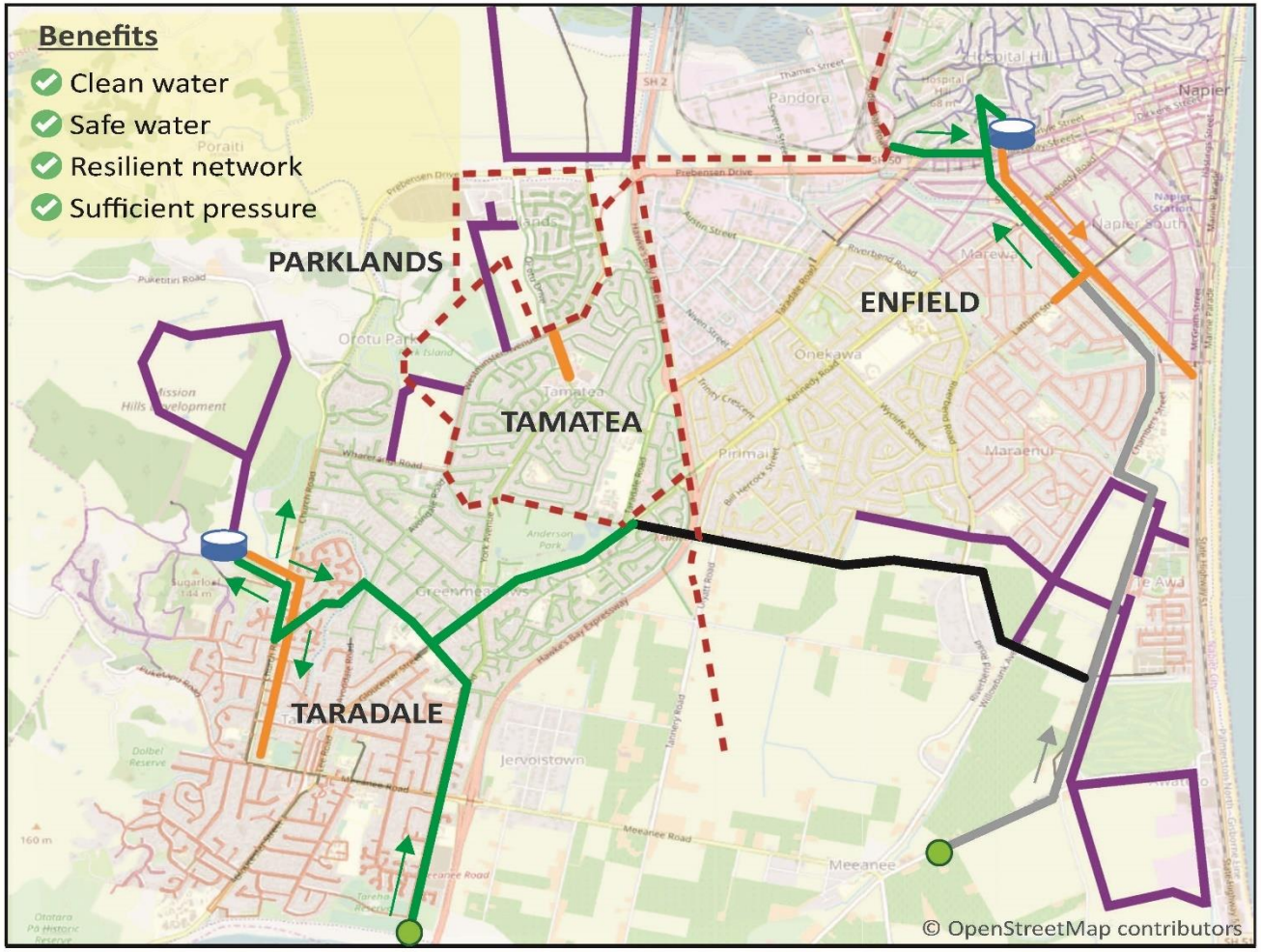
- Greenfield developments
- Proposed distribution main
- Upgrades from previous stage
- Reservoir
- Proposed new pressure zone delineation
- Bore field (location determined in previous stage)

Level of Service: Sufficient capacity to achieve 20m minimum pressure and FW2 fire protection under future demand.

Operation: N/A

Cost Estimate: 3.5M assumes current Enfield Reservoir location

Napier Water Supply Master Plan



Legend (only key elements shown)

- Greenfield developments
- Proposed distribution main
- Proposed dedicated rising main
- Existing pipe, can be used as rising main
- Existing rising main
- Reservoir
- Proposed new pressure zone delineation
- Bore field, potentially new location for pipe extentions and treatment

Level of Service: Sufficient capacity to achieve 20m minimum pressure and FW2 fire protection under future demand.

Operation: N/A

Cost Estimate: $40.6M

5. Recommendations

It is recommended that:

- NCC reviews and confirms the work programme presented in this document.
- NCC stages the work programme (1-, 3-, 10- and 30-years horizons), either based on available budget or on required outcomes.
- NCC continues the investigations currently under-way for the most urgent tasks, which will allow other tasks to be started:
    - "Clean water" driver:
        - Understand the mechanisms at play in the discoloration episodes.
        - Confirm preferred bore locations.
        - Confirm the treatment strategy.
        - Clarify costs associated with the preferred option and update this master plan.
    - "Resilient network":
        - Confirm the preferred location for the Enfield reservoir.
        - Clarify costs associated with the preferred option, in particular the impact on pipe upgrades, and update this master plan.
        - Clarify water demand management objectives and activities.
- NCC undertakes an option assessment comparing:
    - Increasing the network capacity so the Lee Road PRV does not operate, even under FW2 fire demand (as per this master plan).
    - Relying on the Lee Road PRV even for FW2 fire demand.
- NCC undertakes an option assessment comparing:
    - Constructing a new rising main and a new distribution pipe to and from Taradale Reservoir (this master plan).
    - Using the existing 450mm rising main along Church Road as a distribution main and increasing the size of the proposed rising main.
- NCC updates this master plan regularly and when critical new information becomes available, in particular assumptions regarding the population growth, greenfield developments or future water use.

Appendices

Appendix A Costing Assumptions

The cost estimates presented in this report include:

- Construction cost.
- Professional services (planning, design, investigations, stakeholder engagement…)
- Risk and contingency.

Pipe rates were based on figures used for Tauranga City Council since 2009, and anecdotally verified to be still valid in that region. We included a 15% mark-up for professional services and an additional 40% contingency.

Description	**Pipe Diameter (mm)**							
	50	**100**	**150**	**200**	**250**	**300**	**350**	**375**
Pipe & Fittings supply and installation (2008/2009)	$105	$150	$250	$350	$500	$700	$820	$820
incl. Professional Services (15%)	$121	$173	$288	$403	$575	$805	$943	$943
incl. Risks and Contingency (40%)	$169	$242	$403	$564	$805	$1,127	$1,320	$1,320
Adopted rate for 2019 NCC master plan	**$169**	**$242**	**$403**	**$564**	**$805**	**$1,127**	**$1,320**	**$1,320**
	166	237	395	553	791	1107	1297	1297

Description	**Pipe Diameter (mm)**							
	400	**450**	**500**	**525**	**550**	**600**	**700**	**800**
Pipe & Fittings supply and installation (2008/2009)	$900	$983	$1,035	$1,035	$1,150	$1,150	$1,260	$1,360
incl. Professional Services (15%)	$1,035	$1,130	$1,190	$1,190	$1,323	$1,323	$1,449	$1,564
incl. Risks and Contingency (40%)	$1,449	$1,582	$1,666	$1,666	$1,852	$1,852	$2,029	$2,190
Adopted rate for 2019 NCC master plan	**$1,449**	**$1,582**	**$1,666**	**$1,666**	**$1,852**	**$1,852**	**$2,029**	**$2,190**
	1423	1554	1637	1637	1818	1818	1992	2151

There are multiple **miscellaneous items** in the master plan, which were estimated at a high level and captured directly in the schedule of works. Where possible, these were based on experience and recent projects Stantec was involved in.

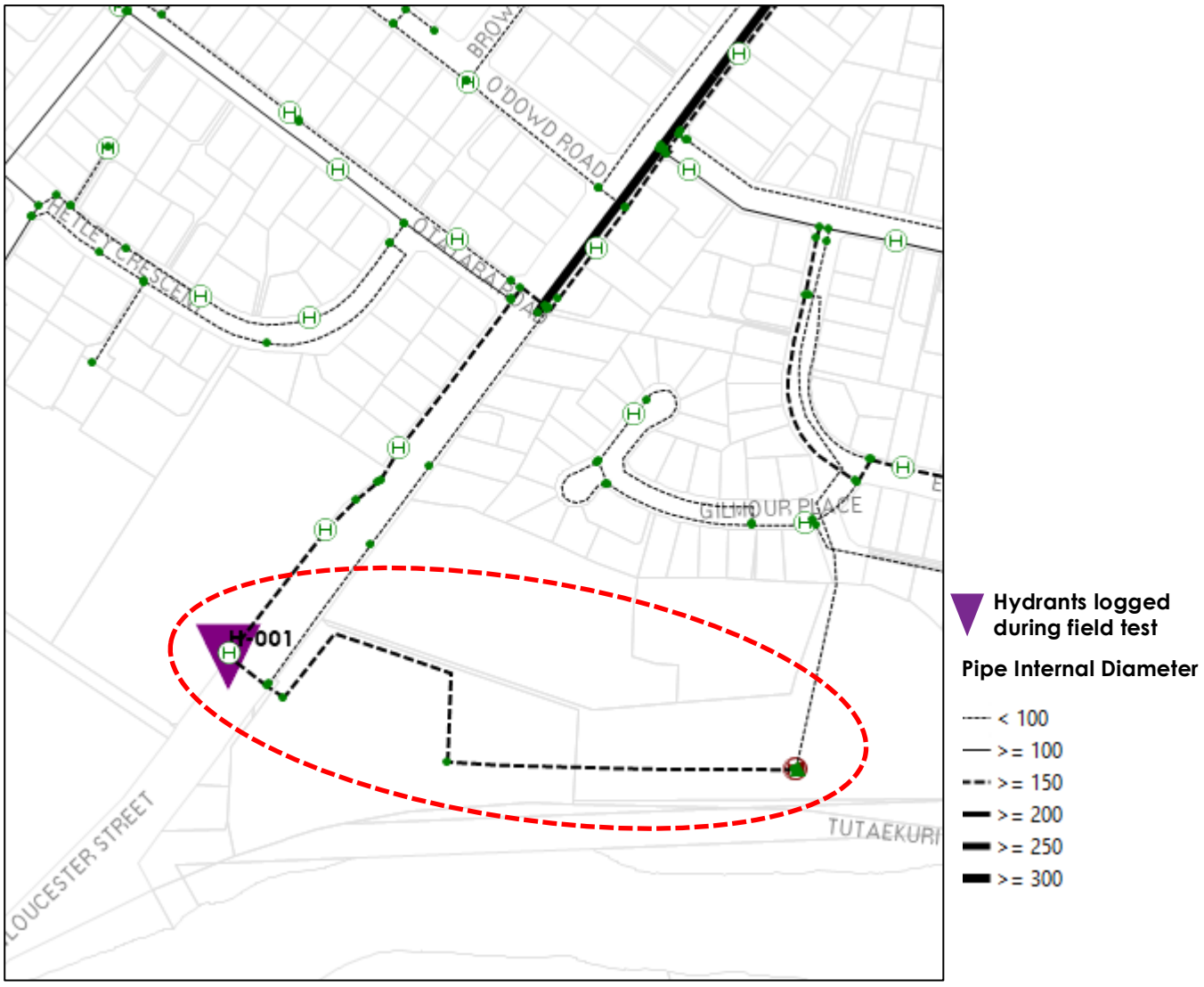
The largest unknown is the cost pertaining to the **Enfield Reservoir upgrade**. Recent reservoir construction works in the Wellington region suggest a cost of $9M for a 11ML reservoir. As the site for the Enfield Reservoir is likely to be challenging, Stantec considers this should be considered a minimum. Recent construction works in Napier suggest a cost closer to $7M. At NCC's request, this $7M figure was included in the master plan, along with $1M to renew the pipework to and from the reservoir.

Appendix B Field Checks

B.1 Gloucester Street

There is a possible restriction along the 200mmØ pipe between Taradale 3 Bore and hydrant H-001.

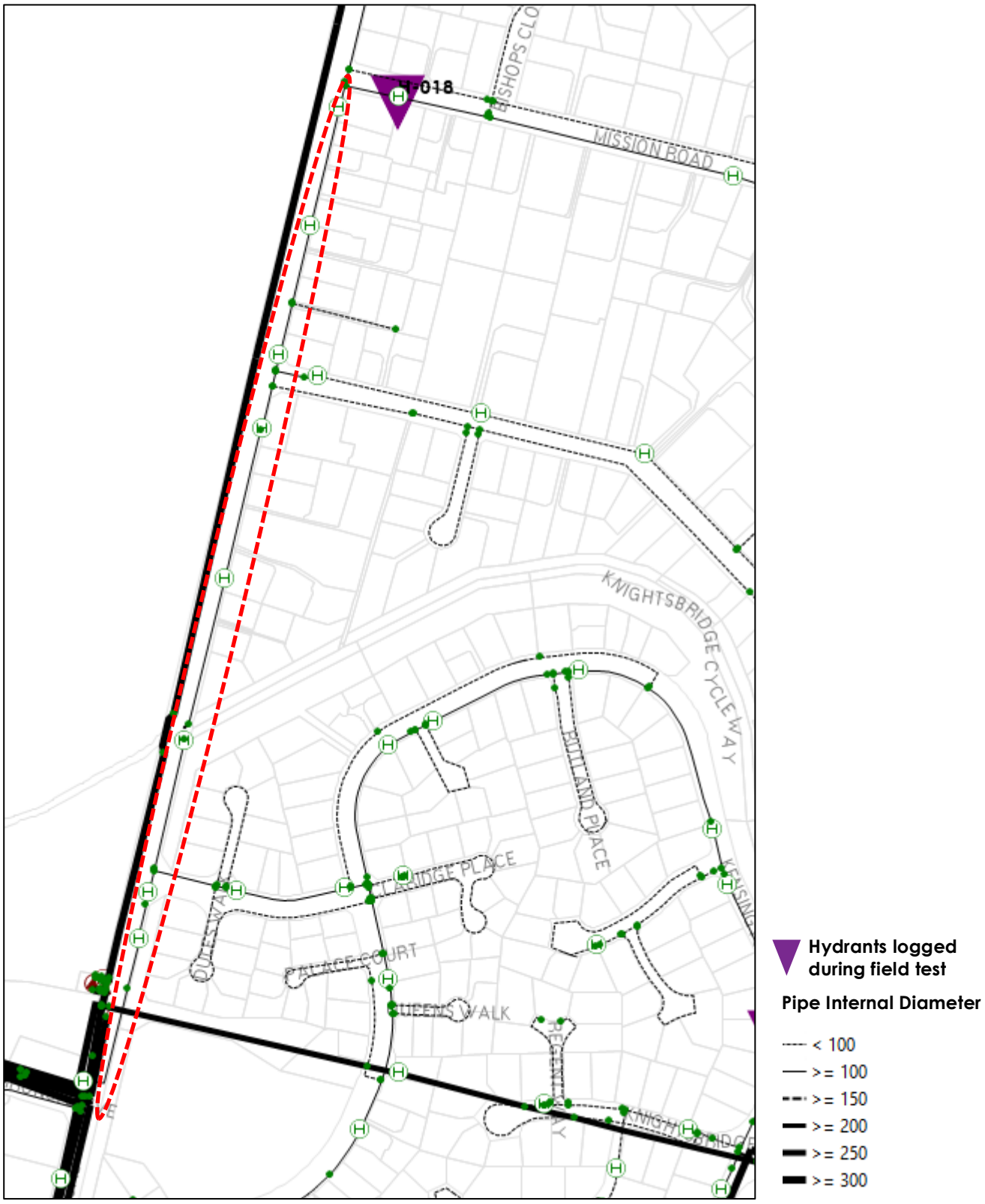
Check all valves along this pipe.



B.2 Church Road

There is a possible restriction along the 150mmØ pipe on Church Road between Tironui Drive and Mission Road, parallel to the 450mmØ Tamatea trunk upstream of hydrant H-018.

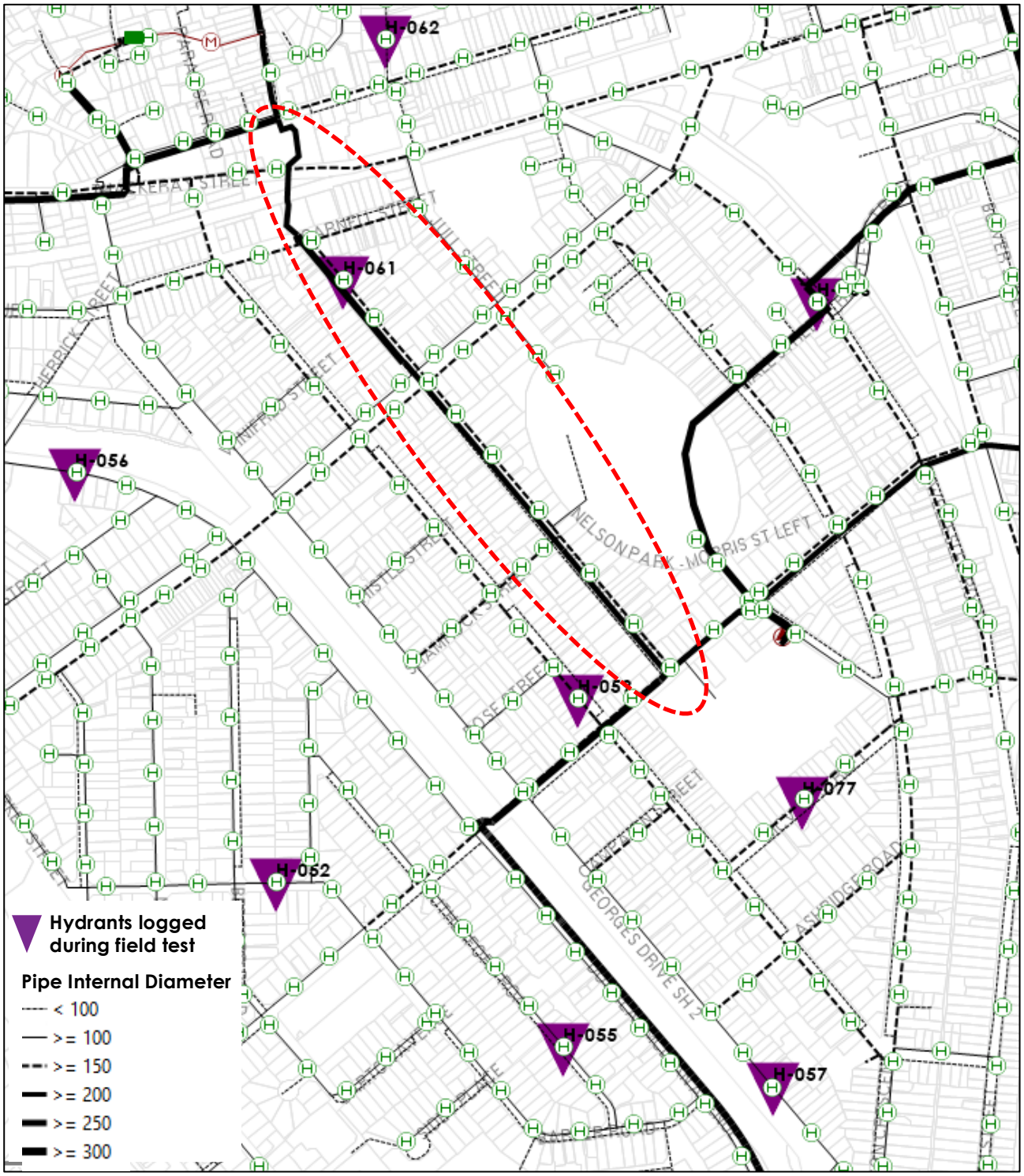
Check all valves along this pipe.



B.3 McDonald Street

There is a massive restriction in the network which affects the hydrants on the right side of the network, some of which are shown below (H-059, H-077, H-055, H-057).

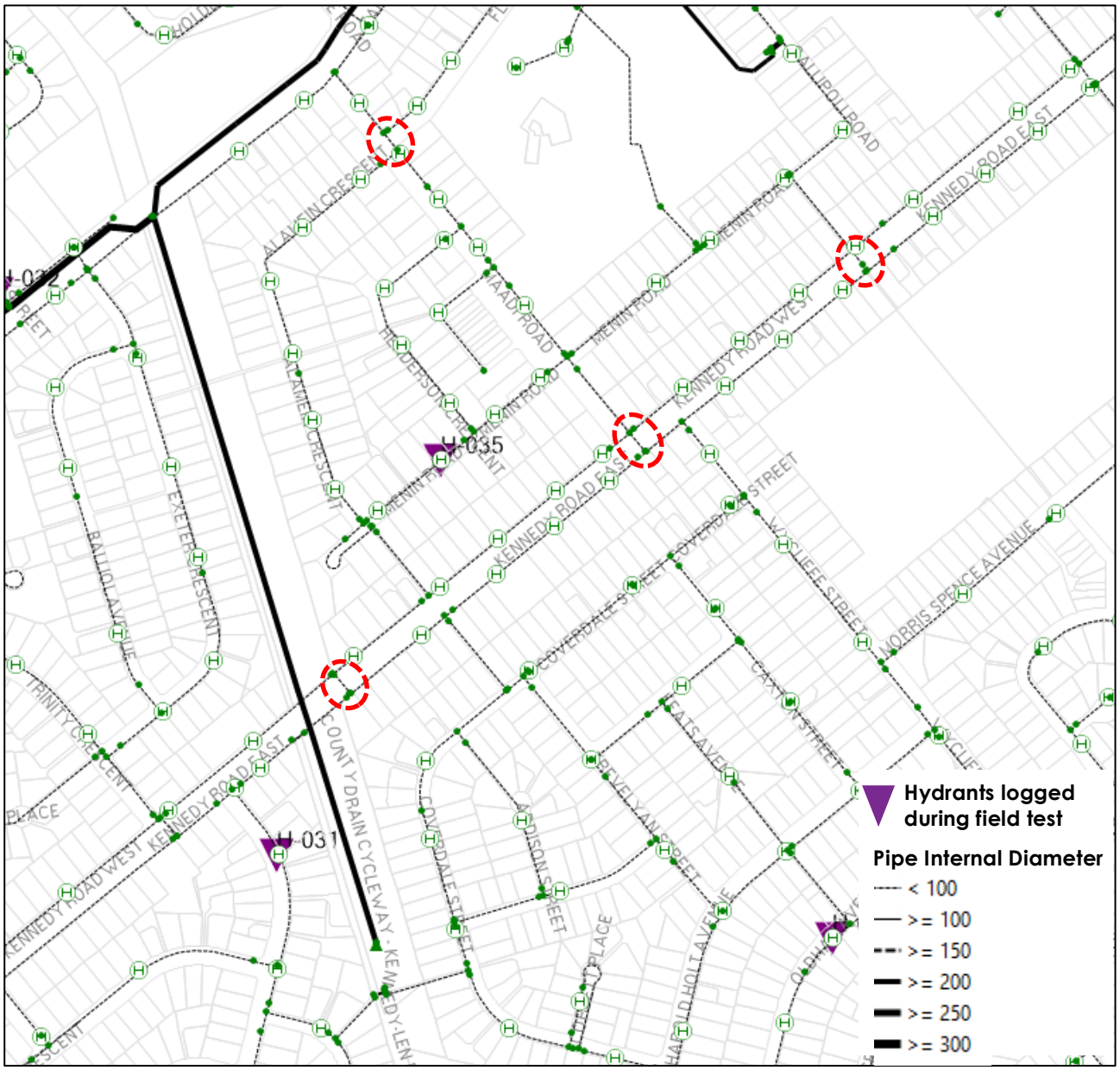
In the model, when a valve was closed in the 300mmØ pipe along McDonald Street, the matches in head between field and model data improved. Check all valves along this main. If checks come back clear of all valves along McDonald Street, the anomaly may be present in other mains and may not be restricted to just one main. A series of hydrant flow tests in the area may be necessary.



B.4 Kennedy Road/Maadi Road

When a combination of valves was closed in the model as shown below, there were improved matches between field data and model results. Opening these valves is likely to improve the pressures in the area. However, the pressure is sufficient in the area with the valves closed. Retaining the valves closed may reduce the number of flow reversals, and therefore limit the risk of discolouration.

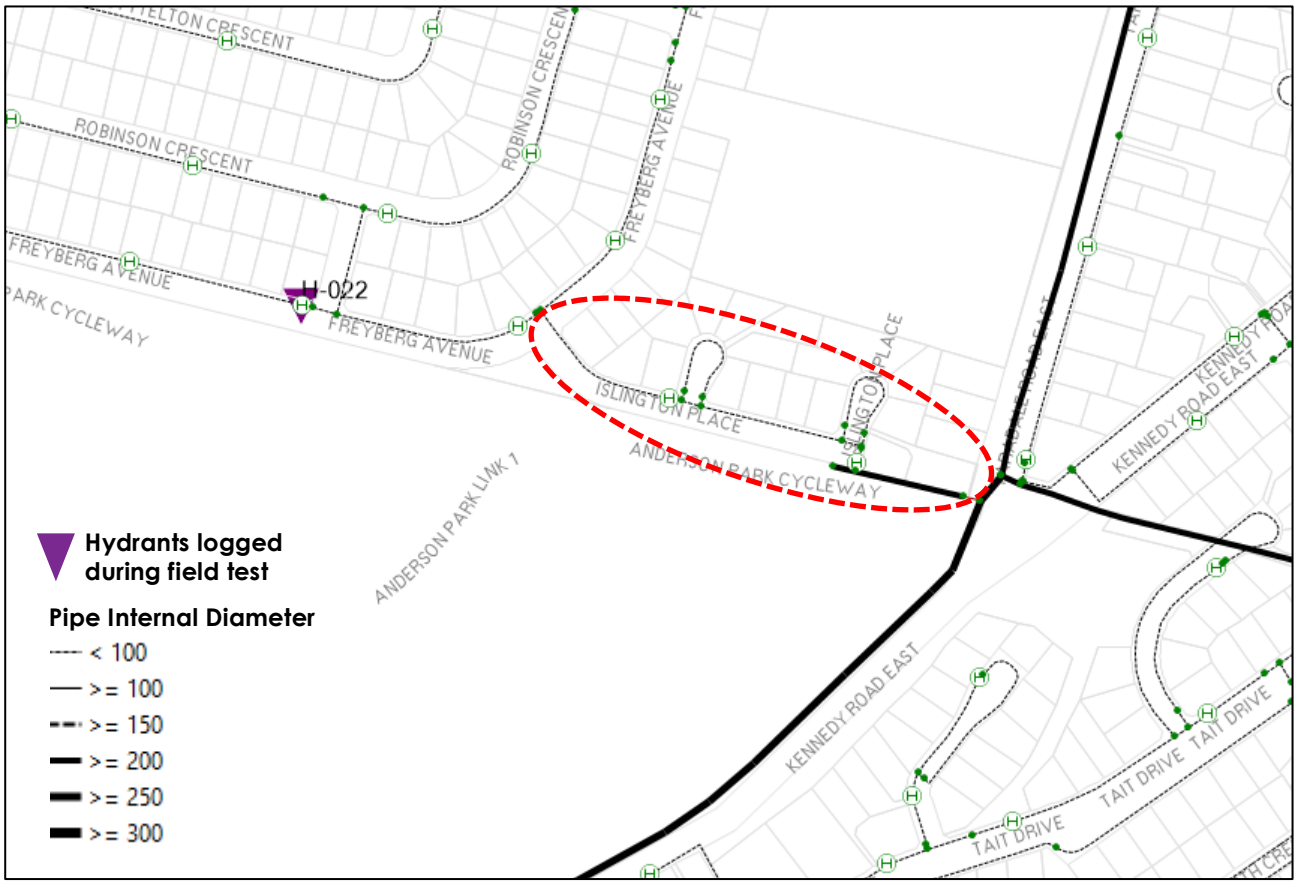
Check all valves along Maadi Road and Kennedy Rod between the County Drain and Douglas McLean Avenue to confirm open/close status for replication in the working model and GIS.



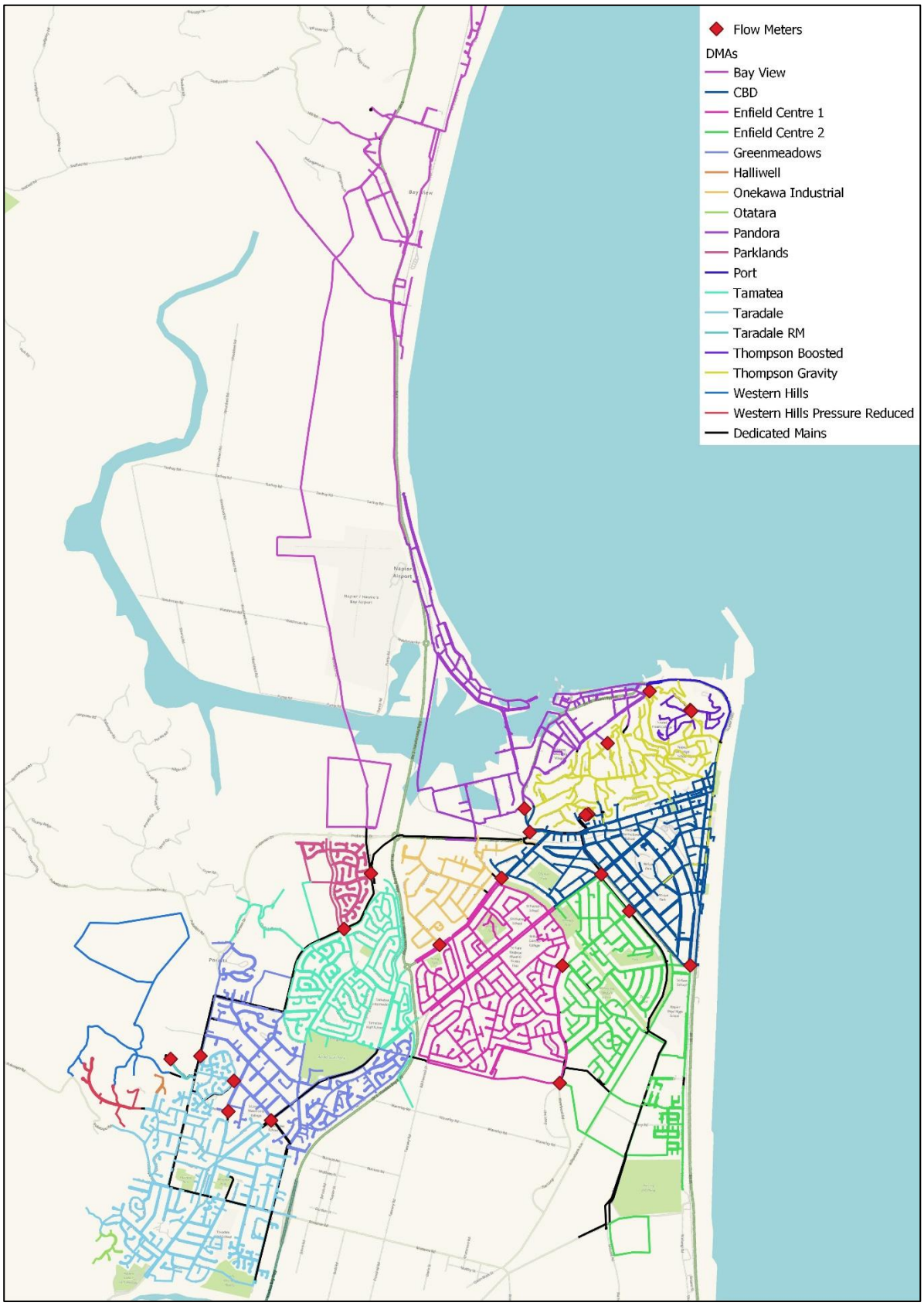
B.5 Islington Place

The model under-predicts the head at H-022 (along Freyberg Avenue). When a valve along the 300mmØ pipe between Kennedy Road and Islington Place was closed, the match between field and model data improved.

Check all the valves along this main and on the 150mmØ main along Islington Place.



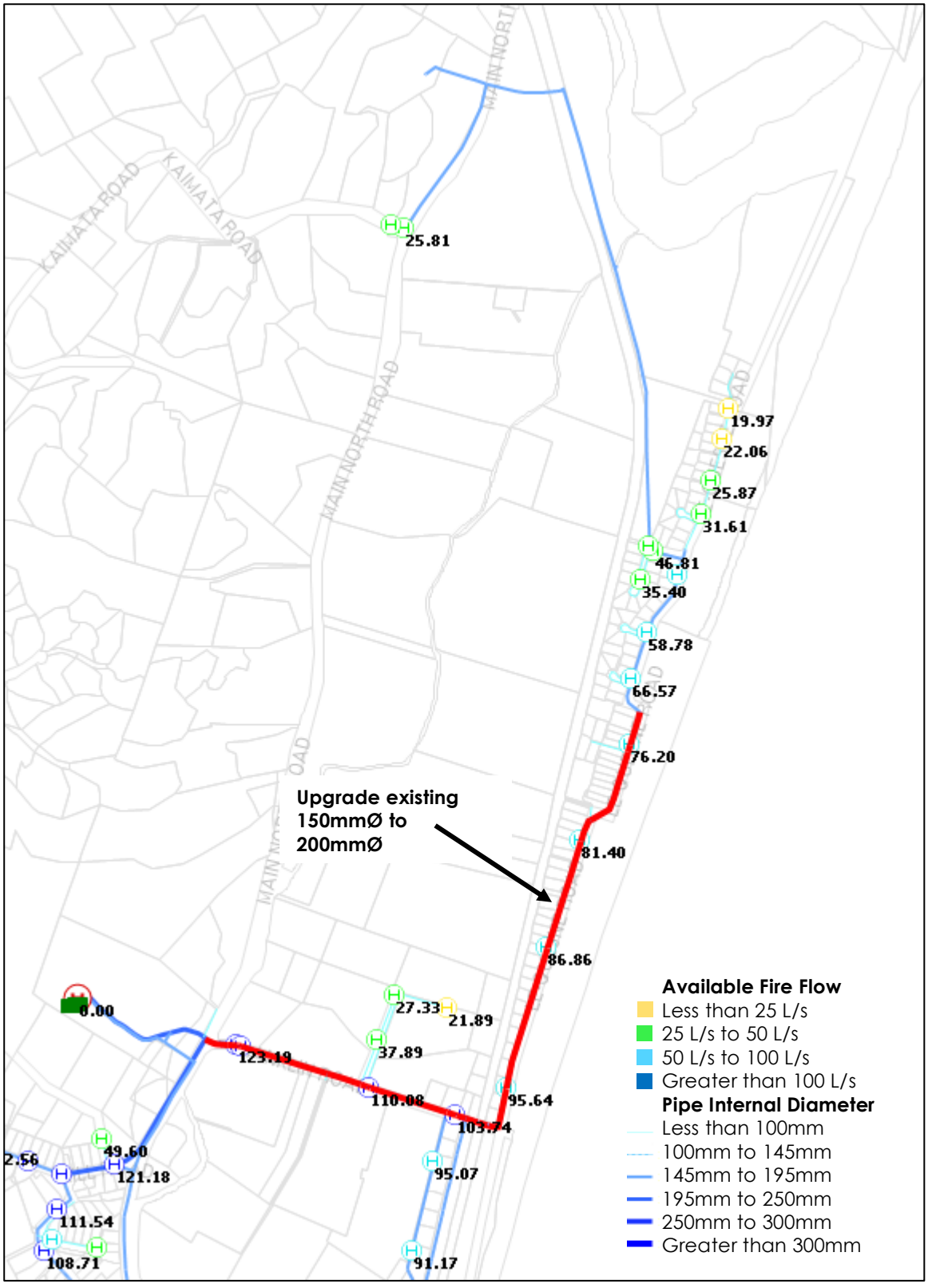
Appendix C Flow Meters



	Meter Location	Pipe Diameter (mm)	Pipe Material
1	Gloucester Street/Osier Road	200	AC
2	Avondale Road/Balmoral Street	150	AC
3	Brompton Drive	300	AC
4	259 Church Road	150	PVC
5	Taradale Reservoir Inlet	350	DI
6	Downstream of Durham PRV	200	PVC
7	Downstream of Pacific PRV	200	PVC
8	Niven Street	200	AC
9	Taradale Road/Riverbend Road	375	ST
10	Riverbend Road/Latham Street	150	CI
11	Riverbend Road/The Loop	300	AC
12	Te Awa Avenue/Georges Drive	150	PVC
13	Latham Street/Douglas McLean Avenue	300	PVC
14	Kennedy Road/Douglas McLean Avenue	150	ST
15	Prebensen Drive	450	DI
16	Enfield Reservoir Inlet	375	ST
17	Enfield Reservoir Outlet	300	ST
18	61 Hyderabad Road	300	AC
19	Downstream of Burns PRV	200	PVC
20	Downstream of Seapoint PRV	200	PVC
21	Thompson Square Reservoir Inlet	150	AC
22	Thompson Round Reservoir Inlet	300	CI

Appendix D Fire Upgrades

D.1 Franklin Road/Le-Quesne Road

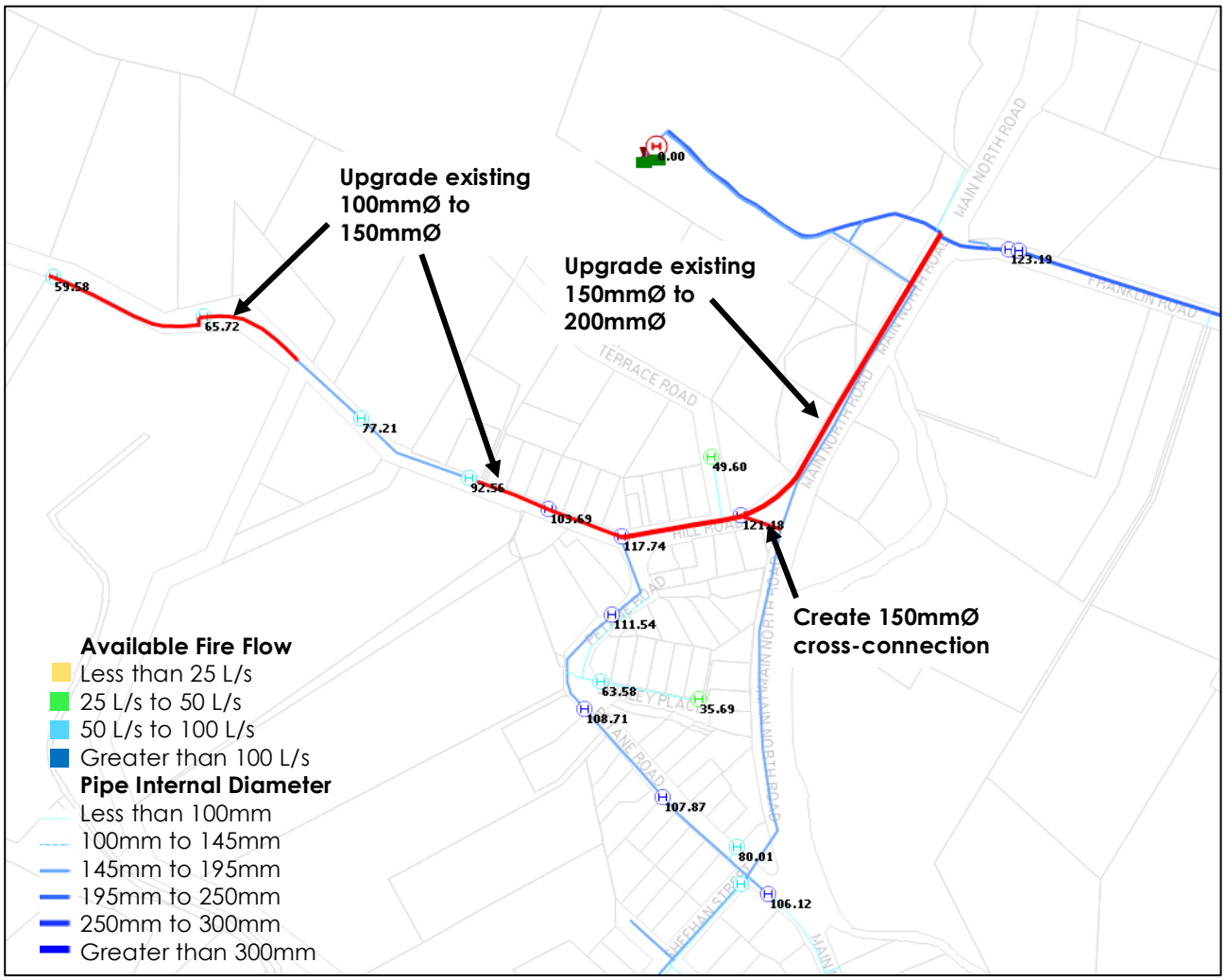


***Available fire flow after upgrade**

D.2 Onehunga Road

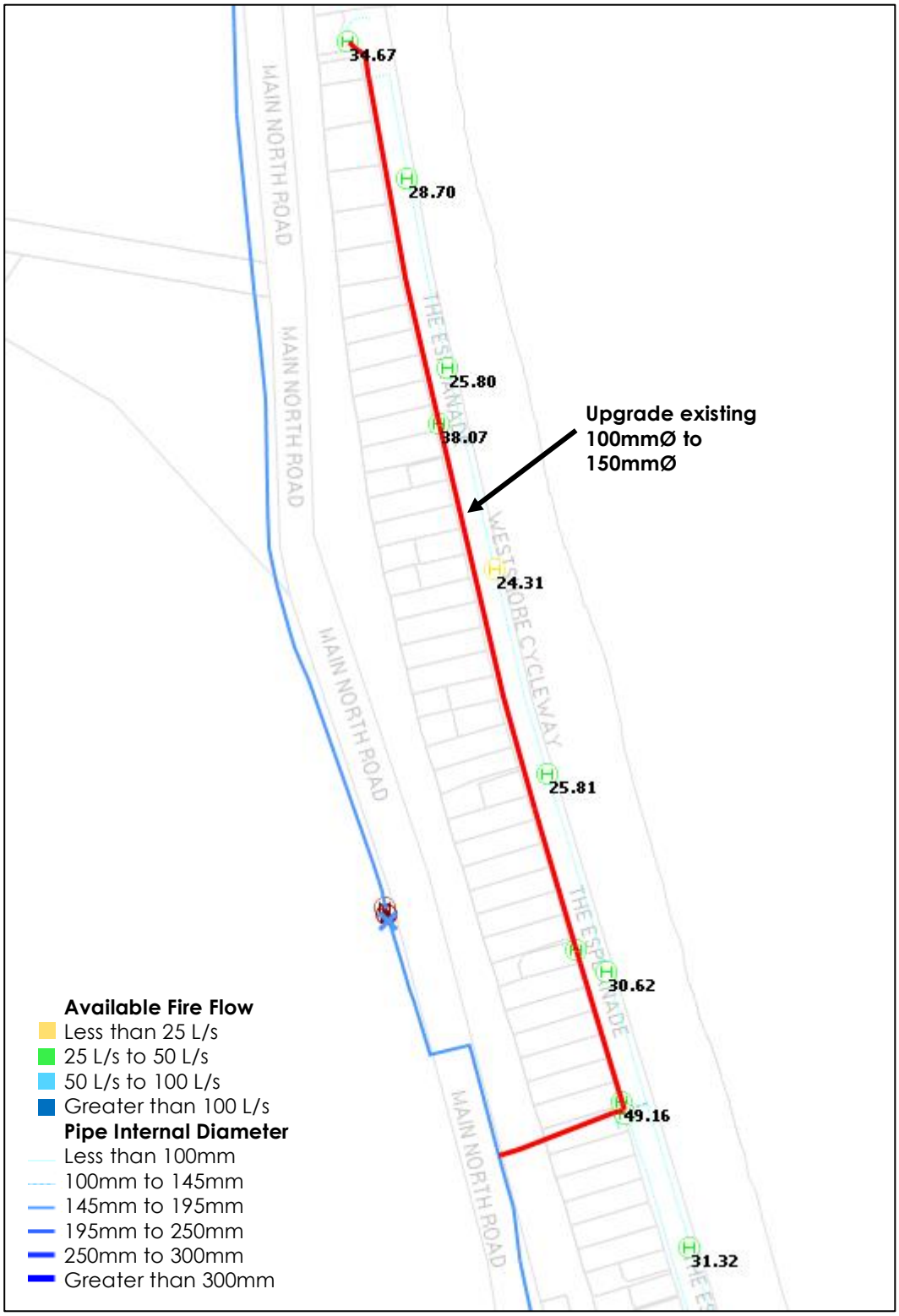
***Available fire flow after upgrade**

D.3 Hill Road



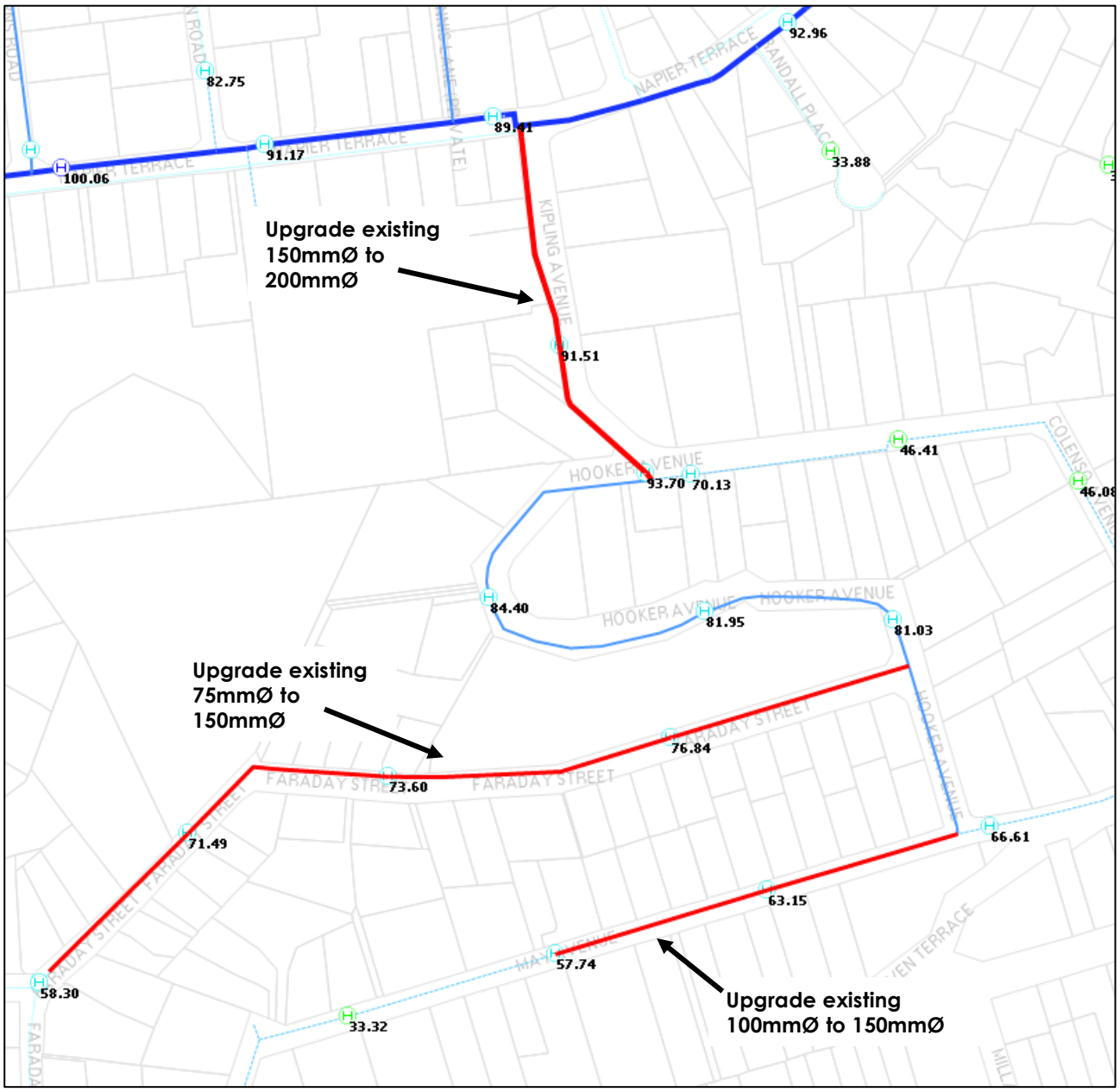
***Available fire flow after upgrade**

D.4 The Esplanade



***Available fire flow after upgrade**

D.5 Kipling Avenue/Faraday Street/May Avenue

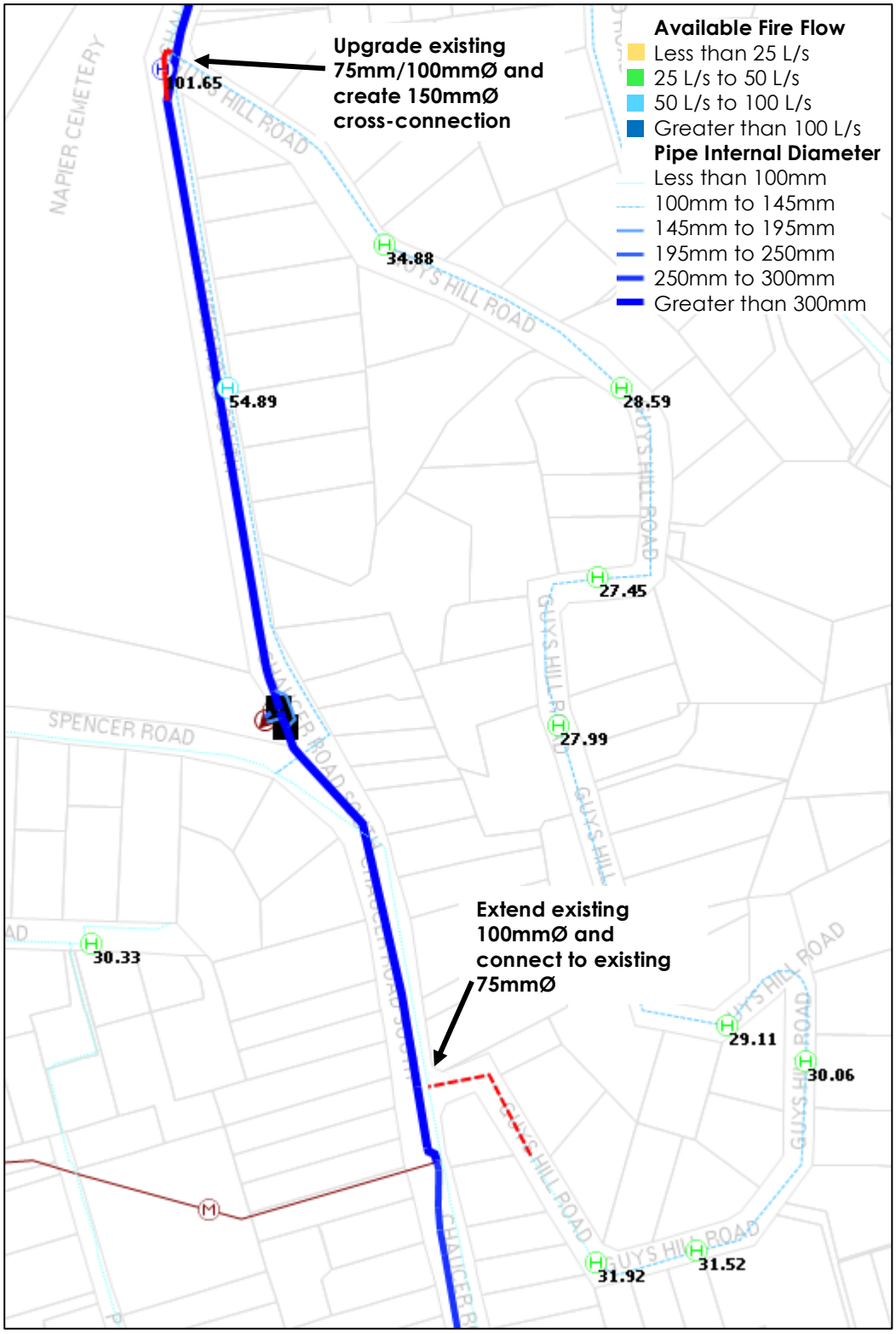


*Available fire flow after upgrade

Available Fire Flow
- Less than 25 L/s
- 25 L/s to 50 L/s
- 50 L/s to 100 L/s
- Greater than 100 L/s

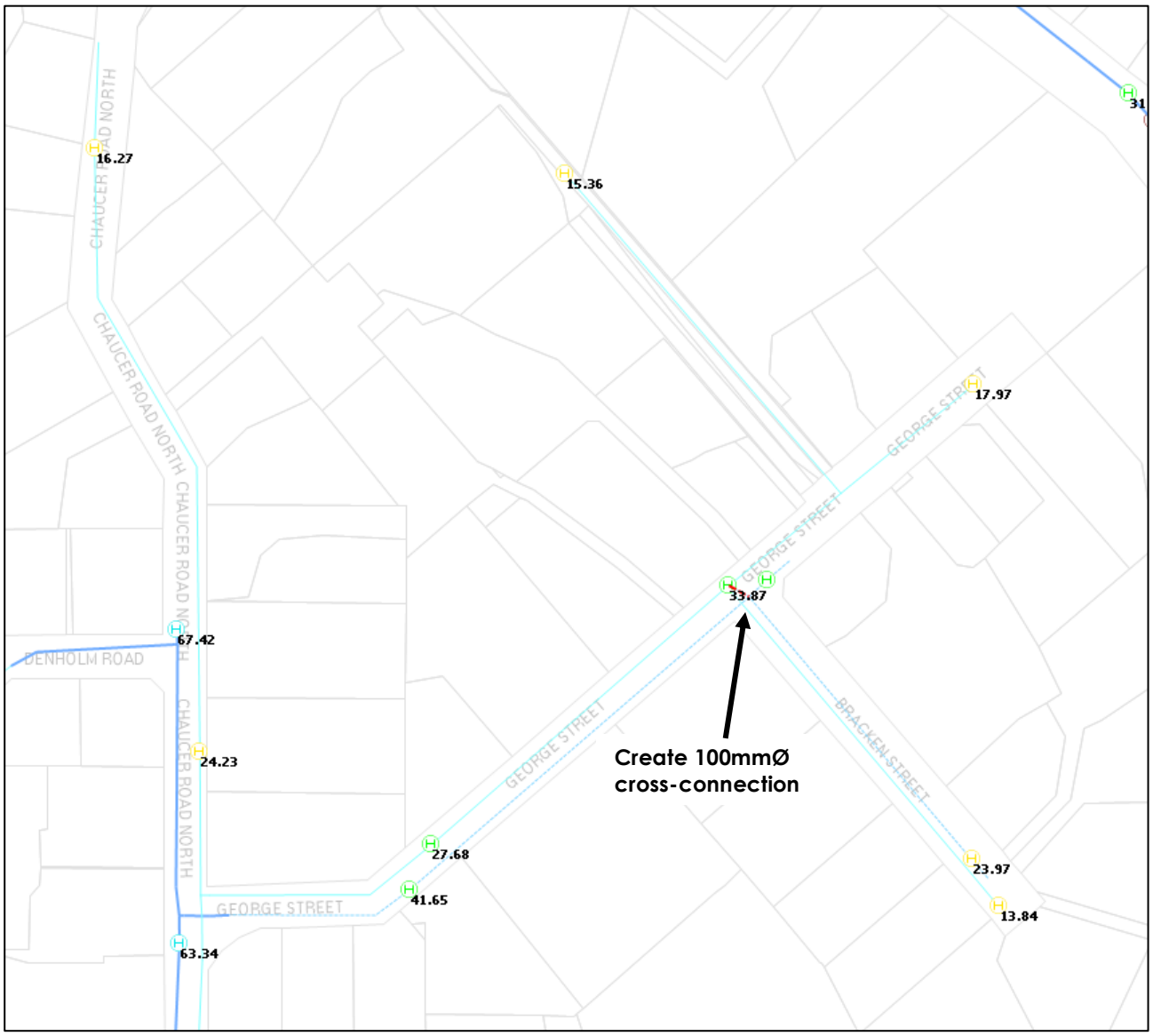
Pipe Internal Diameter
- Less than 100mm
- 100mm to 145mm
- 145mm to 195mm
- 195mm to 250mm
- 250mm to 300mm
- Greater than 300mm

D.6 Guys Hill Road/Chaucer Road South



***Available fire flow after upgrade**

D.7 George Street/Chaucer Road

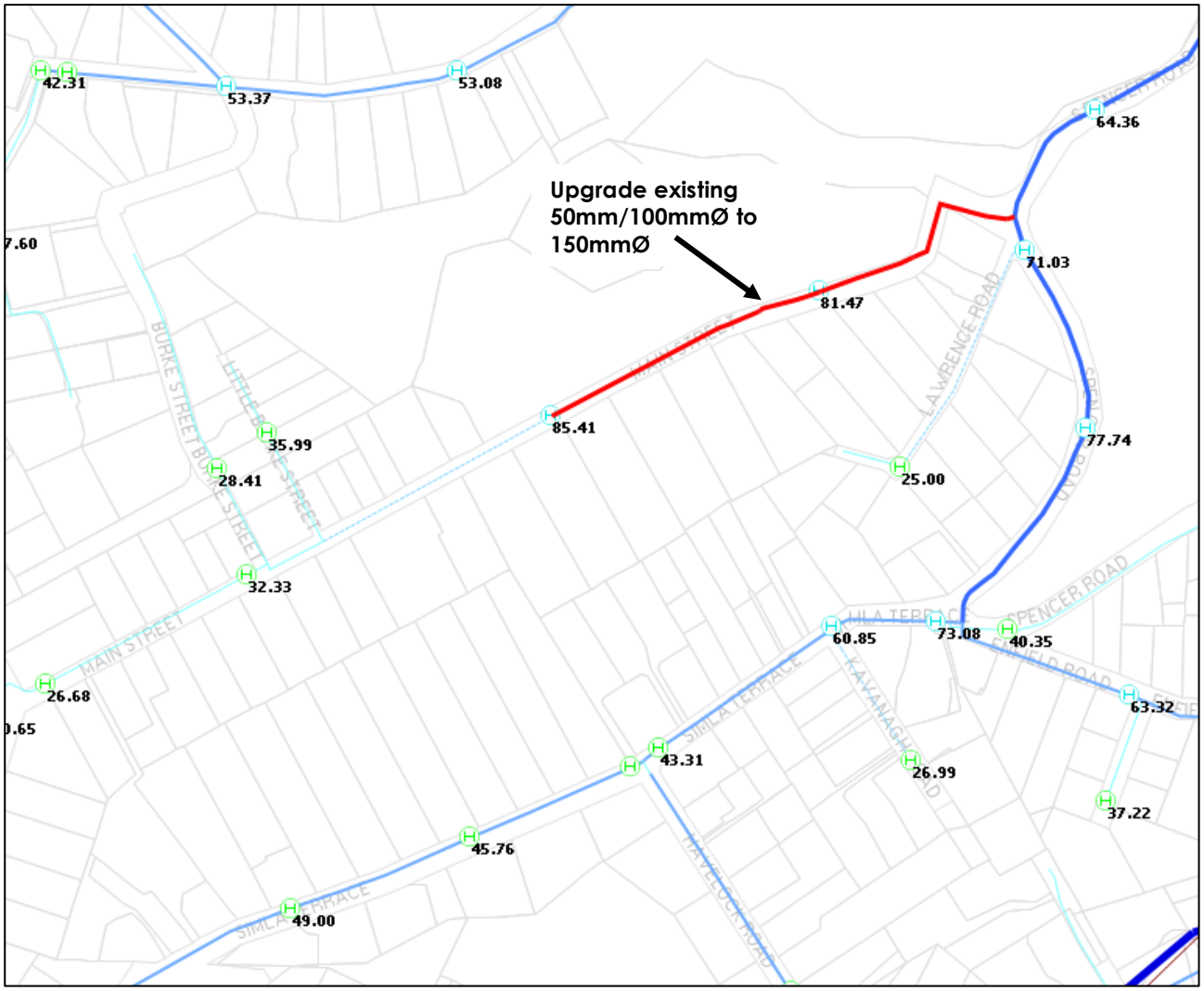


***Available fire flow after upgrade**

Available Fire Flow
- Less than 25 L/s
- 25 L/s to 50 L/s
- 50 L/s to 100 L/s
- Greater than 100 L/s

Pipe Internal Diameter
- Less than 100mm
- 100mm to 145mm
- 145mm to 195mm
- 195mm to 250mm
- 250mm to 300mm
- Greater than 300mm

D.8 Main Street

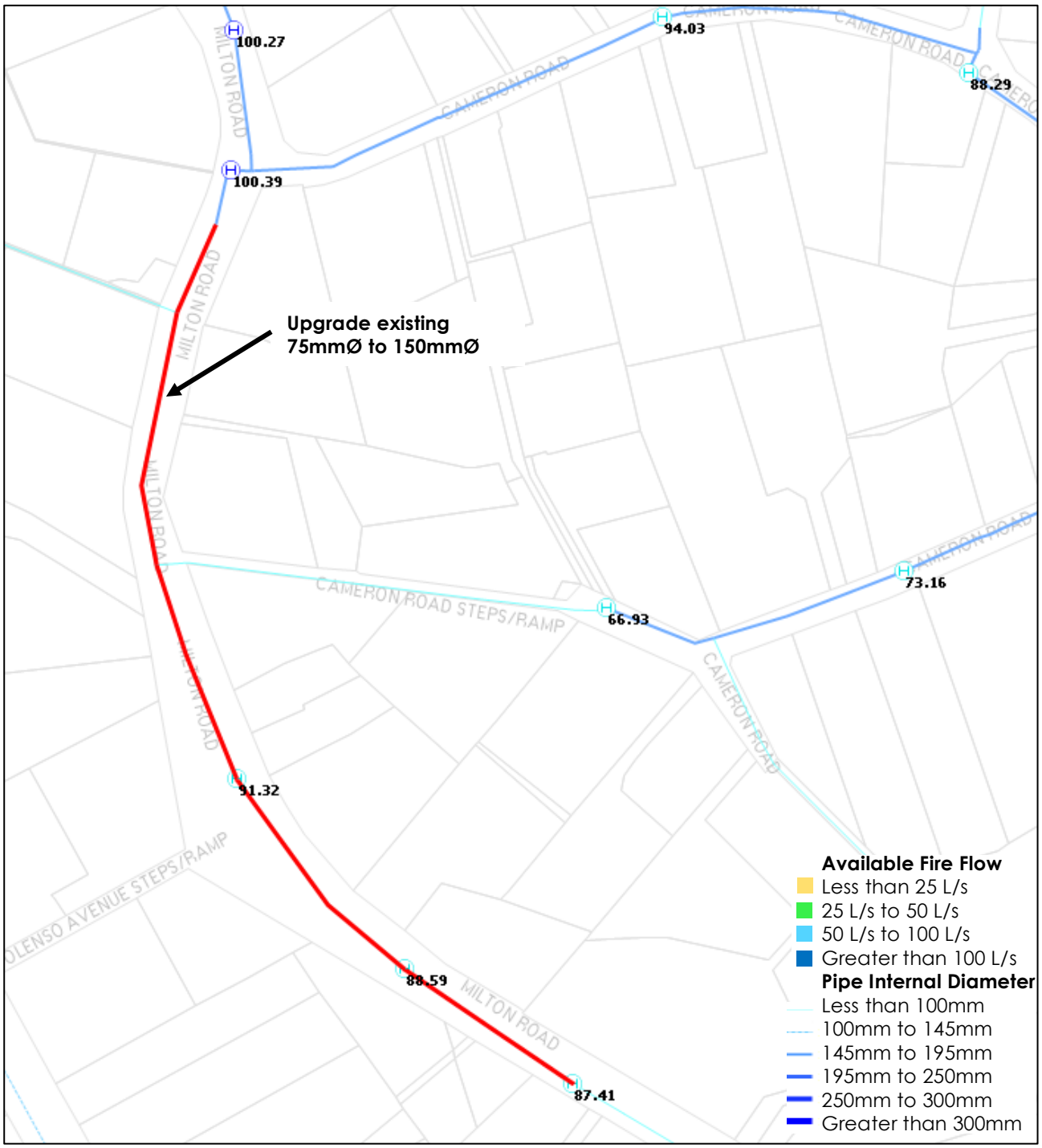


***Available fire flow after upgrade**

Available Fire Flow
- Less than 25 L/s
- 25 L/s to 50 L/s
- 50 L/s to 100 L/s
- Greater than 100 L/s

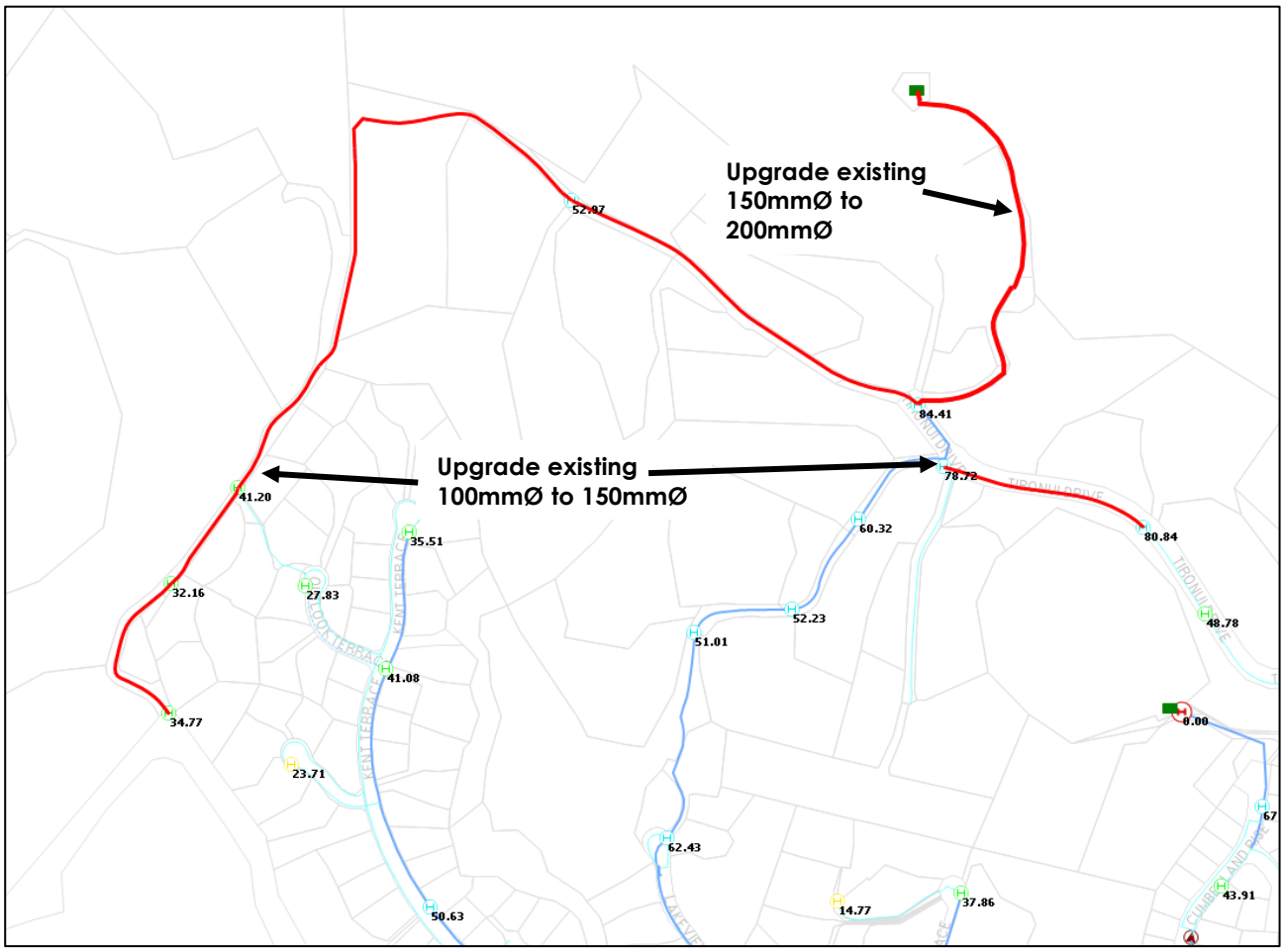
Pipe Internal Diameter
- Less than 100mm
- 100mm to 145mm
- 145mm to 195mm
- 195mm to 250mm
- 250mm to 300mm
- Greater than 300mm

D.9 Milton Road



***Available fire flow after upgrade**

D.10 Tironui Drive/Puketapu Road

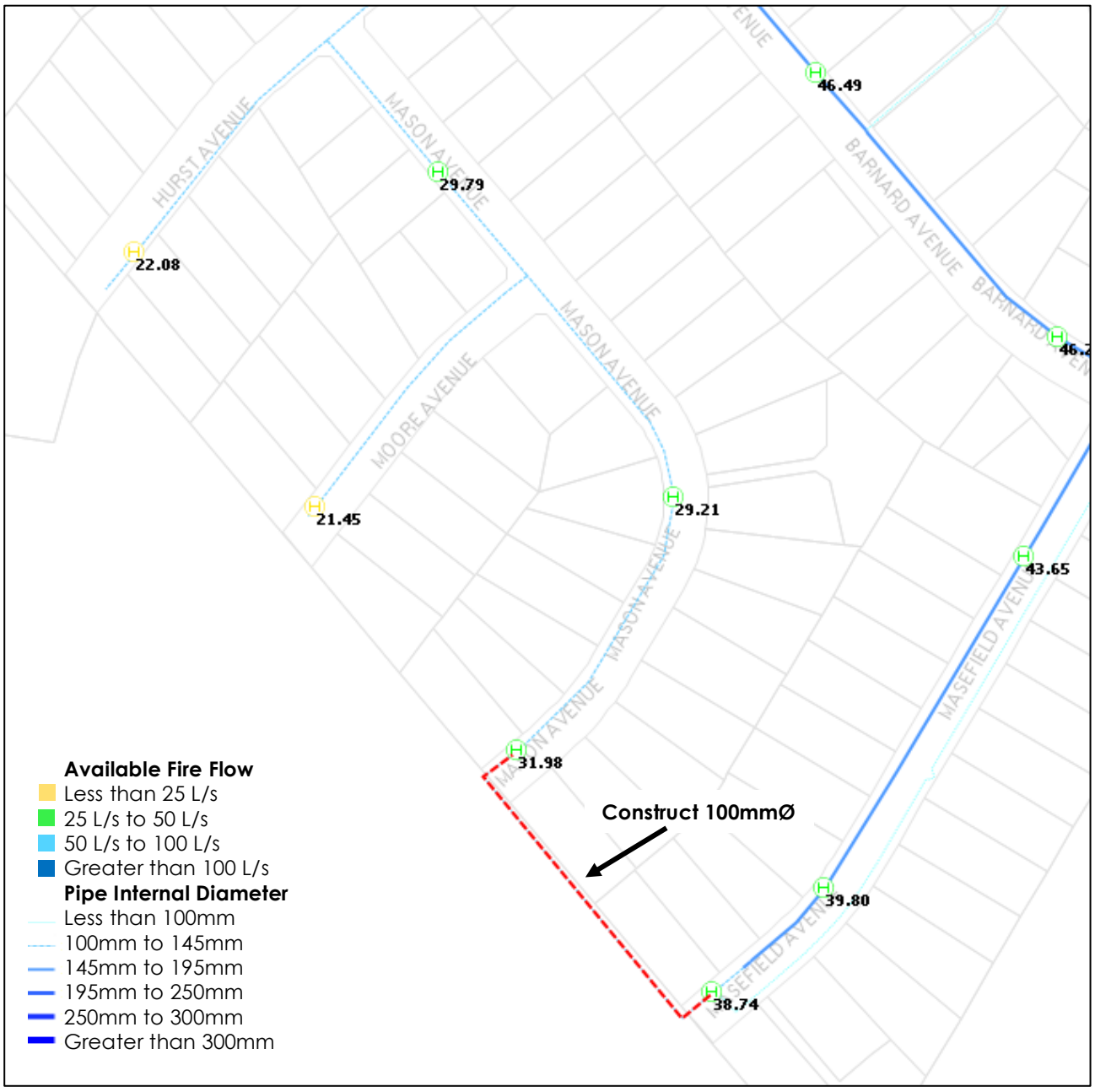


***Available fire flow after upgrade**

Available Fire Flow
- Less than 25 L/s
- 25 L/s to 50 L/s
- 50 L/s to 100 L/s
- Greater than 100 L/s

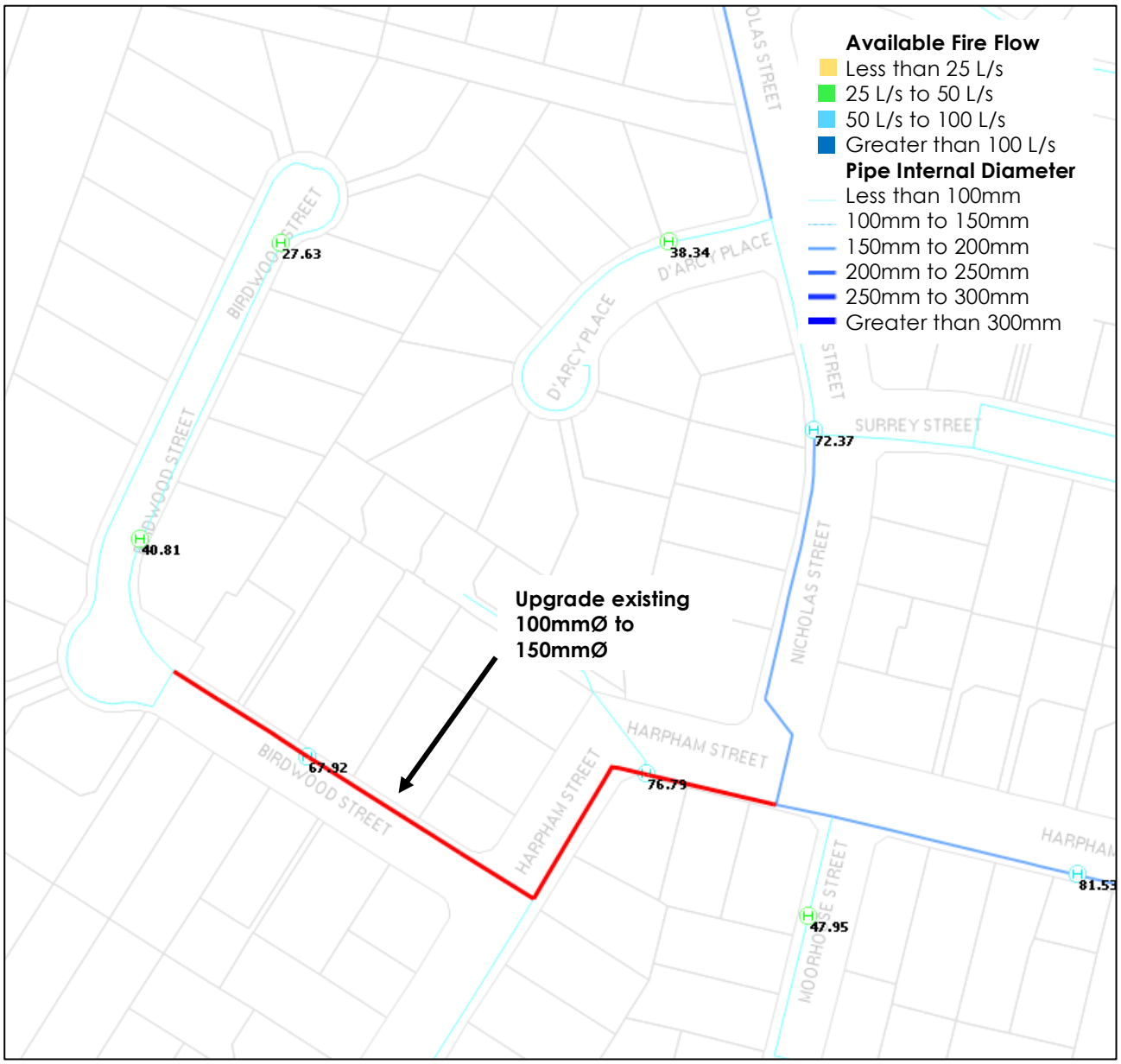
Pipe Internal Diameter
- Less than 100mm
- 100mm to 145mm
- 145mm to 195mm
- 195mm to 250mm
- 250mm to 300mm
- Greater than 300mm

D.11 Mason Avenue/Masefield Avenue



***Available fire flow after upgrade**

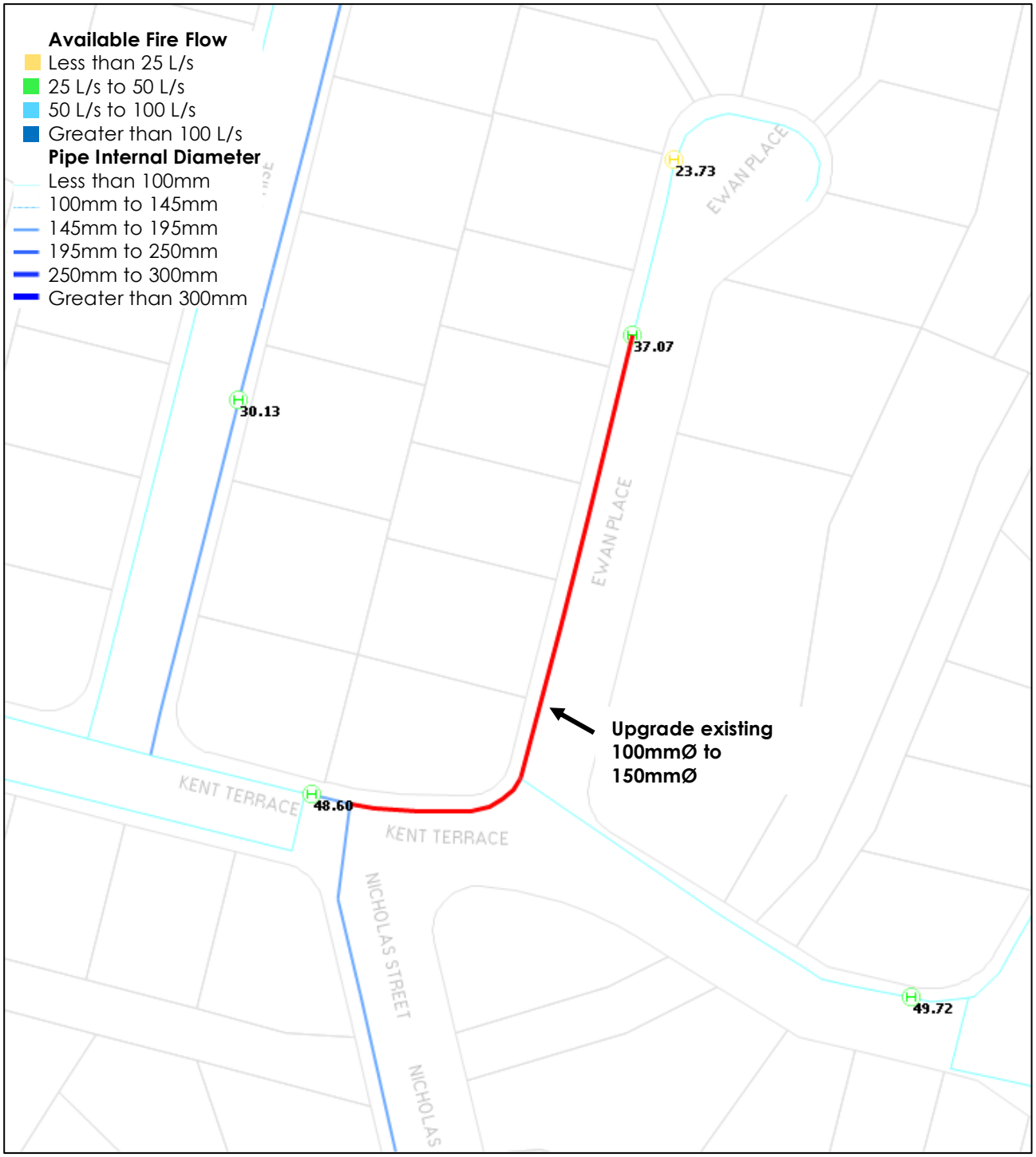
D.12 Birdwood Street/Harpham Street



***Available fire flow after upgrade**

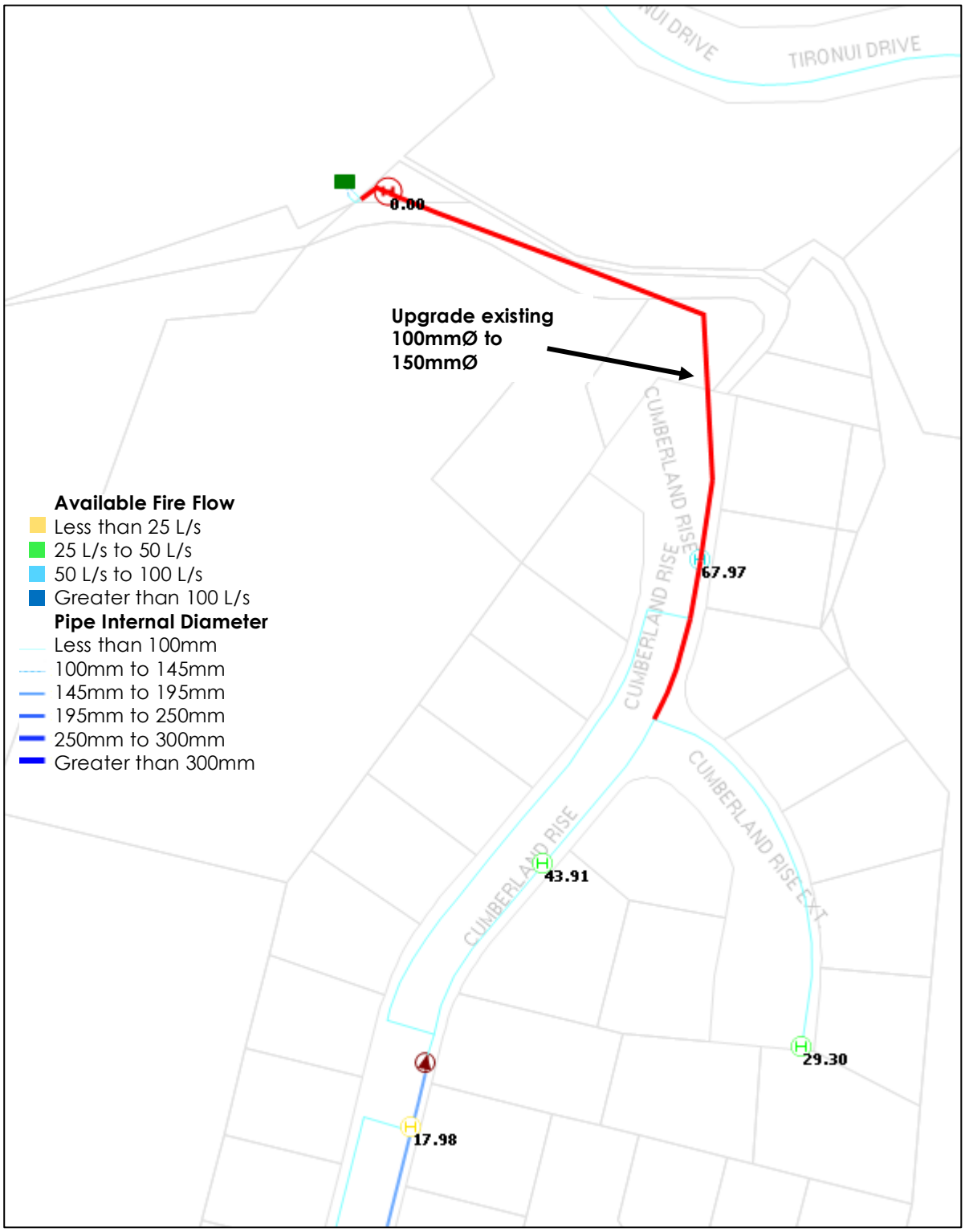
Available Fire Flow
Less than 25 L/s
25 L/s to 50 L/s
50 L/s to 100 L/s
Greater than 100 L/s
Pipe Internal Diameter
Less than 100mm
100mm to 145mm
145mm to 195mm
195mm to 250mm
250mm to 300mm
Greater than 300mm

D.13 Ewan Place/Kent Terrace



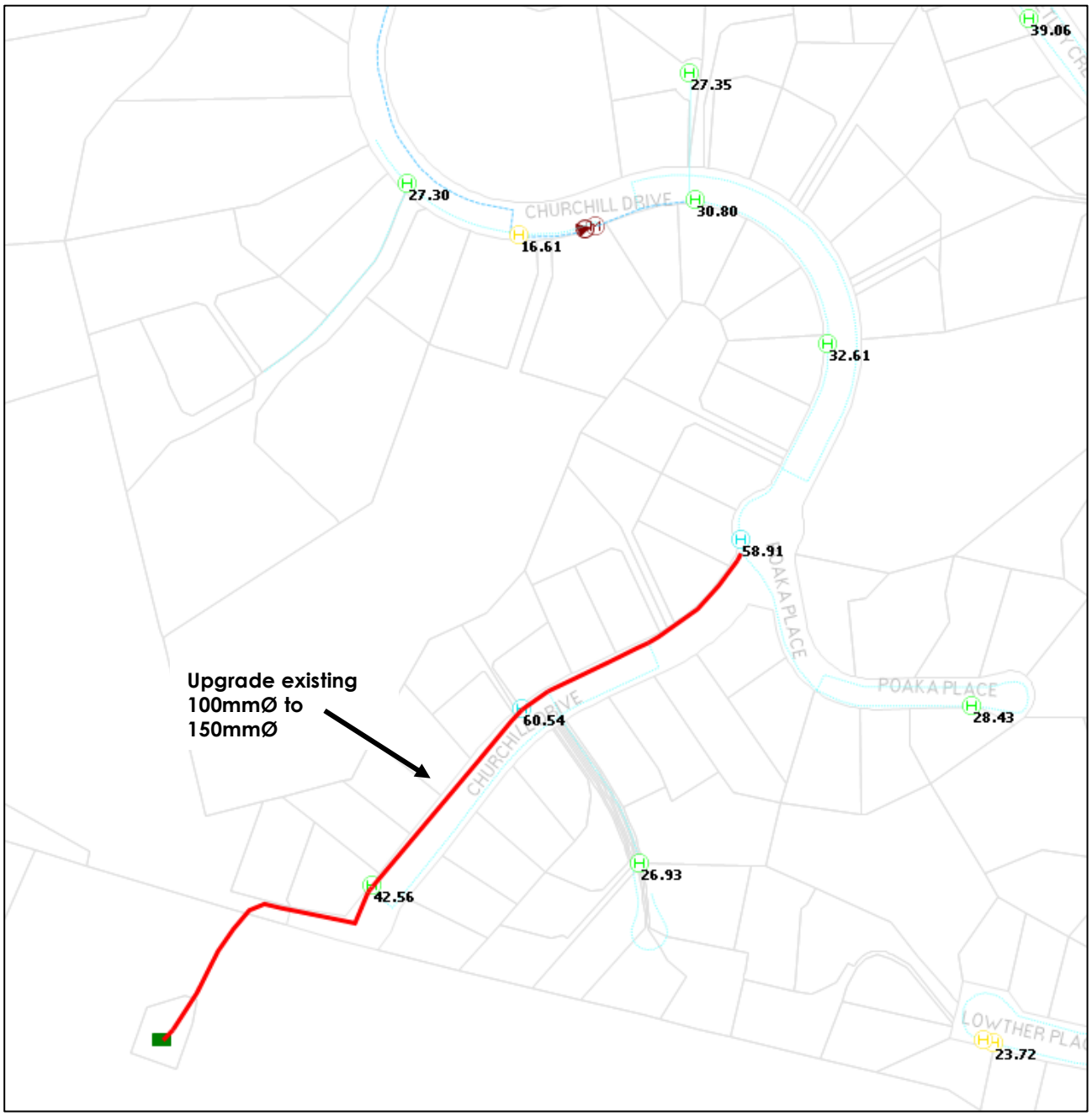
***Available fire flow after upgrade**

D.14 Halliwell



***Available fire flow after upgrade**

D.15 Otatara

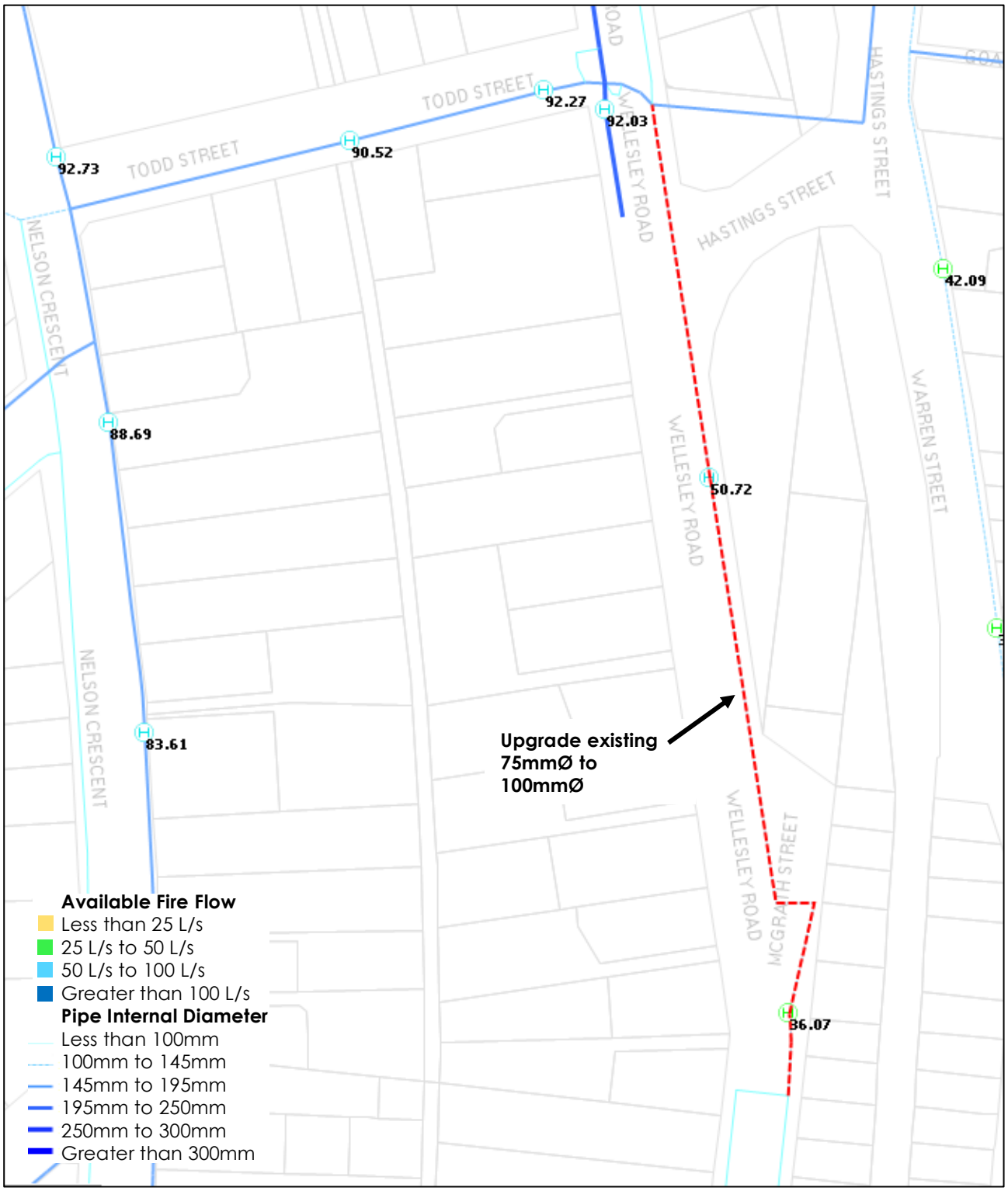


***Available fire flow after upgrade**

Available Fire Flow
- Less than 25 L/s
- 25 L/s to 50 L/s
- 50 L/s to 100 L/s
- Greater than 100 L/s

Pipe Internal Diameter
- Less than 100mm
- 100mm to 145mm
- 145mm to 195mm
- 195mm to 250mm
- 250mm to 300mm
- Greater than 300mm

D.16 Wellesley Road



***Available fire flow after upgrade**

Appendix E Master Plan, Packages and Tasks

Package	Activity	Outcome category	Tasks	Cost	Risks, opportunities	Status
Package 1	Reduce the manganese load	S, C	1-1: Investigate discoloration issues further (chemical and hydraulic).	$ 50,000	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	In progress. **High priority** as it enables several other tasks to proceed.
			1-2: Seek alternative bore locations with less manganese (Taradale side).	$ 100,000	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	In progress. **High priority** as it enables several other tasks to proceed.
			1-3: Seek alternative bore locations with less manganese (Enfield side).	$ 100,000	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	In progress. **High priority** as it enables several other tasks to proceed.
			1-4: Potentially create new bore sites (Taradale side).	$ 200,000	Cost estimate is a place holder only. It requires previous tasks to be completed	Requires 1-1 and 1-2
			1-5: Potentially create new bore sites (Enfield side).	$ 200,000	Cost estimate is a place holder only. It requires previous tasks to be completed	Requires 1-1 and 1-3
			1-6: Potentially install manganese treatment (Taradale side)	$1,000,000	Cost estimate is a place holder only. It requires previous tasks to be completed	Requires 1-1, 1-2 and potentially 1-4.
			1-7: Potentially install manganese treatment (Enfield side)	$1,000,000	Cost estimate is a place holder only. It requires previous tasks to be completed	Requires 1-1, 1-3 and potentially 1-5.
Package 2	Delineate Taradale / Enfield	S, C	2-1: Close all valves between Taradale and Enfield to delineate both systems.	$ 10,000		Can be started any time

			2-2: Close all valves between Greenmeadows and Tamatea. Durham PRV to feed the Tamatea area. Additionally, close the 350mmØ connection from the Durham PRV going north along Ororu Drive. Additionally, change the Tannery Booster suction from downstream of the Pacific PRV to upstream of the PRV.	$ 50,000	High velocities and head loss downstream of Durham PRV may lead to substandard pressure and/or discolouration. This needs to be monitored and managed.	Requires 2-1.
Package 3	Dedicate Taradale	S, C	3-1: Construct a new 450mmØ dedicated rising main from the Taradale bores to the Taradale Reservoir (4,100m in length).	$6,470,000	Cost estimate based on current T6 location.	Requires 1-1 and 1-2, potentially 1-4
			3-2: Construct a new 600mmØ outlet pipe from Taradale Reservoir (490m in length) and upgrade existing 150mmØ to 450/375mmØ along Church Road down to Puketapu Road (1,410m in length).	$2,900,000	May be reduced/optimised if existing rising main is used as a distribution main, and proposed rising main is upsized.	Requires 3-1 to confirm sizing
			3-3: Upgrade existing 150mm 1973 AC pipe along Waterhouse Street to 200mm, from Puketapu Road to O'Dowd Road (640m in length). Additionally, upgrade existing 200mm 1972 AC pipe along Puketapu Road to 300mm, from Church Road to Gloucester Street (400m in length). Additionally, upgrade existing 100mm cross-connection at the intersection of Howard Road and Frickleton Street to 150mm (50m in length). Additionally, upgrade existing 100mm cross-connection at the intersection of Gloucester Road and Roskilda Crescent to 150mm (50m in length). Additionally, upgrade existing 100mm 1972 AC pipe along Elliott Street and Murphy Road to 150mm, from Howard Road to Frickleton Street (520m in length).	$1,080,000	May not be required if Lee Road PRV is retained for emergencies	Can be started any time
			3-4: Set all PRVs on the Taradale side to not operate under normal peak demand, except for Durham PRV.	$ 5,000		Requires 3-2
			3-5: Upgrade existing 200mm/150mmØ pipe along Durham Avenue to 300mm/250mmØ, from Westminster Avenue to Southwark Avenue (110m in length).	$ 120,000		Requires 2-1 and 2-2.

Package 4	Dedicate Enfield	S, C, P, R	4-1: Identify site for new Enfield Reservoir	$ 50,000		In progress. **High priority** as it enables several other tasks to proceed.
			4-2: Procure new Enfield Reservoir	$8,000,000	Significant unknown about construction costs	Requires 4-1
			4-3: Complete the Awatoto rising main. Construct 450mmØ dedicated rising main from Latham Street to Enfield Reservoir (1,580m in length)	$2,490,000	Cost estimate based on current Enfield Reservoir location	Requires 1-3 and 4-1, potentially 1-5
			4-4: Construct a new 450mmØ dedicated rising from Prebensen Drive/Hyderabad Road to the Awatoto dedicated rising main on Carlyle Street (650m in length).	$1,030,000	Cost estimate based on current Enfield Reservoir location	Requires 4-1
			4-5: Investigate and eliminate network restrictions found during calibration.	$ 50,000		Can be started any time
			4-6: Set all PRVs on the Enfield side and McLean PS to not operate under normal peak demand.	$ 5,000	Assumes no upgrade to Chaucer Booster PS	Requires 4-1 to 4-5
Package 5	Manage demand	R	5-1: Undertake active leakage detection and repair.	$3,000,000	Based on $100,000 per year over 30 years	Can be started any time
			5-2: Construct 300mmØ cross-connection between the existing 150mmØ and 500mmØ mains on Latham Street (35m in length). Additionally, upgrade existing 100mm 1975 AC pipe along Blenheim Street, to 150mm (170m in length). Additionally, upgrade existing 100mm 1950 CI pipe laid along the Ford Street accessway, to 150mm between Taradale Road and No60 / Superfly amusement Park (330m in length).	$ 300,000	May not be required, depends on 4-1	Can be started any time
			5-3: Form DMAs (closed valves and flow meters).	$3,300,000		Requires 3-4
Package 6	Connect Awatoto to Taradale	R	6-1: Construct 350mmØ Awatoto to Taradale rising main along Kennedy Road so the Awatoto bores can supply Taradale Reservoir (1,620m in length).	$2,140,000		Requires 3-1
Package 7	Rationalise Thompson Reservoir pipework	R	7-1: Investigate and upgrade the existing pipework at the Thompson reservoirs.	$ 300,000	Cost estimate is a place holder only. This tasks needs to be scoped in more detail.	Can be started any time
Package 8	Ensure FW2 Fire Flow Availability	P	8-1: Upgrade existing 150mmØ pipe along Franklin Road/Le-Quesne Road to 200mmØ, between Main North Road and No. 48 Le-Quesne Road (1700m in length).	$ 920,000		Can be started any time

			8-2: Upgrade existing 100mmØ pipe along Onehunga Road to 150mmØ, between No. 190 and No. 262 Onehunga Road (790m in length).	$ 320,000		Can be started any time
			8-3: Upgrade existing 150mmØ pipe along Hill Road to 200mmØ, between Terrace Road and Petane Road (130m in length). Additionally, construct a new 150mmØ cross-connection between the existing 150mmØ pipe at the proposed 200mmØ pipe at the intersection of Main North Road and Hill Road (near node Asset ID XXXX000002, 50m in length). Additionally, upgrade existing 100mmØ pipe along Hill road to 150mmØ, between Franklin Road and Terrace Road (350m in length) and between Petane Road and No. 80 Hill Road, excluding the existing section of 150mmØ pipe in between (430m in length).	$ 450,000		Can be started any time
			8-4: Upgrade existing 100mmØ crossing the property at No. 54 The Esplanade to 150mmØ (90m in length). Additionally, upgrade existing 50mmØ/75mmØ pipe along The Esplande to 150mmØ, between No. 54 and 99 The Esplanade (680m in length)	$ 310,000		Can be started any time
			8-5: Upgrade existing 150mmØ along Kipling Avenue to 200mmØ, between Napier Terrace and Hooker Avenue (170m in length). Additionally, upgrade existing 75mmØ along Faraday Street to 150mmØ, between Hooker Avenue and Smale Terrace (410m in length). Move the boundary valve to south of the hydrant at the intersection of Smale Terrace and Faraday Avenue. Additionally, upgrade existing 100mmØ along May Avenue to 150mmØ, between Hooker Avenue and No. 23 May Avenue (180m in length).	$ 330,000		Can be started any time
			8-6: Extend existing 100mmØ pipe at No. 4 Guys Hill Road and connect to the existing 75mmØ pipe along Chaucer Road South (50m in length). Additionally, upgrade existing 75mmØ/100mmØ main at the intersection of Chaucer Road South and Guys Hill Road to 150mmØ (10m in length), and create a 150mmØ cross-connection between existing 350mmØ rising main and proposed upgraded pipe (10m in length).	$ 20,000		Can be started any time

			8-7: Create a new 100mmØ cross connection between the existing 75mmØ and 100mmØ pipes at the intersection of George Street and Bracken Street.	$ 1,000	This deficiency may be addressed by the development of The Loop greenfield.	Can be started any time
			8-8: Upgrade existing 100/50mmØ pipe along Main Street to 150mmØ, between Spencer Road and No. 25 Main Street (260m in length).	$ 100,000		Can be started any time
			8-9 Upgrade existing 75mmØ pipe along Milton Road to 150mmØ, between Cameron Road and No. 6 Milton Road (230m in length).	$ 90,000		Can be started any time
			8-10: Upgrade existing 100mmØ pipe along Tironui Drive/Puketapu Road to 150mmØ, between No. 62 Tironui Drive and No. 255 Puketapu Road, excluding the existing section of 150mmØ pipe in between (1700m in length). Additionally, upgrade existing 150mmØ pipe outlet from Western Hill Reservoir to No. 82 Tironui Drive to 200mmØ (460m in length).	$ 900,000		Can be started any time
			8-11: Construct a new 100mmØ pipe between existing 100mmØ pipe at Masefield Avenue and existing 100mmØ pipe at Mason Avenue (130m in length).	$ 30,000		Can be started any time
			8-12: Upgrade existing 100mmØ pipe along Birdwood Street/Harpham Street to 150mmØ, between Nicholas Street and No. 12 Birdwood Street (220m in length).	$ 90,000		Can be started any time
			8-13: Upgrade existing 100mmØ pipe along Ewan Place/Kent Terrace to 150mmØ, between Nicholas Street and No. 9 Ewan Place (130m in length).	$ 50,000		Can be started any time
			8-14: Upgrade existing 100mmØ pipe to 150mmØ from Halliwell Reservoir to Cumberland Rise Extension (210m in length).	$ 80,000		Can be started any time
			8-15: Upgrade existing 100mmØ pipe to 150mmØ from Otatara Reservoir to Poaka Place (340m in length).	$ 140,000		Can be started any time
			8-16: Upgrade existing 75mmØ pipe along Wellesley Road to 100mmØ, between Todd Street and No. 26 Wellesley Road (270m in length).	$ 70,000		Can be started any time
Package 9	Enable growth	P	9-1: Extend distribution as part of greenfield developments	None	Cost estimate not included, paid by developer.	Build as part of greenfield developments

		P	9-2: Construct a new 375mmØ outlet main from Enfield Reservoir up to Thakeray Street (380m in length). Additionally, upgrade the existing 100mmØ main along SH51 to 300/375mmØ outlet pipe from Thakeray Street up to Te Awa Avenue (2,170m in length).	$3,040,000	May not be required, depends on 4-1 and 5-1	The exact time when this is required is not clear. Depends on growth and other activities.
		P	9-3: Construct a new 300mmØ main along Latham Street from Douglas McLean Avenue to Barker Road (230m in length).	$ 250,000	May not be required, depends on 4-1 and 5-2	The exact time when this is required is not clear. Depends on growth and other activities.
			9-4: Upgrade existing 150mmØ 1970 AC pipe along Durham Avenue to 200mmØ, from Southwark Avenue to York Avenue (110m in length).	$ 210,000		Requires 3-3

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