TURNING CONSTRAINTS INTO INNOVATIVE FLOOD MITIGATION OPPORTUNITIES

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ABSTRACT

Parts of Epsom and Mt Eden in Auckland suffer from regular urban flooding. Auckland Council is investigating options to deliver long term benefits in these areas; however, they recognise the need to deliver a solution that will reduce the frequency of flooding in the absence of a catchment-scale solution that may be many years away.

Generally the flooding is a legacy of development in overland flowpaths, reliance on poorly performing soakage and limited existing stormwater infrastructure. A series of additional constraints including; no natural outfall, high groundwater, rock ground conditions and the location of existing services limit opportunities to deliver a cost effective scheme.

This paper outlines the design of a stormwater scheme that includes taking one of these constraints – a large diameter abandoned watermain – and turning it into an opportunity that sustainably re uses an asset that was believed redundant. The scheme also includes turning a local reserve into a multi-functional stormwater storage area and using an existing sewer for the attenuated discharge of stormwater. The scheme provides a cost effective and sustainable solution to manage flood risk to residents which can be readily adapted to provide an improved level of service in the future should the opportunity arise.

KEYWORDS

Stormwater, Flood Alleviation, Reuse of Abandoned Infrastructure, Watermain, Multifunctional Use of Parks, Best Practical Option

PRESENTER PROFILE

James is an experienced engineer and project manager having worked for over 12 years on a variety of stormwater and flood risk management projects in both New Zealand and the United Kingdom, from strategic planning and policy making to detailed design and construction supervision. James has provided stormwater and flooding advice on a number of high profile projects in the UK including the London 2012 Olympics, Drain London Surface Water Management Plans and the Southampton Strategy Flood Risk Management Strategy. He is currently Opus' project manager for the St Andrews/St Leonards Road flood risk mitigation project.

1 INTRODUCTION

1.1 THE PROBLEM AREA

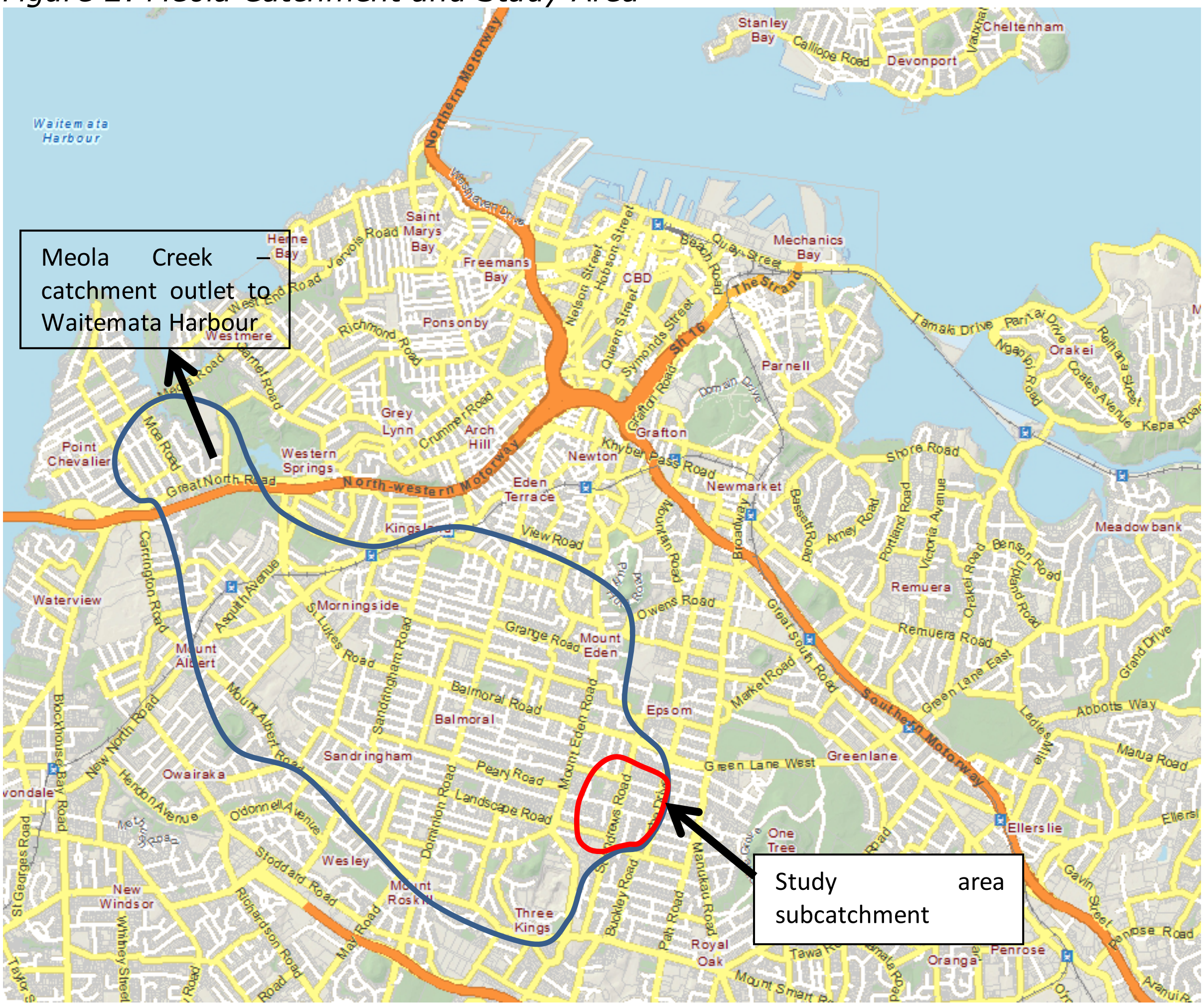
Figure 1: St Leonards Road, Epsom

The study area for this paper is located in the inner Auckland suburb of Epsom – specifically the residential roads of Landscape Road, St Andrews Road and St Leonards Road (Figure 1).

The local area is dominated by residential land use, with much of the housing dating from the 1900s-1930s. Since the 1990s there has been a large amount of 'in fill' housing.

The study area subcatchment is located at the top of the Meola Stream catchment (Figure 2). The topography is steep, and the underlying geology is dominated by volcanic tuff with relatively low permeability.

Figure 2: Meola Catchment and Study Area



Mapping Source: Auckland Council GIS Viewer

1.2 THE PROBLEM

For the last 15-20 years, flooding of properties, garages, and habitable floors has occurred during small to medium rainfall events in Landscape, St Andrews and St Leonards Roads (Figure 3). Auckland Council has recorded many flooding complaints from residents during this period. Flooding in the area has been exacerbated by:

1. Lack of a trunk stormwater network or open channel for discharge and conveyance of stormwater out of the subcatchment.

2. Historic reliance on soakage for stormwater disposal in the subcatchment with much lower soakage capacity than in the wider area.

3. Development blocking natural overland flow routes.

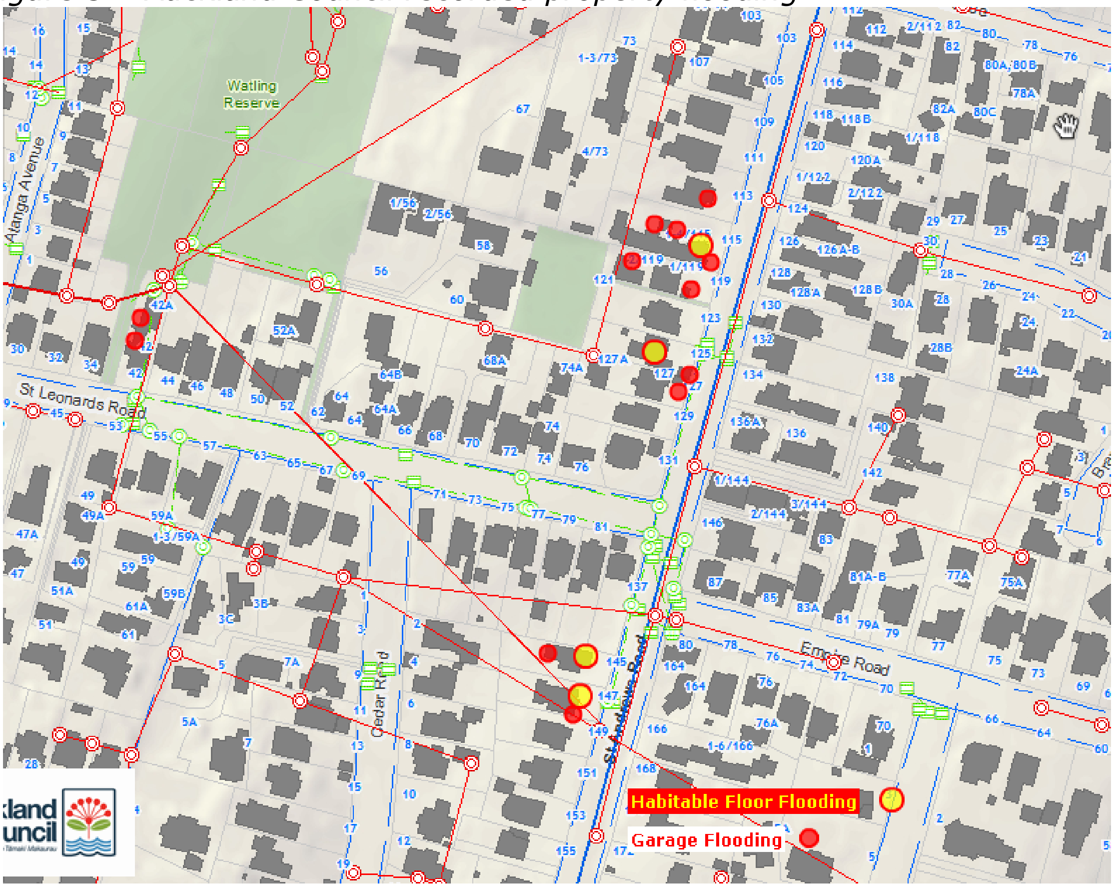
4. Lack of a 'natural' overland flow route out of the subcatchment. Development near Mt Eden Road, at the downstream end of the subcatchment, is slightly raised above the surrounding land, holding back overland flow.

5. Insufficient road maintenance and high leaf fall - blockage of catchpits and soakholes.

At present, there is a limited stormwater network draining St Leonards Road and Watling Reserve that discharges to the Edendale Branch combined sewer.

During high frequency rainfall events (e.g. 1 in 6 month event), overland flow is generated; stormwater flows into the carriageway, overwhelms the limited street network and underperforming soakholes, and flows through topographical depressions and valleys to flood private property.

Figure 3 – Auckland Council recorded property flooding



Source: Auckland Council St Andrews Project Plan

Attempts had been made in the past by the legacy Council (Auckland City Council Transport) to reduce flooding in the subcatchment through constructing additional soakholes and reshaping footpaths and driveways.

1.3 PROJECT OBJECTIVES

A strategic study for flood risk management in the wider Meola catchment is underway however, in the short term, there is a recognised need to address the frequent flooding complaints from residents in the subcatchment. The Council identified the following objectives for managing the flood risk in the subcatchment:

1. Deliver a solution in the short term to reduce flooding to residents.

2. Do not increase the risk of combined sewer overflows by increasing stormwater flows to the Edendale Branch Sewer.

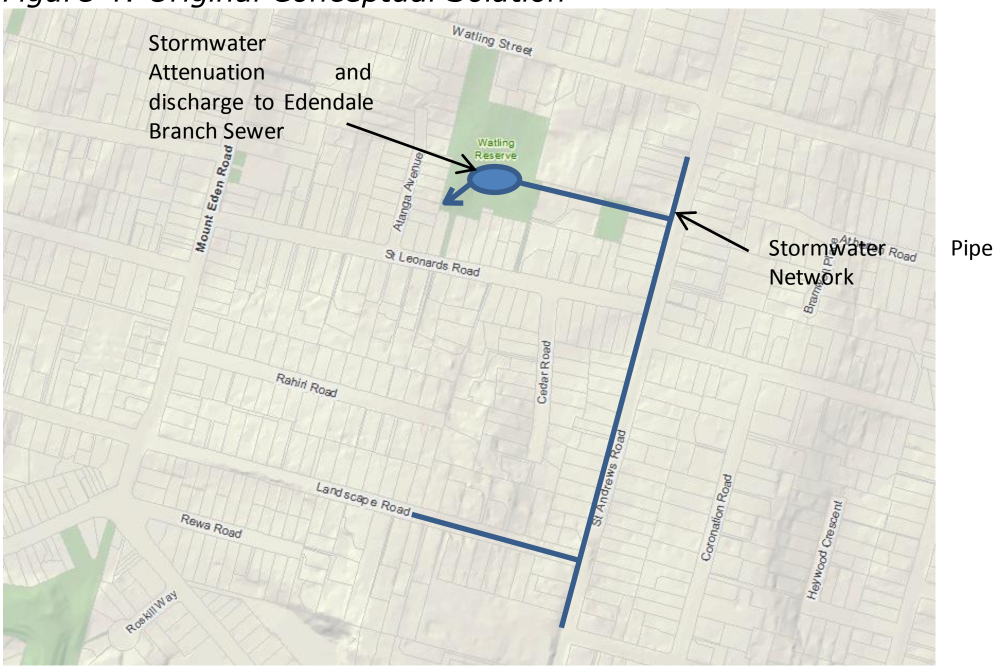
2 THE CONCEPTUAL SOLUTION

Auckland Council identified a conceptual option of providing 1 in 50 year ARI level of service for the subcatchment, in accordance with legacy Council design standards. The solution (Figure 4) included:

- Piping stormwater to Watling Reserve through a new stormwater network in the carriageway.
- A storage pond in the Reserve to attenuate flows and discharge to the local sewer (Edendale Branch Sewer). The steep topography and highly urbanised environment make Watling Reserve the logical location for stormwater attenuation.

However, a number of constraints were identified through the preliminary design investigations, including groundwater levels, the location of existing assets, parks usage, tree constraints, and limitations of the modelling that had been done. These necessitated a rethink of the conceptual option.

Figure 4: Original Conceptual Solution



Mapping Source: Auckland Council GIS Viewer

2.1 CONSTRAINTS TO THE CONCEPTUAL OPTION

A series of investigations were undertaken to verify the feasibility of the conceptual option for the subcatchment. These included:

1. Field investigations including topographic survey, geotechnical study, groundwater monitoring and locating existing assets;

2. Consultation with key stakeholders/specialists including Auckland Council Parks and their arborist, Watercare, and residents;

3. Hydraulic modelling of the existing and proposed stormwater scheme to inform the level of service achievable, and determine the impact on the wastewater network (the Edendale Branch Sewer).

These investigations demonstrated that a series of constraints that limited the feasibility of the conceptual option and the ability to deliver to the level of service originally envisaged. The constraints identified are shown in Figures 5 and 6 and described below:

1. The Edendale Branch combined sewer is the only available discharge option and it is already a source of downstream overflows during storm events. Watercare has advised that there is no further capacity in this combined network.

2. Intensive existing development limits 'opening up' overland flowpaths.

3. A 760mm diameter abandoned trunk watermain in Landscape Road and St Andrews Road limits the alignment options for constructing a new stormwater system.

4. Maintaining the value of the public open space (and trees) in Watling Reserve means a 'dry' attenuation area is preferred. Valuable public open space would be lost by the creation of a permanent pond.

5. High groundwater levels in Watling Reserve mean storage below existing ground levels is at risk from groundwater intrusion, resulting in a loss of storage capacity.

6. The proximity to adjacent properties limits the height of any embankment possible in Watling Reserve and therefore the volume of storage available for above ground detention.

Figure 5: Subcatchment conveyance and discharge constraints

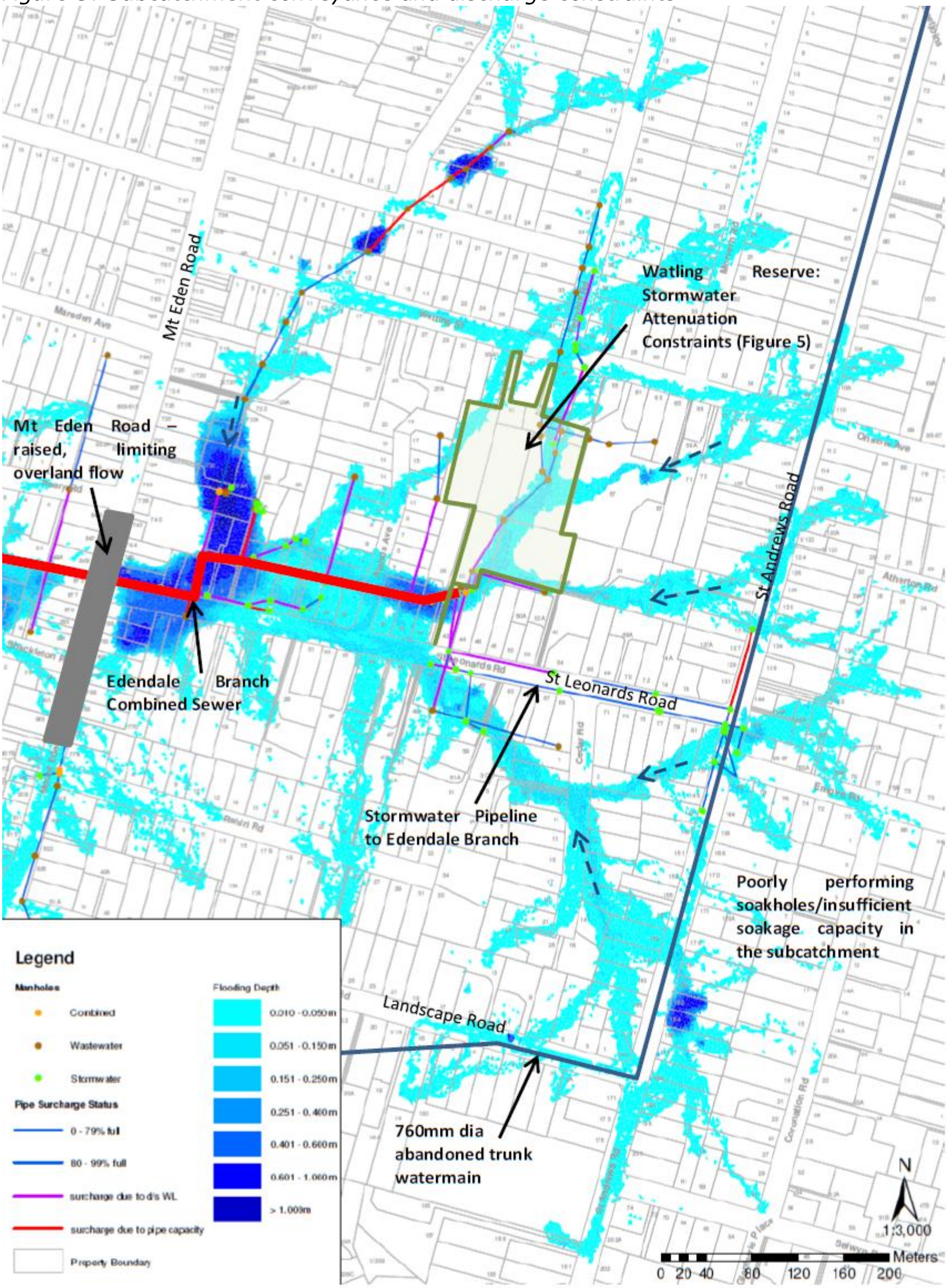
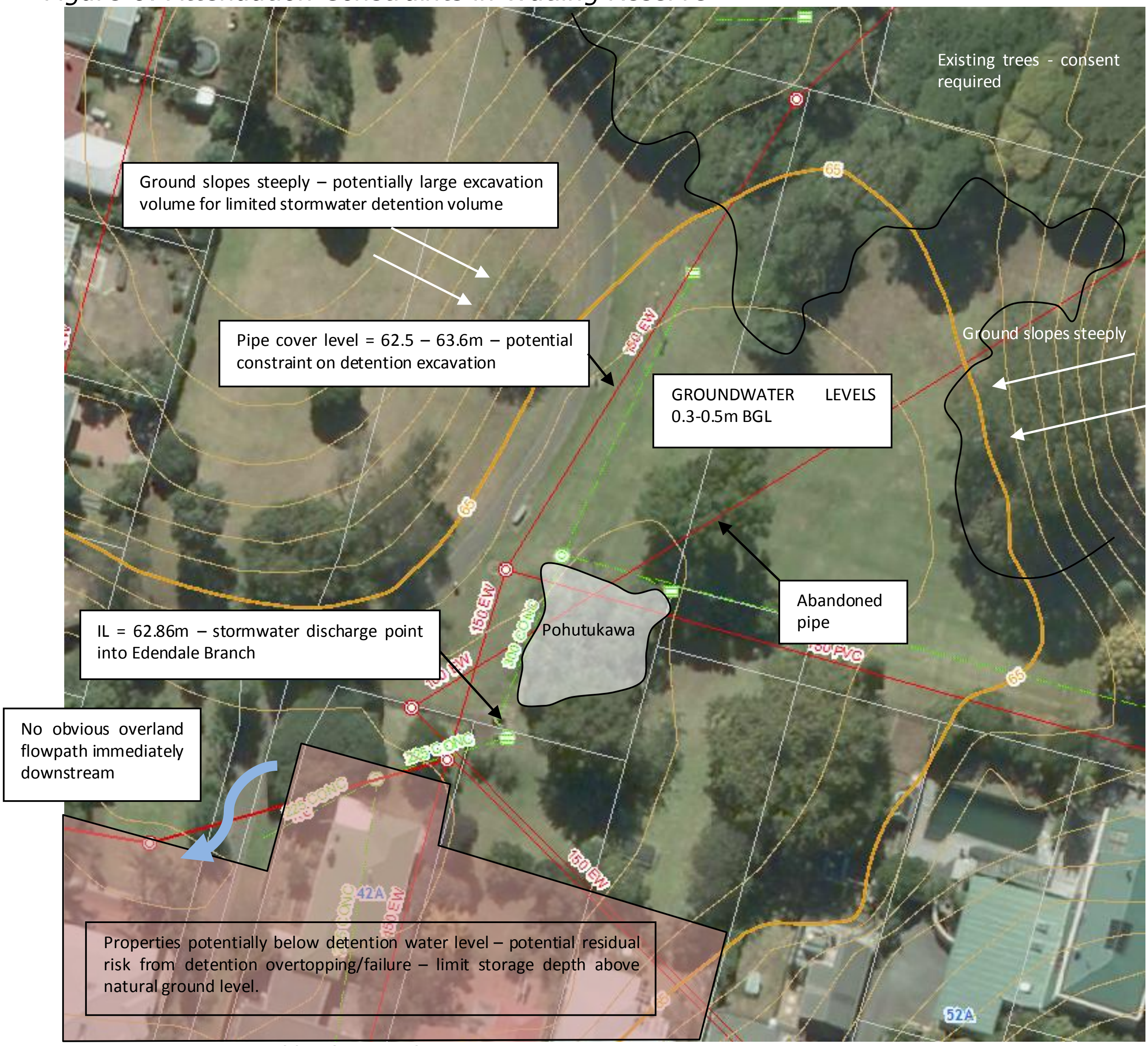


Figure 6: Attenuation Constraints in Watling Reserve



Mapping Source: Auckland Council GIS Viewer

3 A SUBCATCHMENT STRATEGY

Given the significant site constraints, the first step in developing a solution for the subcatchment was to refine the project objectives by identifying the 'must haves':

1. There has to be a demonstrable reduction in the frequency and extent of property flooding.
2. Any infrastructure built must be able to meet the future needs of the subcatchment.
3. The solution should be acceptable to Watercare Services Limited in terms of discharge of stormwater to the combined sewer.
4. The benefits of the flood alleviation option need to out-weight the costs.
5. Minimise disruption to already frustrated residents.
6. Maintain the amenity value of the highly used Watling Reserve and any works in the park needs to be acceptable to Auckland Council Parks.

Additionally, whatever form the solution took needed to address the likely changes to private drainage in the future. There is a lack of capacity within the private soakhole drainage systems, such that a pipe reticulation network in the road will ultimately need to collect runoff from private property as well as public areas. However, prior to any private connections being made, stormwater on private property is expected to runoff into the carriageway where its ability to enter the proposed pipe network will be limited by inlet capacity (size and number of catchpits).

3.1 REVISING THE PROJECT OBJECTIVES

Within this context and our knowledge of the constraints, a 'high level' review of all options to mitigate flooding was again required, under a revised project objective -

What could be done to reduce the frequency of flooding to residents, without compromising the future needs of the catchment or creating assets that need to be upgraded in the future, and what level of service would it have?

Any cost-benefit analysis would need to consider the current benefit (i.e. level of service provided to properties in the current situation) against the cost. If the level of service (benefit) was reduced compared to the original conceptual solution, it would be necessary to reduce costs to arrive at a similar cost-benefit.

4 DEVELOPING OPTIONS AMID CONSTRAINTS

The 'high level' review by the project team identified options for managing flooding in the subcatchment, including:

1. Do Nothing.
2. Targeted/proactive maintenance – clearing catchpits, etc.
3. Buy houses currently at flood risk and use for flood management.
4. Retrofit flood resilience/resistance measures to flood prone properties.
5. Additional soakage.
6. Pipe stormwater to known soakage area.
7. Create overland flow paths through road corridor.
8. Implement a Council policy for new development in a combined sewer catchment.
9. Implementation of detention tanks or other 'at source' measures in existing properties.
10. New pipe network to the existing Edendale Branch discharge point.
11. New pipe network plus attenuation to the existing Edendale Branch discharge point.
12. Use the abandoned Watercare trunk water main for storage/conveyance.
13. Oversized pipes/underground storage in road network.
14. Strategic intervention as part of a catchment wide solution.
15. Improve the private drainage in flooding prone properties.

Options were assessed considering:

Site Constraints	• Designing a solution that is adaptable to the long term needs of the catchment –making sure the system doesn't require another upgrade in the future vs. higher benefit-cost ratio now. • Abandoned watermain limiting alignment. • Not moving the flooding problem from one area to another. • Space and use constraints in Watling Reserve – trees and visual impacts. • The basalt/tuff geology - no soakage and high groundwater in Watling Reserve. • No additional capacity in Edendale Branch Sewer.
Opportunities	• Potential for long term cost savings through adaptable design. • Potential to use the watermain as a Stormwater asset – saving on cost and minimising disruption. • Part of the subcatchment is already reticulated – potential to connect to this system. • Potential dual use of Watling Reserve. • Controlled discharge into the Edendale Branch Sewer.

The outcome of the Options Assessment identified that there was no 'silver bullet' solutions to address flooding in the subcatchment; a combination of options would be required even if they could not all be deliverable as part of this project. Specifically, options:

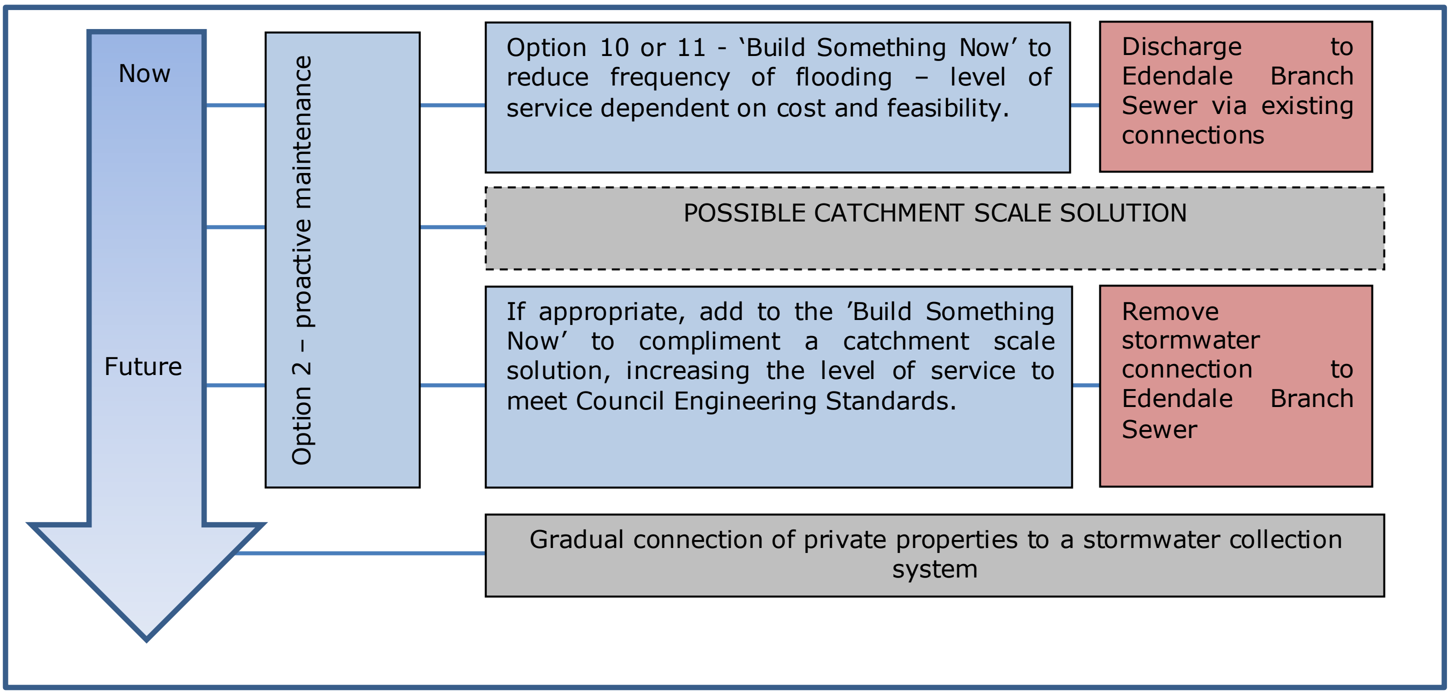
- 10 and 11 Local capital investment – in the short to medium term a capital investment to address existing deficiencies in the Stormwater system.

- 14 Strategic, catchment-wide intervention – high cost solution, part of a bigger scheme to manage flood risk in the catchment (currently being investigated by Auckland Council).

- 2 Maintenance – ensuring flooding is not exacerbated through proactive action (e.g. Auckland Transport removal of debris from catchpits). However, this option doesn't deliver an improved level of service.

Figure 7 draws the project objectives, current and future scenarios and short listed options into a conceptual subcatchment strategy.

Figure 7: Current and Future Situation



5 DEVELOPING THE BEST PRACTICAL OPTION SOLUTION

Developing a 'best practical solution' focussed on what Option 10 or 11 might look like. Option 2 and Option 14 were outside the scope of what the project team could influence in the short term. The main steps in determining the best practical option were understanding:

- Whether the abandoned watermain would meet the engineering requirements of a stormwater pipeline.
- The available storage in Watling Reserve taking into account constraints and opportunities identified.
- The level of service these assets would provide, either in combination or separately, both now and in the future.

5.1 REUSING THE ABANDONED WATERMAIN

The Huia No. 2 trunk water supply pipeline is located in Landscape Road and St Andrews Road, where a 760mm cement lined steel section of the pipeline is no longer in use. Reusing the watermain for stormwater management offers the opportunity to significantly reduce the cost of a new pipeline and reduce construction disruption for residents.

Investigation from data provided by Watercare Services Ltd indicated:

- The watermain's horizontal alignment lies close to the alignment a new stormwater pipeline would potentially take from Landscape Road, down St Andrews Road to St Leonards Road.
- The vertical alignment generally follows the ground profile from Landscape Road to St Leonards Road and down St Andrews Road from Watling Street to St Leonards Road (Figure 8). Valves and change in vertical alignment near the intersection of St Andrews and St Leonards Road meant that this section of pipe could not be used.

- The condition assessment report prepare by Asset Specialists (2009) noted that:
  - *"Failure from internal corrosion is considered unlikely unless there are areas known or suspected of having no lining…In such places pin hole leaks can be expected within 20 years".*
  - *"Failure from external corrosion may occur within 20 years".*

- The condition assessment and decision to abandon the watermain was undertaken on the basis of meeting the requirements of a trunk pressure water asset. The asset has significant potential for no (or low) pressure stormwater storage or conveyance, subject to a stormwater specific condition assessment.

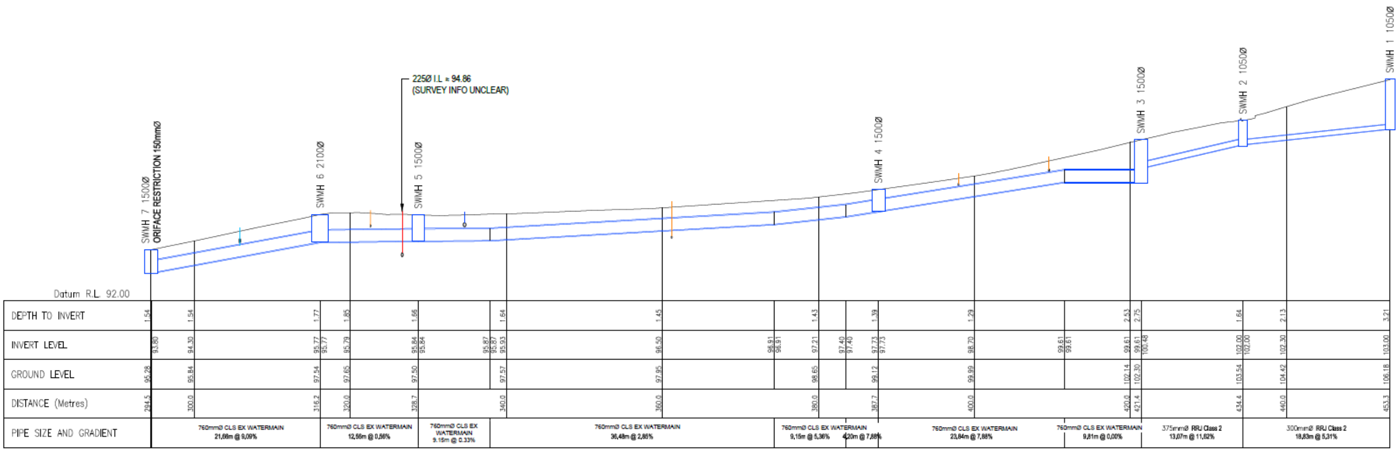
Notably, the abandoned watermain does not comply with Auckland Council's Engineering Design Standards relevant to a new stormwater pipeline constructed on the same horizontal and vertical alignment. Specifically, in a number of locations it has less than 1m cover. A contingency of pipe lining is being considered by Auckland Council to address any loading concerns, should it be required.

Hydraulic modelling (InfoWorks CS 2D) was used to test the pipeline hydraulics and determine the level of service able to be provided in the short term where private properties are not directly connected to the pipeline but flow overland into the carriageway, and in the long term where residential properties have been directly connected to the pipeline through lateral connections.

Hydraulic modelling predicted:

- The abandoned watermain has sufficient capacity to accommodate the 1 in 50 year ARI event for the upstream subcatchment in the long term.
- The pipeline could significantly reduce the extent and depth of flooding to properties along Landscape Road and St Andrews Road in a 1 in 50 year ARI event if all private property upstream were connected to the pipeline and a catchment solution was in place.
- In the short term, where properties are not directly connected to the pipeline, the reduction in flood extent and depth is not as extensive due to the uncontrolled runoff into the road, however there is additional capacity in the pipeline.
- Throttling flow in the abandoned watermain (e.g. at each manhole) enables the pipe to be used for storage as well as conveyance in the short term, prior to discharge into the Edendale Branch sewer.
- A significant improvement in the existing inletting is required to collect runoff that flows from neighbouring properties into the carriageway.

Figure 8: Abandoned watermain longsection in Landscape Road



5.2 MULTI-FUNCTIONAL STORMWATER DETENTION IN WATLING RESERVE

The steep topography and highly urbanised environment make Watling Reserve the logical location for stormwater attenuation in the subcatchment, however the ability to deliver storage is significantly limited by the site constraints.

5.2.1 TYPE OF STORAGE

Through consultation with Auckland Council Parks, a ‘dry’ detention area was considered the most appropriate option for attenuating stormwater on the basis that:

- Park use can be maintained for the majority of the time whereas a wet pond or wetland would result in the loss of usable area.
- Capital and operating costs of underground storage (e.g. crates or oversized pipes) is generally greater per cubic metre of storage than aboveground solutions. The maintenance of crates can also be expensive.

Following a rainfall event, the area of the park used for storage is likely to be water logged for extended periods - in particular during the winter when groundwater levels are high. However, for much of the year, the park’s existing use and amenity will be maintained.

5.2.2 AREA AND LOCATION OF STORAGE

Three layout options were considered for the dry detention facility and tested using hydraulic modelling for a range of return period scenarios:

1. Option 1: Single storage, no tree constraints – maximises the natural valley shape of the park to deliver the necessary storage (Figure 9).

2. Option 2: Single storage, avoids existing trees – maximises storage in the south of the park within the constraints identified in Figure 6 (Figure 10).

3. Option 3: Dual storage, avoids existing trees – maximises storage across suitable landform in the park and within the identified constraints (Figure 11).

Figure 9: Option 1- Single storage, no tree constraints

Mapping Source: Auckland Council GIS Viewer

Figure 10: Option 2: single storage area, avoid most trees

Mapping Source: Auckland Council GIS Viewer

Figure 11: Option 3 - dual storage area, avoid most trees

Mapping Source: Auckland Council GIS Viewer

5.2.3 LEVEL OF STORAGE

Monitoring has indicated that the groundwater during winter was 0.2-0.3m below the surface in the locations identified for storage. Consequently, storage below ground level was considered impractical and storage would need to occur above ground.

5.3 DETERMINING LEVEL OF SERVICE

The key considerations that will determine the level of service provided by the watermain and the storage in Watling Reserve are:

- Demonstrating that the discharge to the Edendale Branch sewer is not increased; and
- The visual impact and residual risk of above ground storage in Watling Reserve is not considered significant.

The design of any storage relates to the short term solution only (i.e. without direct private property connections that might occur in the future). The early stages of modelling demonstrated that it was impractical to provide storage in Watling Reserve that would meet the long term needs of the subcatchment.

Even in the short term, the available storage Watling Reserve limits the level of service possible from the proposed solution. The following two sections consider the implications of providing different levels of service.

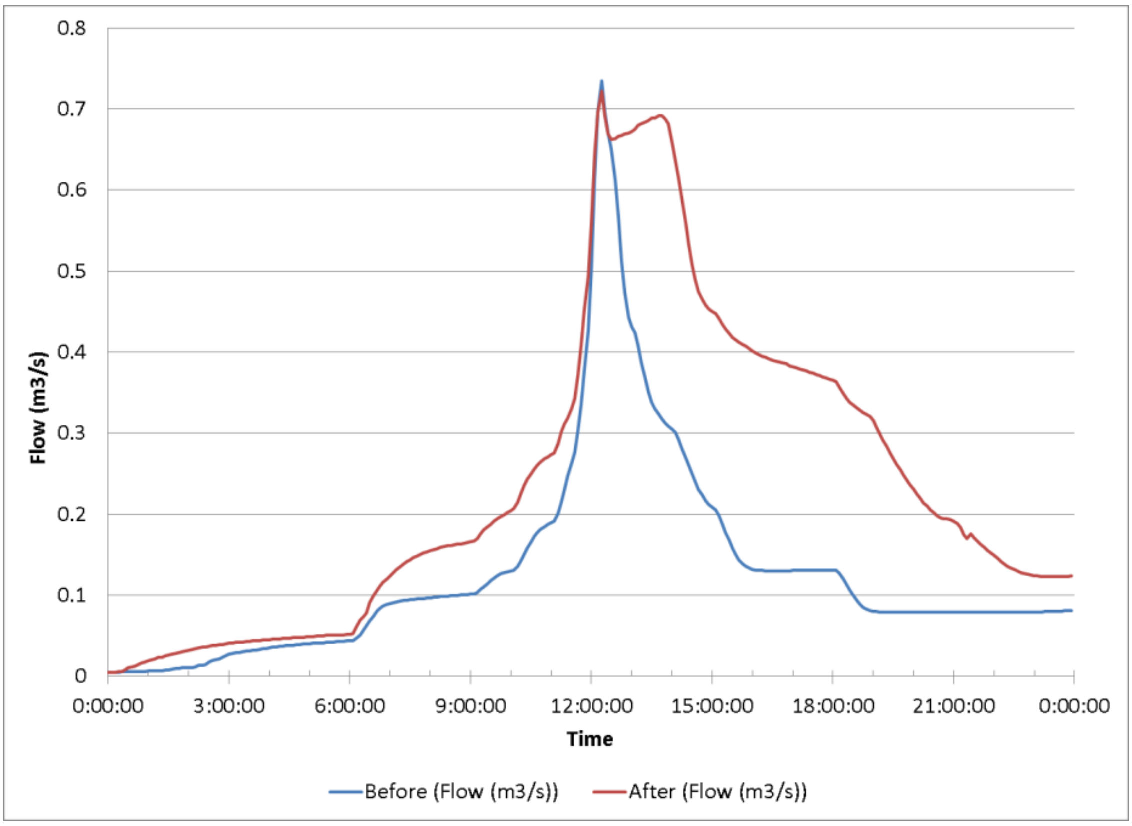
5.3.1 1 IN 10 YEAR ARI LEVEL OF SERVICE

To achieve a 1 in 10 year level of a service in the subcatchment would require a bund approximately 2-2.5m high (4000m^3 storage) along the southern boundary of Watling Reserve and a 1.5m high bund (1200m^3) in the centre of the park. Consultation with Auckland Council Parks indicated this would not be acceptable to the local community due to the visual impact, effect on park users, and residual risk to people and property immediately downstream – this bund option does not comply with the subcatchment strategy 'must haves'.

Additionally, modelling indicated the attenuation of this flow resulted in significant, prolonged discharge of stormwater to the Edendale Branch Sewer, which currently flows overland and does not enter the sewer (or gradually enters over a much longer period as flooding subsides). Under the proposed solution, the volume of water discharged into the Edendale Branch sewer was predicted to increase compared to the baseline situation. Again, this does not comply with the subcatchment strategy 'must haves'.

While the abandoned watermain would significantly reduce flooding in the upstream catchment, the overall effect during the 1 in 10 year event would be to increase the discharge to the Edendale Branch sewer from the detention area in Watling Reserve (Figure 12) and would require a bund that is significantly higher than acceptable.

Figure 12: 1 in 10 year ARI Event - Pre- and Post- Scheme Hydrographs of the Edendale Branch Sewer at No.34 St Leonards Rd.



Increasing (combined sewer) flooding in one area by reducing it in another was not considered a sustainable approach to managing the flooding.

Overall, a 1 in 10 year ARI level of service was not considered practical and would not meet the must have requirements.

5.3.2 1 IN 2 YEAR ARI LEVEL OF SERVICE

A reduced level of service to a 1 in 2 year event was then considered. Specifically:

- A bund 1.5m high (max.) would control overland flow through Watling Reserve only and reduce the extent and depth of flooding to properties along the south side of Watling Reserve. A low flow outlet (max 25 l/s) would limit flow into the Edendale Branch sewer. The bund would only have a minor overall visual impact on the park and would be accommodated into the overall park landscape through effective shaping and planting which would maintain and enhance the existing use and amenity.

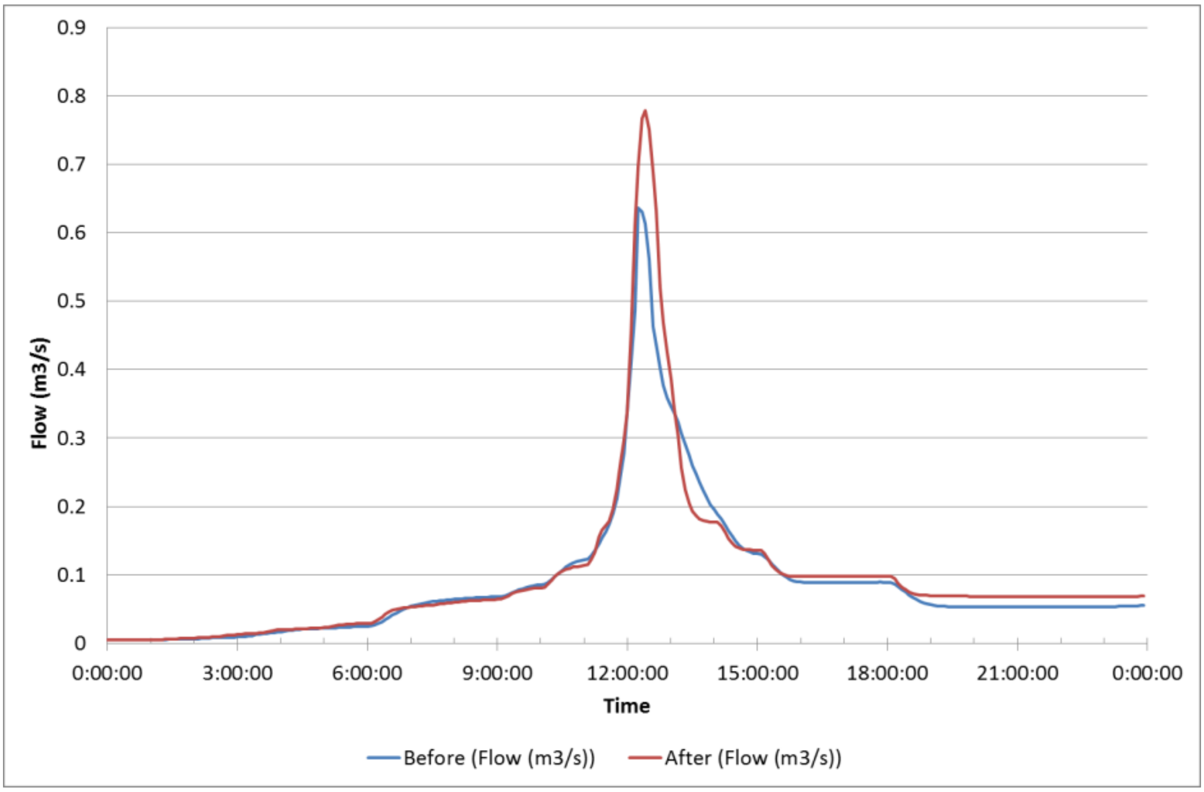
- It was not considered practical to discharge the runoff from St Andrews Road through a new pipeline to storage in Watling Reserve due to the increased bund height necessary and large flow rate into the Edendale Branch sewer. Instead, it was proposed to throttle each manhole on the abandoned watermain pipeline and use the oversized pipe for storage as well as conveyance.

- Runoff from St Andrews Road would be discharged, via the abandoned watermain, into the existing 525mm diameter stormwater pipe in St Leonards Road. Modelling indicates this pipe has sufficient capacity during a 1 in 2 year ARI event. From here it would discharge into the Edendale Branch sewer through an existing connection.

This option would significantly reduce the risk to properties in the subcatchment during the 1 in 2 year ARI event. However, some overland flow would still be expected and there would be little change in the extent or depth of flooding during more extreme events (e.g. 1 in 10 year event). Results of this modelling indicated the peak flow into the Edendale Branch sewer would increase by 170 l/s (Figure 13).

Working with Watercare, Auckland Council identified a number of catchpits immediately downstream of the subcatchment that are in high permeability fractured basalt and are connected to the Edendale Branch sewer. By providing stormwater disposal through groundwater soakage for these catchpits and removing the sewer connection, around 170l/s could be taken out of the Edendale Branch, compensating for the predicted increase in flows arising from the 1 in 2 year level of service option.

Figure 13: 1 in 2 year ARI Event - Pre- and Post- Scheme Hydrographs of the Edendale Branch Sewer at No.34 St Leonards Rd



5.4 THE PROPOSED SCHEME

A 1 in 2 year ARI level of service is deliverable in the short term and would not compromise a greater level of service should a long term catchment-scale solution be constructed.

This provides a cost effective and adaptable scheme by:

- Reusing abandoned infrastructure for stormwater conveyance and storage (Figure 16).
- Throttling flow in the abandoned watermain pipeline to provide attenuation. These throttles can be removed in the future to increase the level of service if a catchment scale solution is delivered.
- Controlling overland flow through Watling Reserve using a grassed 'bund' to retain and control the storm water discharge (Figure 15).
- Compensate for the predicted increases in stormwater discharged to the Edendale Branch sewer by disconnecting catchpits in areas with highly permeable geology and discharging this flow to groundwater.

Figure 15: Watling Reserve Overland Flow Routes and Proposed Detention Bund

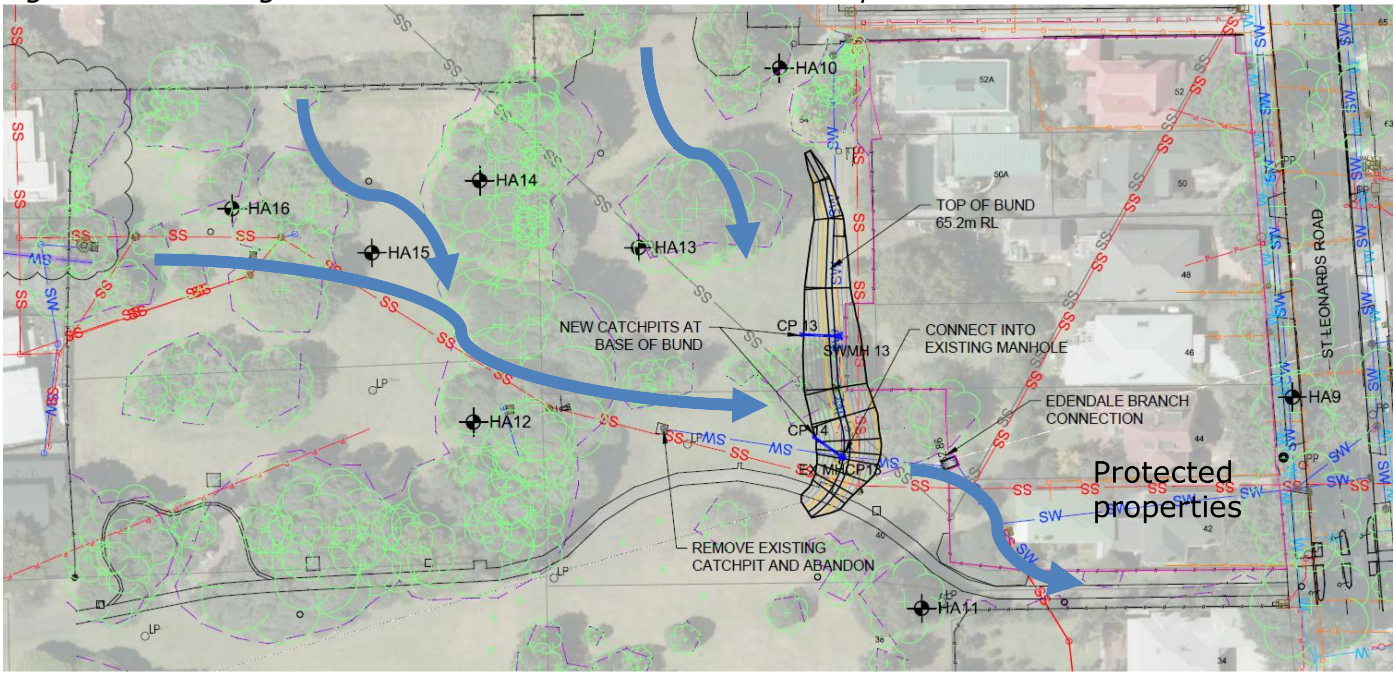
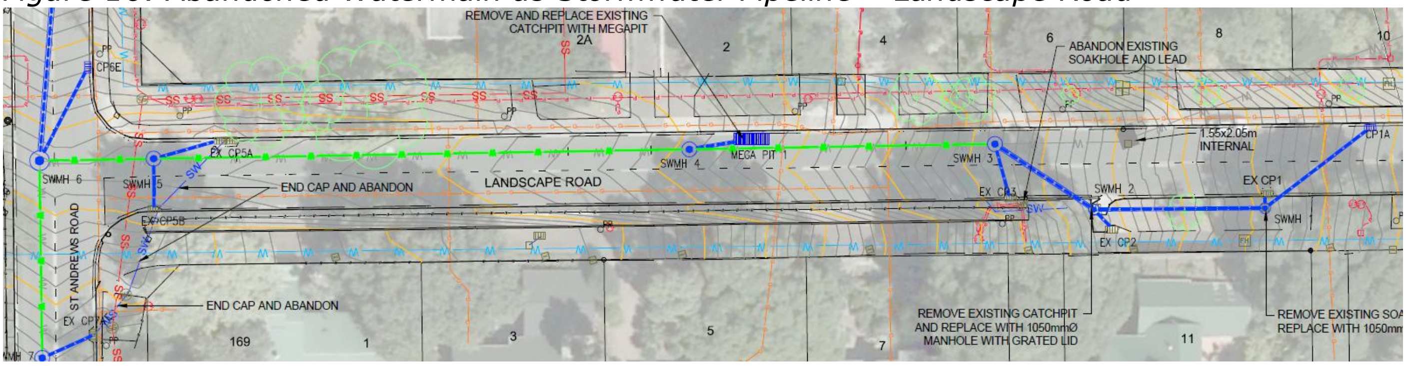


Figure 16: Abandoned Watermain as Stormwater Pipeline – Landscape Road



6 CONCLUSIONS/LESSONS LEARNT

- Delivering a scheme to manage flooding should consider the best pragmatic option rather than simply focus on standards. This enables decision makers to deliver solutions that best meet the long term needs of the community. In this case, providing a 1 in 2 year ARI level of service in the short term provides a balance between short term flood management benefit, maintaining public amenities, and meeting the needs of future generations through integration with Auckland Council's overall catchment management objectives.

- Providing adaptability in developing the design is crucial to the effective use of community funds in the short term. In this case, sizing infrastructure for future needs also provided short term benefit, whilst being easily adaptable should a catchment-wide solution be developed in the future.

- There is merit in reviewing abandoned infrastructure and assessing whether there is a secondary use for the community. The abandoned trunk watermain in St Andrews Road and Landscape Road was a constraint to the design of a new stormwater reticulation network. However, the watermain's location and size meant it could be used for stormwater conveyance and stormwater attenuation in the short term. This provides a solution that reduced project costs overall and enabled Auckland Council to deliver a cost effective scheme now that would otherwise have had an unfavourable benefit-cost ratio. It additionally enabled Watercare to transfer responsibility for an asset it no longer had a use for.

- It is important to re-evaluate project objectives each time new data becomes available. In this case, site investigations demonstrated a 1 in 50 year level of service was unlikely to be achievable in the short term. It was necessary to take a step back and reassess the overall strategy for the subcatchment in the context of the short and long term needs of the community.

- Design constraints need to be considered in detail at the conceptual option stage so that the feasibility of the preferred scheme is known. In this case, if groundwater monitoring or more detailed hydraulic modelling had been undertaken, the level of service and nature of the scheme achievable would have been more clearly understood from the project outset.

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DISCLAIMER

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