STORMING AHEAD: WATER INFRASTRUCTURE FOR GROWTH

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ABSTRACT (500 WORDS MAXIMUM)

Hutt City Council (HCC) was granted $99 M of funding through the Infrastructure Acceleration Fund (IAF) to deliver stormwater and wastewater infrastructure improvements to enable growth, a project now known as Water Infrastructure for Growth (WIG). The stormwater infrastructure improvements are aimed at removing impediments to housing for predicted population growth in Lower Hutt in the late 2020s and 2030s. This intensification will be entirely brownfield redevelopment. The WIG project is critical to enabling the local stormwater network to keep pace. Its growth-and future-oriented objectives (rather than seeking to solve a present-day flooding problem), and immediate infrastructural focus, are challenging the project team to ensure the project benefits can be realised over time.

Stopbanks provide the wider area with fluvial flood protection from Te Awa Kairangi – the Hutt River, but the low-lying area behind the stopbanks is prone to stormwater flooding. Moreover, the existing stormwater infrastructure in the Opahu Stream catchment, behind the stopbanks, is already at capacity. Even accounting for the on-site storage required under HCC's District Plan, the frequency and intensity of stormwater flooding is projected to worsen with future growth, and particularly as the effects of climate change and sea level rise continue to be realised. HCC has identified various preferred intensification areas and types of development within the catchment. The scale of predicted future flooding is too great a problem to overcome through reliance on hydraulic neutrality and minor network upgrades alone.

This project is currently at feasibility and optioneering stage, with potential solutions being assessed against: (i) the additional capacity they provide in the primary network; (ii) the level of reduction to flood hazard in the preferred growth areas; and (iii) affordability. Given the significant existing constraints, the upgrades will require pumped solutions to convey stormwater from the Opahu Stream to Te Awa Kairangi. However, early in the optioneering stage the project team explored options that sought to maximise the use of Water Sensitive Urban Design concepts such as: (i) utilising and enhancing existing overland flow paths, (ii) improving stream conveyance/daylighting, and (iii) detention storage on areas of existing green space.

In addition to the infrastructure improvements which are the focus of the WIG project, the work has brought into sharp focus a need for a broader approach to maximise project benefits in the face of uncertainty. Some lessons learnt and recommendations for wider

implementation include identifying and preserving overland flow paths in the course of development; masterplanning and steering development into areas better able to be serviced by stormwater infrastructure, while implementing stricter hydraulic neutrality requirements outside of these areas; and identifying large publicly owned sites for on-site stormwater management.

This paper will provide a summary of the infrastructural solutions being considered for this brownfield urban intensification, and the wider actions that are likely to be required in order for predicted growth to be enabled without increasing flood risk to current and future residents.

KEYWORDS

hydraulic neutrality, intensification, housing, brownfield development, growth, flooding, pumping, masterplanning

INTRODUCTION

HCC and the IAF (distributed through Kāinga Ora – Homes and Communities) have jointly funded stormwater upgrades required to facilitate building of up to 3,520 new houses in the lower Hutt Valley. HCC has also committed to funding of the wastewater pipeline upgrade required to support this additional growth, although this paper will focus on the stormwater infrastructure only.

There is currently no masterplan for this intensification. Therefore, although the housing enablement objective for the funding was clear from the start of the project, how the stormwater upgrades are to be achieved has been left open.

The story of the project to date has been one of:

- exploring stormwater upgrade options.
- the definition of how success will be achieved in this catchment.
- what is the best use of the available budget to enable new dwellings.

This paper will focus on the following key challenges of this project:

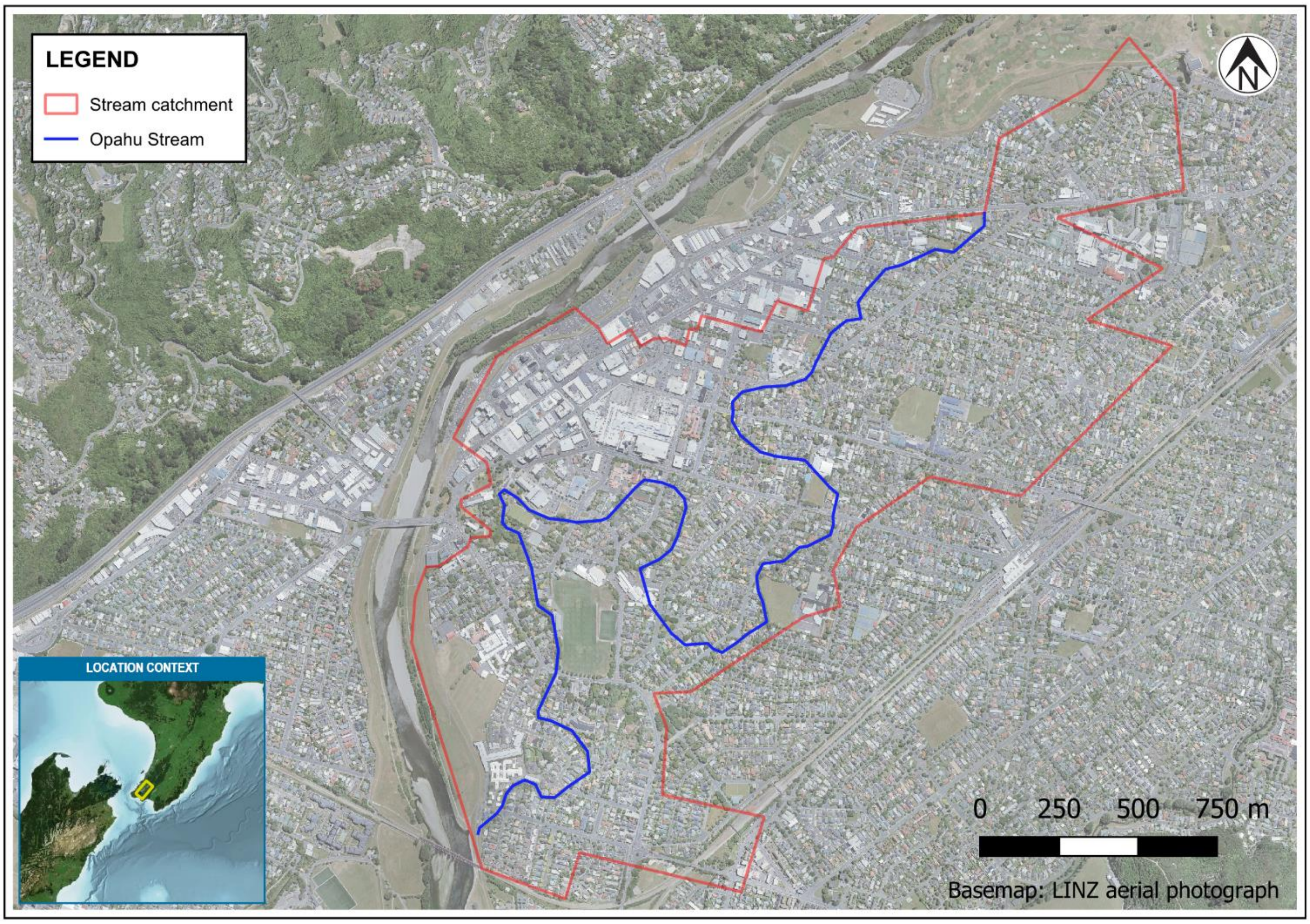
1. How to define and achieve success in the absence of masterplanning and fixed design criteria? What are suitable metrics and how to choose options that maximise these?
2. The related need to shift the mindset away from the traditional approach of solving existing flooding problems, to infrastructure as a driver of growth.
3. How to prioritise sustainable infrastructure solutions?

This paper first presents the background to the project and some important context, then follows with a discussion around how the project has addressed these key challenges to date.

Project area

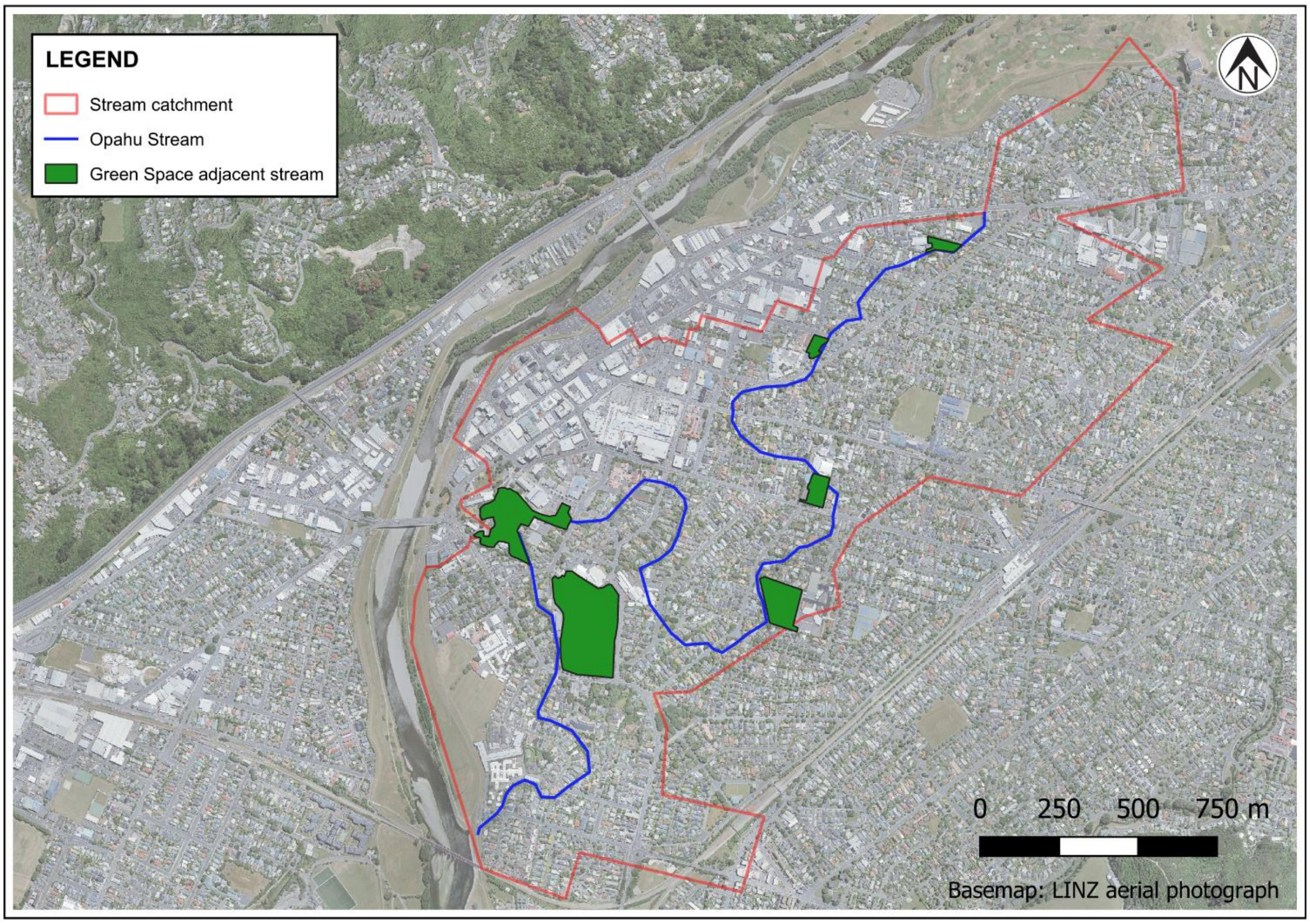
The project area for the upgrade is the Opahu Stream catchment, shown in Figure 1 below.

Figure 1. Project area



The catchment includes most of the Lower Hutt CBD and is heavily urbanised. The stream itself is very constrained and has little green space along its length. It is very flat, with a fall of approximately 7.1 m along its 5.3 km length (0.13% or 1 in 750). A considerable length of the stream is culverted. Figure 2, below, shows the green space along the stream corridor. This consists mostly of school playing fields, with no public green space except the Hutt Recreation Ground and Riddiford Gardens (the two larger spaces at the downstream end).

Figure 2. Green space adjacent to the Opahu Stream



Much of the stream in its upper and middle reaches, where not culverted, is constrained between buildings (see for example the photo in Figure 3, below). The Opahu Stream flows only intermittently in its upstream reach.

Figure 3. Photo showing typical stream constraints

Due to the existing level of urbanisation within the catchment, it is expected that all new housing growth will be brownfield development, i.e. housing intensification/mixed use development, rather than greenfield. The figure of 3,520 new dwellings is not based on any specific plans for new developments per se. This housing growth is expected to be delivered in the 2020s and 2030s by a mix of private and public development, with no specific large renewal projects yet planned.

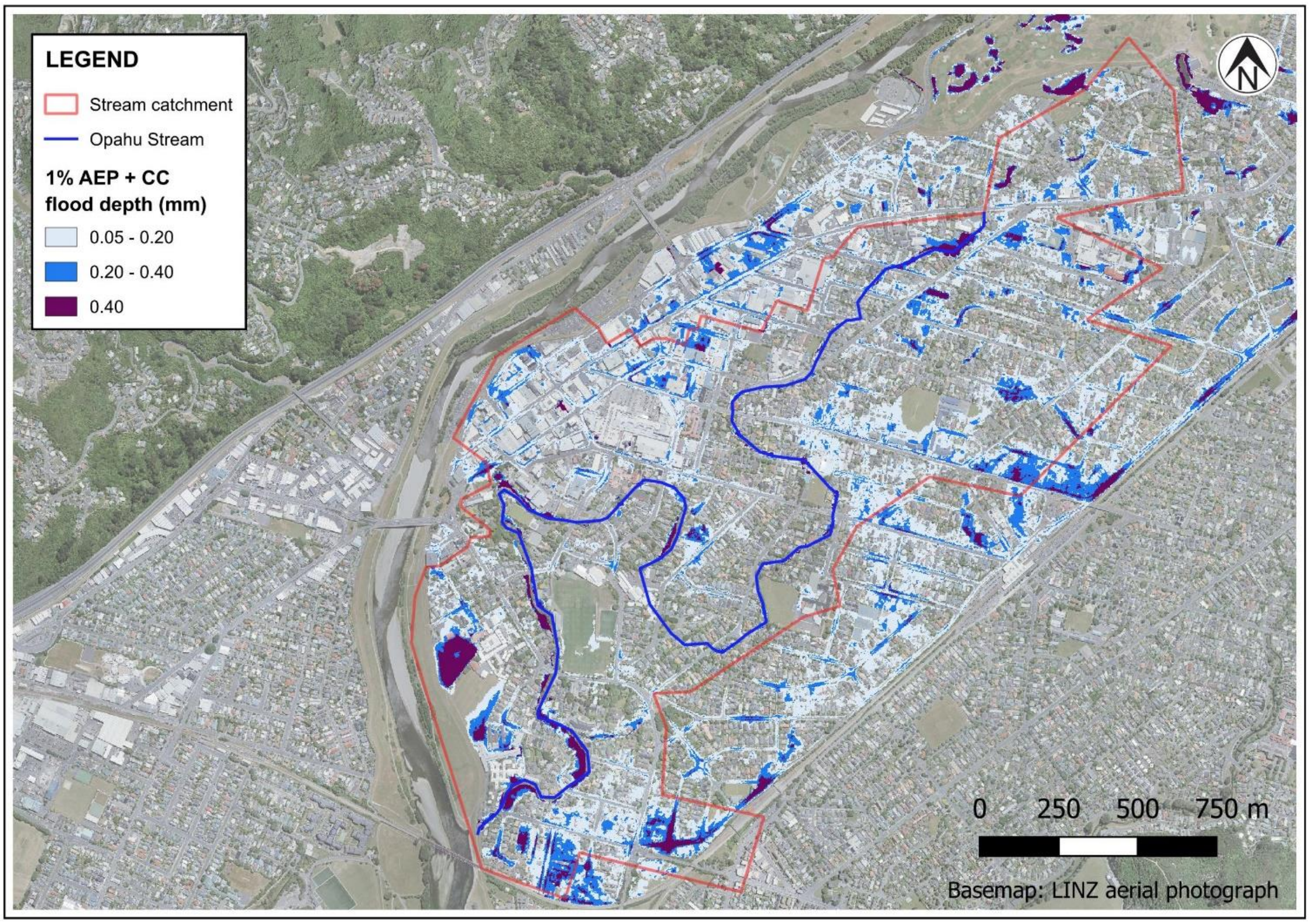
The project area is protected by stopbanks from fluvial flooding from Te Awa Kairangi – the Hutt River. This stopbank protection is being upgraded through the City Centre reach of Te Awa Kairangi by Greater Wellington Regional Council (GWRC).

Stormwater network flooding in the catchment

An existing pump station (Opahu Pump Station) at the stream's confluence with Te Awa Kairangi, built in 2008, has a capacity of 9m^3/s. The Opahu Pump Station was constructed to mitigate an existing problem of flooding of properties in the lower reach of the stream.

Hydraulic modelling was carried out by Stantec, using a cut-down version of an existing Wellington Water Limited model (Stantec, 2022) and Wellington Water's latest requirements for climate change allowances[1] (+CC). This high-level, catchment-scale modelling resulted in the flood depths shown in Figure 4 below for a 1% Annual Exceedance Probability (AEP) event. The Opahu Pump Station is included in this model. Flood depths and extents in a 10% AEP +CC event are considerably less but still significant, indicating that the primary network has insufficient capacity for this event. 10% AEP +CC is Wellington Water's target level of service for new and upgraded primary infrastructure (Wellington Water, 2021).

Figure 4. 1% AEP +CC flood depths



Project constraints

The major physical constraints affecting the development of stormwater upgrade options have been:

- The degree of urbanisation and very limited green space along the stream, as noted above.
- A high density of underground services, particularly in areas where bulk water pipelines are present such as Knights Road.

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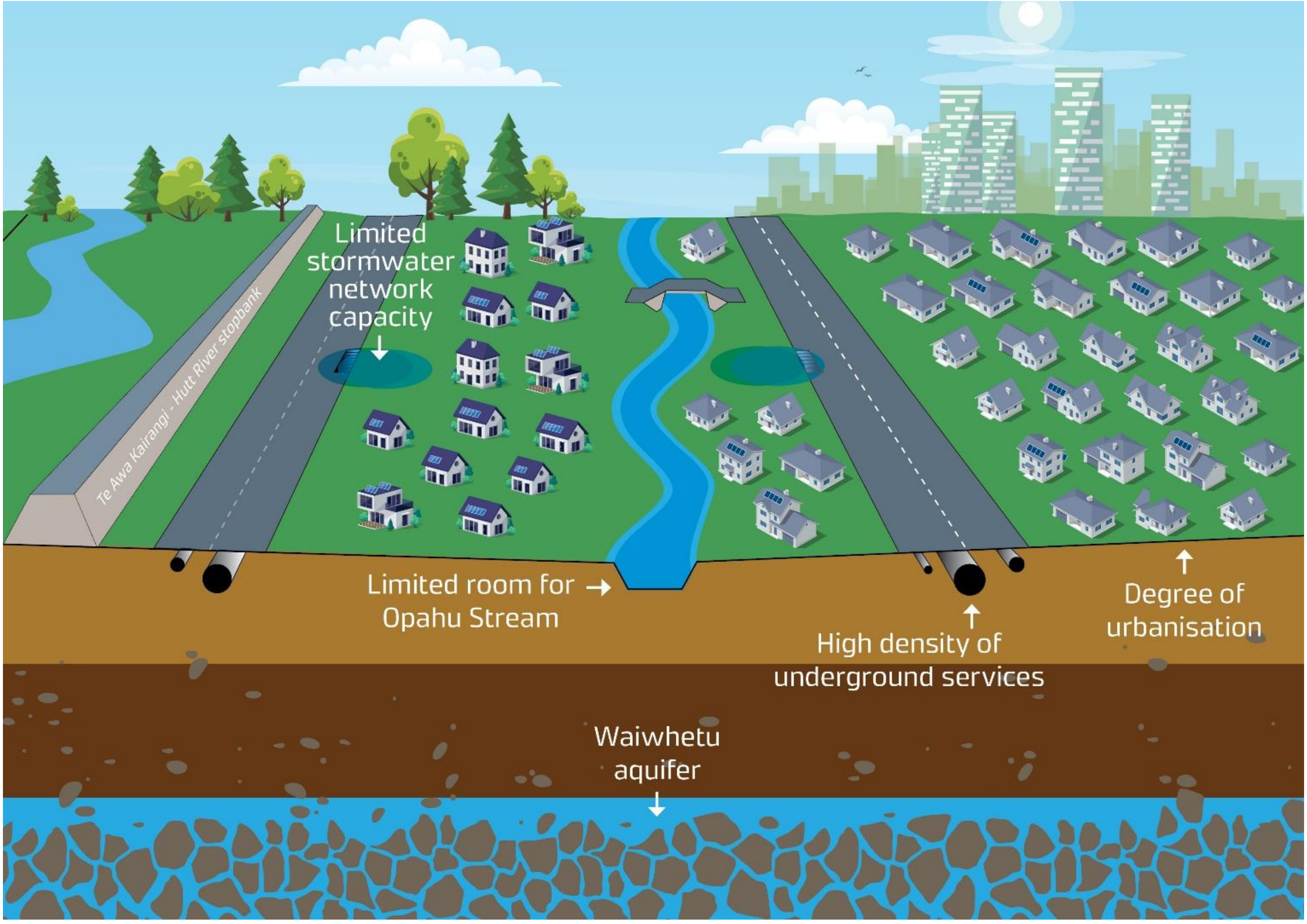
[1] Rainfall increase in line with HiRDs v4 for the RCP 8.5 scenario to year 2100. Relative sea level rise out to 2130 using the SSP5-8.5M scenario.

- The Waiwhetū aquifer. The top of this artesian aquifer, from which up to 60% (in summer) of the drinking water supplying Wellington, the Hutt Valley, and Porirua is drawn, lies at a depth of between 15 m to 20 m in this area. The aquitard thickness is variable, and also thins/becomes leakier northwards within the project area. The drinking water supply bores are located in the vicinity of Knights Road, within the urban area.
- Capacity of the Opahu Stream. As mentioned above, the stream is very flat and laterally constrained, often lying in a tight gap between buildings. It is crossed by numerous road culverts, driveway crossings and more informal structures. Its modelled capacity varies but in general terms is approximately 0.5 m^3/s at the upstream end, 1.5 m^3/s mid-reach and 6 m^3/s at its downstream end (increasing to 9 m^3/s in the vicinity of the pump station).
- Limited existing stormwater network capacity. The existing pipe network has a large number of pipes laid with very minimal fall, often considerably less than 0.5%, which limits the flows that can be reasonably conveyed (even when considering pipe upgrades). Wellington Water's target 10% AEP +CC level of service for new or upgraded infrastructure is not met within large areas of the existing network. Even accounting for the on-site storage required under HCC's District Plan, the frequency and intensity of stormwater flooding is projected to worsen with future growth and particularly as the effects of climate change and sea level rise continue to be realised. Due to the flatness of the catchment, road crowns obstruct overland flow paths, resulting in many cases in modelled ponding to a depth of several hundred millimetres behind the road.
- Existing Te Awa Kairangi stopbanks. The stopbanks, in combination with high tailwater levels in the Hutt River, limit the outlet capacity of the Opahu Stream. This has been resolved, at least to a large extent, by the Opahu Pump Station. The stopbank owner, GWRC would prefer to see outlets combined rather than approving new penetrations through the stopbank, leading to a long-term rationalisation in the number of outlets. The flood risk posed by outlets through a stopbank is two-fold:
    - backflow through the outlet during river floods, flooding areas behind the stopbank, and
    - piping, scour, and geotechnical (seismic) risks posed by the outlet to the stability of the stopbank itself.

In addition to the physical constraints above, the project has a tight delivery timeframe, driven by current and future demand for growth. This means that, whichever infrastructure upgrades are identified must be able to be delivered within a timeframe of 3 to 4 years from start to finish, to keep pace with housing demand.

Figure 5. Physical constraints



DISCUSSION

Key challenges

As touched on in the introduction, there are three key challenges that have been the focus of the project to date. The following describes the journey taken to address these.

Challenge 1. How to define success in the absence of masterplanning and design criteria? What are suitable metrics and how to choose options that maximise these?

A workshop was held with the client and key technical stakeholders early in the project, in mid-2023. The purpose of this workshop was to define what success looks like for this project and agree a design approach. We recognised at this point that our design approach would not be to a particular level of service, but rather to develop stormwater upgrade options that provide for the greatest number of potential new homes while remaining within budget.

A design philosophy was agreed, with its main focus on:

- Flooding within the identified growth area (project area) in a 1% AEP +CC event.
- Flooding of existing residential homes (number of flooded floor levels) and their access.
- Flooding of arterial roads identified by HCC.

These metrics changed over time towards improving trunk capacity for intensification without making flooding worse, as described under Challenge 2 below.

As the location of the anticipated 3,520 new homes was broadly defined as being anywhere in the catchment, it is difficult to use traditional definitions of success such as: Applying solution 'A' leads to a defined level of service improvement in the study area. The area is too large and has too many interconnected subcatchments to apply this approach at a feasibility study level of detail. Our solution was to assess options against each other based on their relative ability to have as broad an impact as possible, therefore maximising resilience of the preferred option to uncertainties regarding where development may be desired.

In picking the project up at the feasibility design stage, Tonkin & Taylor Ltd (T+T) and Mott MacDonald agreed with HCC and Wellington Water that the options considered in a previous study by Stantec in 2021 (Stantec, 2021) would be opened out again to consider a wider range of options, with the intention of putting these through a longlist, shortlist and preferred option process. As well as wanting to ensure we were choosing the best option that fitted within the budget, we identified tight timeframes and corresponding risk around consenting and property acquisition, meaning that the decisions had to be well-grounded and documented. A multicriteria analysis (MCA) approach was chosen to guide the decisions on shortlist options and then again for the selection of a preferred option. The cost of the options was considered in parallel with the MCA but was not one of the factors scored.

Types of options considered

A range of infrastructural options were investigated, including:

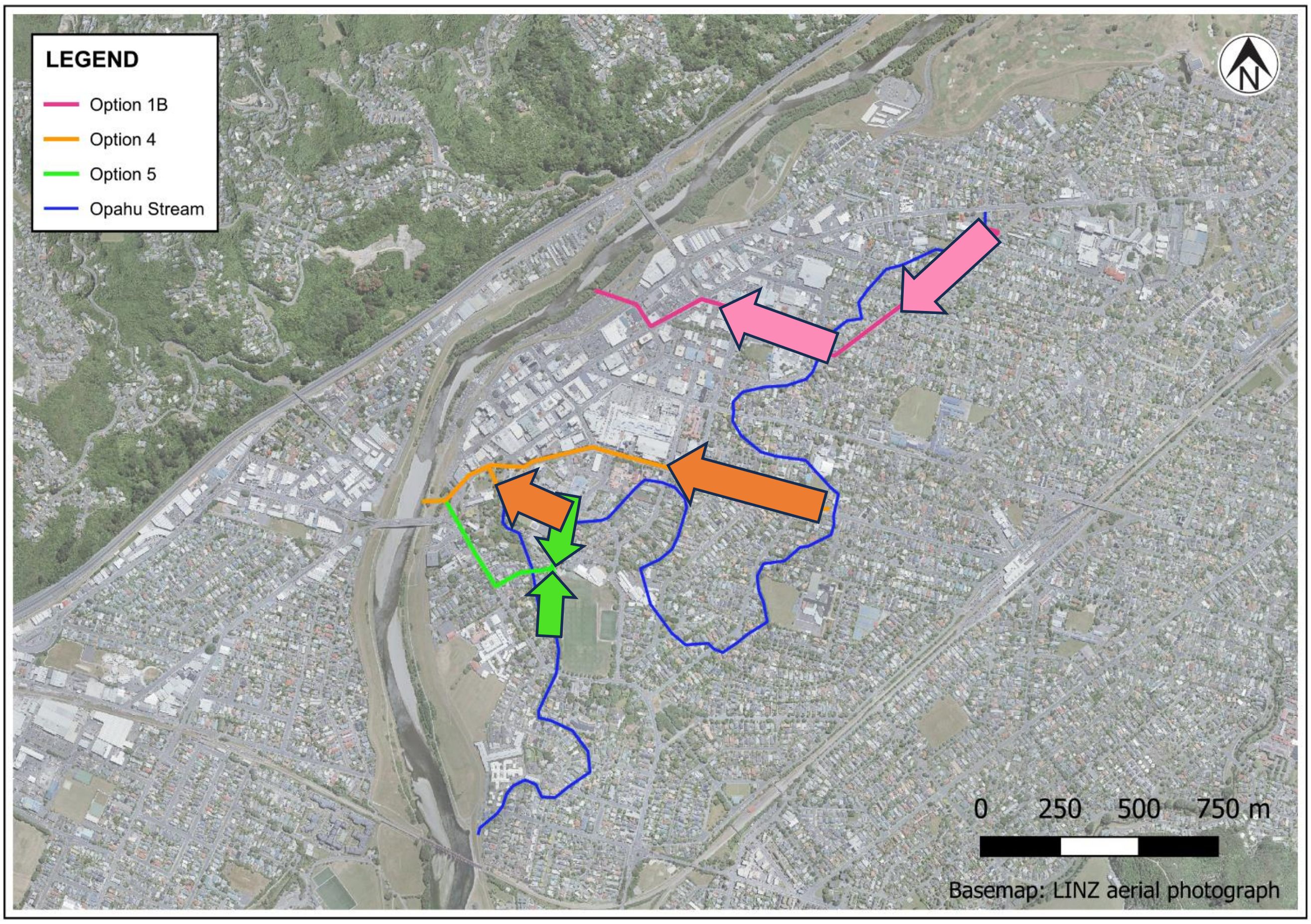
- Large gravity pipelines from the Opahu stream to Te Awa Kairangi.
- Pump stations on the Opahu Stream with rising mains to Te Awa Kairangi.
- Detention storage on a number of school playing fields adjacent to or near the stream.
- Improving stream conveyance/daylighting in the upstream reach.
- Improving stream conveyance to the existing Opahu Pump Station.
- Large scale detention storage in large open areas.

Improved source control measures for individual sites were outside the scope of this project. However, some potential improvements for larger publicly owned sites are included in future recommendations.

Simplified hydraulic assessments were carried out initially, with more detailed hydraulic modelling then carried out for the shortlisted options.

A number of factors were reflected in the selection of the shortlist, but only options involving pump stations on the Opahu Stream with rising mains to Te Awa Kairangi were assessed as having the potential to make a big enough impact on either the stormwater network capacity or flooding to enable the level of housing development required. The three shortlisted options are shown on Figure 6, below. They are; Option 1b (northern), Option 4 (central), and Option 5 (southern).

Figure 6. Shortlisted options



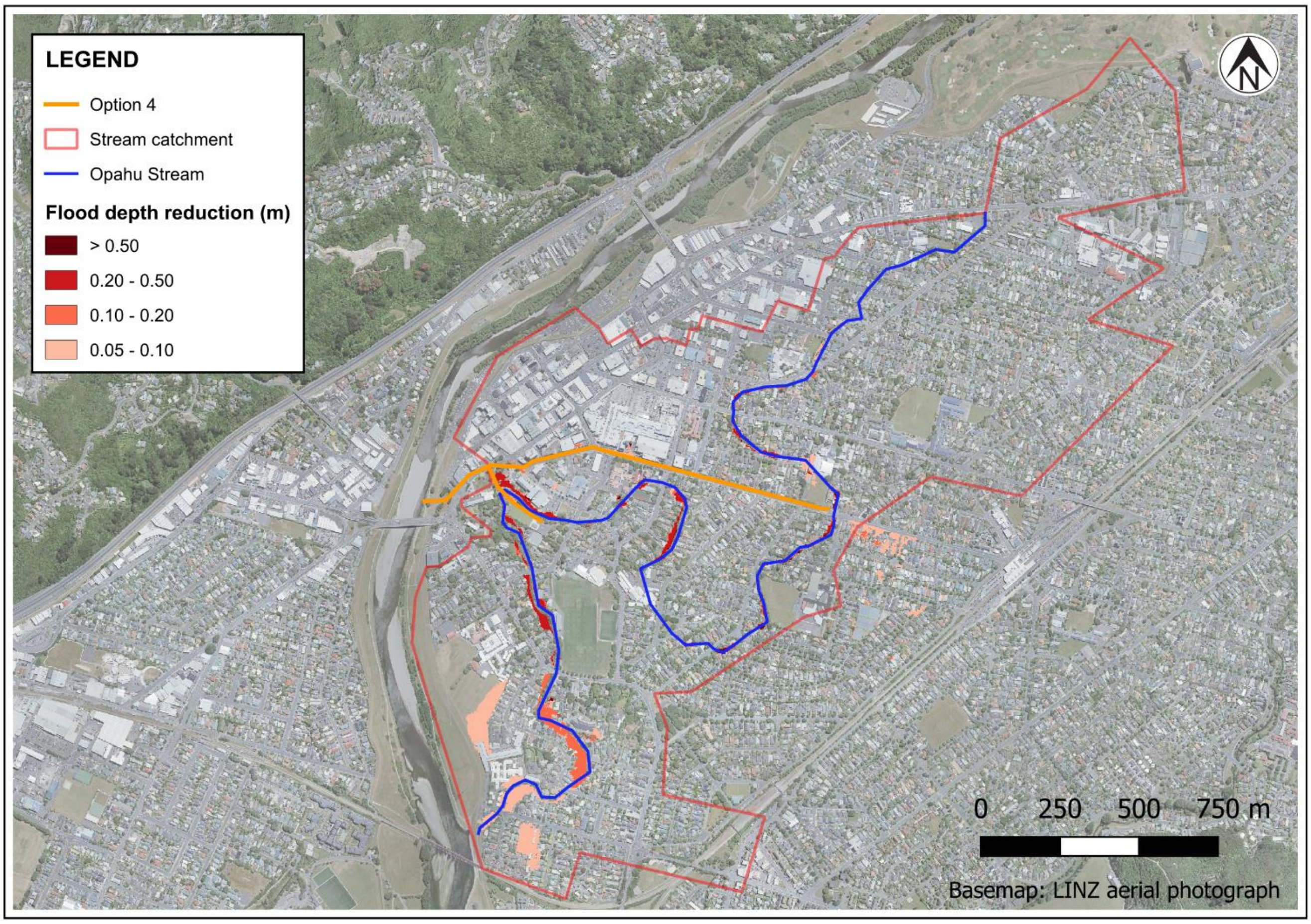
Challenge 2. The need to shift the mindset away from the traditional approach of solving existing flooding problems, to infrastructure as a driver of growth.

There was a general understanding within Wellington Water and HCC that the stormwater network capacity would be a constraint on development within the Hutt City catchment. However, there was little understanding of the specific causes of the constraint and the scale of what it would take to resolve this. Given that the Opahu Stream is the trunk spine of the stormwater network in this catchment, it was thought that improving its capacity would likely lead to better network performance. This was the approach taken to solve an existing flooding problem at the downstream end of the stream in 2008, with the construction of the Opahu Pump Station.

A high-level analysis was undertaken by Stantec in 2021 (Stantec, 2021) which in the end proposed two locations where water could be removed from the stream and pumped to Te Awa Kairangi. The basic premise of this study was that by removing the tailwater constraint in the trunk network, connected parts of the network would have more capacity. This study used a flooding reduction metric of estimated residential floors flooded (for existing properties).

Further modelling carried out by Stantec on the shortlist options yielded a surprising result: that the impact of the options did not generally extend very far from the stream itself. An example of this finding is shown in Figure 7, below.

Figure 7. Difference in 1% AEP + CC flood depths for shortlist Option 4



Whilst the previous study identified a significant capacity constraint in the stream, this further hydraulic analysis identified various additional constraints within the network itself. Principally, these are:

- ponding (often at some distance from the stream), due to the generally unfavourable fall in the primary pipe network severely limiting its capacity.
- the lack of functioning secondary flow paths able to convey water to the stream when the pipe network is overloaded (these are often obstructed by roads, sometimes with a cascade pattern).

This means that while improving the stream capacity must be done if we are to reduce flooding, we would also need to do more to connect areas of flooding to the stream. An agreed pivot in approach at this stage had us looking for areas that we could connect with reaches of the stream/trunk network where the capacity would be improved by one or another shortlist option. The idea was to look for relatively inexpensive and low-tech solutions that could be added to one or more of our shortlist options. We identified six areas where this seemed feasible and we had high-level solutions modelled for these, in conjunction with their associated shortlist option.

The proposed conveyance improvements in these areas generally consisted of:

- Roadside swales.
- Piped crossings of roads with scruffy dome inlets/outlets.
- Lowered driveways to create or enhance overland flow paths.
- Detention storage in existing car parking areas.

Several of these 'add-ons' provided good drainage to the stream and represented good incremental value in terms of the area of land with reduced flooding. However, the additional costs still did not meet our threshold of 'inexpensive' and including these additional works would have pushed the overall costs well beyond the project budget. Additionally, the area of land where flooding was reduced was nowhere near what would be required to enable all the new development to occur on previously flooded land.

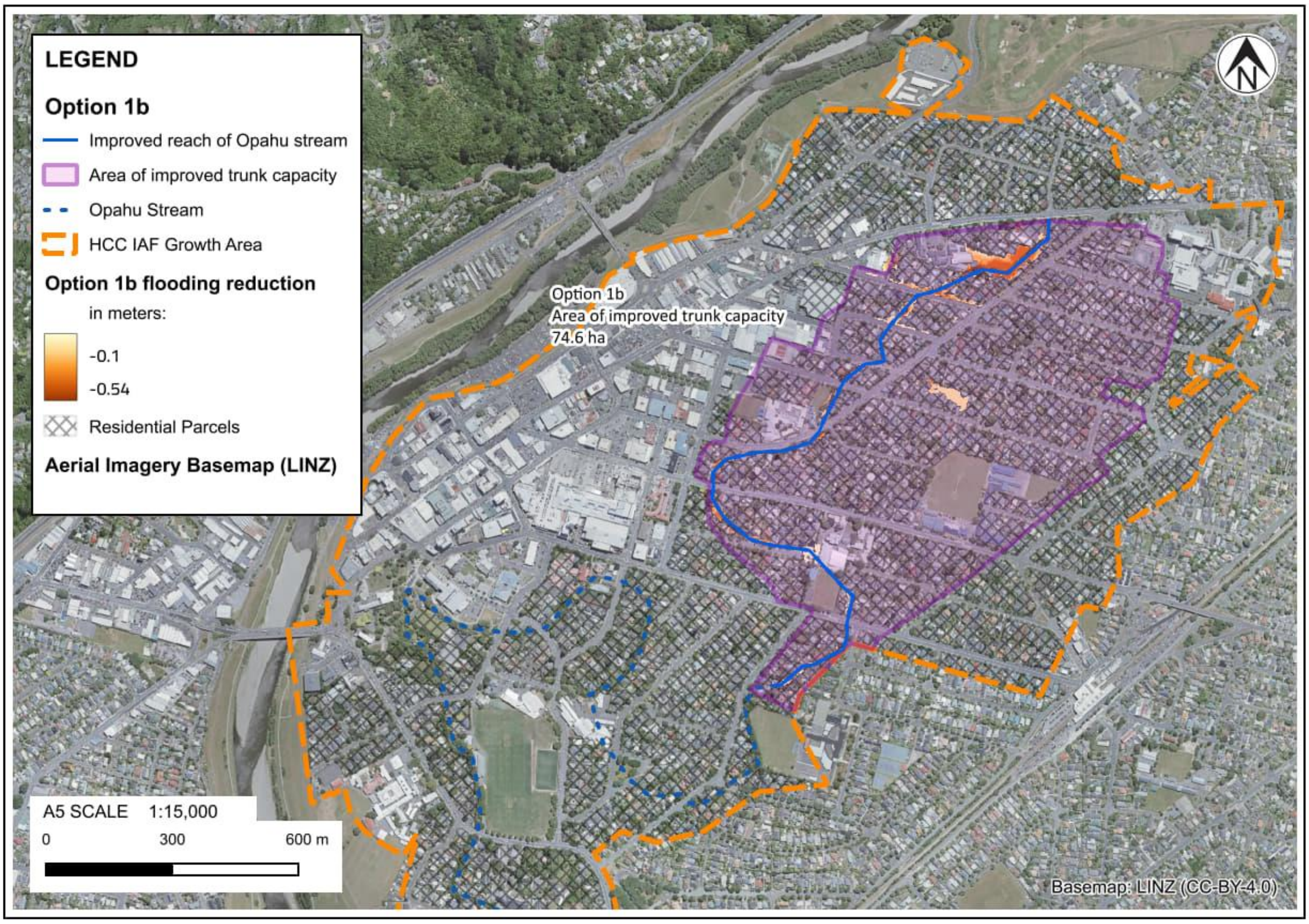
Using a different mindset to approach the problem

At this point, the focus of the project moved to upgrading trunk capacity in the Opahu Stream, in order to enable **intensification on the non-flooded land**. This offers two main advantages:

1. A more sustainable and resilient approach, in that we are encouraging development away from the hazard (avoid/prevent) rather than seeking to remove the hazard (control/resist). There are some areas of flooding (such as deeper and/or faster flooding near the stream, or in concentrated overland flow paths) where development should be avoided entirely.
2. Development potential is less limited. Providing that infrastructure solutions are practical and affordable, there are potentially greater reaches of land which can be unlocked for development.

Existing development in the CBD is in effect close to 100% impermeable: therefore, housing development occurring within this area is not expected to worsen stormwater runoff. This is an interesting outcome in itself, as it implies that the need for stormwater investment to serve new development in the CBD should be relatively small. Outside of the CBD, however, initial estimates of post-intensification runoff (based on broad assumptions about the nature of this development) indicated that, even with the requirements in the HCC District Plan for detention of roof runoff, greater flows could be expected. This led us to use the hydraulic modelling results to identify the 'benefit reach' of the stream due to each option, using a threshold of a 100 mm water level reduction. Combined with the mapping of the existing stormwater networks draining to the stream, this allowed us to translate this reach to an approximate 'benefit area', as shown in Figure 8 below.

Figure 8. Option 1B approximate area of benefit from improved trunk capacity



To assist with estimating benefits, HCC provided the project team with two styles of intensified redevelopment within existing residential areas, being:

- terraced townhouses (2 - 3 storey), with an average density of 31 dwellings per hectare (**lower density**), and
- walk-up apartments (3 storey), with an average density of 200 dwellings per hectare (**higher density**).

The residential land counted within the benefit areas shown in Table 1 below deliberately does not include the CBD, even though some mixed-use development is being encouraged in this area, as intensification in the CBD is expected to be (at worst) hydraulically neutral.

Table 1. Potential number of new dwellings within each option's benefit area

Option	1B	4	5
Higher density	10,300	14,200	6,600
Lower density	1,600	2,200	1,000

Using this alternative metric, any of the shortlisted options can potentially enable the development of the targeted 3,520 new homes, consisting of a mix between walk-up apartments and high-density townhouses. Work is ongoing by HCC to consider other drivers of development location, such as walking catchments and the suitability of existing housing stock for redevelopment. These considerations will feed into the selection of a preferred option using a similar MCA process as was used in deciding the shortlist.

A key lesson learnt is that, in both the previous study and in the initial direction setting of this stage, the focus was on solving problems that we could see which in this case meant measuring the project against a reduction in flood hazard area. This proved impractical and overly costly. 'Solving' a problem can itself be ill-defined. The switch to a development-driven, outcomes-based mindset demonstrated that the proposed solutions could provide for future development in areas where there is not currently a significant flood (or other) hazard, which is a more sustainable and resilient approach.

Another important lesson learned by the project team, through conversation with developers and HCC officers, is that the location of suitable Three Waters infrastructure is one of the biggest drivers for where development will occur despite all the best intentions of masterplanning. Three Waters infrastructure upgrades are often very expensive relative to other costs, so developers will seek to develop on brownfield sites firstly in areas where there is spare capacity in the network, so their developer contributions are minimised. Therefore, the wider lesson for future stormwater projects is that that there is an ability to drive where development will occur through where we provide our solutions and the type of solutions we provide. Masterplanning should take developer economics into account as well as infrastructure servicing.

Challenge 3. How to prioritise sustainable infrastructure solutions?

Although only pump station options made the shortlist (as described above), a wide range of solutions was considered. Including sustainable (blue/green) infrastructure has proved very challenging. Doing the mahi to understand what some more sustainable solutions could deliver, and where, has left the door open for them. Some examples that are currently outside of the project scope include:

- Some of the identified add-on solutions to flooding near the stream, described above, may still provide a meaningful and value-for-money flooding reduction for existing properties. These could be brought back into the project scope if cost savings are found in other areas. They also provide indications of areas to prioritise in stormwater network upgrade planning, or when specific areas are identified for intensification.
- Identifying, protecting, and enhancing overland flow paths provides the opportunity to enhance conveyance/connectivity of the secondary network and reduce flood risk over time, as properties are redeveloped.
- While our preliminary calculations have shown that the current District Plan requirements for roof runoff tanks would not fully account for the additional runoff likely under intensification, they do show that this degree of detention makes a significant difference. In the CBD, where impermeable surfaces are already at close to 100%, future redevelopment including detention storage has the potential to actually decrease peak flows.

- Future developments can be designed to maximise the use of their common spaces for stormwater management/multi-use infrastructure, and to maximise their permeable area. Hydraulic neutrality requirements for new developments may also become stricter in the future, in terms of needing to match not only stormwater peak runoff rates but total volumes as well.
- During the options development process, we identified some publicly owned sites that appear to be significant runoff contributors to the stream (e.g. Hutt Hospital and some schools). It would be worth exploring whether on-site detention can be incorporated into future redevelopment at the sites, or in some cases (e.g. school playing fields) whether on-line detention can be added along the stream.

CONCLUSIONS

The WIG project has not yet been completed but the project team has already identified several important recommendations/observations that will sit alongside the delivery of the infrastructure solutions. These are outlined below:

1. Enabling housing intensification by solving areas of existing flooding has proved to be impractical, as well as being expensive per hectare. Flooding in this catchment, and likely others across the Hutt Valley which share a similar mix of constraints, is a distributed problem that requires multiple decentralised solutions along with trunk infrastructure.
2. Encouraging development on flood-free land and creating capacity in the system to mitigate any increased runoff from additional development and climate change is the preferred, and only affordable, approach.
3. There are opportunities to improve the existing flooding situation, if desired in the future, by leveraging off the improved trunk capacity that will be delivered by this project. Smaller add-on projects can provide good incremental value in reducing flood depths and extents. There may also be opportunities for improving conveyance in particular reaches of the stream where specific constraints are identified.
4. There may be additional opportunities to improve the existing flooding situation through reviewing planning rules to encourage more permeable surfacing such as porous paving, green roofs etc. However, in this location, council would need to work closely with technical experts to assess the return on investment of different options. These opportunities would likely be realised over long term urban renewal timeframes.
5. Stormwater improvements and Three Waters improvements more generally can be a significant influencer and driver of development in brownfield locations. This is also something to think about when planning level of service upgrades ("if you build it, they will come") – and something that has long been known about in relation to new roading infrastructure.
6. It can be difficult for technically minded people to move from achieving a defined level of service to solving a less well-defined problem.
7. Allowing for future growth may well be a matter of planning for what is not there rather than fixing the problem that you can see.

8. In addition to increasing trunk capacity there may be other measures needed depending on the desired location for development. This was beyond the scope of this project. However, some of our thoughts are presented below:
    a. Ensuring new developments continue to retain a large amount of their runoff on site, aiming for hydraulic neutrality (or as best as can be achieved). HCC's District Plan already has some provisions for this.
    b. Network improvements to ensure new developments can connect to the stream. This should include identifying, protecting and, where possible, enhancing overland flow paths in preference to investing in upsized primary infrastructure.
    c. Masterplanning of new development (with developer involvement into which areas are most cost-effective) to ensure that these measures can be adequately planned for and programmed.
9. Some publicly owned sites appear to have potential for on-site management of stormwater and/or development of online detention storage beside the stream. This is likely to have a localised impact.
10. Any redevelopment within the CBD that includes detention storage will result in reduction in flow rates, due to the very high existing proportion of impermeable surfaces. These opportunities should be pursued as low-hanging fruit.

ACKNOWLEDGEMENTS

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