Plan Change E

Roxburgh Crescent Rezoning

Stormwater Servicing Assessment

January 2024

PAPAIOEA PALMERSTON NORTH CITY

This document was prepared by Palmerston North City Council, Transport and Infrastructure Division.

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A	WORKING DRAFT	04/2019
B	FINAL	09/2022
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E	Revised hydrological analysis (DRAFT)	01/2024

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1 Introduction

This report summarises the assessment of the stormwater servicing requirements for Roxburgh Crescent residential re-zone. Specifically, this assessment involved a high-level review of the proposed residential rezoning and subdivision to determine its likely impact on the surrounding environment and the measures required to mitigate any adverse impacts from the development. The assessment has been undertaken using the preliminary development plan information provided by McIndoe Urban in the context of the Palmerston North City Council's proposed Roxburgh Crescent Re-zone and Structure plan (section 32 plan change), as shown in Figure 1.

The proposed Plan Change (PC) area is roughly a 4.5-hectare block of land located to the east of the city centre in Hokowhitu, adjacent to the Manawatū River. The area is bounded by the Manawatū River and Roxburgh Crescent Reserve to the east and Ruahine Street to the west. The area is currently zoned industrial surrounded by typical residential lots. Figure 2 provides an overview of the Roxburgh Crescent residential re-zone extents, shown in blue. Of that area approximately 0.44-hectares is the public roading corridor.

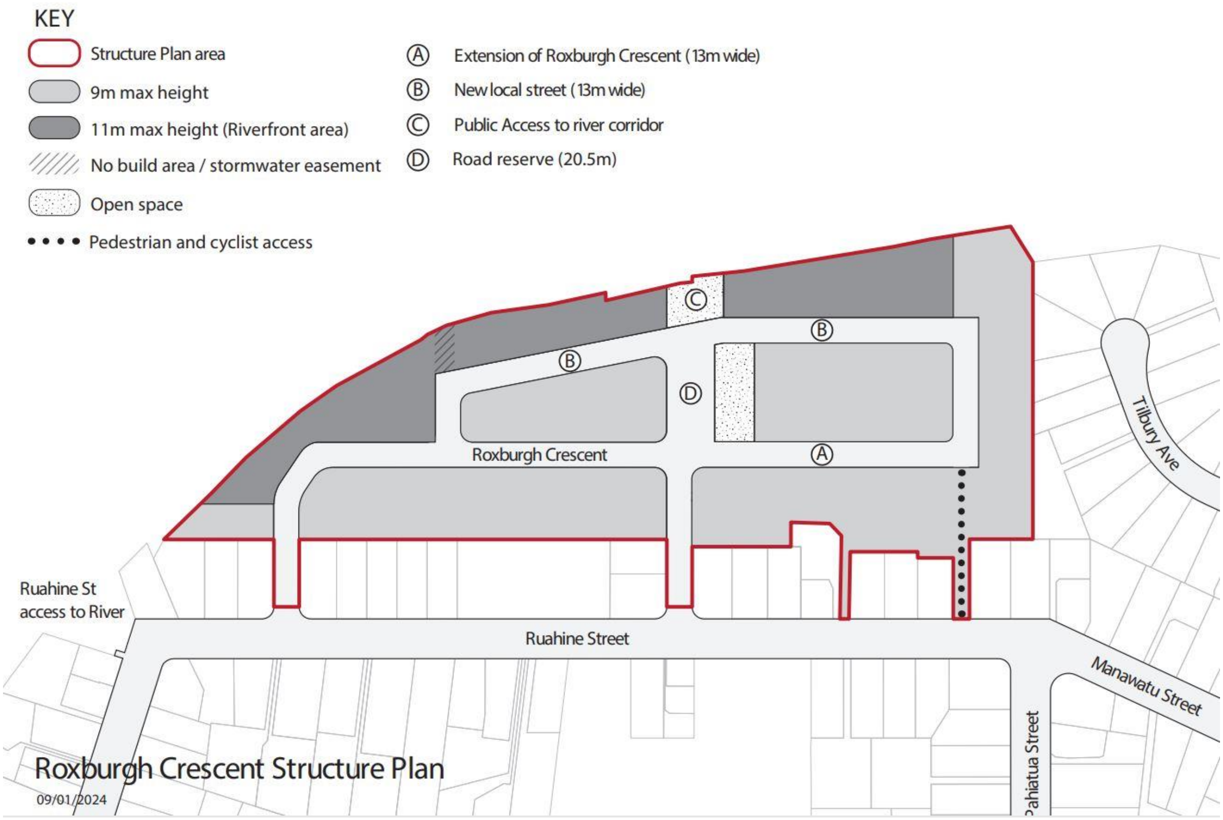

Figure 1: Roxburgh Crescent Structure Plan

Figure 2: Roxburgh Crescent Re-zone Area

2 Stormwater Services Assessment

2.1 Existing Stormwater Services

The PC area is currently serviced by a stormwater network comprising pipes ranging from DN225 to DN750, with a direct DN750 outfall to the Manawatū River. The outfall serves a total catchment area of approximately 18 hectares. A 2.5m high stopbank protects the area from flooding from the Manawatū River. The existing network consists of reinforced concrete pipe (RC) installed in 1964. Based on the expected lifespan of RC, it is not currently considered in need of renewal in the foreseeable future (i.e. next 30 years); however, part of the network does not meet the required minimum pipe size as per the current *Engineering Standards for Land Development* (ESLD) (see highlighted section in Figure 3 below), and a condition assessment of the network has not been undertaken to confirm the expected remaining life.

The existing Council reticulated stormwater network in the vicinity of the Roxburgh Crescent Residential Re-zone Area is detailed in **Error! Reference source not found.**Figure 3 below. The network splits into 4 sub-catchments at the corner of Ruahine Street and Roxburgh Crescent south, and at Newcastle Street and Surrey Crescent (refer Figure 4). The Newcastle Street catchment appears to split flow evenly to the Roxburgh Crescent outfall and the Crewe Crescent network. Ruahine Street continues down Manawatu Street to the Crewe Crescent network, however there is a high-level overflow into the Roxburgh Crescent network.

Figure 3: Existing stormwater network (network below minimum diameter requirements highlighted in yellow)

Figure 4: Flow splits (circled in blue) **and general flow direction** (split flows as dashed arrows)

2.1.1 Existing Stormwater Treatment

The existing area is zoned industrial and is currently comprised of mostly impervious surface. There are no stormwater treatment devices installed in the network apart from road sump catchpits.

2.2 Stormwater Runoff Assessment

2.2.1 Existing Network Capacity

Based on the draft masterplan prepared by McIndoe Urban, a "no build area" has been identified along the existing stormwater main alignment to the river. A review of the title does not show an existing easement. As such, it is necessary that the stormwater main alignment is taken into consideration as part of development to enable future access and maintenance of the stormwater network. Council's preference would be a publicly owned right-of-way or drainage reserve. It is important that this easement enables future maintenance of the stormwater network, preferably by designating it as a publicly owned right-of-way.

Due to the anticipated modification and development following the re-zoning, in particular to the alignment and design of the road corridors, a check of the capacity of the current infrastructure has been completed.

An assessment was undertaken to confirm the level of service provided by the current stormwater network and outfall using a high level model of the existing network. The model includes all stormwater mains draining to the Roxburgh Crescent and Waterloo Crescent (Crewe Crescent) outfalls.

The modelling was performed using the PCSWMM software (Computational Hydraulics International, 2021). PCSWMM is a spatial decision support system for the U.S. Environmental Protection Agency SWMM 5 software. The model requires input of topographical features (catchment area, flow length, slope), ground cover conditions (imperviousness, depression storage, surface roughness), infiltration parameters (infiltration capacity, drying time), rainfall (design storm hyetograph), and drainage paths (channel length, geometry, roughness) in order to calculate stormwater runoff for an event based simulation. An overview of the PCSWMM model of the existing network is shown in Figure 5.

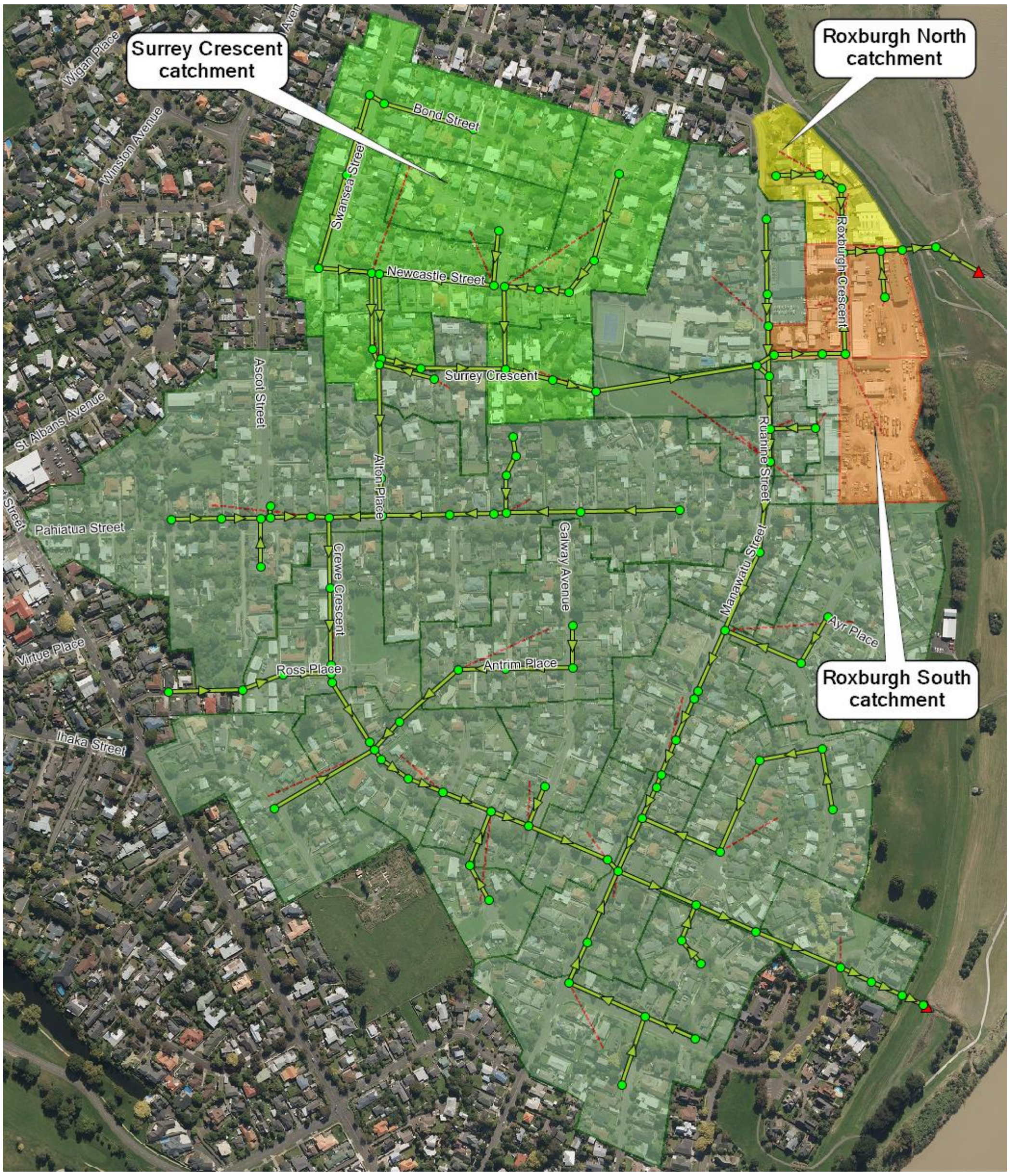

Figure 5: Overview of PCSWMM model of existing network and subcatchments

The following parameters and assumptions were used in the model development and assessment:

- Rainfall intensities using the updated NIWA rainfall data were used for the assessment and are summarised in Table 1 and Table 2 below. Historical rainfall intensities have been used for the pre-development (existing) scenario, and post-development scenarios include an adjustment for climate change (+ CC) using RCP 6.0 for 2081-2100. These rainfall intensities were used to develop 24-hour nested storm events that embed all design durations.

- The boundary condition (tailwater elevation) at the Manawatū River outfalls were determined using engineering judgement and information from Horizons. A 2-year river water level was applied in conjunction with 10-year rainfall in the catchment at the direction of Horizons. This was assumed due to the large size of the Manawatū River catchment, meaning peak discharge from the network is likely to occur before peak water levels occur on the River, and the low likelihood of high River water levels coinciding with peak rainfall in Palmerston North.

  Horizons provided peak annual flows (1923-2023) and the rating curve (stage –flow relationship) for the Manawatū River at the Teachers College flow gauge, approximately 3.4 km downstream of the Roxburgh outfall. A 2-year peak river flow was calculated from the peak annual flows provided at Teachers College. This was then converted to a river level at the Waterloo and Roxburgh outfalls using the river gradient and applying the Teachers College rating curve. The RL calculated for the Waterloo outfall seemed plausible (approximately 0.3 m above the outfall invert), however the RL calculated for the Roxburgh outfall seemed too high and would imply the reserve adjacent to the river is inundated during a 2-year river flood event. The Manawatū River is wider at the Roxburgh outfall when compared to both Teachers College and the Waterloo outfall, indicating that the Teachers College rating curve is likely not appropriate to apply at the Roxburgh outfall. In lieu of other information, the river water level at the Roxburgh oufall was assumed to be at the top of the outfall channel discharging to the Manawatū River. At this water level, the adjacent reserve would not be inundated which is a rational assumption during a 2-year flow event.

  The following tailwater conditions were applied in the model:

  - Waterloo Crescent outfall: 28.1 m RL (NZVD2016)
  - Roxburgh Crescent outfall: 28.5 m RL (NZVD2016)

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- The existing network is based on GIS asset data downloaded at the time of this assessment. Missing lid levels were assigned based on LINZ LiDAR and missing invert levels were assigned based on pipe gradients provided in the GIS asset data (where available) or interpolating between upstream and downstream invert levels.

- Catchments were delineated based on existing topography and the existing stormwater network. Catchment delineation is shown in Figure 5.

- Only stormwater reticulation mains were modelled. Sumps and sump leads were not included in the model. Subcatchments were attached to the downstream node in the network. This assumes sufficient inlet capacity, which is a common modelling technique when evaluating pipe network capacity.

- The SCS curve method was used to calculate run-off for the existing industrial land use and proposed residential land use. The curve numbers applied are provided in Table 3 (assuming Type C soils).

Table 1: Rainfall intensities (mm/hr) (NIWA HIRDS v4, Historical Data)

ARI	AEP	10 min	20 min	30 min	1 hr	2 hr	6 hr
2	50%	39.9	27.2	21.8	14.9	10.2	5.4
5	20%	54.3	36.7	29.3	19.9	13.5	7.07
10	10%	65.7	44.2	35.2	23.8	16	8.34

Table 2: Rainfall intensities (mm/hr) (NIWA HIRDS v4, RCP 6.0 for 2081-2100)

ARI	AEP	10 min	20 min	30 min	1 hr	2 hr	6 hr
2	50%	47.8	32.6	26.1	17.9	12.1	6.26
5	20%	65.6	44.4	35.4	24.1	16.2	8.27
10	10%	79.7	53.6	42.7	28.9	19.3	9.8

Table 3: Curve numbers

Land Use	Curve Number
Existing residential (50% pervious)	86
Parks/greenspace	74

Roxburgh Crescent industrial area (0% pervious)	98
Plan Change area – post-development (45% pervious residential lots)	89
Plan Change area – post-development (30% pervious residential lots)	91

A comparison between runoff calculated using the SCS curve method and the Rational method was carried out and showed agreement.

Existing Land Use

The 10% annual exceedance probability (AEP) rainfall event (or 1 in 10-year annual recurrence interval) (historical rainfall) event was run with the existing network and existing land use. The results are shown in Figure 6. A zoomed in map showing spill volumes from the manholes within the Surrey Crescent and Roxburgh Crescent catchments is shown in Figure 7. The model predicts surcharging (shown in orange) through much of the pipe network, extending from the Surrey Crescent catchment through to Roxburgh Crescent, and including the DN225 main on Roxburgh North. Seven manholes in the Surrey Crescent catchment are predicted to spill during the 10% AEP (historical rainfall) event. The DN675 stormwater main from Surrey Crescent through to Roxburgh Crescent is deep and, although surcharged, is not predicted to spill. This surcharging through much of the network is due to pipe capacity; when the tailwater condition at the Manawatū River is removed the network is still predicted to be surcharged. The DN750 Roxburgh Crescent outfall is also shown to be surcharged. This section of pipe is surcharged due to the tailwater condition applied at the Manawatū River causing the outfall to be submerged. The DN750 pipe is not surcharged due to capacity, however this is likely only due to capacity constraints and spilling upstream limiting the flow to the outfall. Historically significant parts of the stormwater network in Palmerston North were sized for the 20% AEP rainfall event (or 1 in 5-year ARI), so it is not uncommon that the model predicts insufficient capacity and spilling along this branch based on current engineering standards.

Spilling is also predicted at a number of manholes throughout the network draining to the Waterloo Crescent outfall. Spilling predicted at manholes at the north end of Crewe Street and on Crewe Crescent are likely to be causing the observed flooding at low spots / depression areas in the topography on Crewe Crescent (further discussed in Section 2.2.2).

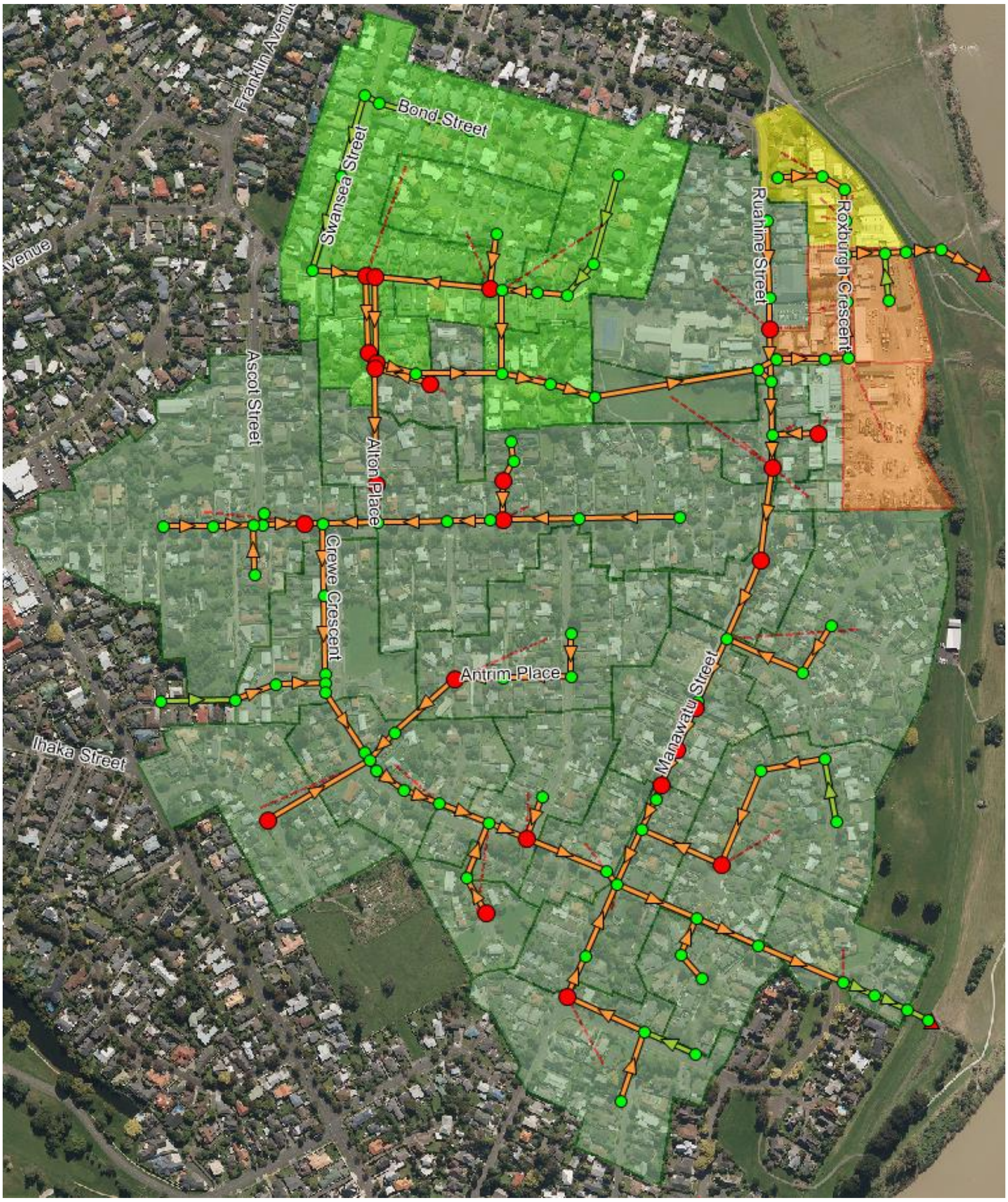


Figure 6: Pre-development (existing land use) flow results for 10% AEP (Historical rainfall) event . (Surcharged pipes are shown in orange and red circles indicate spilling manholes)

Figure 7: Zoom in of results for pre-development (existing land use) 10% AEP (Historical rainfall) event. [Surcharged pipes are shown in orange and red circles indicate spilling manholes. Spill volumes are shown in ML (1000 m³)]

Stormwater networks are typically designed not to surcharge during the design event. That is, the pipe should not exceed the pipe full capacity in the 10% AEP. A high-level check on the pipe full capacity was therefore carried out using the Manning's equation, assuming a manning's value of 0.013. This was compared to the peak runoff from the upstream catchments (assuming no network constraints and all of the flow can be conveyed to the outfall). The results are summarised in Table 4 below. The results indicate that the outfall also does not have sufficient capacity to carry the required flows.

Table 4: Summary of pre-development (existing land use) peak runoff (10% AEP) and pipe capacity for Roxburgh Crescent

	Catchment Area (ha)	Runoff (m^3/s) (Historical Rainfall)	Runoff (m^3/s) (Climate Change Rainfall)	Pipe Diameter (mm)	Pipe Slope	Full Pipe Capacity (m^3/s)
Roxburgh North	1.4	0.10	0.12	225	0.00999	0.045
Surrey Crescent	12.8	0.55	0.73	675	0.00126	0.298
Roxburgh South	16.1[1]	0.73[1]	0.96	675	0.0033	0.482
Outfall	17.5	0.83	1.08	750	0.0019	0.489

[1] Includes Surrey Crescent catchment.

In addition to having insufficient capacity, the section of DN225 stormwater main (Roxburgh North) is currently below the minimum diameter now required for public reticulation.

Future Land Use

The assessment above shows that the existing stormwater network within Roxburgh Crescent, including the outfall to the Manawatū River, is undersized for the 10% AEP assuming existing industrial land use. A check on the limit of imperviousness in the Roxburgh Crescent PC area was first assessed to see if that would resolve surcharging in the network. That is, given the existing land use is currently considered 100% impervious, the gains from reducing the impervious area (or increasing the pervious area percentage) were determined to identify at what percentage (if any) the network could achieve Council's required level of service.

The PC area was set to be fully pervious (100% percent pervious, or 0% impervious) to compare the results to the existing development scenario. In the 10% AEP rainfall event, the DN675 diameter main through Roxburgh Crescent is still shown to be surcharged. This shows there is no limit to impervious area in the Roxburgh Crescent Re-Zone Area which can be imposed to completely resolve surcharging through the existing DN675 stormwater mains and meet Council's required level of service. This means network upgrades would be required to bring the network up to the required level of service.

To represent the future residential development within the PC area, a percent pervious of 30% was adopted for the proposed residential lots in the proposed re-zone area. Based on this, a weighted average of 28.4% pervious was calculated for the PC area using the proportion of road reserves, residential lots and greenspace shown in the Structure Plan (refer to Table 5 below).

An additional scenario with 45% pervious residential lots was used[1], equating to an overall percent pervious of 39.5% (also shown in Table 5). This was carried out to understand the effect of having a lower pervious percent requirement, which is discussed later in section 3.3.1.

Table 5: Summary of percent pervious for Plan Change area

Land Use	Percentage of Plan Change Area	Percentage of 45% Pervious Residential Lots	Percentage of 30% Pervious Residential Lots
Residential	74%	45%	30%
Greenspace	3%	100%	100%
Road reserves / carparks	23%	14%	14%
Weighted Average		**39.5%**	**28.4%**

In the post-development scenario, the DN225 on Roxburgh North has been upgraded to a DN300 diameter to meet PNCC's *ESLD*. No other network upgrades have been included.

The initial post-development scenario assumes 28.4% pervious (30% pervious residential lots) through the PC area. Runoff for the Surrey Crescent, Roxburgh North and Roxburgh

[1] As recommended by urban designers

South catchments are summarised in Table 6 for the existing and post-development scenarios. The results for the 10% AEP + CC event are shown in Figure 8.

Table 6: Pre- and post-development peak runoff for the contributing catchments in the 10% AEP rainfall event

Catchment	Area (ha)	Pre-development Run-off (m^3/s) *Existing Land Use , 10 % AEP Historical Rainfall*	Post-development Run-off (m^3/s) *Proposed Land Use (30% Pervious Residential Lots) , 10% AEP + CC*
Roxburgh north	1.4	0.10	0.11
Roxburgh South	3.3	0.18	0.20
Surrey Crescent	12.8	0.55	0.73

The upgrade to the DN300 diameter has resolved the predicted surcharging of this main. The main from the Surrey Crescent catchment and down through Roxburgh Crescent and to the outfall is shown to be surcharged as in the pre-development scenario. There are eight manholes predicted to spill in the Surrey Crescent catchment. As expected, based on the initial pervious percentage check, the number of manholes predicted to spill and spill volumes are greater in the post-development scenario than in the pre-development scenario (refer to Table 7). This is attributed to the increase in rainfall due to climate change and not due to land use changes in the PC area.

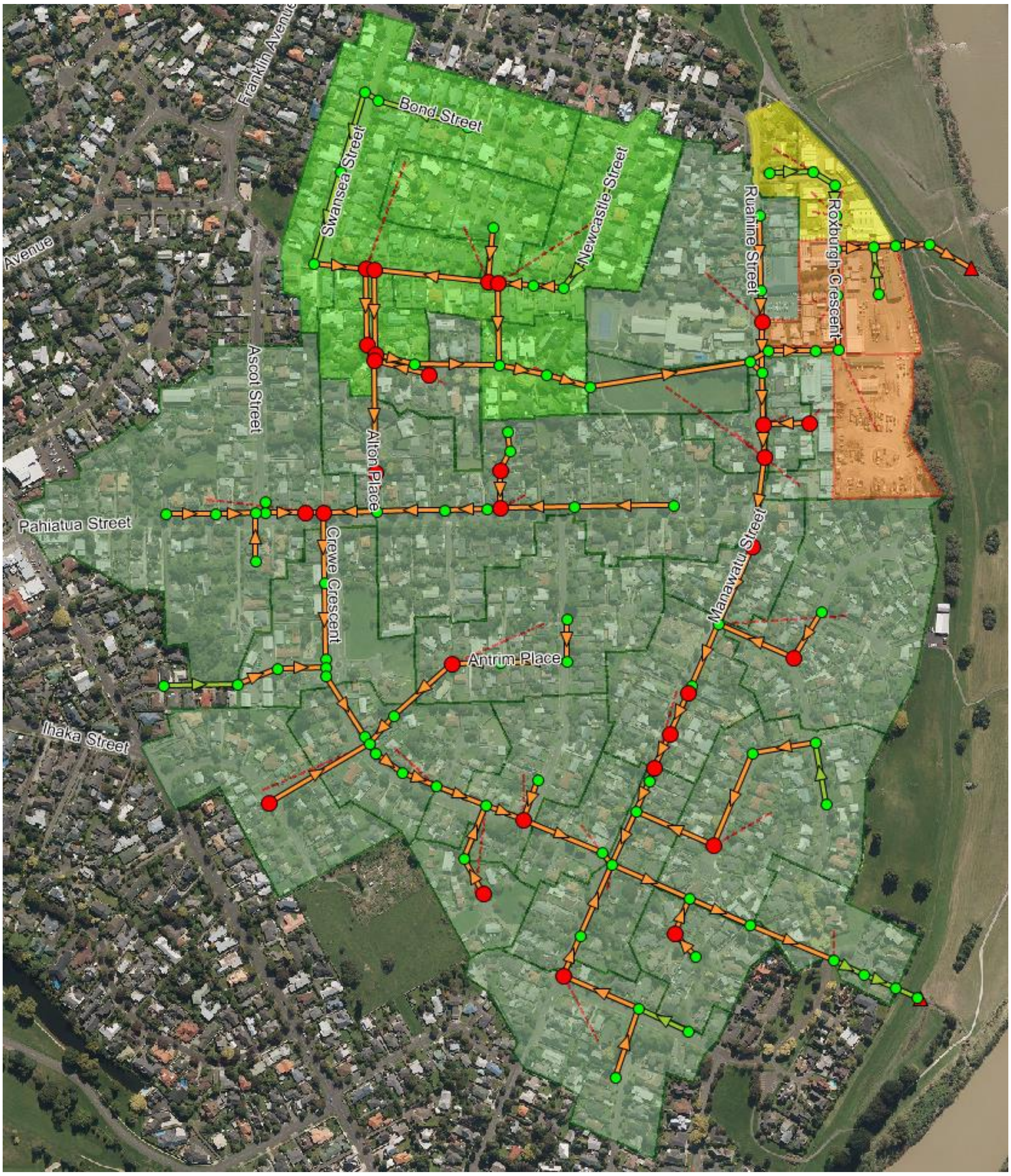


Figure 8: Results for 10% AEP + CC event with existing network and proposed land use (30% pervious residential lots in Roxburgh PC area). (Surcharged pipes are shown in orange and red circles indicate spilling manholes)

The results of the assessment summarised in Table 4 indicate the stormwater network through Roxburgh Crescent does not meet the 10% AEP + CC (1 in 10-year ARI event with climate change) standard set for the existing land use. This includes the outfall to the Manawatū River. The level of service still cannot be met with reductions in the PC area, highlighting that the network is undersized for the catchment in general. However, the level of service can be improved by re-zoning to residential development with restrictions on impervious area, but network upgrades, including an upgrade through the stopbank, is required to provide the standard level of service. This is discussed further in Section 3.3 under the recommended stormwater management strategy.

2.2.2 Flood Risk

The PC area is located adjacent to the Manawatū River stopbanks. Therefore flood risk was evaluated for localised rainfall within the urban area, as well as flood risk from the Manawatū River.

Localised Flood Risk

Based on the city-wide TUFLOW stormwater model developed by Tonkin and Taylor in 2017, the Roxburgh Crescent Residential Re-zone Area is not susceptible to flooding in extreme rainfall events because it is not situated in a low lying area or located within an overland flow path. Figure 9 shows the maximum predicted ponding depth in the 2% AEP and 1% AEP +CC rainfall events. Any ponding shown is localised and likely to be eliminated as part of any earthworks. It should be noted that the results do not show any ponding predicted to be less than 0.05m.

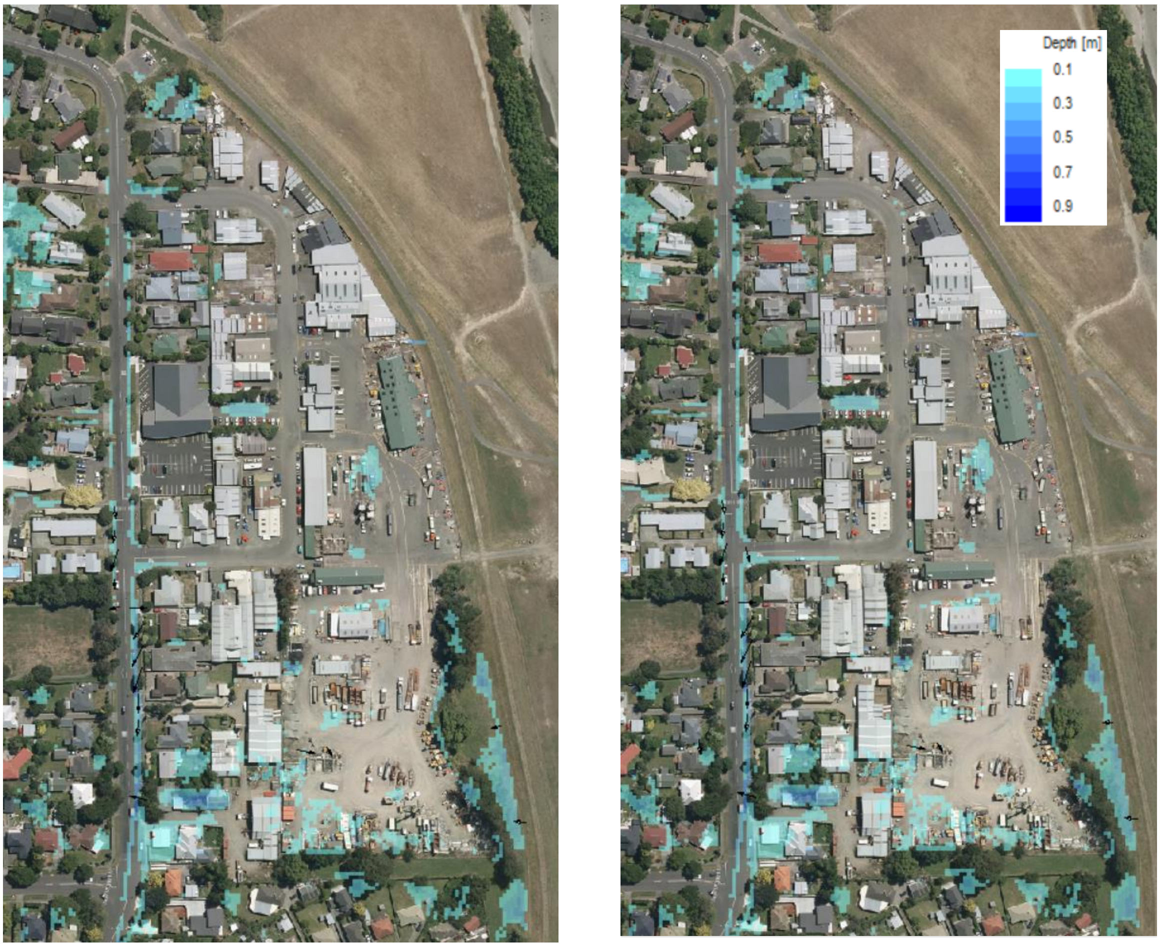


Figure 9: TUFLOW maximum ponding depths for 2% +CC and 1% AEP +CC rainfall events

There are recorded flooding incidents upstream on Surrey Crescent, and the stormwater model does indicate some risk of flooding to habitable dwellings in that area in the 10% AEP +CC rainfall event (see Figure 10 below). Flooding is also predicted along Pahiatua

Street, which is downstream of the Roxburgh Crescent catchment in terms of ground level. The areas of flooding predicted in the TUFLOW model are also supported by the manholes and parts of the network predicted to spill in the PCSWMM model during the 10% AEP + CC event (refer to Figure 6).

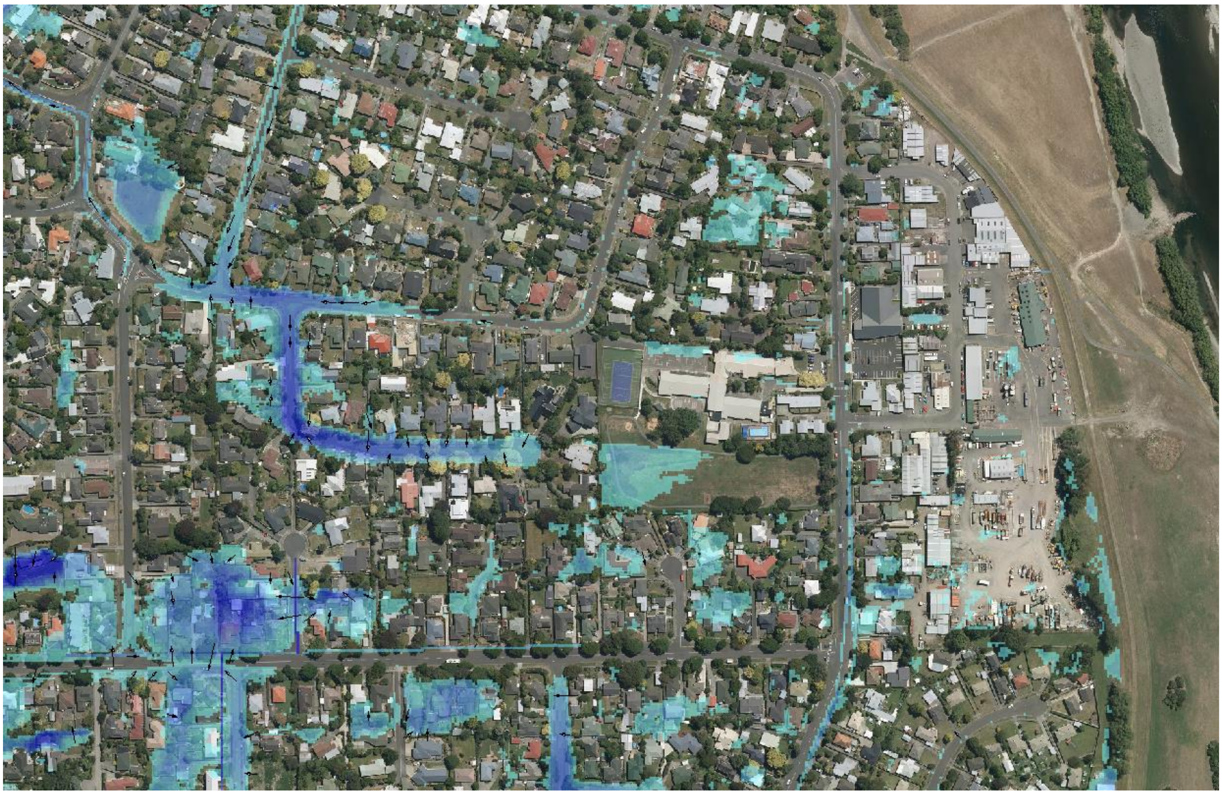


Figure 10: TUFLOW maximum ponding depths for 10% AEP +CC rainfall event

Given that the existing land use in the PC area is industrial, the change to residential land use is not considered likely to result in any increase in the risk of flooding within the site or upstream as it is anticipated that the percentage of impervious area will decrease with residential lot development. Redevelopment of this area is also not expected to exacerbate the flooding along Pahiatua Street as long as the catchment boundaries are maintained. That is, recontouring of the Roxburgh Crescent area must not alter the existing overland flow paths or increase the catchment area discharging overland to Ruahine Street. As such, regrading of the existing carriageway in a way that would change the catchment routing down Ruahine Street is not allowed, but minor recontouring of individual sites to drain to the carriageway within the structure plan area will not impact the wider catchment flooding.

Since the existing network will need to be upgraded anyway, there is an opportunity to improve the level of service and flooding in the wider catchment by further upgrading the stormwater network through Roxburgh Crescent. However, this is contingent on the pipe through the stopbank being upgraded. Options have been developed and are further discussed in Section 3.3.

Manawatū River Flood Risk

The stopbanks form part of the Lower Manawatū Flood Control Scheme (LMS) operated by Horizons Regional Council. Along the urban area of Palmerston North they provide a protection level of a 0.2% AEP flood event. Around 1993 (approximate), Horizons carried out a "special project review"[2] of the LMS to review the existing (circa 1993) flood protection measures and recommend works to mitigate against flood hazard, specifically for the Palmerston North urban area. A series of stopbank breaches were modelled representing different types of failure mechanisms. Key findings from that study, as it relates to the PC area, are listed below. It is important to note that improvements to the LMS have been made since the time of the study, including the construction of a primary stopbank closer to the river at the Palmerston North Golf Club. Therefore, the probability of these failures occurring is likely to be lower than what was mentioned in the report and copied below.

- "Of the water that escapes from the river at the College of Education, or further upstream, between 70% and 90% is channelled back into the river again in vicinity of Fitzherbert Bridge and the Esplanade." (page 8)

- The "Fitzroy Bend" by Roxburgh Crescent is the part of the circa 1993 stopbank most at risk of undermining during a 3,450 m^3/s flood event (1% AEP, original design standard). However, since the time of this report, it is understood that mitigation measures have been put in place to reduce the likelihood of this happening.

- Due to the presence of sandy gravel, the section of stopbank near the PC area is susceptible to stopbank foundation failures when flood levels approach the (circa 1993) stopbank crest.

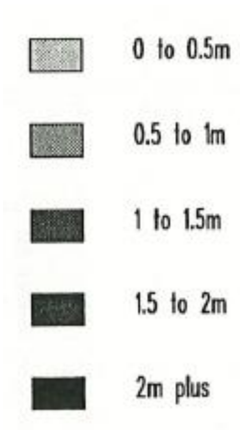
- Based on the 1993 stopbanks at Fitzroy Bend, there is a 15% probability of failure during a flood of 3,450 m^3/s (1% AEP), increasing to 85% when the flood size reach 4,000 m^3/s (0.2% AEP).

Despite the relatively low probability of the stopbank being breached, there is still the consequence of the stopbank breach to consider. The figures below are copied from the report for two different river flow scenarios. Unfortunately only a black and white scanned copy of the report is available, so differentiating between the different flood depth colours is difficult.

3,500 m^3/s in river	

[2] *Lower Manawatu Scheme Special Project – Palmerston North Flood Protection*, Manawatu-Wanganui Regional Council, G S Doull (no date)

Flood Depth



4,500 m^3/s in river

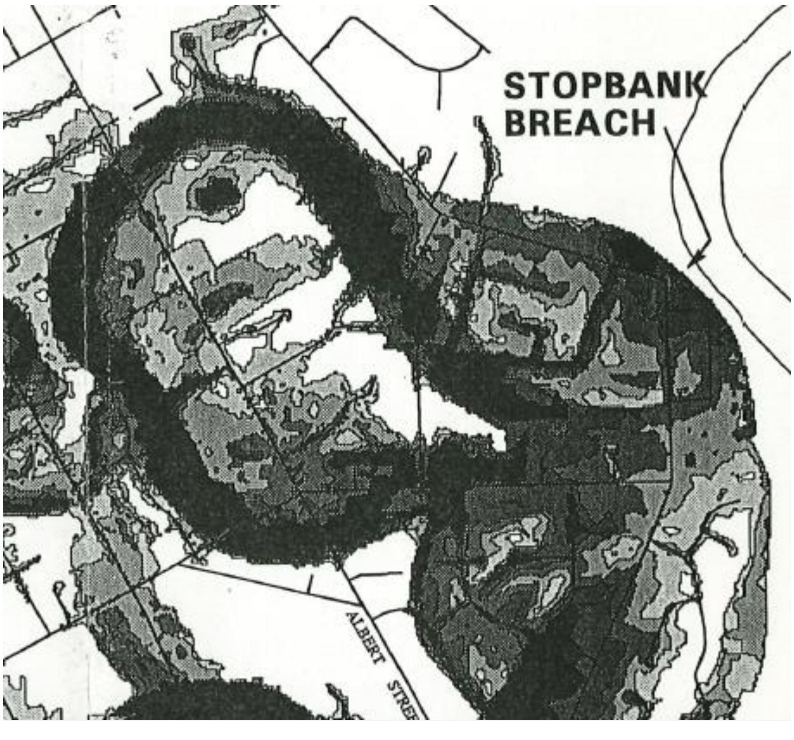


Figure 11: c. 1993 Horizons Stopbank Breach flood depths

The potential consequence (hence damage) is relatively high, however the probability of the damage occurring is low. In the more extreme river event, it appears that the flood depths could be as deep as 2 m for the northern part of Roxburgh Crescent, with lesser depths as you move south.

The stopbanks act as a mitigation measure to protect the urban area from river flood events, up to the 0.2% AEP. If we consider a 100-year lifespan for development, then the probability of the stopbanks failing over the next 100 years is 15%. However, given that significant upgrades to the stopbank have occurred since this study was completed, it is expected that the probability over 100 years would be less than 15%.

Horizons recommended that "if very young or very old people (i.e at risk) are to be concentrated in such an area, [PNCC] would be well advised to take flooding issues [from a stopbank breach] into account when considering [planning consents]" (page 20).

2.3 Existing Stormwater Servicing Summary

The Roxburgh Crescent Residential Re-zone Area is not subject to inundation in events up to the 1% AEP + CC, and re-zoning of the Roxburgh PC area is not expected to worsen or accelerate flood hazard risk to the neighbouring catchments.

Review of the stormwater network shows that the existing reticulation in Roxburgh Crescent is not adequately sized for the 10% AEP rainfall event and does not provide the required level of service for the existing industrial development. In order to better understand the existing network constraints and impact of future development, further analysis was carried out using a PCSWMM hydraulic model.

The modelling found that the required level of service cannot be met with the existing network, irrespective of limiting the impervious area of the PC area. However, in order to facilitate development and increase the level of service provided by the existing network, the post-development scenario has been calculated assuming 30% pervious residential lots and an upgrade of the existing DN225 diameter on Roxburgh North to a DN300 main to meet PNCC's engineering standards. This single upgrade and increased perviousness in the PC area proposed through re-zoning to residential land use still does not meet Council's level of service requirements, nor does it result in post-development peak flows matching pre-development peak flows. Spill volumes in the Surrey Crescent catchment increase, and network surcharging and spilling cannot be fully resolved by limiting the impervious area in the PC area.

As part of streetscape upgrades and/or major re-construction of the existing road on Roxburgh North, the stormwater network on Roxburgh North is required to be upsized to DN300 to comply with engineering standards. Further network upgrades to enable development and achieve Council's standard level of service are also required. This is further discussed in Section 3.3, Stormwater Quantity Management.

3 Stormwater Management

3.1 Overview

Council stormwater activities are governed by a range of statutory planning instruments which have been used to develop and define PNCC performance standards. These include the Resource Management Act, National Policy Statements and Regional Plans such as Horizons Regional Council One Plan. Council is required to manage the effects of any development on stormwater so the effects of development are less than minor and do not exacerbate existing flood and quality effects.

Historically, Councils levels of service for stormwater management have been relaxed in the absence of the application of strict standards in the Manawatū Region. Horizons Regional Council has signalled its intention to require in future resource consents that all current and future urban stormwater discharges be managed, so it is incumbent on Council to ensure stormwater effects from any development are effectively managed in anticipation of future qualitative and quantitative standards being applied.

In general, land development increases stormwater runoff volumes due to increases in impervious area, but development also contributes to increases in contaminant discharges due to the additional contaminants generated by both the construction works and the on-going activities and transport movements due to increased residential and commercial activity. Because the existing land use is industrial and most of the site is already impervious, the predicted change in runoff volumes, flows and contaminant discharges associated with conversion to residential land use is considered to be negligible with the possibility of a slight improvement. However, given the future regulatory intentions of the Regional Council, and the requirements for greater attenuation and reductions in contaminant discharge to the receiving environment, Palmerston North City Council has adopted policies and engineering requirements which require mitigation of stormwater runoff and contaminant discharge for any subdivision development and re-zone area. The redevelopment of the Roxburgh Crescent Residential Re-zone Area still triggers such a requirement.

Council will therefore require implementation of specific stormwater management solutions as outlined in Sections 3.2 and 3.3 below. The application of stormwater volume and quality mitigation practices is typically referred to as water sensitive design (WSD). The mitigation solutions are typically designed to limit effects through retarding initial rainfall loss by promoting infiltration via pervious surfaces, increasing the time of concentration to reduce peak runoff volumes and flow velocities, and providing treatment to remove some contaminants at source or prior to discharge. Council typically requires the design to incorporate a treatment train (series of treatment stages between the source and outfall) to remove a broad range of contaminants including gross pollutants as well as sediment, metals and hydrocarbons. For this plan change Council has selected the treatment device that is to be used to support development (refer to Section 3.2).

3.2 Stormwater Quality Management

To ensure that the discharge of contaminants via stormwater runoff is minimised, Council has determined the following minimum requirements for lots and road reserve areas within the re-zone area:

- Roof leaders are to be connected directly to the stormwater network; otherwise treatment in the roading corridor will need to be sized to include on-lot generated runoff.
- All roofs are to be zinc and heavy-metal-free. This is now considered standard practice.
- The surface runoff resulting from the first 5mm of any rain event from the road carriageway and property driveways draining to the road shall be treated prior to entering the piped stormwater network. This will require the design and inclusion of

approved treatment devices within the road reserve to capture and treat the initial runoff volume.

Bioretention devices filter stormwater through a vegetated filter bed made of natural soil or engineered media. Depending on its design, bioretention may also perform a hydrological detention function by reducing runoff volumes and detaining runoff flows. Specific devices include rain gardens, tree pits, stormwater planters and bioretention swales.

For the Roxburgh Crescent Residential Re-zone Area , the use of a high-flow bioretention / biofiltration device that is designed to minimise the footprint by using filtration media with a high infiltration capacity is necessary to manage stormwater quality.

The Filterra® treatment system is considered to be an acceptable solution as these systems are effective in treating typical roading corridors within confined areas,and can be easily integrated within the roading corridor design. For example, a single square metre of Filterra® can treat approximately 270 m^2 of catchment area. Examples of high-flow biofiltration devices like Filterra® have been provided in Figure 12 below.

Any development within the site will need to demonstrate how this treatment requirement will be met.

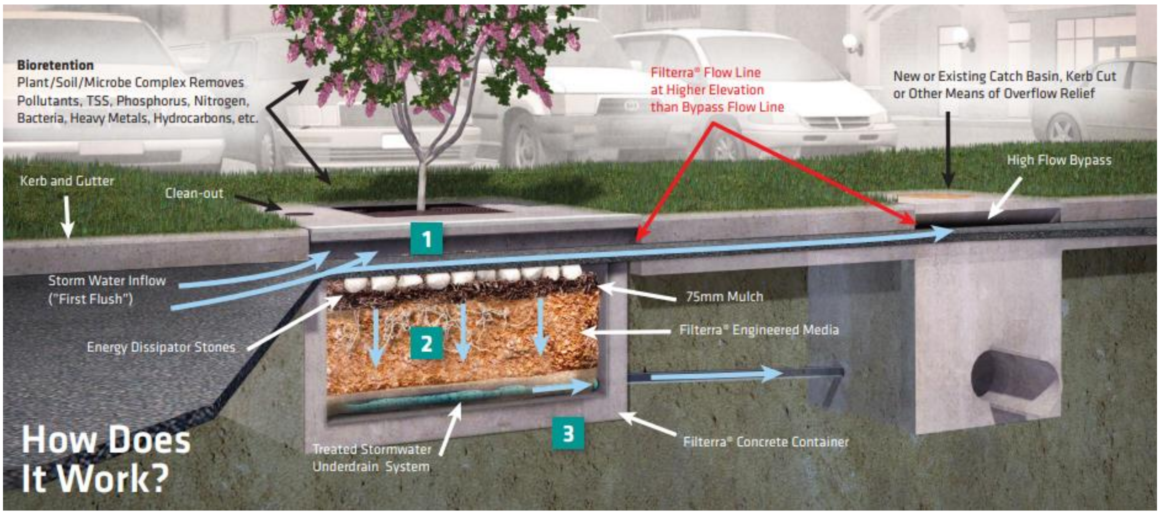


Figure 12: Filterra® Tree Pit examples

The above treatment device is appropriate for residential land use, however does not address specific contamination concerns that may relate to the existing industrial land use. As development occurs, an appropriate contaminated land assessment is required, highlighting the necessary mitigation to ensure contaminants do not enter the stormwater network during (and after) construction. This will need to be accompanied with an appropriate erosion and sediment control plan relating to contaminated land. It is noted that consents relating to a change in land use will likely be required under the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health. These matters would be assessed through that process.

3.3 Stormwater Quantity Management

To ensure that stormwater discharge volumes and runoff peak flows and velocities are appropriately managed, development must implement appropriate WSD measures. This includes the incorporation of greenspaces to provide treatment, both on-site and within the public road corridor. This also typically includes a limit to the impervious area, or minimum pervious percentage be met. This is often connected to a combination of the level of service provided by the existing receiving network and flood risk in the wider catchment.

Typically, onsite attenuation in the form of storage tanks can be used to mitigate the increase in stormwater runoff generated when the impervious area is greater than what has been allowed for. This is typically done so as not to overwhelm the receiving network by limiting the peak runoff to pre-development peak runoff levels. However, given that the PC area is at the downstream end of the catchment, attenuating any flow onsite may adversely impact the upstream catchment. This site is also constrained by the hydraulic capacity of the existing network. Therefore, attenuating flows is not an option and minimising the runoff generated from the site is required.

As discussed in Section 2.2.1, the DN675 through Roxburgh Crescent and DN750 outfall to the Manawatū River does not have sufficient capacity to accommodate existing development, nor does it have capacity to convey future residential land use with increased perviousness from the existing land use. To provide the Council's current level of service, network upgrades will be required. Horizons Regional Council (Horizons) was consulted in early June 2023 to discuss the feasibility of upgrading the outfall through the stopbank. Horizons advised that it would only consider an upgrade to the outfall if it provided wider catchment benefit, and did not just allow for development in the Roxburgh Crescent Residential Re-zone Area (refer Appendix A). Therefore a high-level catchment-wide optioneering assessment was undertaken to determine if an upgraded outfall could help alleviate flooding in the catchment and provide council's required current level of service. Due to the anticipated timeframe to secure funding and implement the upgrades, a two-stage development process is proposed for the PC:

- Stage 1 is for residential development that can occur before an upgrade to the stormwater outlet to the Manawatū River has been constructed and is operational;
- Stage 2 is for residential development that can occur once the upgraded outlet is operational.

Due to the network constraints, Stage 1 involves a higher requirement for pervious areas than in Stage 2, once network upgrades have been completed. Property owners in the PC area may choose to accept higher pervious area restrictions under Stage 1 or, alternatively, may reach an agreement with Council to bring forward the upgrades proposed under Stage 2 to develop to a lower pervious area requirement. This would likely involve an agreement where the developer finances the upgrades sooner, in return for offsetting development contributions.

These two stages are discussed below.

3.3.1 Stage 1: Existing Outfall

Stage 1 applies before upgrades to the network are carried out to achieve Council's current standard level of service. Based on the hydraulic assessment carried out on the existing stormwater network in Section 2.2.1, the net pervious percentage across the entire PC area (including lots and the roading corridor shown in the structure plan) is to be 28.4% (equivalent of 30% pervious area on residential lots). Although the standard level of service is not met with this requirement and the change in land use does not completely offset the increase in run-off with climate change projections, Council is willing to accept this pervious requirement for Stage 1.

However, if only part of the PC area is developed, the pervious requirements for the developed lots will need to be set to achieve an overall pervious area of 28.4%. That is, a higher pervious area would be required to offset the existing industrial. There is a certain limit where this may not be feasible. It is understood from council's urban design experts that the highest pervious percentage feasible for the lot sizes proposed in the PC is 45%. Council is therefore prepared to accept a minimum pervious area of 45% (55% impervious area) to all residential lots in Stage 1, even though this does not meet pre-development conditions. A comparison of the pre-development and post-development scenarios assuming 45% pervious residential lots and 30% pervious residential lots was carried out. The network results are shown in Figure 13 and manhole spill volumes are presented in Table 7 for comparison. With the 45% pervious residential lots, there is a minor reduction in spill volumes in the Surrey Crescent catchment compared to the 30% pervious residential lots, but the pre-development conditions are still not met. This confirms it is not possible to achieve pre-development conditions with pervious area restrictions alone, on residential lots in the PC area.

Table 7: Summary of manhole spill volumes pre- and post-development in the Surrey Crescent catchment for the 10% AEP rainfall event

Manhole ID	Manhole Location	Pre-development Spill Volume (m^3) *Existing Network, Existing Land Use, 10 % AEP (Historical Rainfall)*	Post-development Spill Volume (m^3) *Existing Network with DN300 Upgrade on Roxburgh North, Proposed Land Use – 30% Pervious residential lots, 10% AEP + CC*	Post-development Spill Volume (m^3) *Existing Network with DN300 Upgrade on Roxburgh North, Proposed Land Use – 45% Pervious residential lots, 10% AEP + CC*
2854	Newcastle Street & Surrey Crescent	1	6	6
3688	Newcastle Street & Surrey Crescent	51	222	220
2844	Newcastle Street & Goodwyn Crescent	42	132	132
3698	Newcastle Street	0	65	64
3689	Surrey Crescent	498	696	693
2853	Surrey Crescent	2	22	22
4384	Surrey Crescent	90	156	156
3691	Surrey Crescent	5	35	26

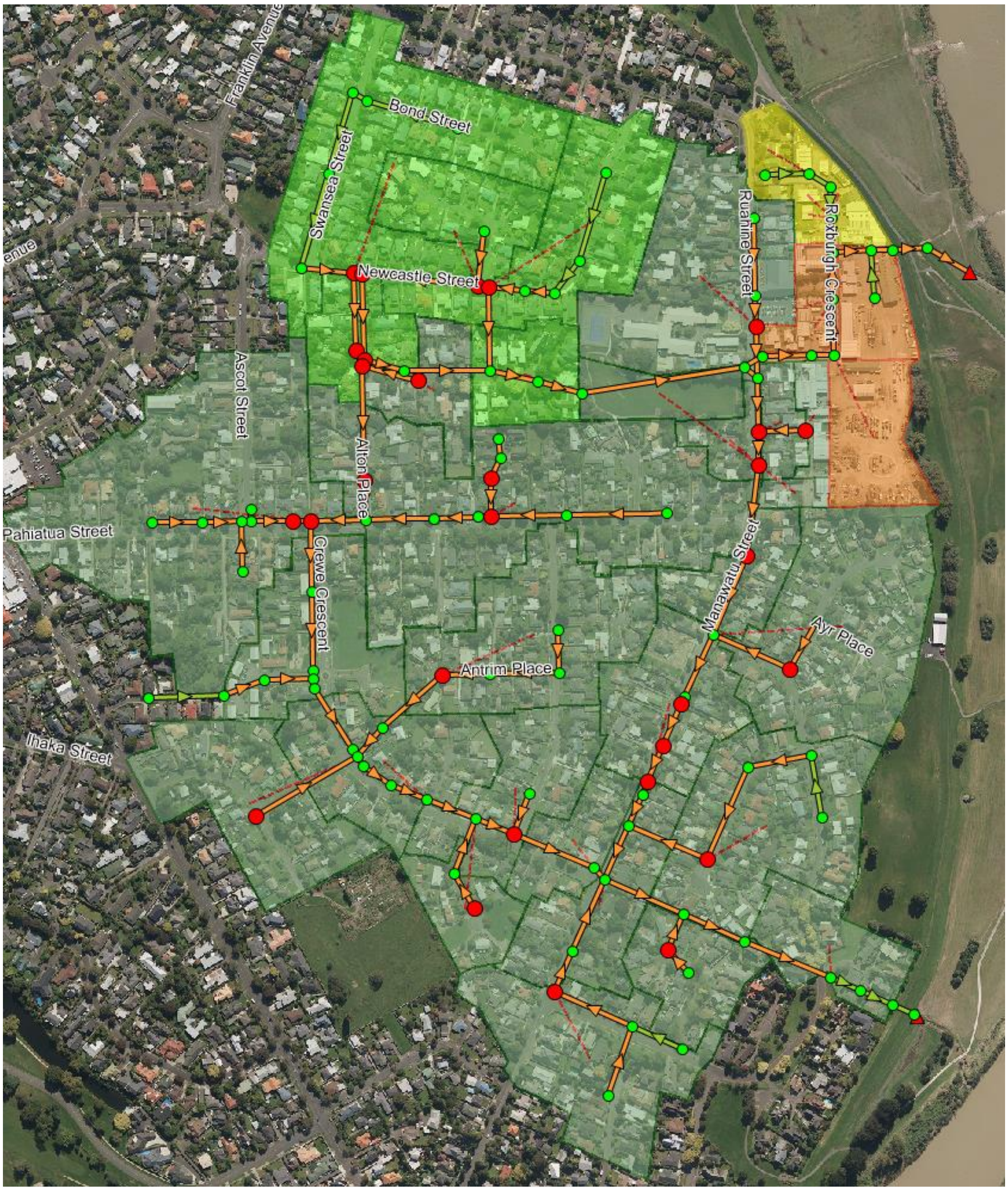


Figure 13: Results for 10% AEP + CC event with existing network and proposed land use (45% pervious residential lots in Roxburgh PC area). Surcharged pipes are shown in orange and red circles indicate spilling manholes.

Before the outfall is upgraded the following would need to apply:

- Minimum pervious area as required to achieve 28.4% net pervious area across the entire PC area (equivalent to 30% pervious residential lots if the entire PC area is developed), but no less than 45% (i.e. maximum 55% impervious area) on all lots.
- The stormwater main on Roxburgh North be upgraded to at least DN300

It is recommended that the percentage of pervious area be fixed and be achieved on all lots as a minimum. Because this is a relatively high pervious limit compared to recent development, developers may want to consider the use of pervious pavements or other technologies that can provide some of the same benefits as hardstand area, but still allows stormwater to infiltrate into the ground to help meet this requirement. This includes:

Concrete paving blocks (permeable and porous)

Porous asphalt

Porous concrete

Resin bound aggregates

Examples are provided in Figure 14. Guidelines on where these materials are suitable for use can be obtained from *Water Sensitive Design for Stormwater: Treatment Device Design Guideline*, Wellington Water.

Figure 14: Examples of pervious pavements to replace typical hardstand areas

3.3.2 Stage 2: Network Upgrades

Stage 2 applies when the existing stormwater network has been upgraded to alleviate flooding in the upstream catchment based on programmes within the Long Term Plan (LTP)[3], and to meet the required level of service to enable future residential development. The upgrades will be sized for 30% pervious residential lots (equivalent to 28.4% pervious across entire PC area).

If and when the upgrades are completed and in operation, the following impervious requirements will apply to the Roxburgh Crescent Residential Re-zone Area:

[3] At the time of this assessment a programme of works has been proposed in the LTP, however has not yet been confirmed.

Minimum 30% pervious percentage on residential lots

It is recommended that the percentage of pervious area be fixed and be achieved on all lots as a minimum. This assumes the existing DN225 in Roxburgh North is upgraded to DN300.

As discussed in Section 2.2.1, Future Land Use, the pipe through the stopbank requires an upgrade. The upgrade will need to demonstrate an improvement to the wider catchment, and not just what is required to enable development for this plan change. An analysis has therefore been completed (attached in Appendix B) to identify what improvements could be made in the wider catchment. The TUFLOW model was consulted to see where the flood risks are and the relevant catchments as they relate to the Roxburgh Crescent stormwater network. Areas known to be susceptible to flooding include Pahiatua Street and Crewe Crescent. Both the Pahiatua Street and Crewe Crescent catchments discharge to the Crewe Crescent outfall. Therefore, in order to enable the upgrade at Roxburgh Crescent, a catchment diversion would be required.

In considering the assessment in Appendix B, there is sufficient evidence to demonstrate that an upgrade to the existing outfall alongside some changes to the pipe network would provide benefit to the wider catchment. This would support a Horizons resource consent application to upgrade the outfall through the stopbank.

Based on the results, Option 4 is recommended, which redirects the Pahiatua Street stormwater network (and upstream catchment) to the Roxburgh Crescent outfall. This option was then further refined to understand the likely reduction in flooding and to refine the pipe size to inform the LTP. The level of service for the refined Option 4 has been defined such that there is no surcharging in the network due to pipe capacity during a 10% AEP +CC event.

The design basis for the network upgrades is as follows:

30% pervious residential lots in the PC area (equivalent to 28.4% pervious across entire PC area),

Sized to convey the 10% AEP + CC event,

No surcharging in the new network due to pipe capacity, and

As far as practicable, reduce and resolve spilling in the existing network serviced by the upgraded network in the 10% AEP +CC event.

To achieve no surcharging due to pipe capacity a DN900 pipe was determined to be the minimum outfall size required through Roxburgh Crescent. The conceptual pipe through Roxburgh Crescent has been set to the same invert elevation as the existing network to transfer flow from the existing network. This means the pipe is up to 6 m deep through Roxburgh Crescent and almost 8 m deep through the stopbank. The average pipe grade through Roxburgh Crescent is 0.2 - 0.4%.

Cross-connections to the existing network in Roxburgh Crescent have been included to transfer flow from the existing network through Roxburgh Crescent to the new pipe to help alleviate flooding upstream. The depth and size of the cross-connections were set to transfer as much flow as possible from the existing network before any surcharging due to pipe capacity was predicted in the new pipe.

To help alleviate flooding on Crewe Crescent, a DN900 pipe was sized to divert flows from Crewe Crescent to the Roxburgh Crescent outfall. The conceptual pipe grade is 0.17%.

Not all spilling in the Surrey Crescent catchment was able to be resolved with the new Pahiatua/Ruahine Street bypass pipe in the 10% AEP +CC event. At most spilling manholes, the upgrades are predicted to partially offset the increase in spill volumes due to climate change but do not achieve pre-development (with historical rainfall) predicted spill volumes. The spilling in the Surrey Crescent catchment is largely due to insufficient capacity in the local network and resolution of the spilling would require upgrading some of the local network into Surrey Crescent. Upgrading the existing stormwater main up Alton Place to the first manhole (MH3163) provided only a limited reduction in spilling at only one manhole in the Surrey Crescent catchment. Further reducing flooding in this catchment would be best achieved by upsizing and lowering the existing stormwater main extending north up Alton Place and through private property to the Surrey Crescent catchment, and creation of a new cross-connection to transfer flow from the existing DN525 on Surrey Crescent into the upgraded pipe draining south on Alton Place. Further network upgrades would also likely be required up to Newcastle Street to fully resolve all spilling in the Surrey Crescent catchment. These additional upgrades would be extensive and include the upgrade of pipes through private property. For now, Council intends to proceed with the new bypass pipe on Pahiatua Street only, which provides some reduction in spilling in the Surrey Crescent catchment.

The network results with the upgrades are shown in Figure 15 below. Note that the surcharging shown through the new pipe is due to the tailwater effects from the Manawatū River. The influence of the river extends far upstream due to the depth and shallow grade of the network. For example, the invert level of the existing manhole MH3701 located at the intersection of Ruahine Street and Roxburgh Crescent, has an invert of 28.2 m – 0.3 m lower than the tailwater condition assumed at the River outfall.

The model still predicts spilling at a number of manholes on Ruahine Street, Crewe Crescent and through the network to the Waterloo Crescent outfall. The spill volumes predicted through Crewe Crescent have reduced with the upgrades due to the diversion of part of the upstream catchment to the Roxburgh Crescent outfall, but have not been fully resolved. Complete resolution of the predicted spilling in these areas would require upgrades in the network draining to the Waterloo Crescent outfall.

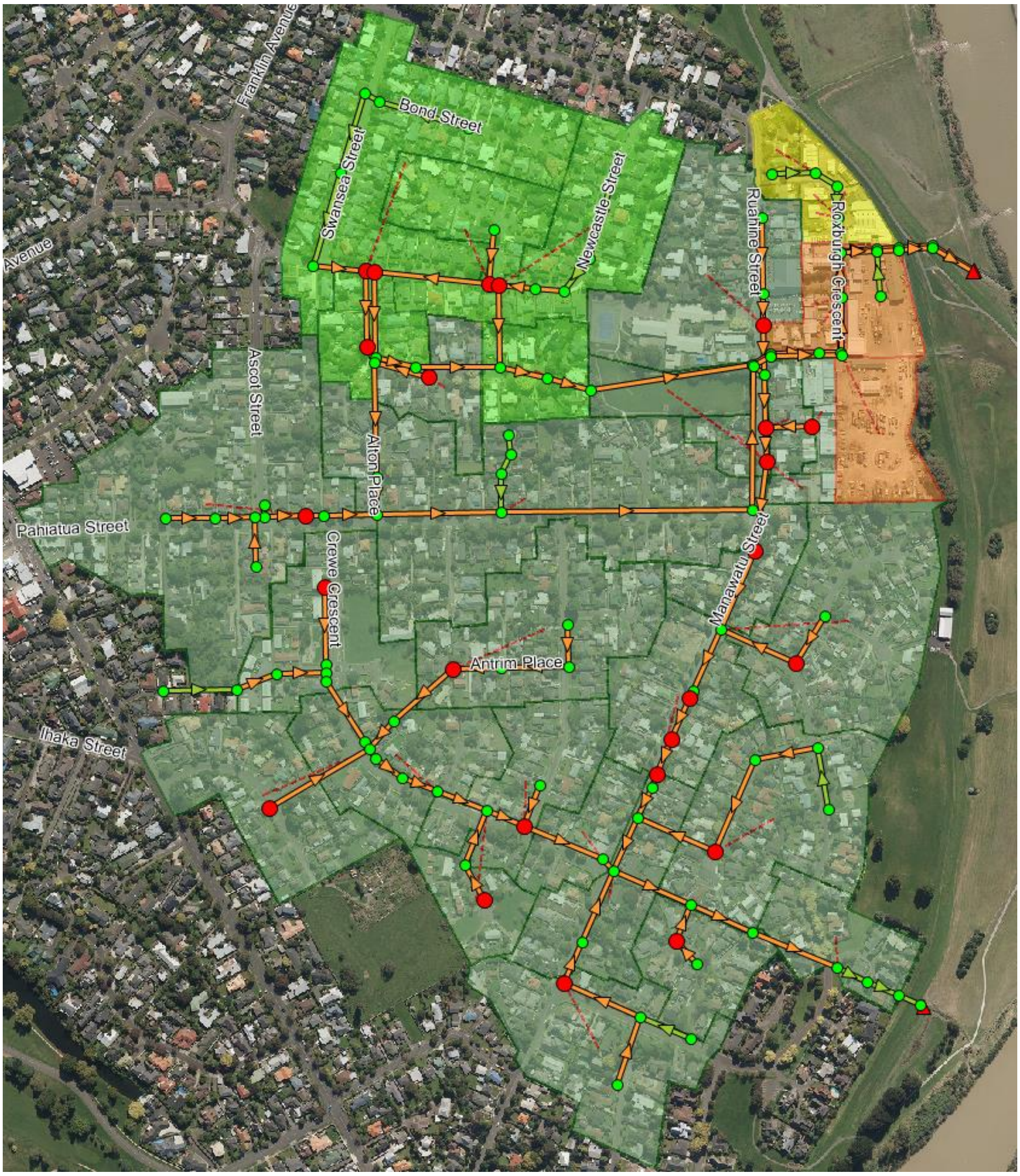


Figure 15: Results for 10% AEP + CC event with upgraded network (Stage 2) and proposed land use (30% pervious residential lots in Roxburgh PC area). Surcharged pipes are shown in orange and red circles indicate spilling manholes

16The network upgrades are shown on the map in Figure 17Appendix C. This has been budgeted for in the Long Term Plan, as discussed in Section 4.

Figure 17: Recommended network upgrades

Table 8: Summary of manhole spill volumes for 10% AEP rainfall event

Manhole ID	Manhole Location	Spill Volume (m^3) *Existing Network, Existing Land Use 10% AEP (Historical)*	Spill Volume (m^3) *Existing Network with DN300 upgrade on Roxburgh North, 30% pervious residential lots in plan change area, 10% AEP + CC*	Spill Volume (m^3) *Upgrades, 30 % Pervious Residential lots in plan change area, 10% AEP + CC*
2854	Surrey Crescent	1	6	5
3688	Surrey Crescent	51	222	125
2844	Surrey Crescent	42	132	124
3698	Surrey Crescent	0	65	36
8119	Ruahine St	520	811	806
3689	Surrey Crescent	498	696	199
2853	Surrey Crescent	2	22	0
4384	Surrey Crescent	90	156	128
3691	Surrey Crescent	5	35	0
8123	Ruahine St	0	4	4

348	Ruahine St	144	255	255
3163	Alton Place	134	260	0
8137	Pahiatua St	757	1255	0
8065	Pahiatua St	215	333	1
3161	Crewe Crescent	0	241	MH removed in upgrade
96	Manawatu Street	418	642	641
3704	Waterloo Crescent	0	17	17
N/A - Private MH outside 6 Dresdan Crt	Pahiatua St	194	247	0
N/A - 565 Ruahine Street	Ruahine St	1	13	13
353	Dorset Crescent	272	488	468
364	Buxton Place	63	85	42
2255	Earl Place	0	15	15
2272	Manawatu Street	163	337	317
2251	Erin Street	0	0	0
17853	Waterloo Crescent Outfall	0	0	0
21057	Manawatu Street	183	240	208
8076	Crewe Crescent	0	0	3
8197	Antrim Place	510	894	452
349	Manawatu Street	124	215	206
8597	Manawatu Street	22	100	96
365	Ashford Ave	1	1	1
8216	Crewe Crescent	205	584	244

The high-level concept follows the route of the existing stormwater network, however consideration should be given to the structure plan. The wide boulevard that provides public access to the river corridor could also serve as the new stormwater corridor. In that case, the stormwater main would still be directed to the existing channel outfall to avoid a new discharge to the river.

As discussed above, the existing DN750 is still required to service the catchment. Using the new roading layout in the Structure Plan would yield the following options:

1. Abandon the existing DN750 and increase the diameter of the new main so the entire catchment is conveyed by a single pipe and only one stopbank penetration;

2. Redirect the DN750 outfall to follow the new route with dual pipes to the outfall; or

3. Keep the DN750 where it is.

Constructability of the stopbank penetration would need to be considered, as there is a limit to what can be carried out via microtunnelling. A new dual pipe solution may be preferrable because the DN1050 could potentially be reduced with upsizing of the DN750.

It is anticipated that Horizons will require input into these options, which can be explored as part of detailed design.

3.4 Stormwater Management Plan

A high-level Stormwater Management Plan (SMP) will be required for treatment of stormwater runoff prior to discharge to the stormwater network and to demonstrate how the pervious area requirement will be met. Provided that the proposed stormwater mitigation measures are in accordance with this servicing assessment, the SMP will not need to be prepared by a suitably qualified stormwater design consultant with experience in Water Sensitive Design (WSD) concepts and elements.

The SMP must address the following:

a) Scoping of the subdivision layout and how it will connect to the existing drainage system;
b) Demonstrate how the development, including future development of lots, will be able to meet the impervious area limit;
c) Treatment of runoff prior to discharge to the primary network;
d) Protection of treatment devices and treatment of runoff during all phases of construction;
e) Outline how the development will hydraulically relate to its surrounding environs, including assessment of overland flow paths and potential flood impacts of proposed development and/or any proposed earthworks.

The SMP will be separate to any environmental management plans associated with development of potentially contaminated sites.

The Roxburgh Crescent Residential Re-zone Area is unique in that the re-zoned land has an existing public roading corridor. As such, coordination with the Council will be required in order for the appropriately sized treatment device to be provided in the roading corridor.

4 Funding

A high-level engineer's estimate was completed for the Stage 2 network upgrade option (refer to Appendix C).

The cost estimate is based on the following assumptions:

- Unit costs are based on recent tender rates and rates in QV Builder for the Palmerston North region, extrapolated to the proposed depth of the new pipeline. Open trenching has been assumed for most of the pipeline except a 60 m section through the existing stopbank where micro-tunnelling has been allowed for.
- Costs are GST exclusive.
- A 10% allowance has been included for Preliminary and General items.
- An 8-10% allowance has been included for design fees.
- A 30% construction contingency has been included.

The budget cost to complete the Stage 2 work (in 2023 $) is approximately $4.0 million, which includes design, consenting and construction. This has been accounted for in the proposed LTP programme[3], with construction costs allocated in Years 4 and 5. This has a 70/30 split between two programmes: 2324 - Urban Growth – Stormwater Roxburgh Crescent Infill and 1060 – City-wide - Stormwater Network Improvement Works, respectively. For the purposes of development within the Roxburgh Crescent PC area, the growth funding can be further proportioned based on the contributing catchment area, which is 13.5% of the entire catchment. As such, it is anticipated that approximately $0.4 million will be funded from the Roxburgh Crescent PC area.

As part of the next stage, a feasibility assessment is recommended to confirm the pipe corridor and existing services along the pipe alignment. This may impact the proposed construction methodology and cost estimate.

5 Summary

Council is looking to improve stormwater runoff quality prior to discharge to the Manawatū River. As part of the re-zone and redevelopment of Roxburgh Crescent, stormwater management is essential to mitigate the effects of development and ensure development does not adversely impact the receiving system or upstream catchment. As such, Council has determined the following is required:

- Water sensitive design elements must be incorporated in the development through the use of high-flow bioretention / biofiltration devices to mitigate both stormwater quantity and quality impacts within the road reserve.
  - The preferred device outlined in Section 3.2 minimises the footprint by using a high infiltration capacity media.
  - An acceptable solution is the Filterra® tree pit, which requires approximately 1 square metre of Filterra® be provided per 270 m^2 of contributing catchment area.

Roofing and other surfaces must be free of zinc and other heavy metals and contaminants. This is now considered standard practice.

Roof leaders are to be directly connected to the stormwater network; otherwise the runoff from the roof areas will need to be treated.

The development must promote stormwater infiltration by limiting lot imperviousness area. No attenuation will be allowed to offset additional impervious area.

- Under Stage 1 the minimum pervious area must equate to a combined pervious percentage of 28.4% across the entire PC area, but no less than 45% of the lots being developed.

If an outfall upgrade has been constructed and is operational, then under Stage 2 the minimum pervious area must be 30%.

A general Stormwater Management Plan is required for any development within the re-zone area that addresses both stormwater quality and quantity, as outlined in this assessment. The SMP must identify how the impervious area limit will be met as development occurs, and demonstrate that the development will be appropriately treated.

Due to the existing industrial land use, contaminated land investigations and management plans are required to ensure contaminated runoff does not enter the stormwater network, both during construction and after.

Stage 2 of the PC area is dependent on obtaining Horizons resource consent. A programme has been added to the LTP for construction in Years 4 and 5.

Appendix A. Correspondence with Horizons

Appendix B. Catchment-wide analysis

Introduction

In order to identify what improvements could be made in the wider catchment, the TUFLOW stormwater model was consulted to see where the flood risks are and the relevant catchments. Areas known to be susceptible to flooding include Pahiatua Street and Crewe Crescent. Both the Pahiatua Street and Crewe Crescent catchments discharge to the Crewe Crescent outfall. Therefore, in order to utilize the upgrade at Roxburgh Crescent, a catchment diversion would be required.

Methodology

In order to properly simulate the hydraulics of the network, a high-level PCSMM model (an earlier version of the model discussed in Section 2.2 of the main body of the report) was used to determine the pipe size required for the upgrades. As a starting point, an impervious area of 70% was assigned to the PC area for all of the options. Large subcatchments and approximate invert levels were used to estimate the required pipe size for each upgrade option.

Network Upgrade Options

Figure 18 provides an overview of the 10% AEP rainfall event and the contributing catchments that could be improved by upgrading the outfall. A description of each option evaluated is provided in Table 9. The diversion point identified indicates where the catchment would be redirected to the Roxburgh Crescent network and outfall.

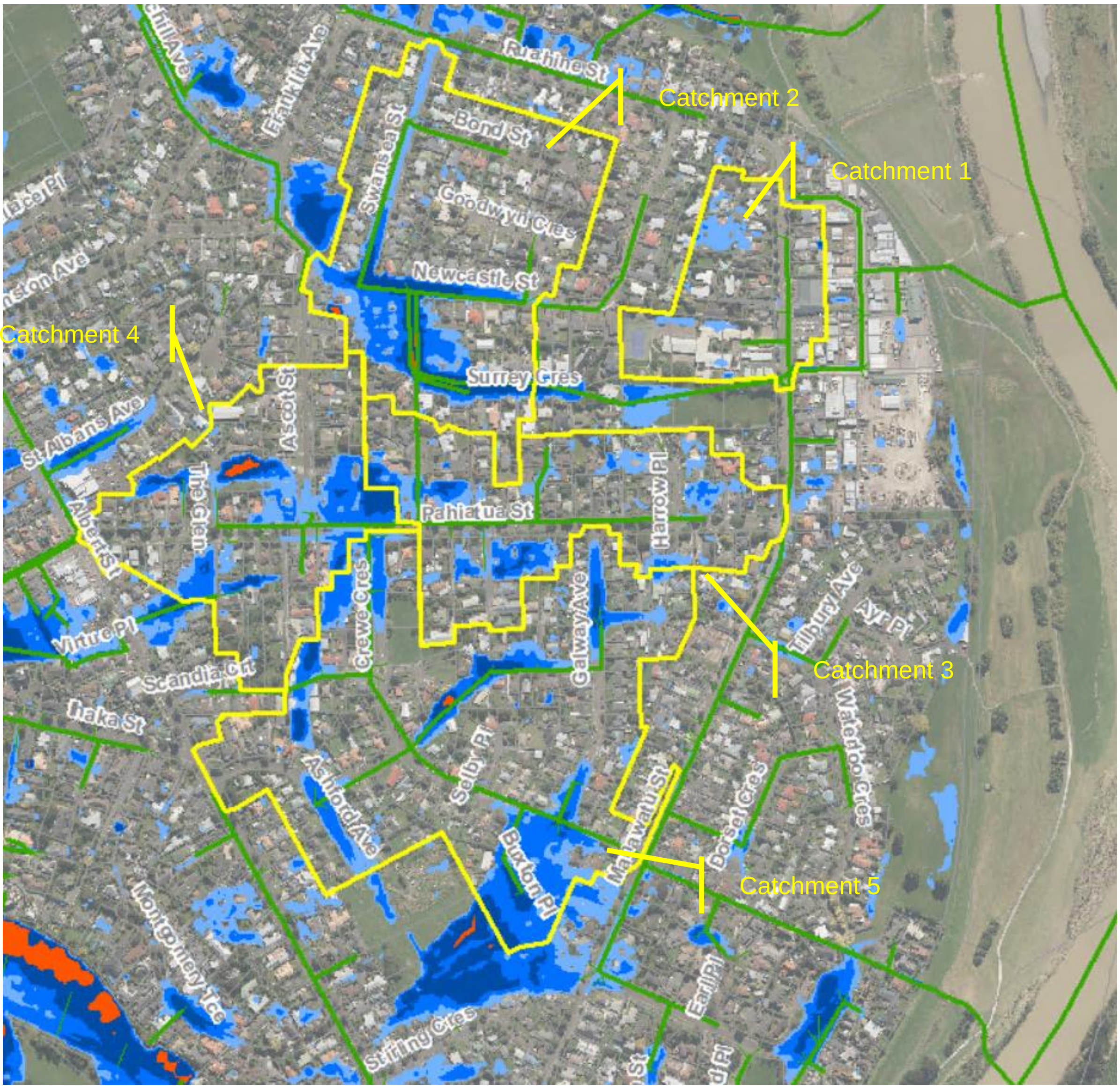
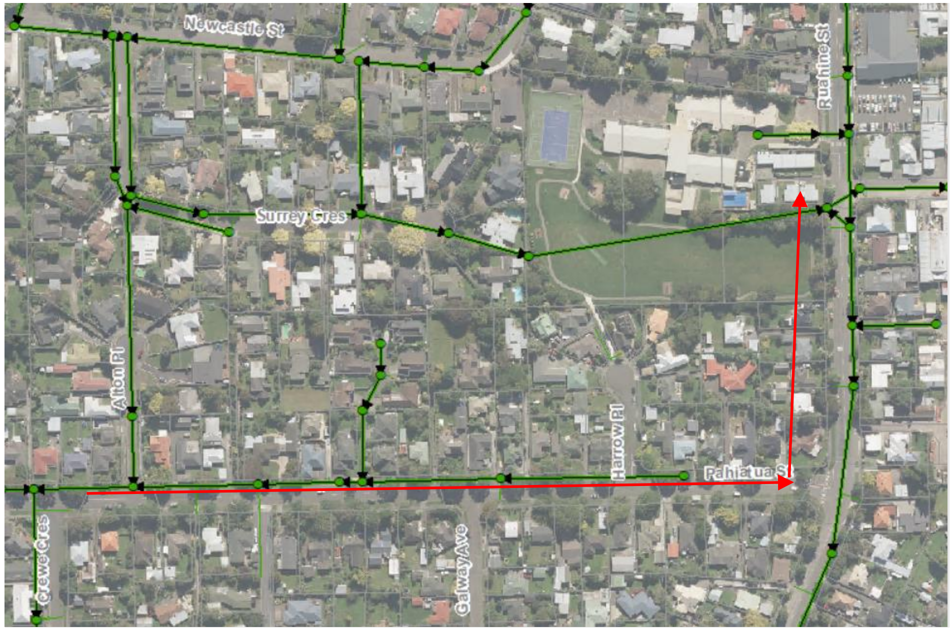


Figure 18: TUFLOW maximum ponding depths for 10% AEP (1 in 10-year) rainfall event with proposed catchment diversions

Table 9: Network upgrade options

Option	Description	Catchment Increase	Diversion Point
1	Redirect the north Ruahine Street stormwater main (catchment 1) to Roxburgh Crescent instead of continuing down Ruahine Street to Manawatu Street. This will reduce the loading on the Manawatu Street network. This option requires connecting the network upstream of SWMH 29217 to the Roxburgh Crescent main the flow split at Ruahine Street and Roxburgh Crescent (south).	10.7%	

2	Redirect all of the Surrey Crescent network (catchment 2) to the Roxburgh Crescent outfall. This will reduce the loading on the Crewe Crescent network, potentially reducing the flooding on Crewe Crescent. This option would require blocking the flow split and upgrading the network from Surrey Crescent to Ruahine Street.	26.9%	
3	Redirect east Pahiatua Street (catchments 2 and 3) at Alton Place to the Roxburgh Crescent outfall. This will reduce the loading on the Crewe Crescent network, potentially reducing the flooding on Crewe Crescent. This option would require a new pipe from Alton Place to Roxburgh Crescent.	28.7%	

4	Redirect east and west Pahiatua Street (catchments 2, 3 and 4) to the Roxburgh Crescent outfall. This will reduce the loading on the Crewe Crescent network, potentially reducing the flooding on Crewe Crescent. This option would require a larger pipe than Scenario 3 from Alton Place to Roxburgh Crescent.	48.6%	

<table>
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<td>5</td>
<td>Redirect the Crewe Crescent network (catchments 2 through 5) to the Roxburgh Crescent outfall. Through upgrades of the Crewe Crescent network, this should significantly reduce the flooding on Crewe Crescent.

This option would require a new pipe along Crewe Crescent and up Manawatu and Ruahine Street to Roxburgh Crescent.</td>
<td>90.4%</td>
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Results

The required pipe sizes for each of the options are presented in Figure 19.

The results show that:

All options require the outfall to be upgraded, ranging from DN825 to DN1350.

All options require the Roxburgh Crescent main to be upgraded, ranging from DN750 to DN1200.

Capturing all of Catchment 2 should not require an upgrade of the existing stormwater main to Ruahine Street.

Diverting Catchments 3 or 4 will require a new main of 600m and 660m in length, respectively.

Diverting Catchment 5 will require an upgrade of Crewe Crescent as well as a new main approximately 1.2km in length.

Based on the results, option 4 is recommended based on the pipe diameters required and pipe lengths. A figure showing the exact pipe diameters and extents is provided in Figure 20. This assumes that the Roxburgh Crescent south network is duplicated rather than upgraded for contractibility reasons.

Figure 19: Network upgrade requirements to service the identified catchments

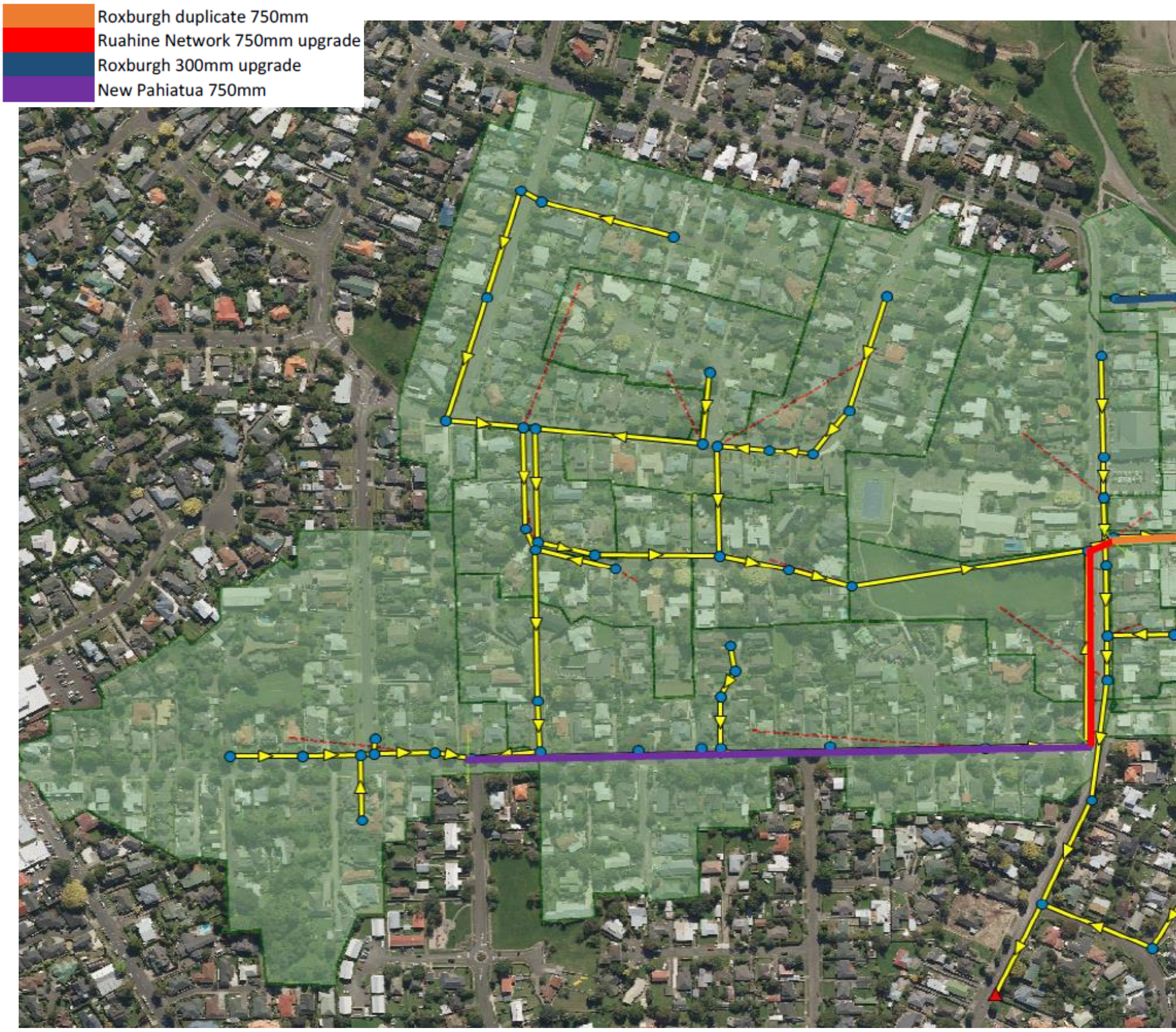

Figure 20: Recommended network upgrades (option 4)

Appendix C. LTP Programme and Cost Estimate Breakdown

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