Proposed Plan Change I: Increasing housing supply and choice

Stormwater Servicing Assessment

	Name	Signature	Date
Prepared by:	Kathryn Mack Reiko Baugham		
Reviewed by:	Veni Demado		
Approved for Issue by:	Jono Ferguson-Pye		29 October 2024

Contents

Figures

Tables

1 Introduction

This report describes the city-wide stormwater services assessment carried out to inform the preparation of the proposed increase in housing supply and choice plan change (PC:I), including how enabling intensification across Palmerston North city would impact stormwater servicing and whether the existing stormwater network can support intensification in the proposed areas. Based on this analysis, recommendations can then be made on how to manage changes to the city-wide stormwater network in ways that are effective long-term solutions.

This assessment has been undertaken using Council's city-wide urban stormwater model. This model was created to identify flood-prone areas across the city, and is not catchment-specific. Therefore, checks against historic flood complaints within Palmerston North City Council (Council) records have also been considered to validate the flooding predicted by the model. This assessment therefore acts as a trigger to identify where further assessment may be required as it relates to the proposed development.

The proposed intensification areas span the length of the city, in areas where set criteria are met (i.e., proximity to bus stops, reserves, schools, etc. as described in the Accessibility and Demand Report). These areas were provided 23 June 2022, as shown in the figure below. All areas are serviced by existing stormwater reticulation (refer Figure 1).

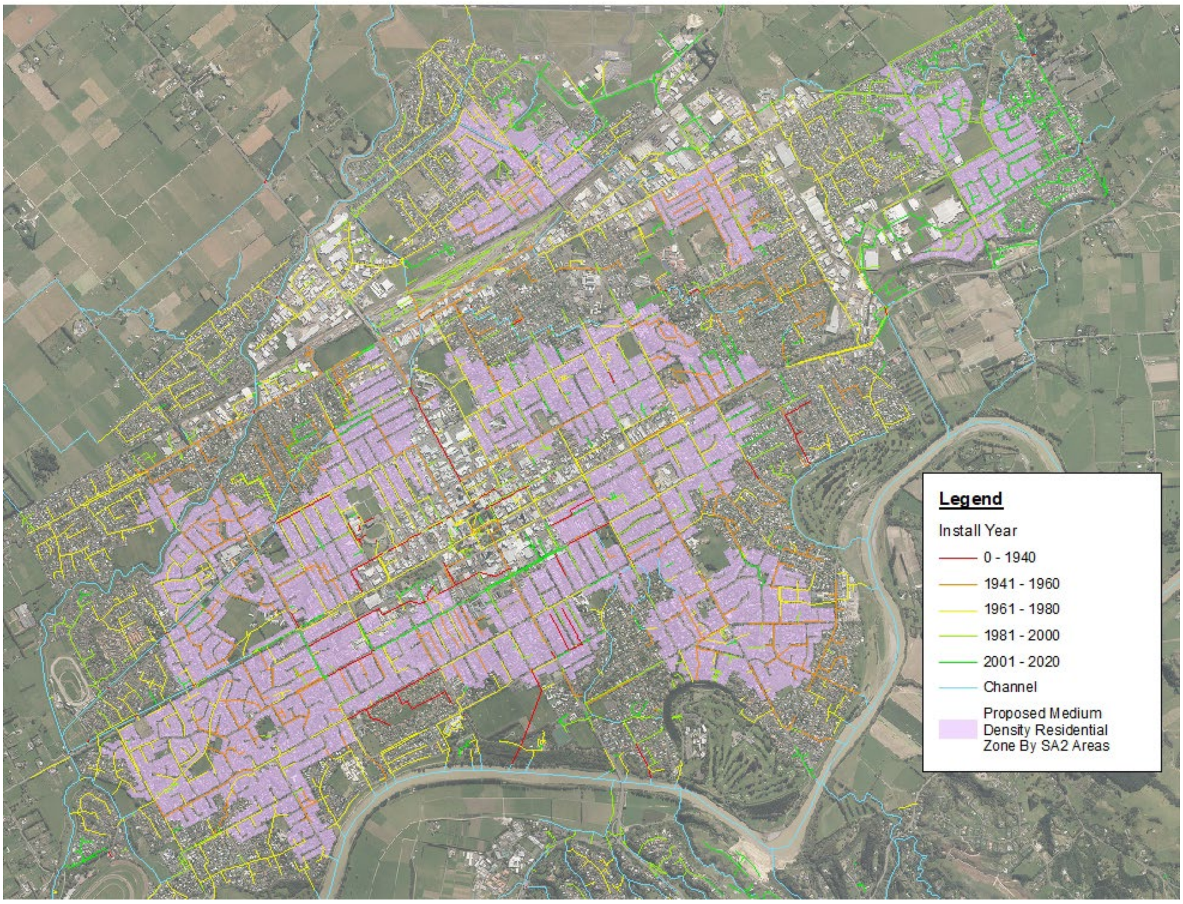

Figure 1: Proposed intensification areas and existing stormwater pipe network

For the purposes of this study, the proposed intensification areas (or Medium Density Residential Zone, MRZ) have been separated into three groups, identified as North, Central and West as seen in Figure 2. Lot yields for these areas are provided in Table 1-1.

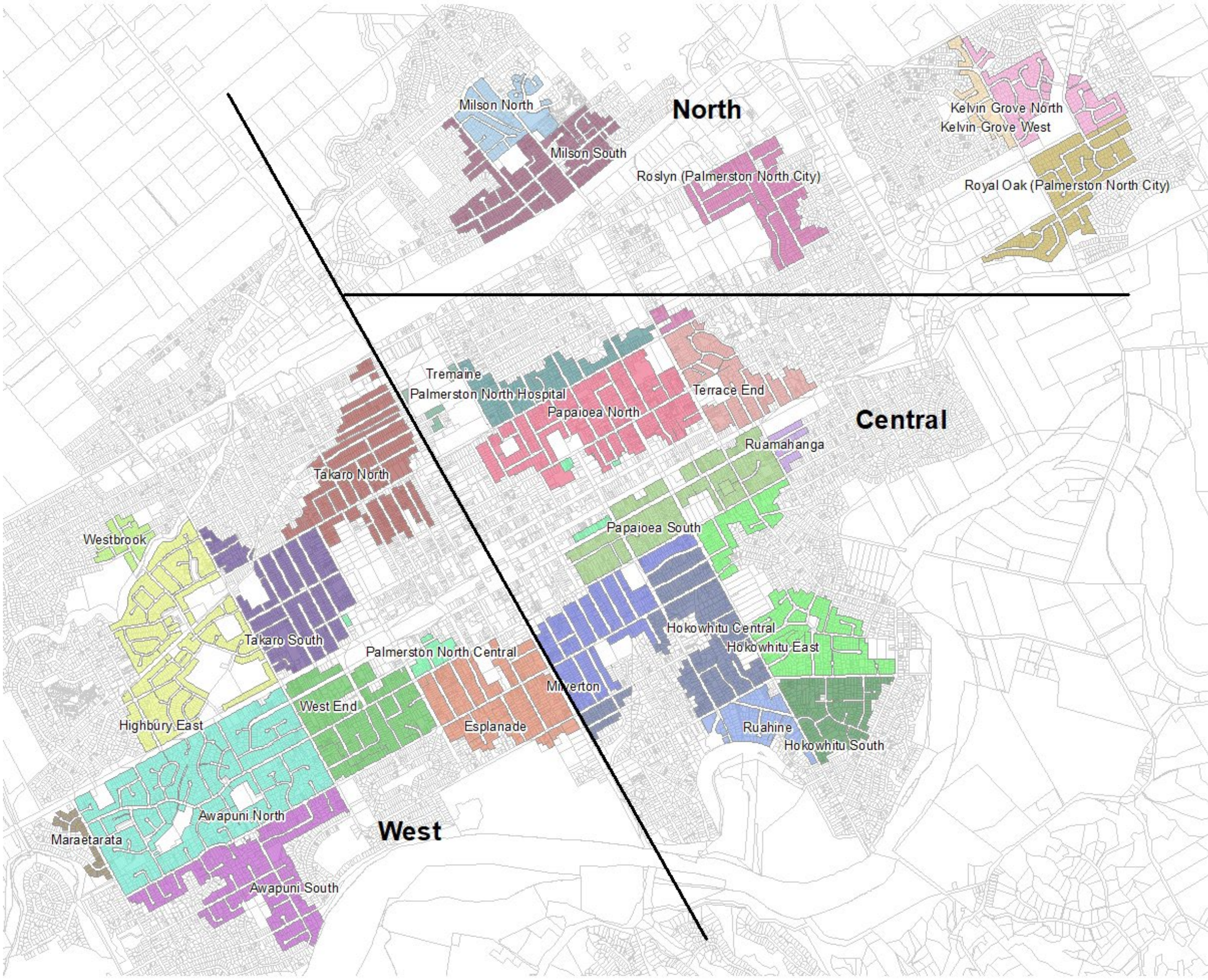

Figure 2: Division of intensification areas

Table 1: Feasible development capacity by SA2 area[1]

Area	Suburbs	Additional properties		
		Short-medium term	Long term	Total
North	Milson (North, South) Roslyn (Palmerston North City) Royal Oak Kelvin Grove (North, West)	1,9 20 0 0	1,19 40 0 0	2,28 60 40 60,40

[1] Development Capacity Assessment, October 2024.

Area	Suburbs	Additional properties		
		Short-medium term	Long term	Total
Central	Hokowhitu (South, East, Central)	24,59, 38	47,118, 75	71, 177,113
	Ruahine	6	12	18
	Milverton	23	45	68
	Terrace End	18	36	55
	Ruamahanga	10	19	29
	Tremaine	10	20	20
	Papaioea (North, South)	41, 20	82,40	122,60
	Palmerston North Hospital	24	48	71
West	Highbury East	12	24	37
	Awapuni (North, South)	34,32	67,63	101,95
	Westbrook	2	5	7
	West End	24	48	73
	Esplanade	32	63	95
	Takaro (North, South)	31,17	61,33	92,50
	Palmerston North Central	2	4	6
	Sub-total	**479**	**952**	**1,427**

2 Existing Stormwater Services

2.1 Existing Stormwater Reticulation

In the areas identified for intensification, the existing stormwater pipes vary significantly in capacity with some areas likely not meeting the level of service requirements for the current development. This may be because the historical level of service for the stormwater network was to convey the 1 in 5-year annual recurrence interval (ARI) rainfall event [or, 20% annual exceedance probability (AEP) rainfall event], whereas current standards[2] require a 1 in 10-year ARI (or 10% AEP) level of service. Another contributing factor to network constraints is the effects of climate change, also resulting in rainfall projections being higher[3] than previous design standards. This means that existing infrastructure may not be sized appropriately. In this case, upgrade of the pipe network is likely required to enable development and meet future stormwater needs. This is further discussed in the stormwater management section of this report.

2.2 Existing Stormwater Treatment

There are no existing stormwater treatment features provided in most of the proposed intensification areas. The exception is a small section of the Roslyn area, which discharges into the Pit Park and Norton Park wetlands.

2.3 Flood Hazard

PNCC owns a TUFLOW stormwater model that is used to identify potential flooding of existing development as at 2019. The model has been used to assess the likely flooding predicted in the 10-, 50- and 100-year ARI events, with the infrequent events accounting for climate change using NIWA's RCP 6.0 climate change scenario, aligning with Council's engineering design standards. A comparison of the RCP 4.5 and RCP 8.5 climate change scenarios has also been undertaken to carry out a sensitivity analysis, which is further discussed in section 2.3.1.

The TUFLOW model is a city-wide model, and therefore coarse in nature. The model was built using TUFLOW software in a modelling approach where a 2D model was constructed with large diameter pipes represented as open channels of equivalent hydraulic performance. The model was built and validated using information obtained from PNCC's GIS database circa 2016 and 2018.

The model was developed to provide PNCC with a tool for identifying areas that are potentially at risk from flood hazard, and not intended for site-specific assessments. The model provides the background into areas prone to flooding and identifies areas where pipe upgrades may be necessary, noting that the model would be considered more conservative (i.e., predict greater flooding than actually occurs) for frequent rainfall events since the piped reticulation is simply modelled as open channels.

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2 *Engineering Standards for Land Development*, PNCC, Fourth Edition, March 2023

3 *Plan Change I: Increasing Housing Supply and Choice - Climate Change Report,* David Watson, October 2024

Figure 3 overlays the proposed intensification areas onto the predicted flooding[4] in a 1 in 10-year ARI event. The modelling indicates that some areas are already prone to significant flooding and that the supporting infrastructure (including overland flowpaths) is not adequately sized for the current level of development. The implications of this are further discussed in section 3.1.2.

4 Flood depths less than 100 mm are not shown as this is considered to be the threshold depth which can be reasonably relied on.

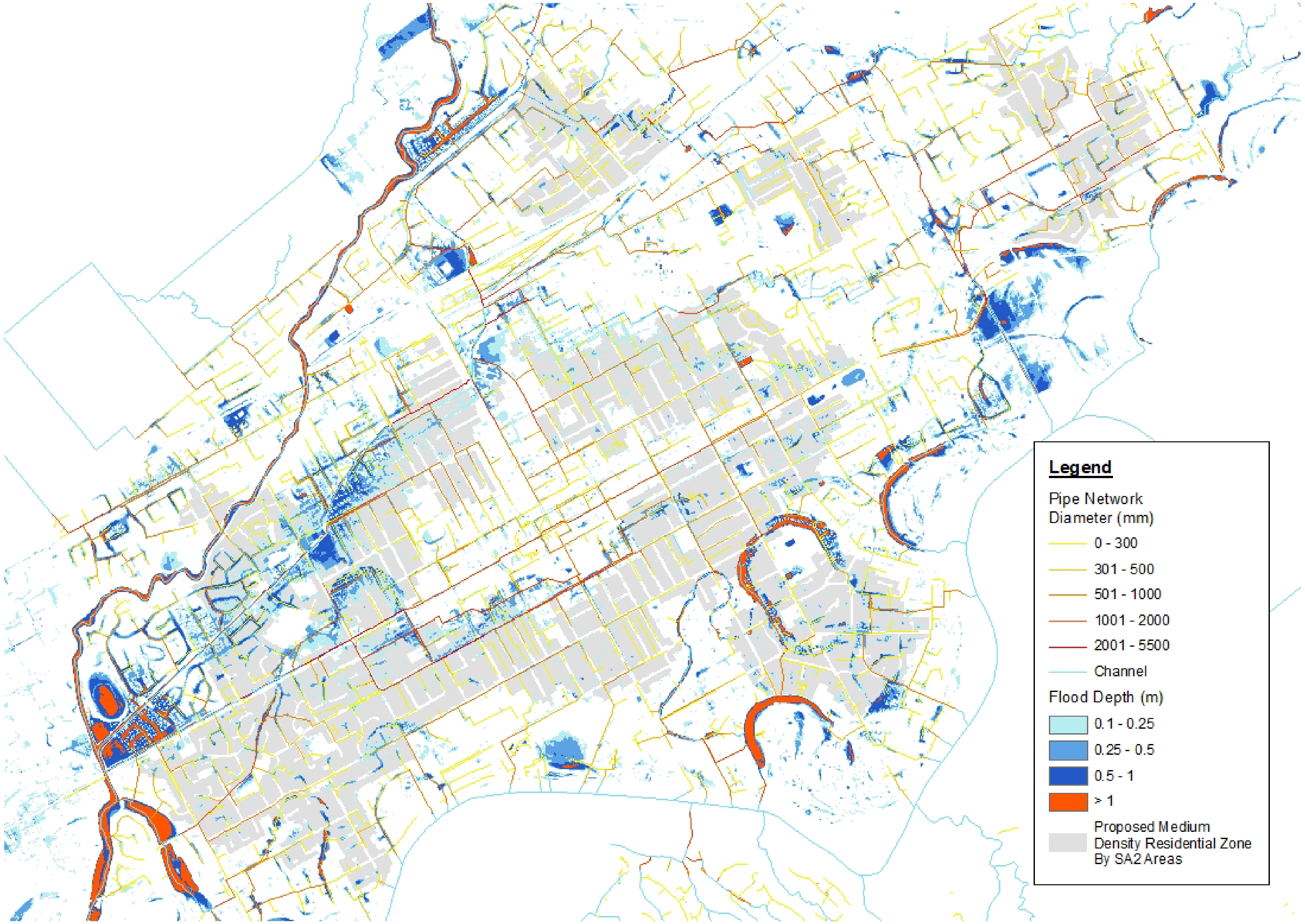


Figure 3: Proposed intensification areas and predicted 1 in 10-year ARI flooding

Since the initial modelling in 2019, Tonkin and Taylor (T+T) have been engaged to make further refinements and upgrades to the model. The main updates consist of including a 1-dimensional pipe network to refine flooding predicted in specific areas and incorporating building footprints to better represent overland flow.

A comparison of the flooding predicted by the two models is presented below in Figure 4. The image shows the depth difference between the 2019 model and current 2023 model.

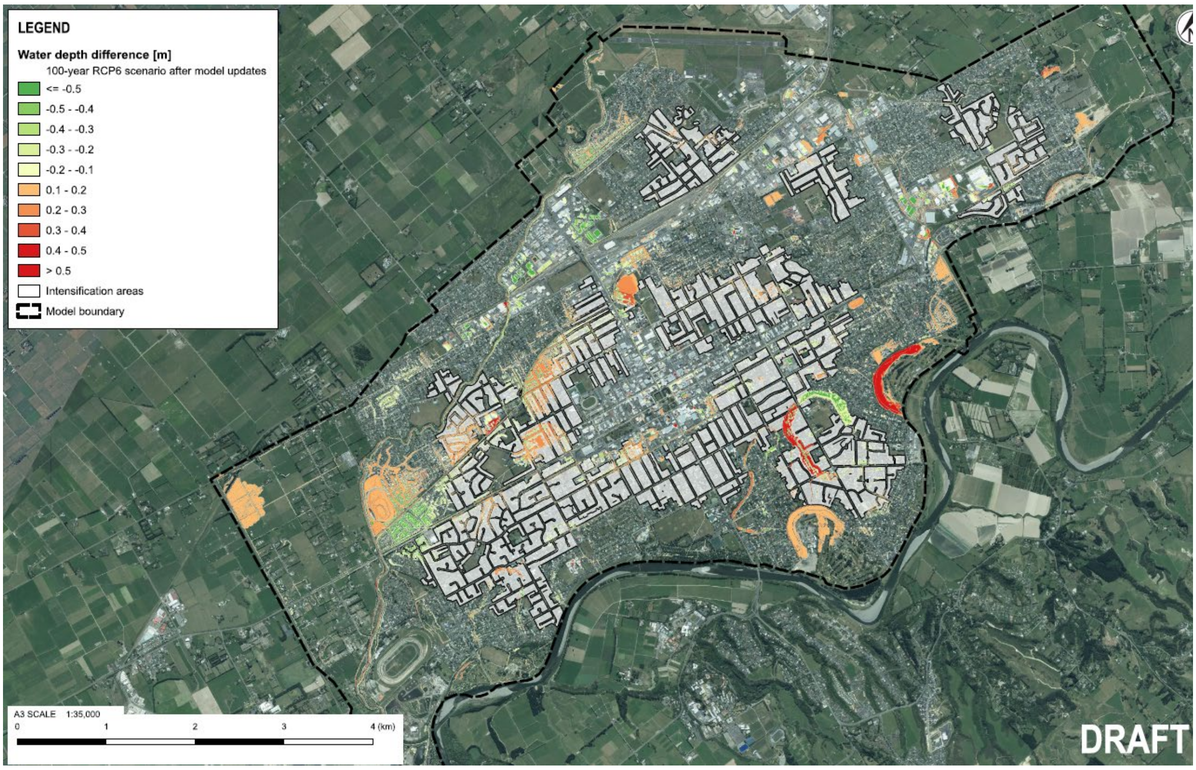


Figure 4: Water depth difference between 2019 and 2023 models for the 100-year RCP6.0 climate change scenario

The majority of the depth increases / decreases are due to 1D pipe network elements being incorporated into the model, and therefore improving the level of confidence of the model. However, the overall model is still considered to be a tool for identifying flood-prone areas only, and should not be considered definitive for making detailed, site-specific stormwater management or flood risk decisions. The intention of this assessment is to identify where site-specific stormwater analysis may be required, with the District Plan guiding the detailed assessment process to determine specific risks and required mitigation.

2.3.1 Climate Change Sensitivity Check

PNCC currently requires climate change scenario RCP 6.0 be considered as part of any flood assessment. However, Council is also aware of the potential for the more conservative RCP 8.5 scenario to come to fruition and the implications that would have on infrastructure. In order to understand the effect of the different climate change scenarios as they relate to flooding in Palmerston North, a sensitivity check was carried out by T+T by modelling the RCP 4.5 and RCP 8.5 climate change scenarios for the 50- and 100-year ARI rainfall events.

Due to the relatively flat nature of Palmerston North, increases in rainfall in major, infrequent events, have minimal effect as the rainfall is spread across a wider area that is already predicted to be inundated. The depth difference between the different climate change scenarios is relatively minor, and therefore the standard of using RCP 6.0 for design is considered to be acceptable. The flood depth maps are provided in Appendix A for reference.

3 Stormwater Assessment

3.1 Status Quo Scenario

Because the proposed plan change has identified growth spread across the entire city, an initial assessment has been carried out to identify areas that may not be able to support the current level of development (status quo).

3.1.1 Existing Reticulation

A high-level spatial assessment has been undertaken to identify areas that may require network upgrades, but where there is no current funding in place[5] to address the existing issues (Figure 5 and Figure 6). As stormwater pipe networks are required to last at a minimum 80 years from installation, any pipes noted to have more than 40 years of remaining life have been identified as they are unlikely to require renewal, which could otherwise be used as an opportunity to upgrade the pipe and increase network capacity. In addition, the TUFLOW stormwater model was used to determine which parts of the network may have capacity constraints, keeping in mind that many parts of the city are still modelled as 2D channels and has the potential to skew the results. As such, the stormwater modelling predicted in the 10-year ARI should not be relied upon to inform actual network capacity.

[5] It is acknowledged that there are budget gaps in the current Long Term Plan for pipe renewals, however Council is currently working on a long term strategy to identify where improvements are required and their associated budget requirements.

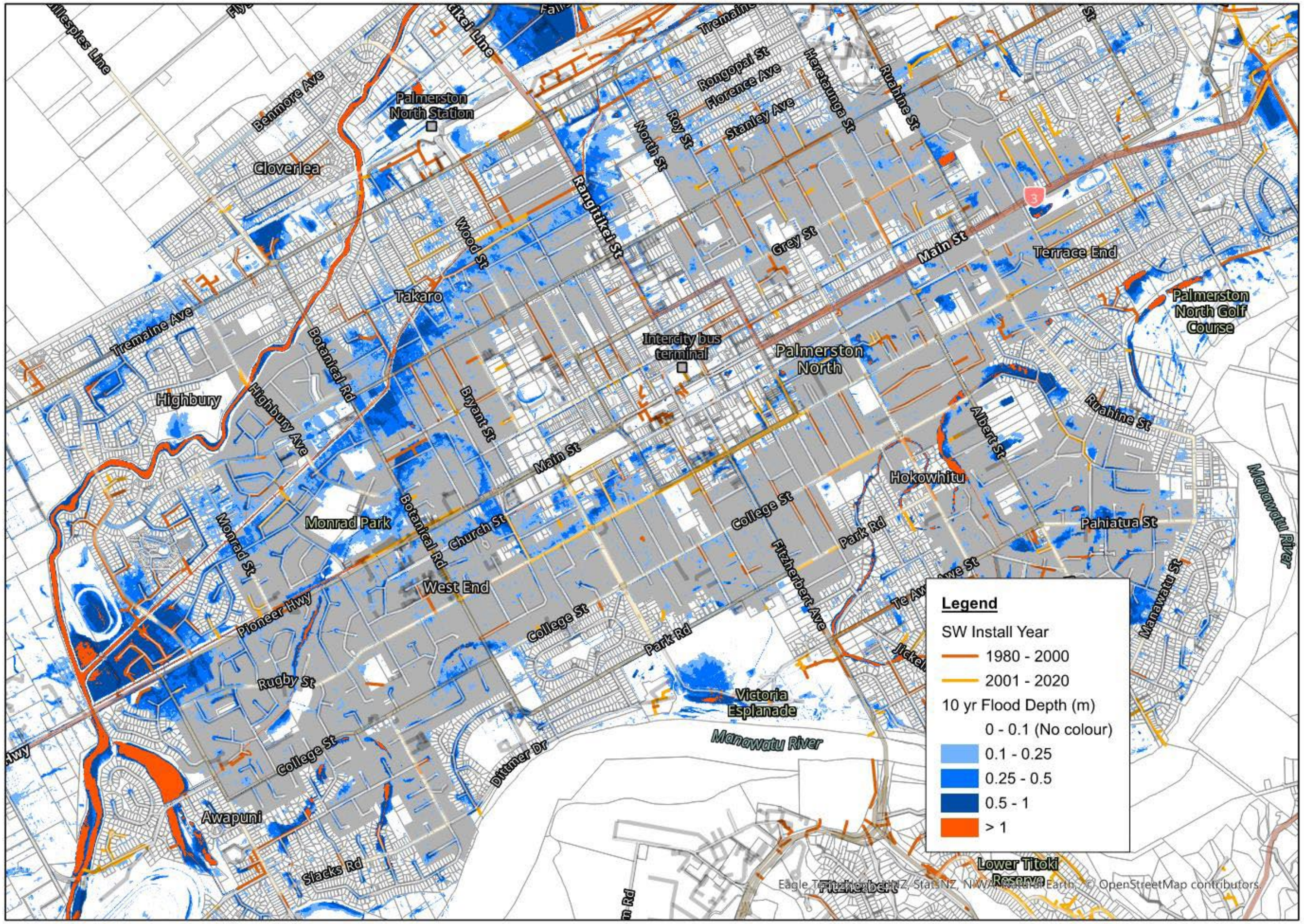


Figure 5: 10-year flood event with pipes younger than 40 years in Central and West intensification areas

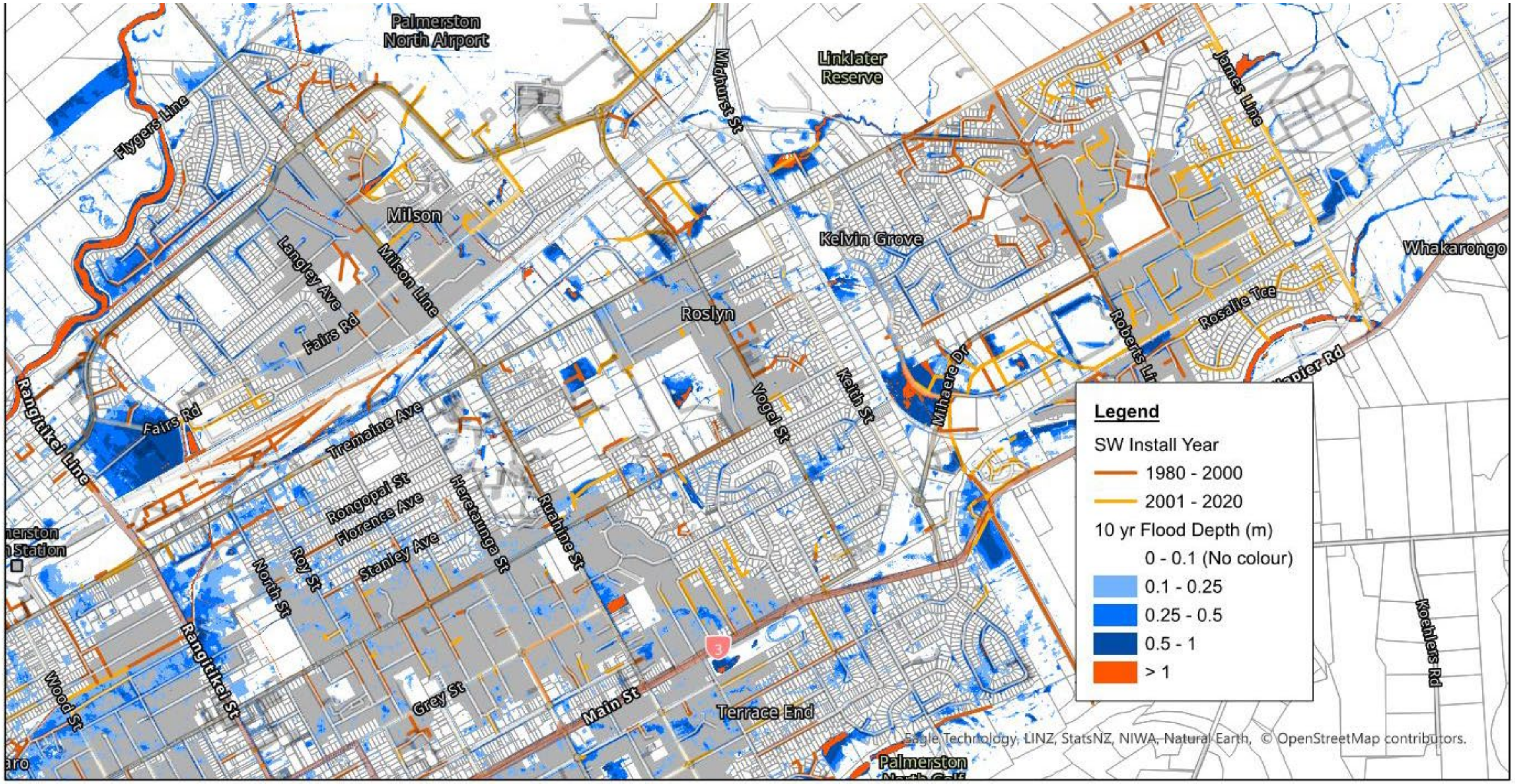


Figure 6: 10-year flood event with pipes younger than 40 years in North intensification area

Based on the above spatial analysis, several areas may be restricted in terms of supporting further development because they are unlikely to have funding identified that could enable a network upgrade. These areas include Kelvin Grove and Royal Oak, which are planned to receive additional housing in 11-30 years. This would increase the stress on the pipe network and is advised against until the pipes can be upgraded.

In many other suburbs with newer pipes, the flooding likely would be resolved with upgrades to the older sections downstream as these are at capacity. However, a site-specific analysis has not been undertaken at this point to confirm those areas.

3.1.2 Flood Risk

In addition to the 1 in 10-year ARI level of service Council requires of new infrastructure with the primary piped network, secondary systems to manage flows beyond the 10-year ARI are required to provide protection in larger events. PNCC requires the following level of service for new development (as per the PNCC ESLD):

- No habitable flooding in a 1 in 50-year ARI (2% AEP) event
- Suitable overland flow paths in a 1 in 100-year ARI (1% AEP) event

A review of the flood modelling shows that some of the proposed intensification areas are situated in flood prone areas. A high-level analysis of flood depths was carried out to identify those blocks of development that contain at least 25% of the area in flood water greater than 150 mm in the 1 in 50-year event. Results of this spatial analysis are provided in the figure below.

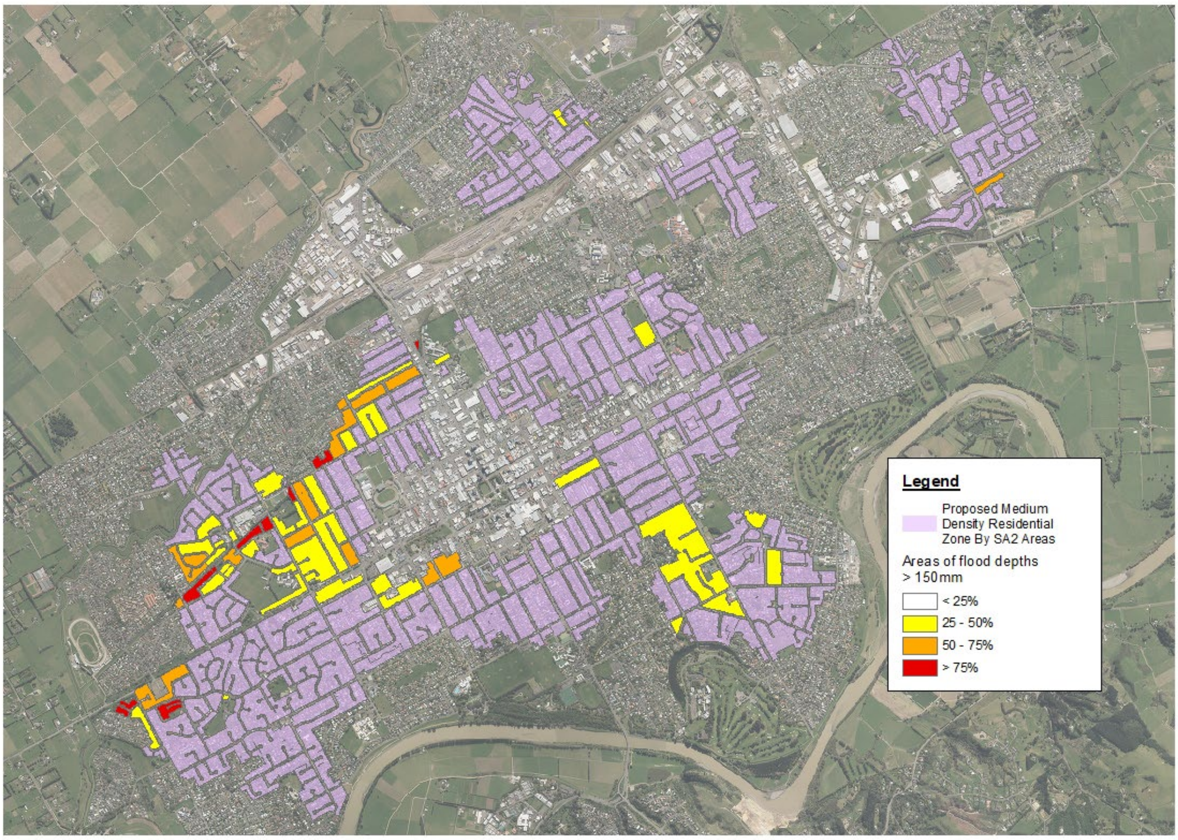


Figure 7: Flood water coverage deeper than 150 mm in the 1 in 50-year event

In order to validate the model results, a comparison of historical complaints of property flooding and the results of the TUFLOW stormwater modelling was mapped to identify areas that are more likely to be susceptible to flood hazard because they have also been observed. The intensification areas with predicted flooding and historical flood complaints are considered to have a higher confidence level in terms of the likelihood of the property being inundated. These areas would benefit from updated modelling and further analysis considering the proposed development and a detailed review of the flood complaints to determine whether the prior flooding was due to resolvable network issues.

The road reserve is typically used for the secondary system in large events. As this plan change is for growth in urban areas rather than greenfield developments, complaints relating to surface flooding in the road reserve have been removed so that only direct property flooding is considered. Appendix B provides an overview of the predicted flood depths in a 1 in 50 and 1 in 100-year ARI events (with an allowance for climate change) and where flood complaints have been noted for each area.

Based on the spatial analysis and mapping exercise, each proposed intensification area has been assigned a likelihood of flood levels based on historical property flood complaints and predicted property flooding in the 1 in 50-year ARI rainfall event. In areas of planned intensification with numerous flood complaints further investigation is needed to determine the suitability of the area, taking into consideration the ARI of the historical event, predicted flooding extent, pipe capacity, and nearby drain blockages. These can then inform the steps required to mitigate future flooding, where practicable. The table below summarises the different flood hazard classifications and the areas they are assigned to. This is also represented in the figures below, which indicate the different variables considered in determining the likelihood of flooding (see Figure 8) and the resultant confidence level of the modelling results (see Figure 9).

Figure 8: Variables considered to indicate the likelihood of flooding using the 1 in 50-year model results and historical complaints

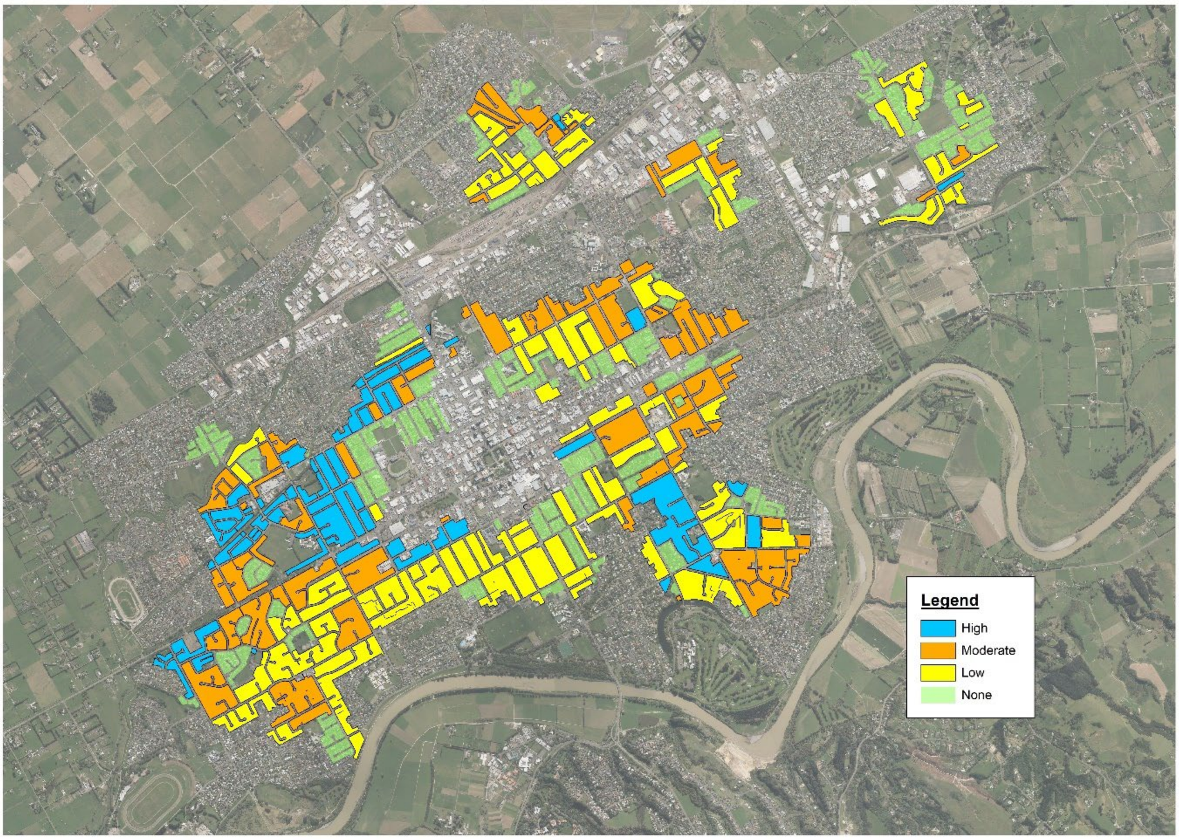


Figure 9: Flood hazard confidence level

Table 2: Predicted flood water level classification

Level of Confidence	**Predicted model water depth > 150mm**	**Prior complaints**	**Intensification areas**
High	affected area of block > 25%	yes	Awapuni (N), Highbury E, Hokowhitu (C, E, S), Maraetarata, Milson (S), Papaioea (N, S), PN Central, Royal Oak, Ruahine, Takaro (N, S), Tremaine, West End
Moderate	affected area of block > 10%	yes / no	Awapuni (S), Milson (N), PN Hospital, Roslyn, Ruamahanga, Terrace End
Low	nil	yes	Esplanade, Milverton, Kelvin Grove (N, W)
None	nil	no	Westbrook

Based on the status quo scenario, it is recommended that intensification in Awapuni, Highbury, Hokowhitu and Takaro is not undertaken as a permitted activity without further detailed analysis as part of a resource consent application, as these areas have previously experienced widespread flooding and may require network upgrades or other catchment-wide improvements to enable further development.

It should be noted that this is a high-level spatial analysis and does not reflect detailed site-specific flood risk. As such, the actual risk in these areas may differ from what is presented above.

3.2 Growth Scenario

Tonkin and Taylor were engaged to determine the effects of intensification across the city and potential mitigation measures required to enable intensification. The proposed intensification areas were modelled with an increased impervious area of 100% in the city centre and 80% elsewhere, resulting in an increase in runoff. The modelling methodology and full details of the assessment are provided in the T+T report (refer Appendix C).

The following figures identify the increase in flood depths as a result of the proposed intensification for the 10-, 50- and 100-year ARI events for all intensification areas.

Figure 10: 1 in 10-year ARI flood depth difference due to intensification (Tonkin and Taylor, 8 May 2023)

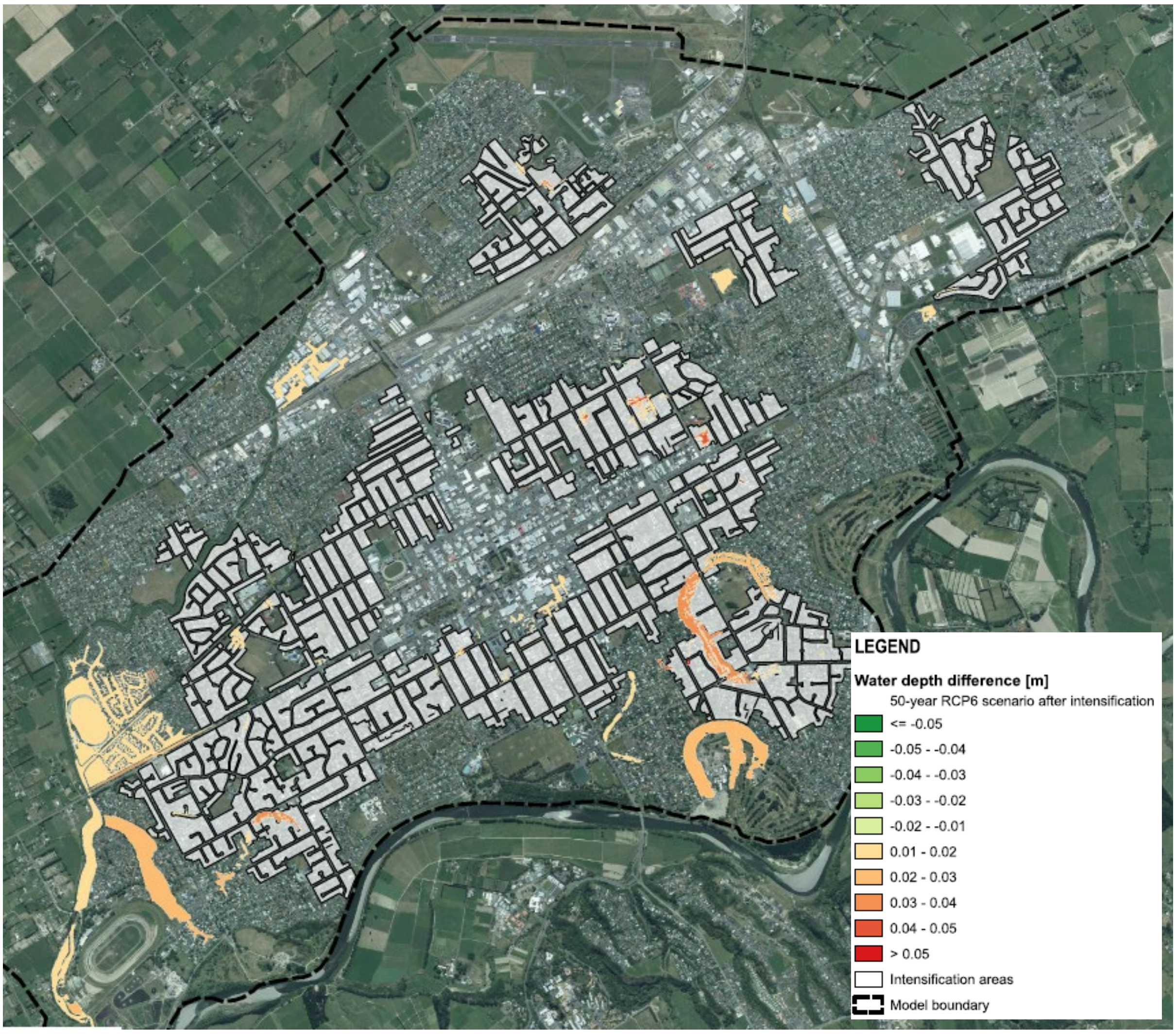


Figure 11: 1 in 50-year RCP6.0 ARI flood depth difference due to intensification (Tonkin and Taylor, 8 May 2023)

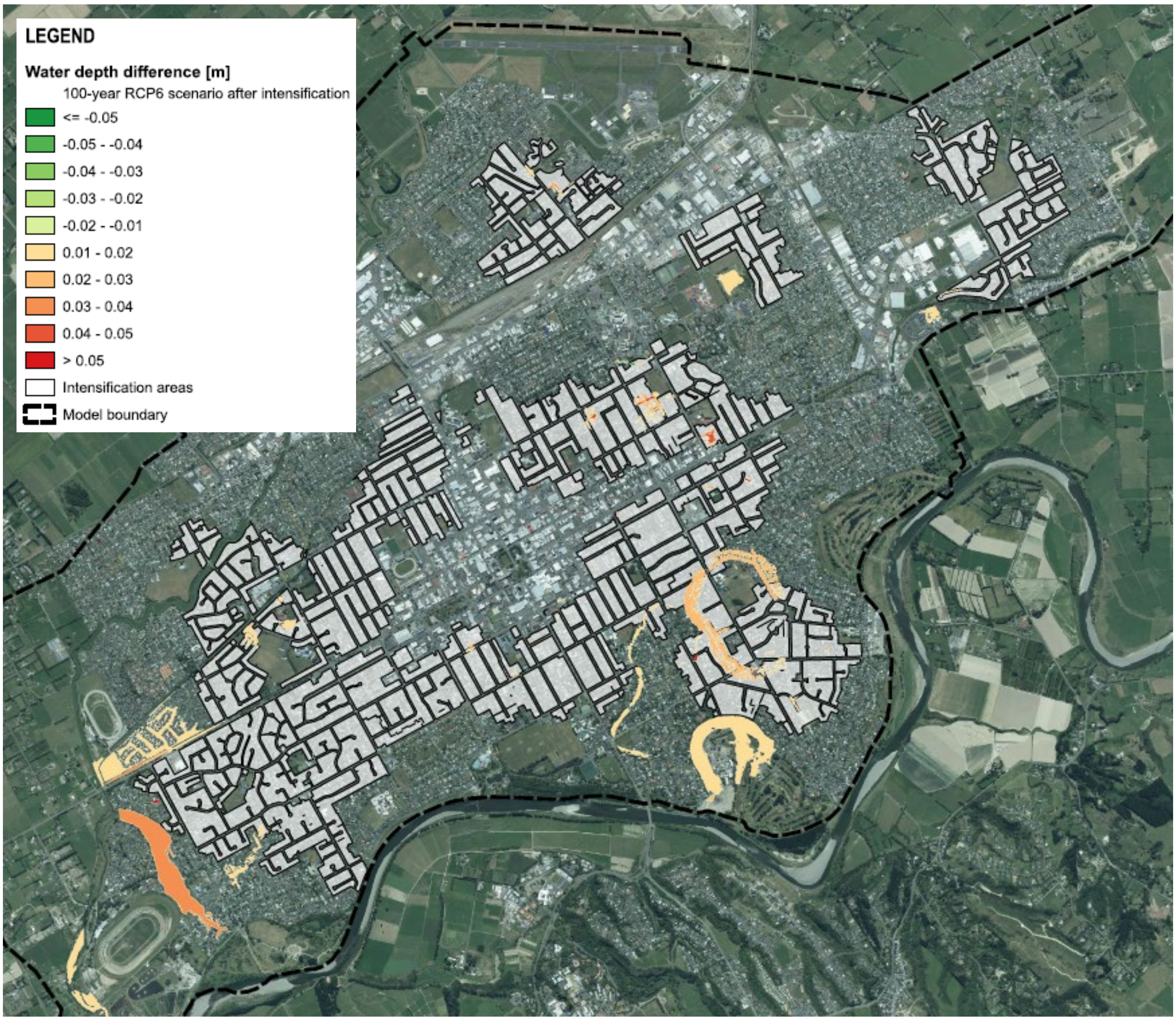


Figure 12: 1 in 100-year RCP6.0 ARI flood depth difference due to intensification (Tonkin and Taylor, 8 May 2023)

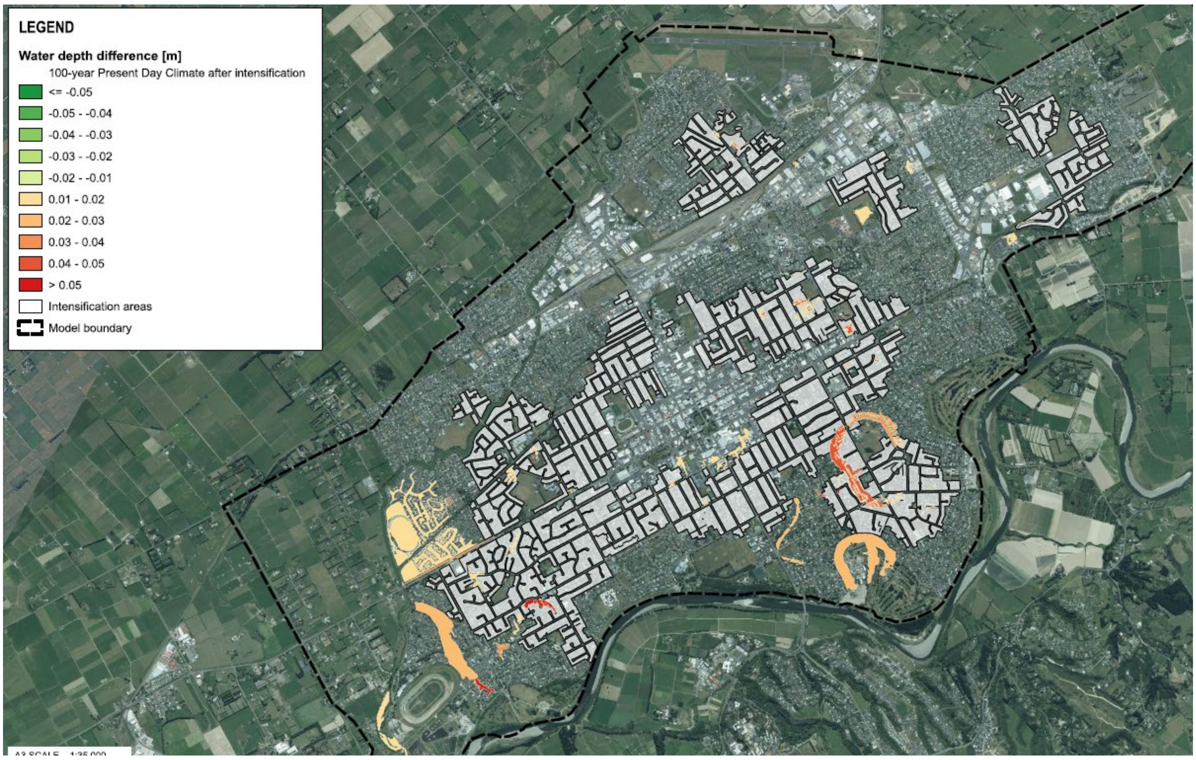
The modelling indicates that several areas proposed for intensification show an increase in downstream flood depths. This includes areas discharging to the Awatea Stream and Mangaone Stream. Conversely, there are several areas that do not appear to show any impact on downstream (or upstream) flooding.

Intensification areas that demonstrate a downstream effect were removed and the remaining areas re-evaluated for their downstream effects. Intensification in the following areas is predicted to not worsen or accelerate flood hazard to the downstream catchment:

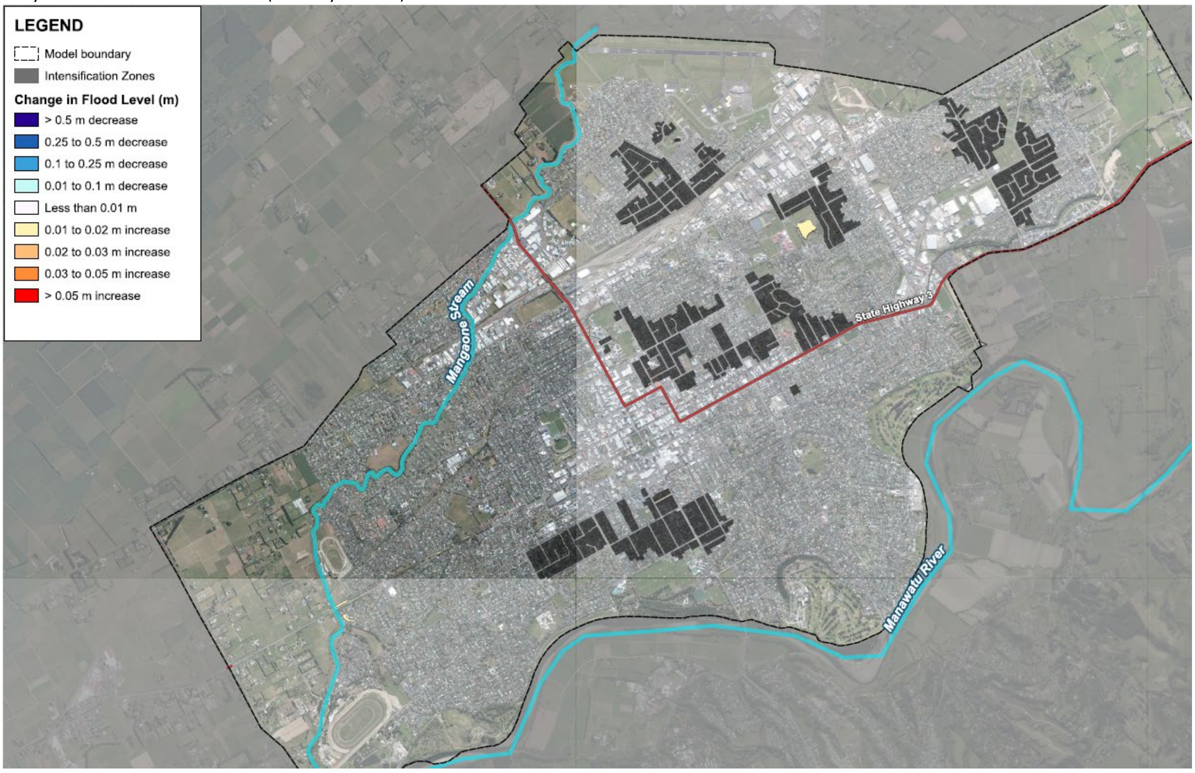
- West End (south of Ferguson Street)
- Esplanade
- Milverton (south of College Street and west of Karaka Street)
- Hokowhitu East (west of Karaka Street)
- Papaioea North (except northeast of Alan Street and Grey Street)
- Terrace End (parts of)
- Palmerston North Hospital (parts of)
- Tremaine

- Roslyn except between Tyne Street and Tremaine Avenue
- Parts of Milson South
- Kelvin Grove North and West
- Royal Oak

The above areas are shown in Figure 13. This shows the depth difference between city-wide intensification and the reduced intensification for the 100-year ARI event.



City-wide intensification (8 May 2023)



Reduced intensification (Scenario 2, 9 July 2024)

Figure 13: Comparison of flood depth changes in the 1 in 100-year ARI (Tonkin and Taylor)

An increase in flooding is predicted in Edwards Pit Park, however it is predicted to be less than 20 mm and is located within a public reserve area. A check of flood depths in more frequent rainfall events (1 in 2- to 1 in 50-year ARI) also shows a slight increase of less than 50 mm, which is considered to be within the tolerance of the model.

The remaining extent of the proposed MRZ not identified in Figure 13 will require site specific stormwater management plans to mitigate the effects of development.

3.3 Final Recommended Growth Areas

Based on network capacity constraints, the likelihood of existing flood risk and predicted increase in flooding as a result of intensification, parts of the following areas are recommended as being suitable for residential intensification as a permitted activity. These areas are also identified in Figure 14 below.

- Roslyn
- Milson South
- Milverton
- Tremaine
- Esplanade
- Papaioea North
- West End
- Terrace End
- Palmerston North Hospital
- Palmerston North Central

Figure 14: Recommended PC:I intensification areas

Portions of the remaining areas are either likely susceptible to flood risk, and therefore will require a site-specific assessment before residential intensification could occur, or have been modelled to show an effect on the downstream catchment, which will also require a site-specific assessment.

4 Stormwater Management

4.1 Overview

Historically, PNCC's levels of service for stormwater management have been relaxed in the absence of the implementation 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 to PNCC's stormwater system.

Clause 3.5(4) of the National Policy Statement for Freshwater Management (NPS-FM) 2020 requires that "every territorial authority must include objectives, policies, and methods in its district plan to promote positive effects, and avoid, remedy, or mitigate adverse effects (including cumulative effects), of urban development on the health and well-being of water bodies, freshwater ecosystems, and receiving environments."

In general, land development increases stormwater runoff volumes as the percentage of impervious areas increase. Development also contributes to increases in contaminant discharges generated by both the construction works and the on-going activities and transport movements due to increased residential and commercial activity. This is true not only for greenfield development, but infill development as well.

Given the future regulatory intentions of the Regional Council, as well as the requirements for greater attenuation and reductions in contaminant discharge to the receiving environment to give effect to Te Mana o te Wai, 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.

Council will therefore require implementation of specific stormwater management solutions through PC:I. 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 sediments, metals, and hydrocarbons.

4.1.1 Rangitāne o Manawatū Environmental Management Plan

The Environmental Management Plan (EMP) recognised and endorsed by Rangitāne o Manawatū, is a guiding document that is to be taken into account when preparing or changing district plans. The EMP details the Rangitāne Te Mana o te Wai statement, which is the backbone of the NPS-FM. The objectives of this statement are as follows:

- Land and freshwater within the Manawatū will be managed in a way that gives effect to Te Mana o Te Wai. This is carried out by:

    - Protecting and restoring the mauri of the Manawatū Awa and coastal lagoons, their tributaries and connections.
    - Recognising and providing for the relationship of Rangitāne o Manawatū with their waters is supported.
    - Recognising water as an interconnected whole.
- To give effect to Te Mana o te Wai, all management of freshwater in the Manawatū shall prioritise:
    - Firstly, the health and well-being of waterbodies and freshwater ecosystems and the ability of mana whenua to uphold these.
    - Secondly, the health and well-being of people interacting with water.
    - Thirdly, the ability of people and communities to provide for their social, economic and cultural well-being, now and in the future.

As it relates to PC:I, the policies and objectives seek to protect and restore the mauri of the awa by:

- targeting potential contaminants through the use of onsite treatment for high trafficable areas; and
- mitigating and managing the effects of increased stormwater runoff volumes.

Although this will be confined to individual sites throughout the wider catchment, this can be coupled with catchment wide solutions that can be implemented by Council and provide resilience through a treatment train approach (i.e., multiple rounds of treatment before final discharge to the receiving environment).

4.2 Stormwater Quality Management

4.2.1 General Practice

Blue green infrastructure (BGI) is an urban design concept that links the built and natural environments as shown below in Figure 20 and Figure 21. A range of BGI assets (Figure 20) can be implemented across the plan change area, depending on the suitability of the environment. The environment created with successful use of BGI (Figure 21) can be a cost-effective long-term option, especially in areas where the existing stormwater network is under-performing, as it can minimise change in impervious area, thereby reducing pressure on the piped network. Combining the built and natural environment can also reduce flood risk and pollution, as it allows for the natural environment to filter contaminants from run-off with tools such as biofiltration, reducing the cost and energy requirements of traditional infrastructure, whilst providing shared spaces that are beneficial to community and environmental outcomes.

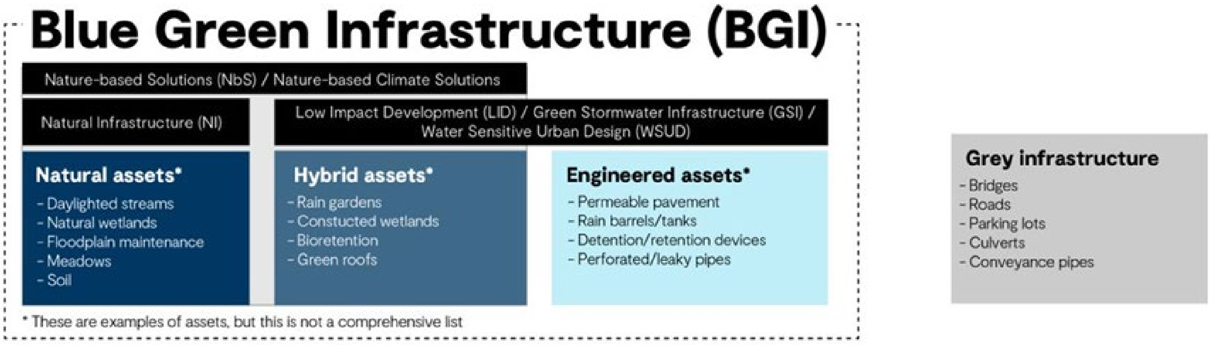


Figure 15: BGI asset breakdown (source GHD)

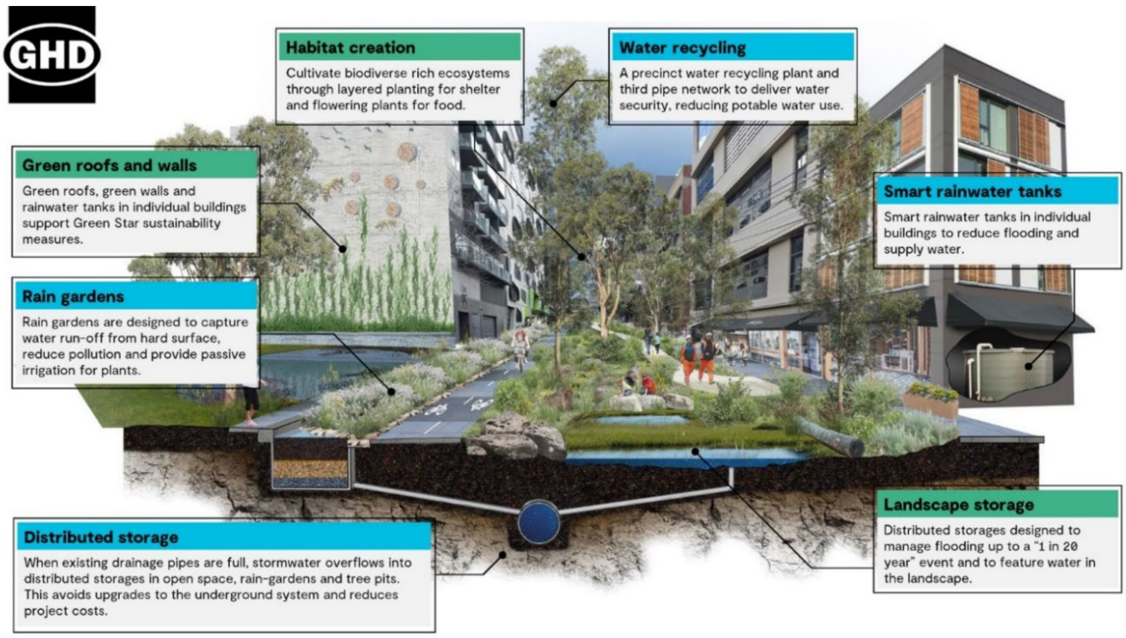


Figure 16: BGI in water sensitive cities (source: GHD)

A large portion of BGI consists of bioretention devices, such as rain gardens and tree pits. Depending on its design, bioretention may perform a hydrological detention function by reducing runoff volumes and detaining runoff flows. Additionally, these devices filter stormwater through a vegetated filter bed made of natural soil or engineered media. Implemented successfully, they increase biodiversity and filter pollutants, but also manage the volume of stormwater runoff. The toolkit provided by GHD in Appendix C of this report can be implemented to make the best decision regarding the lot type and main concerns facing the built and natural environment. To meet environmental standards and ensure that the discharge of roadside contaminants via stormwater runoff is minimised, requiring bioretention tools alongside footpaths and roads is recommended for larger sites.

Figure 17: The benefits of BGI (source; GHD)

4.2.2 Specific Treatment Requirements

Implementation of BGI can be difficult in existing built environments, with options limited due to lack of space. However, solutions are available for the plan change area. These include:

- Raingardens and planter boxes
- Tree pits
- Green roof and green wall
- Hedgerows
- Planted / vegetated swales
- Permeable pavement

In order to manage the effects of intensification, stormwater treatment is recommended for any development that provides more than three (3) carparks[6] (as this will be the source of most contamination). The chosen device will need to be assessed on a site-specific basis due to the variability of soils in Palmerston North.

In addition, all roofing materials should be zinc and heavy-metal-free as these require other specific treatment devices and can adversely affect aquatic life.

4.3 Stormwater Quantity Management

4.3.1 General Practice

To ensure that stormwater discharge volume increases are minimised and runoff peak flows and velocities are managed, it is recommended that developments include appropriate Water Sensitive Design measures. This includes the incorporation of greenspaces to provide treatment for all intensification.

Due to the size of the receiving network in places, impervious area should be limited as much as reasonably practicable for the existing network to provide an appropriate level of service. In some instances, attenuation can be applied for any additional impervious area above the limit. This is typically done so as not to overwhelm the receiving network by limiting the peak runoff to pre-intensification peak runoff. Evaluation of the catchment of the developed area is critical before relying on attenuation as it can impact the upstream catchment.

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 runoff to infiltrate into the ground to decrease the impervious area and better mimic pre-development hydrology.

4.3.2 Specific Stormwater Management

Upgrades required to enable development in the likely flood prone areas will be targeted in the city-wide stormwater strategy that is to be developed. The intention is that the stormwater strategy will help mitigate the flood hazard, with additional mitigation measures required as development occurs.

For those areas that were noted as having a negative downstream impact, a site-specific stormwater management plan will be required to better quantify the impact of the development and to identify the mitigation strategy. This may require post-development flows to match a fraction of pre-development flows due to the constraints on the existing network and existing downstream flood risk. This is due to the fact that development will increase the volume of runoff, and not just the peak flow rate. By further limiting the post-development peak flow, this will reduce the potential for coincidence of elevated flow downstream by the extended release of the flows and additional volume.

[6] Based on the assumption that a developer would provide one car park per unit, and up to three units is proposed to be a permitted activity.

In the absence of a catchment-wide analysis other councils[7] in New Zealand have proposed post-development flows match 80%[8] of pre-development flows in the 100-year event to manage any cumulative hydrological effects, with lower percentages for the more frequent events.

For the areas that were shown to have little to no impact in stormwater flooding, several controls are required:

- A minimum pervious area of 30% is to be maintained; and

- Hydraulic neutrality through the use of on-site stormwater attenuation. It is anticipated that stormwater attenuation can be provided in the form of rainwater tanks that are designed to empty following a rain event (i.e., they must not be used for rainwater harvesting).

4.4 Management Summary

The increase in impervious area proposed in the intensification plans would increase stormwater run-off, however, several features can decrease the impact of development to allow development in some areas. These include:

- Stormwater treatment where four or more car parks are proposed (including garages). The suitability of the chosen treatment devices will need to be confirmed.

- A minimum 30% area of permeable surfaces is maintained.

- Rainwater tanks (or similar attenuation device) are provided at a rate of 18 L for every additional 1 m^2 of new impervious area to mitigate the additional runoff produced in a 10-year ARI (plus climate change) rainfall event.

Ongoing maintenance of the stormwater devices (both treatment devices and attenuation tanks) will be required in order to meet permitted activity status.

Development in the potential flood prone areas will be subject to site-specific stormwater assessments and mitigation measures.

[7] Tauranga City Council, Bay of Plenty Regional Council, Hawkes Bay Regional Council.
[8] Shaver, et. al., 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. EPA.

5 Funding

Network improvements are not required to enable development in the recommended 'green' areas. A city-wide stormwater strategy has been allowed for under the latest Long Term Plan under Program 2536- Future Development Strategy. The total cost allocated for this programme is approximately $150,000, and excludes the actual implementation of the stormwater strategy. It is expected that the stormwater mitigation measures will be paid for through a separate LTP programme (not yet developed), but may also include development contributions.

6 Summary

Land development increases the volume, velocity, and peak flow of stormwater runoff, and has the potential to degrade stormwater quality by generating additional contaminants. Increasing density within an already built environment can be challenging to fully mitigate its effects. As part of the development for the identified growth areas, stormwater management is essential to mitigate the effects of development and ensure development does not adversely impact the receiving system or other properties.

Based on the high-level spatial analysis undertaken, several of the proposed intensification areas have been flagged as at-risk for potential flooding. These will require further modelling to confirm the risk and will also be incorporated under the city-wide stormwater management strategy that is in development.

Other areas were shown to have an effect on other properties through the modelling that was undertaken. These will require a site-specific stormwater management plan to better quantify and mitigate the effects of the development.

Both of these areas (those with potential flood risk and those affecting other properties) may require additional mitigation to address the existing flood hazards. That is, due to the increase in runoff volume post-development, runoff may be further restricted to a percentage of pre-development flows (e.g., 80%) so as not to exacerbate the existing flood hazard. However it should be noted that this is based on a high-level spatial analysis and site-specific flood risk assessments have not been carried out. This relies on model accuracy and therefore must be considered in detail with a site-specific assessment.

Figure 18 below identifies the areas for which further mitigation may be required versus those that could enable intensification as permitted activities. A 'Stormwater Overlay' has been proposed to identify that a site-specific assessment may be required based on the findings of this analysis.

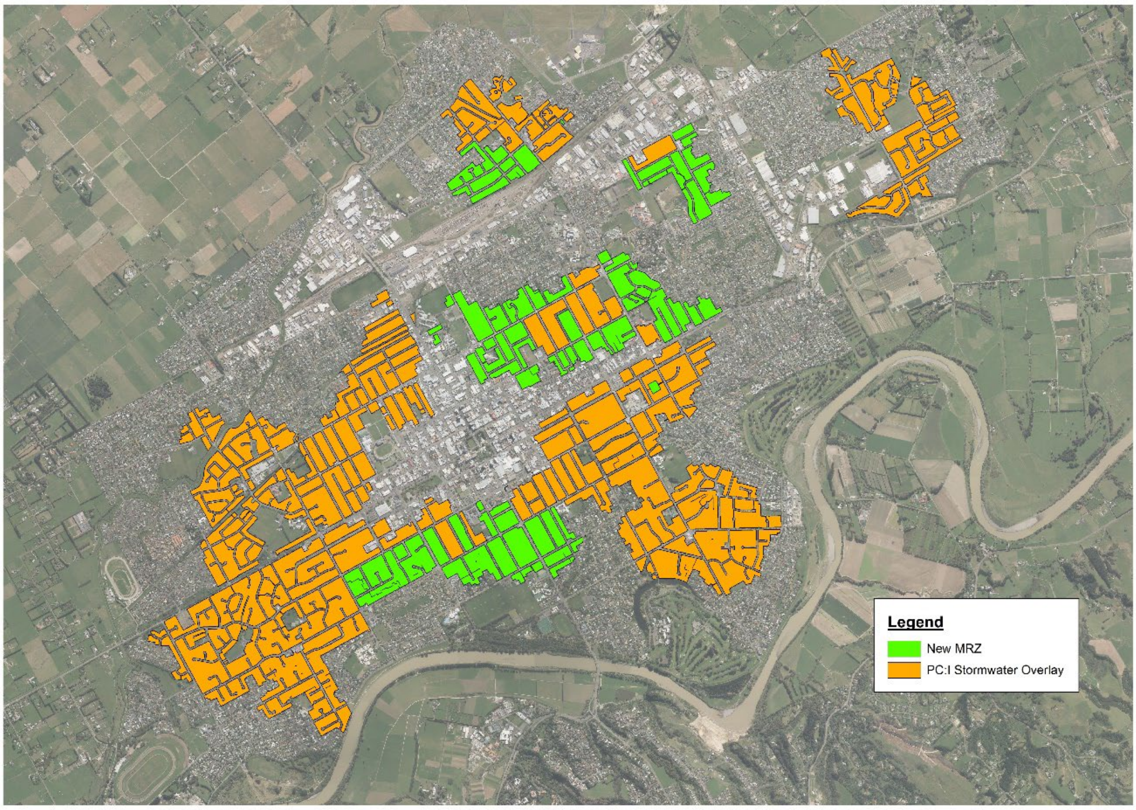


Figure 18: Recommended intensification areas

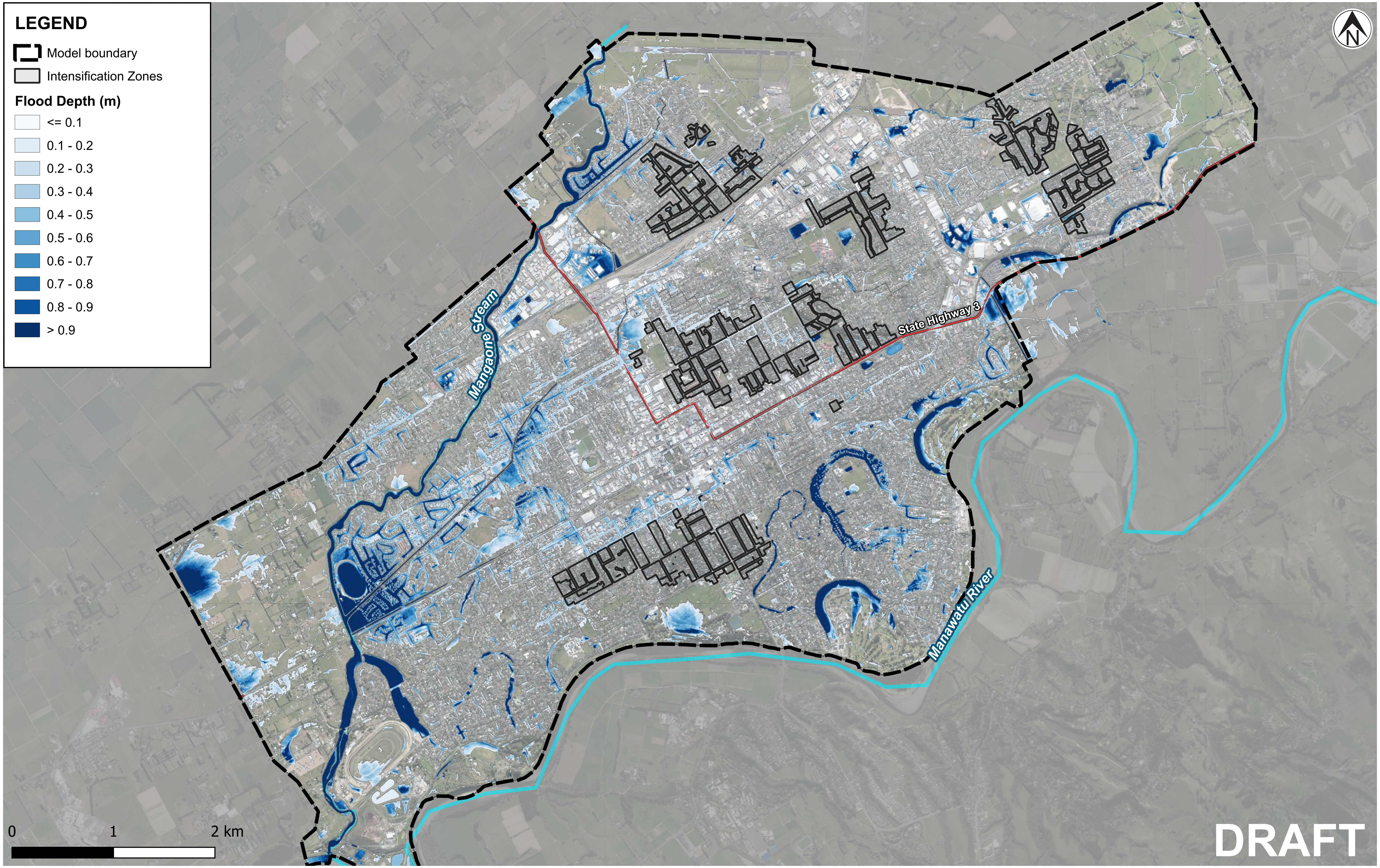
The areas shown in green are those that are shown to have little to no effect provided they meet the following stormwater management requirements to address the increase in stormwater runoff and the additional contaminants from the development:

- An appropriate minimum floor level is assigned based on the latest flood modelling at the time of the consent application (Building or Resource Consent).
- Water sensitive design elements must be incorporated in the development to mitigate both stormwater quantity and quality impacts. This includes avoiding the use of zinc and other heavy-metal materials.
- Stormwater treatment from source to outlet must be incorporated for any development with more than three (3) carparks to effectively treat stormwater runoff from hardstand (assume a water quality volume equivalent of the first 15 mm of any rainfall event).
- The development must promote stormwater infiltration by limiting lot imperviousness area to no more than 70% of the net lot area (or, a minimum pervious area of 30% is required).
- Hydraulic neutrality is to be provided in the form of 18 L for every additional 1 m^2 of new impervious area.
- The development will be subject to ongoing maintenance of the stormwater devices in order to obtain permitted activity status.

Appendix A. Climate change scenario flood comparison maps[9]

[9] .Tonkin and Taylor Ltd, 5 July 2024.

Layout: Drawn by ALWH



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NOTES:
Climate change factor has been applied as per RCP 4.5 Projected to 2130. Where Intensification has been applied, this is a blanket rate of 80% impervious

REV	DESCRIPTION	GIS	CHK	DATE
0	Draft			

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	AUG.24
DRAWN	ALWH	AUG.24
CHECKED		AUG.24
APPROVED		DATE

CLIENT **Palmerston North City Council**

PROJECT **Plan Change Modelling, 2024**

TITLE 50 Year Flood Depth (m) with RCP 4.5 Climate Change

SCALE (A3) 1:35,000 FIG No. FIGURE 9 REV 0

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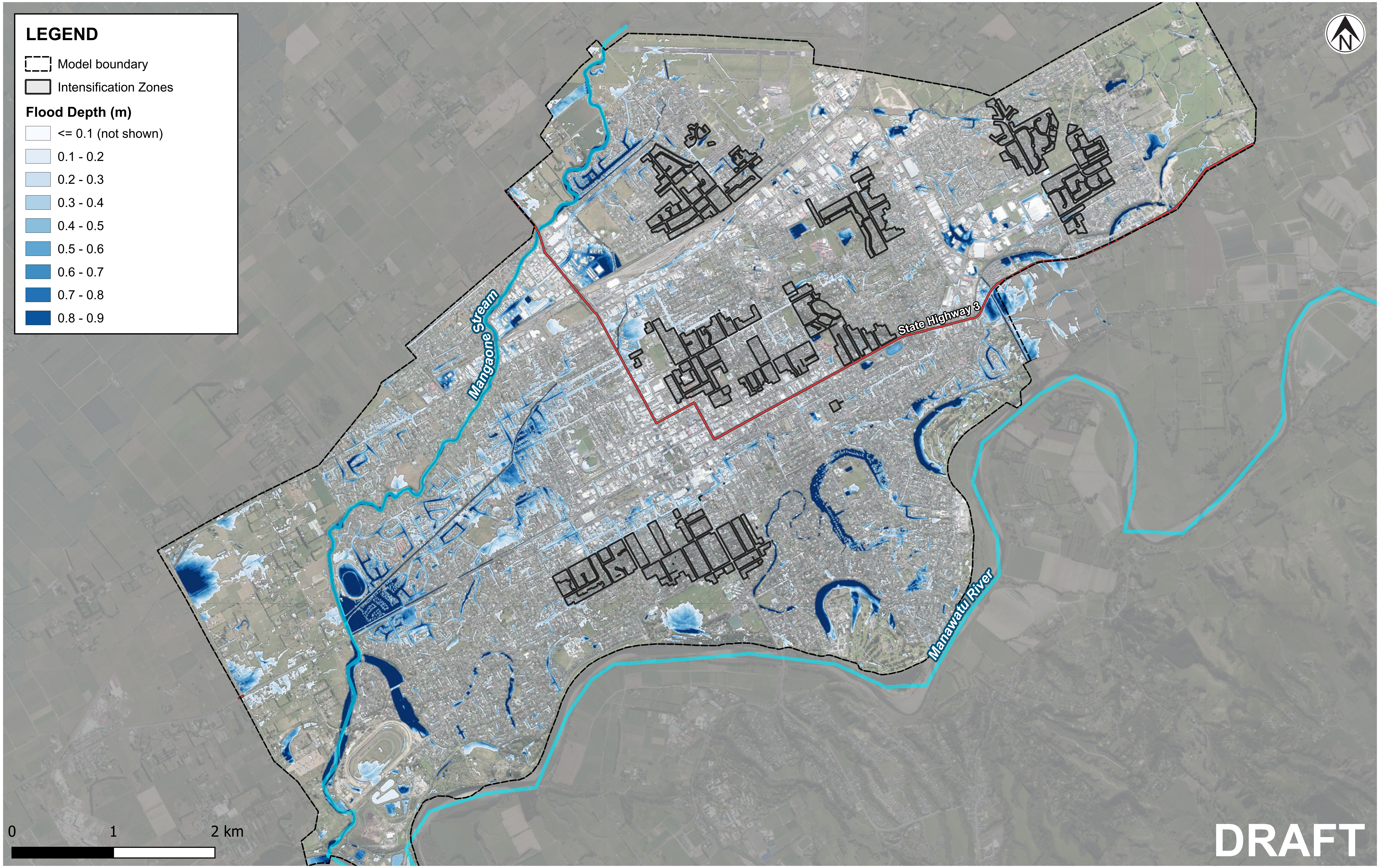

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REV	DESCRIPTION	GIS	CHK	DATE
0	Draft	ALWH	RIBR	05/07/24

LOCATION PLAN

PROJECT No. 851994.2300

DESIGNED	ALWH	JUL.24
DRAWN	ALWH	JUL.24
CHECKED	RIBR	JUL.24

APPROVED DATE

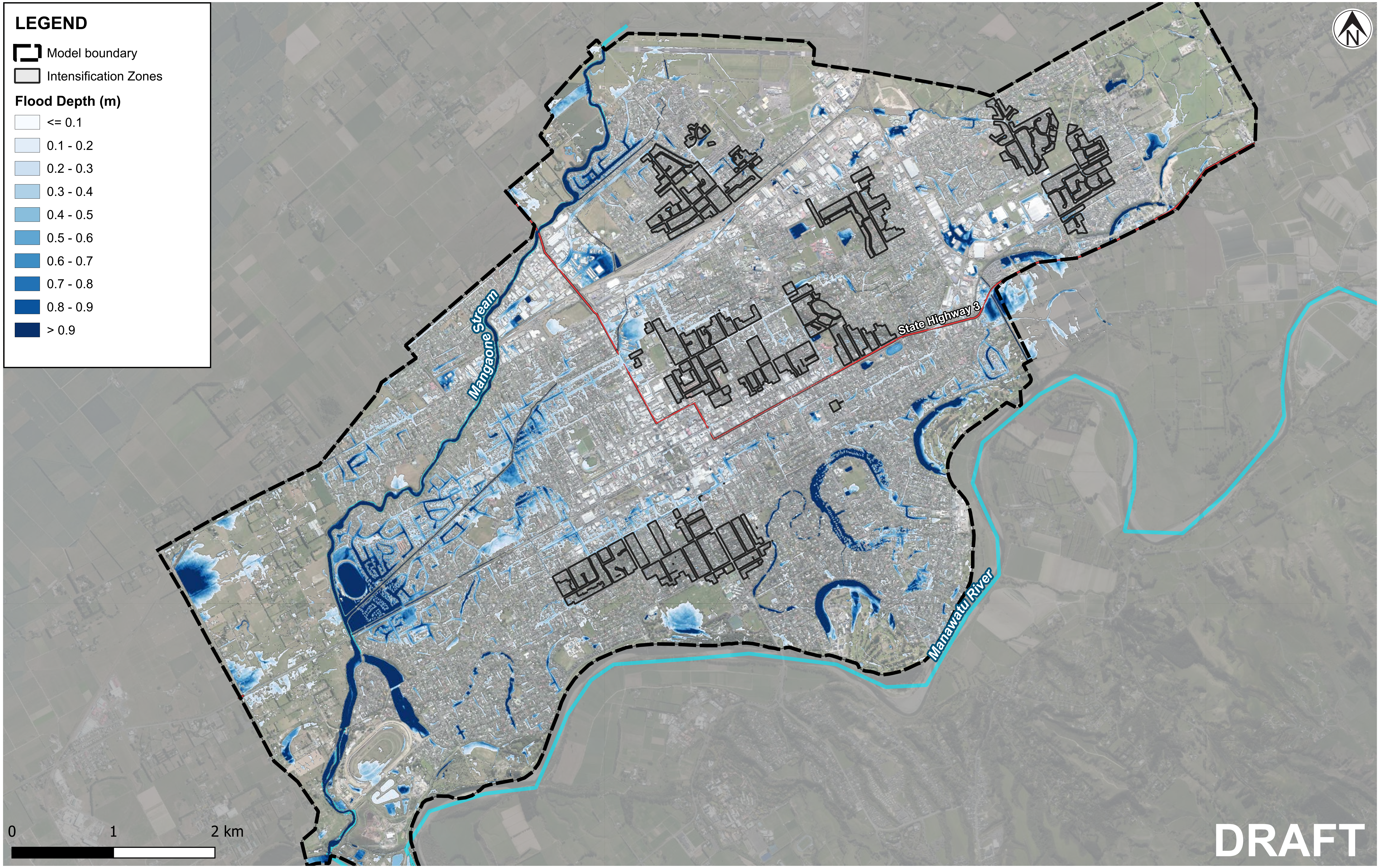
CLIENT Palmerston North City Council

PROJECT Plan Change Modelling, 2024

TITLE 50 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 3. REV 0

Layout: Drawn by ALWH



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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
0	Draft			

LOCATION PLAN

PROJECT No. 851994.2300

DESIGNED	ALWH	AUG.24
DRAWN	ALWH	AUG.24
CHECKED		AUG.24

APPROVED DATE

CLIENT Palmerston North City Council
PROJECT Plan Change Modelling, 2024
TITLE 50 Year Flood Depth (m) with RCP 8.5 Climate Change

SCALE (A3) 1:35,000 FIG No. FIGURE 10 REV 0

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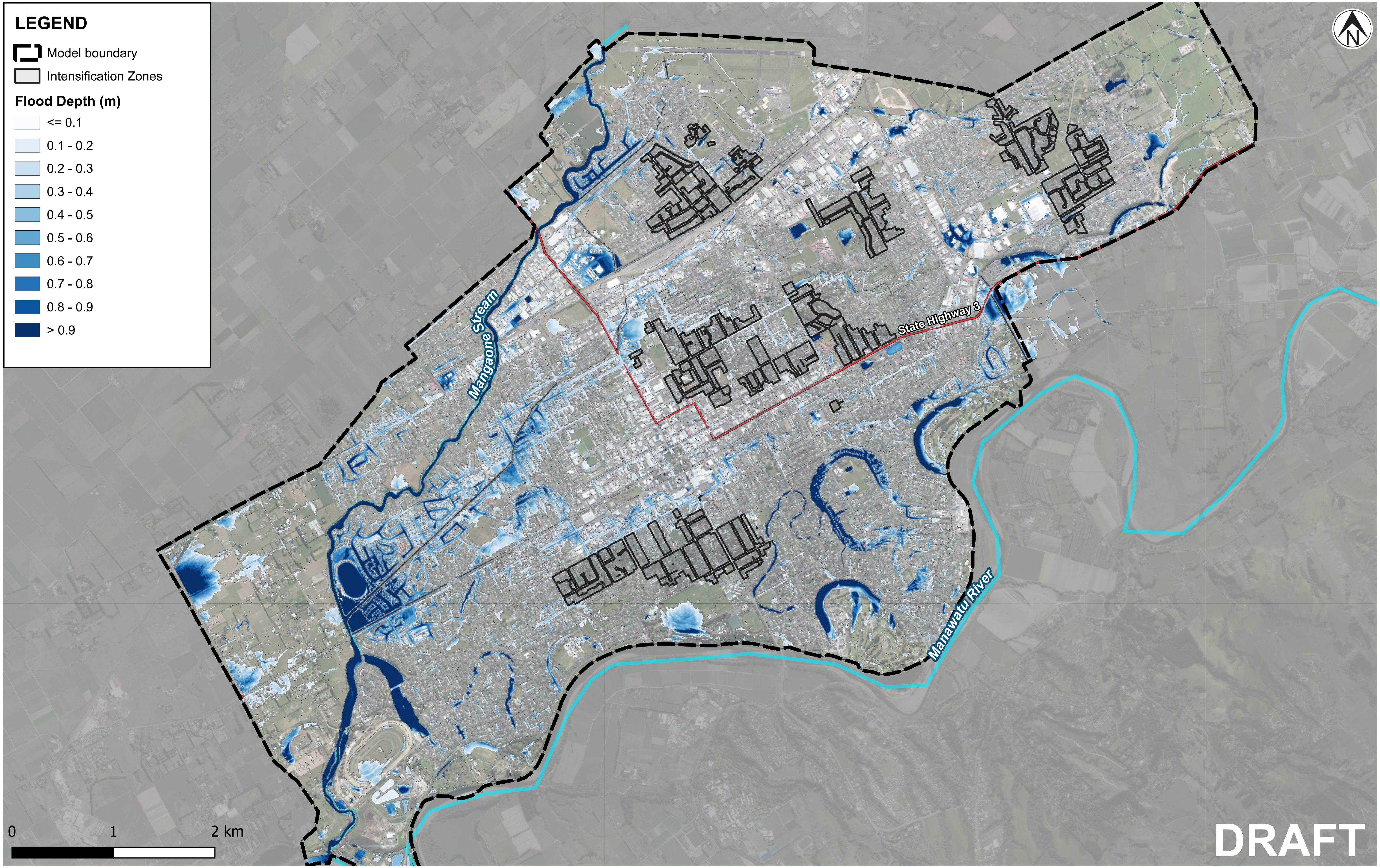

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
0	Draft			

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	AUG.24
DRAWN	ALWH	AUG.24
CHECKED		AUG.24
APPROVED		DATE

CLIENT **Palmerston North City Council**

PROJECT **Plan Change Modelling, 2024**

TITLE 100 Year Flood Depth (m) with RCP 4.5 Climate Change

SCALE (A3) 1:35,000 FIG No. FIGURE 11 REV 0

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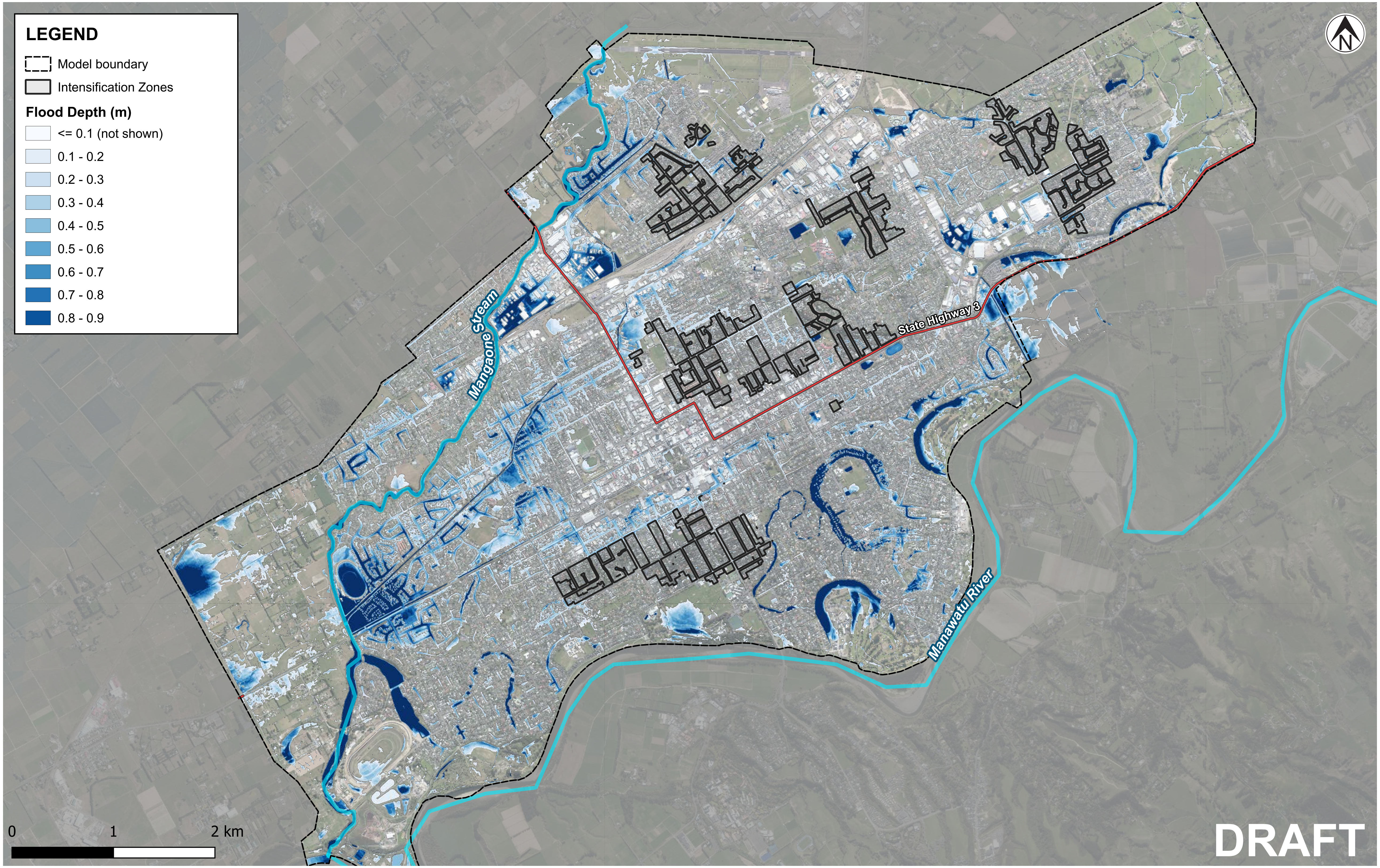
Layout: Drawn by ALWH



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NOTES:
Climate change factor has been applied as per RCP 6.0 Projected to 2130. Where Intensification has been applied, this is a blanket rate of 80% impervious

REV	DESCRIPTION	GIS	CHK	DATE
0	Draft	ALWH	RIBR	05/07/24

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	JUL.24
DRAWN	ALWH	JUL.24
CHECKED	RIBR	JUL.24
APPROVED		DATE

CLIENT Palmerston North City Council

PROJECT Plan Change Modelling, 2024

TITLE 100 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 4. REV 0

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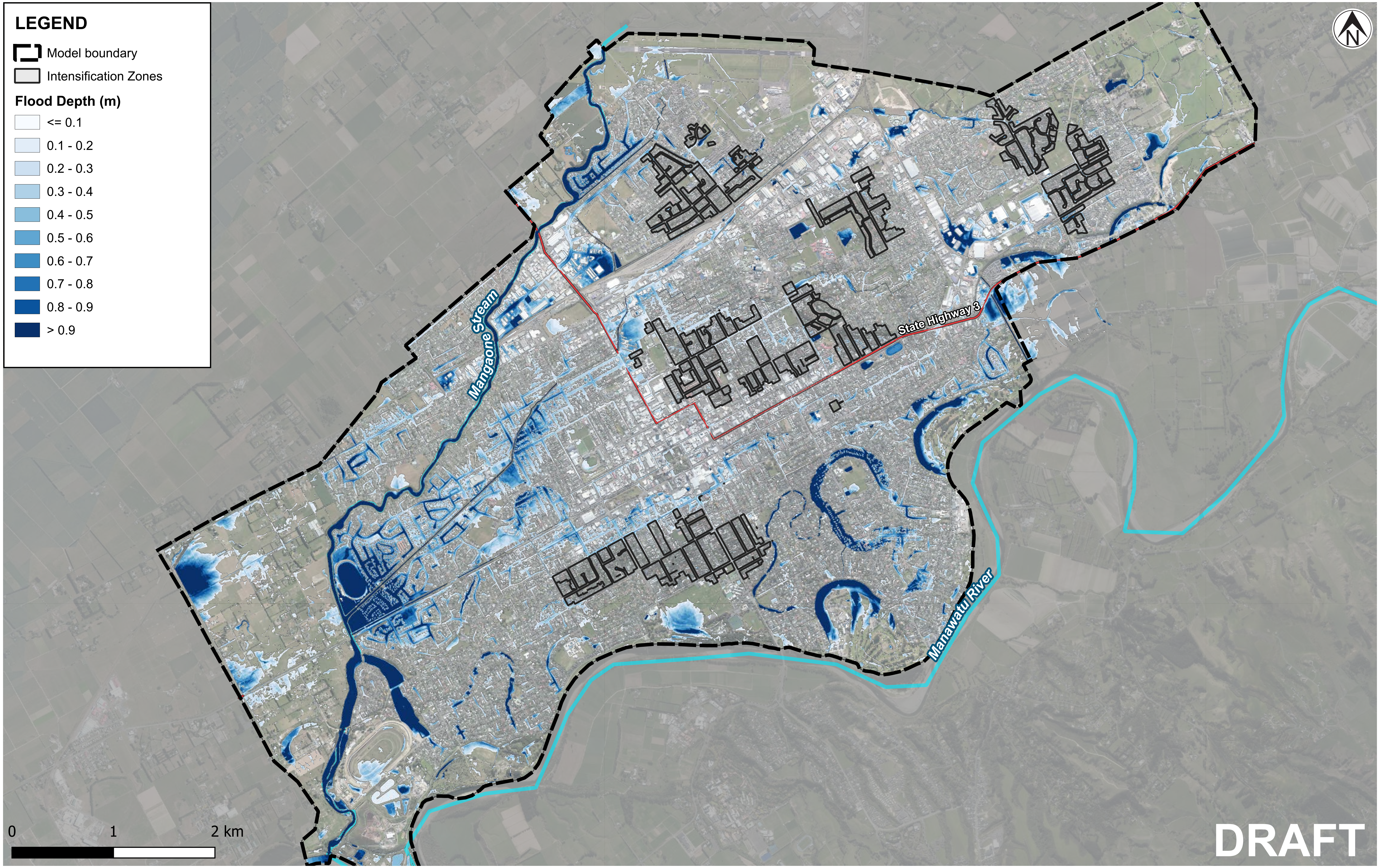

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NOTES:
Climate change factor has been applied as per RCP 4.5 Projected to 2130. Where Intensification has been applied, this is a blanket rate of 80% impervious

REV	DESCRIPTION	GIS	CHK	DATE
0	Draft			

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	AUG.24
DRAWN	ALWH	AUG.24
CHECKED		AUG.24
APPROVED		DATE

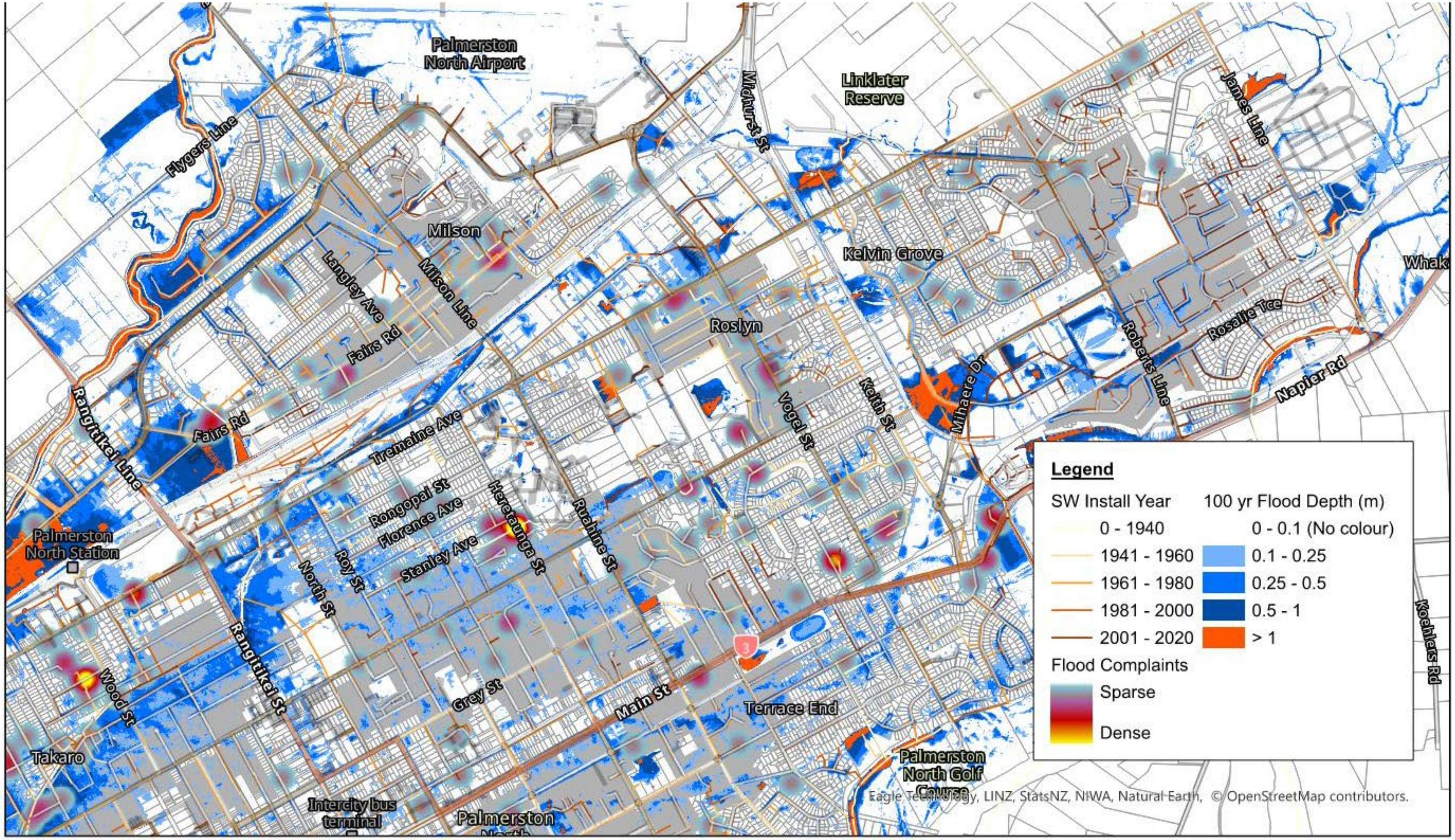
CLIENT Palmerston North City Council

PROJECT Plan Change Modelling, 2024

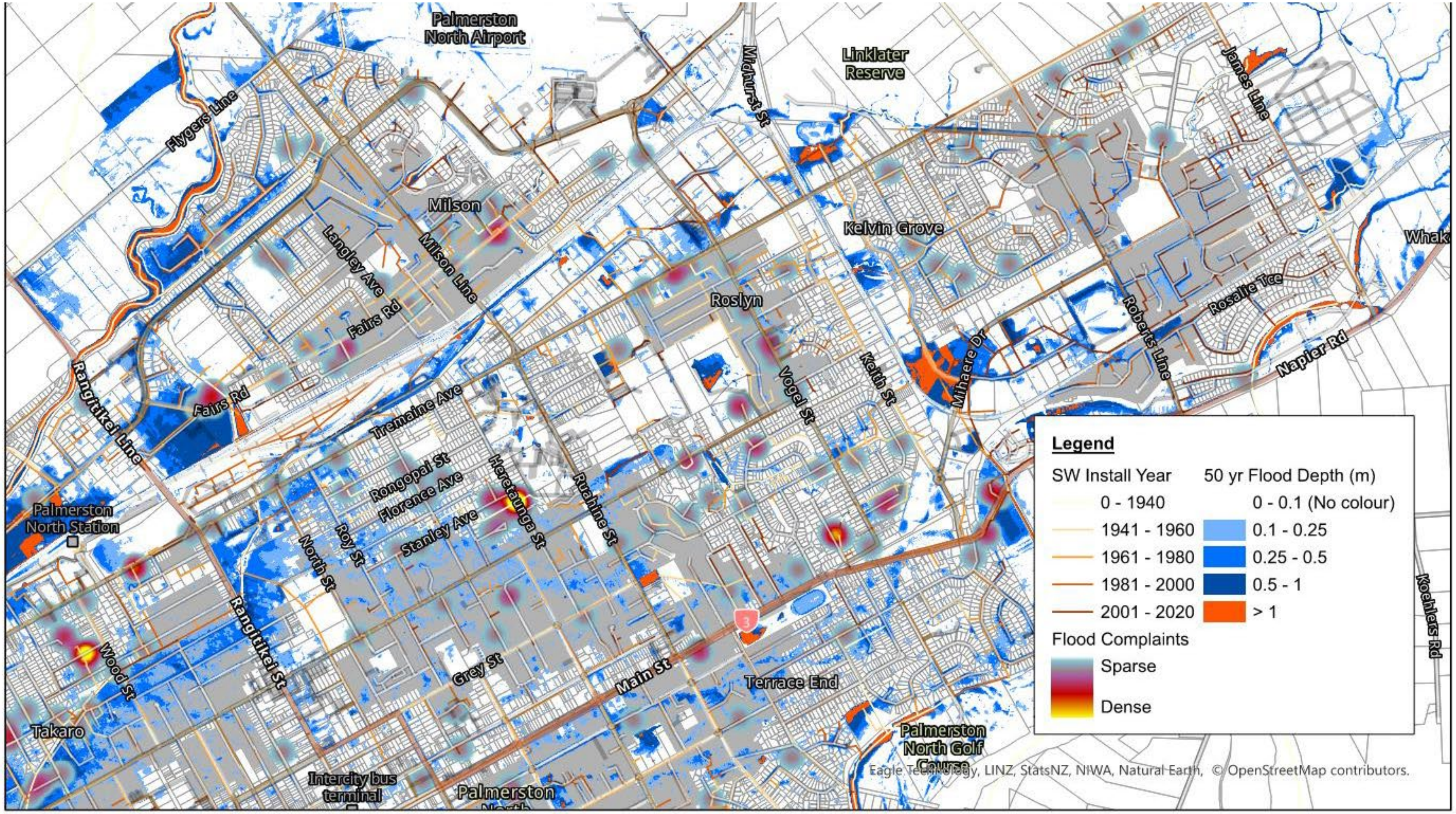
TITLE 100 Year Flood Depth (m) with RCP 8.5 Climate Change

SCALE (A3) 1:35,000 FIG No. FIGURE 12 REV 0

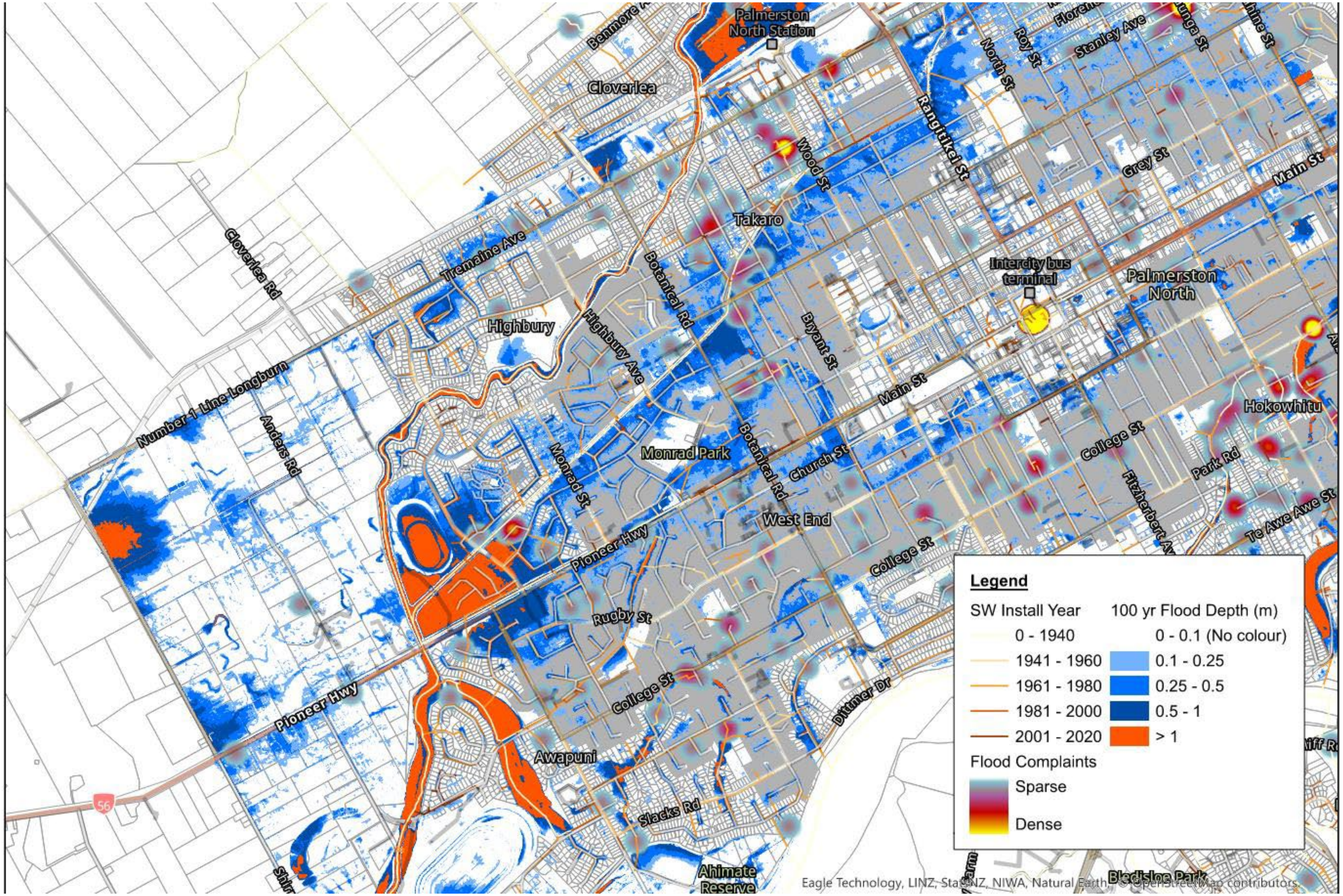
Appendix B. Comparison of predicted model flood depths and actual flooding complaints received



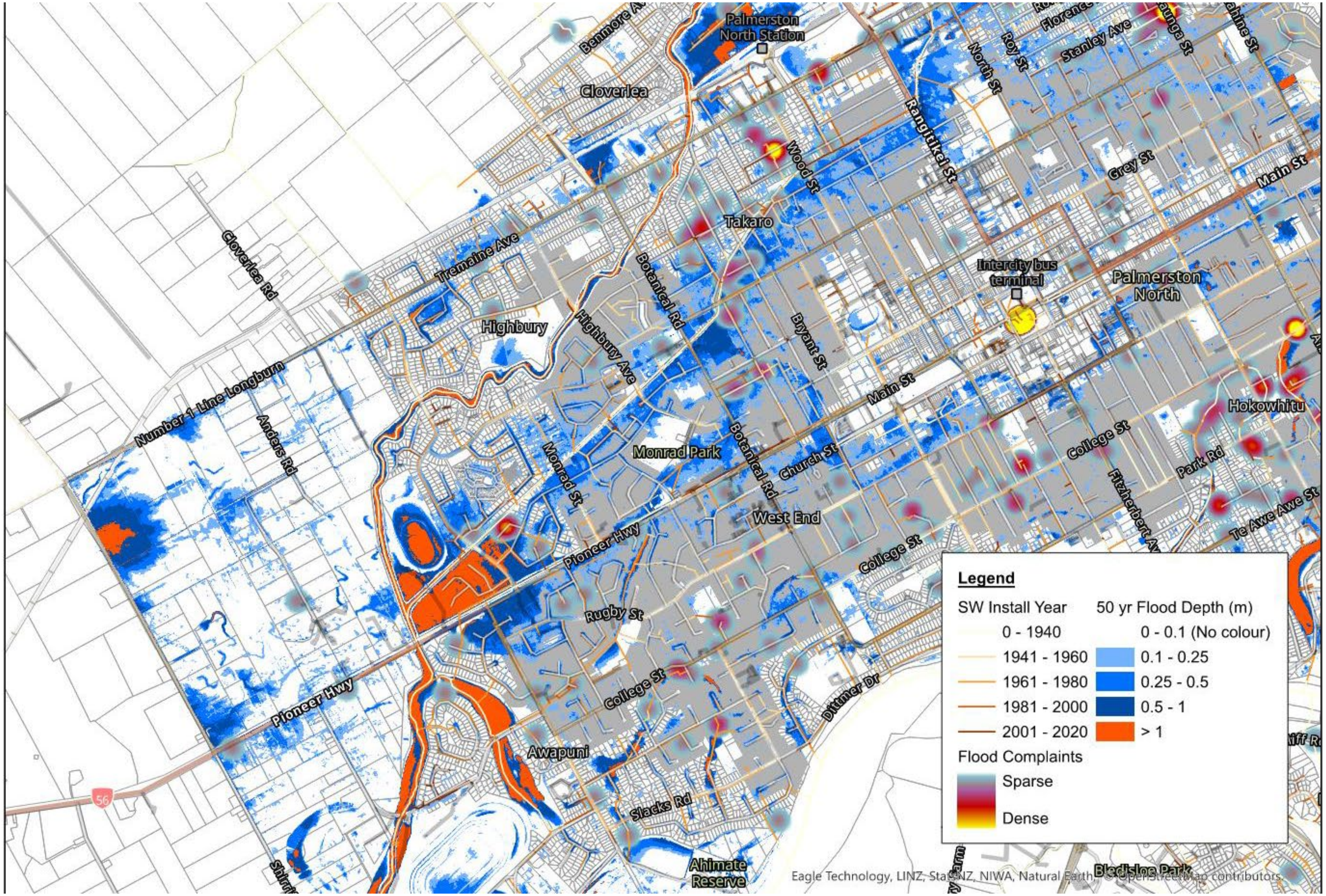
Area North – 1% AEP



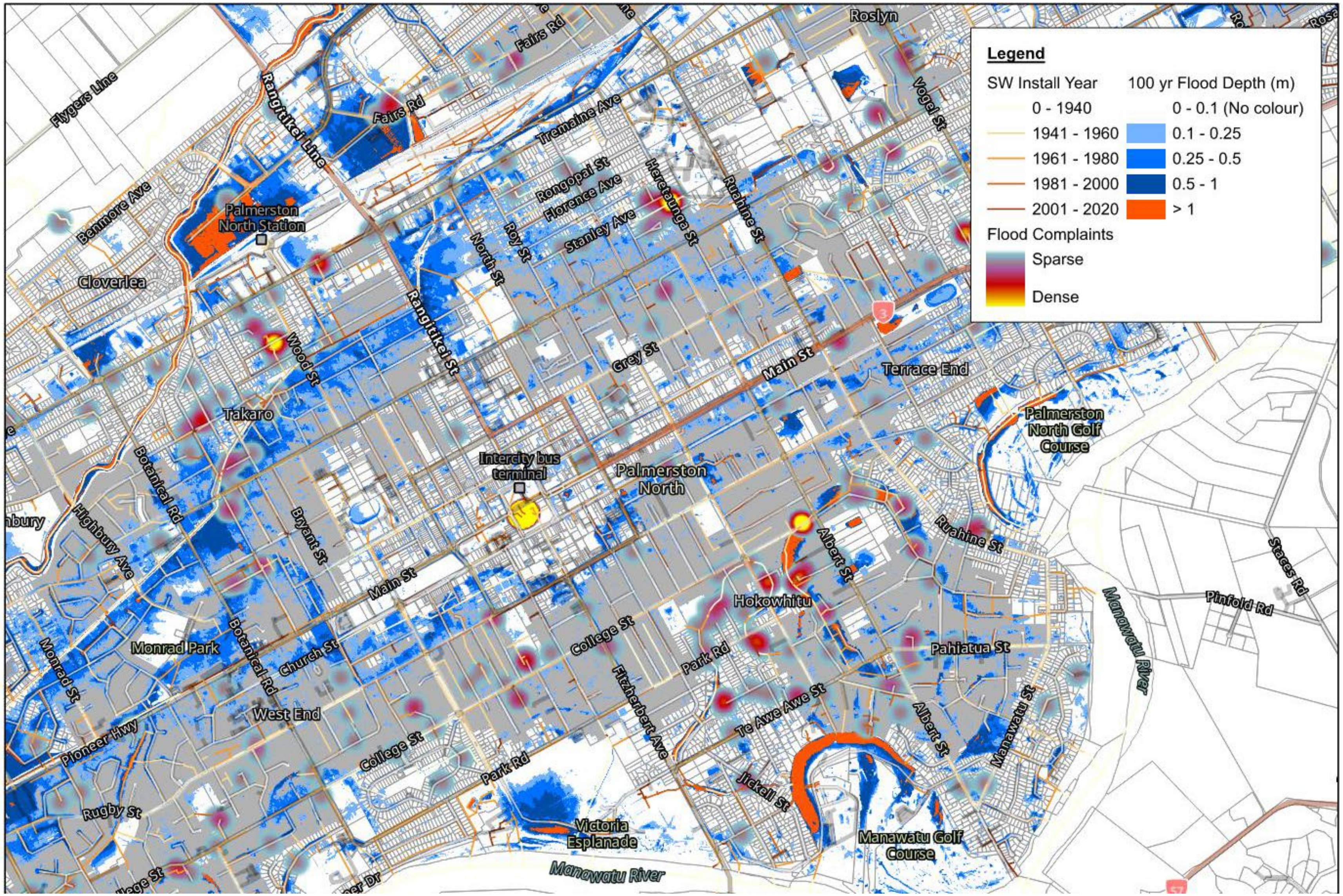
Area North – 2% AEP



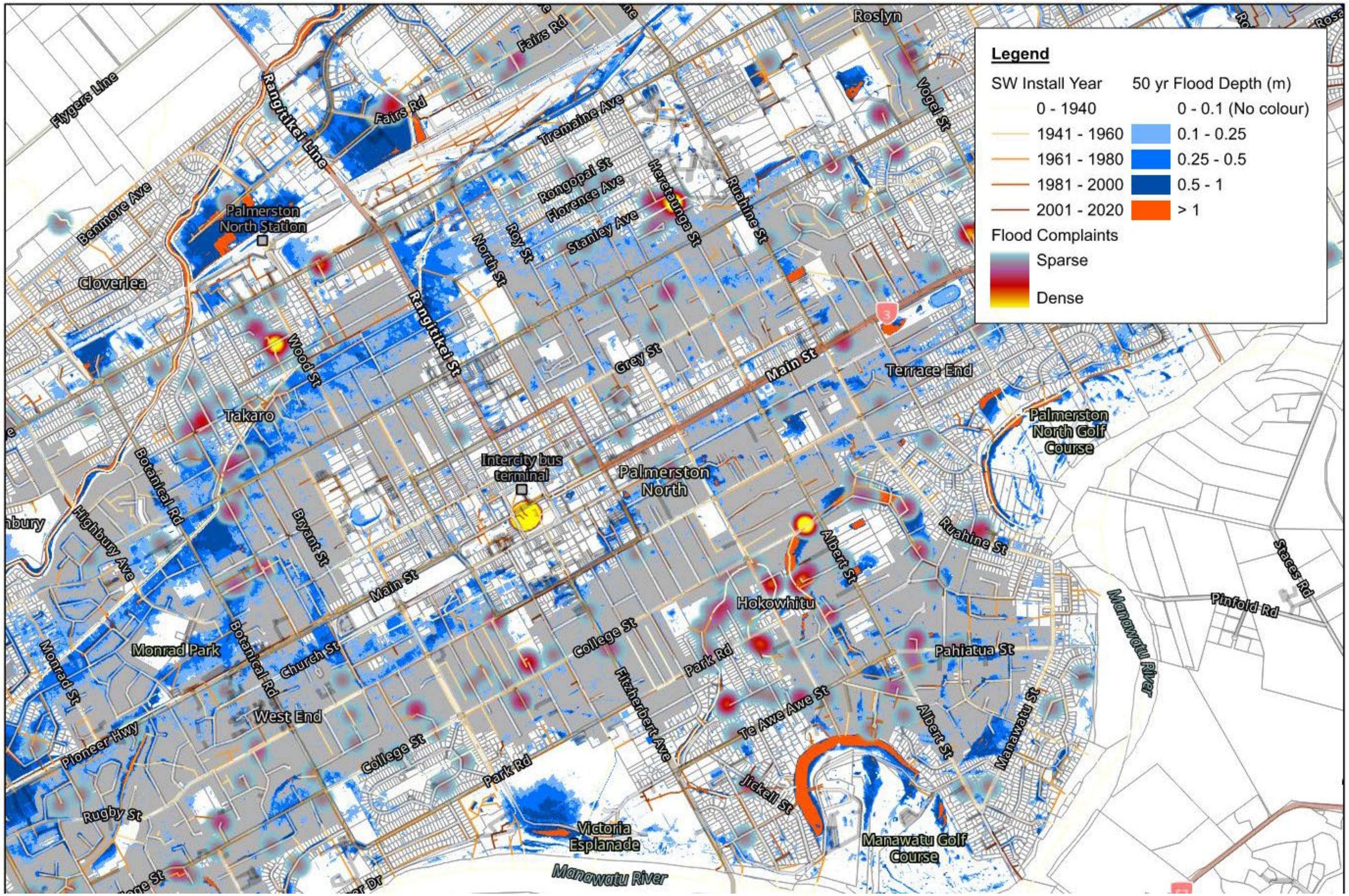
Area West – 1% AEP



Area West – 2% AEP



Area Central – 1% AEP



Area Central – 2% AEP

Appendix C. Citywide Plan Change Intensification – Model Build Report[10]

[10] Tonkin and Taylor Ltd, July 2024.

REPORT

Tonkin+Taylor

Citywide Plan Change Intensification

Model Build Report

Prepared for

Palmerston North City Council

Prepared by

Tonkin & Taylor Ltd

Date

October 2024

Job Number

851994.2300 v2

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Document control

Title: Citywide Plan Change Intensification – Model Build Report					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
22/07/2024	1	Draft	A. White	R. Brunton	S. Aiken
29/10/2024	2	Final	A. White	R. Brunton	S. Aiken

Distribution:

Palmerston North City Council 1 PDF copy

Tonkin & Taylor Ltd (FILE) 1 PDF copy

Table of contents

1 Introduction

Palmerston North City Council (PNCC) has engaged Tonkin & Taylor Ltd (T+T) to undertake a flood hazard assessment to inform the proposed District Plan change on flooding and flood-related constraints relevant to future intensification areas. T+T has undertaken modelling to assist PNCC in determining which parts of the areas proposed for intensification can be progressed with minimal effect on peak flood levels in surrounding areas to support the plan change. The assessment completed under this engagement is a relative assessment comparing changes in impervious surface coverage on peak flood levels and should not be used for setting District Plan rules (i.e. setting finished floor levels) or the assessment of pipe capacity to service these new intensification areas.

This flood assessment utilises the existing Palmerston North City-Wide TUFLOW flood model to assess the effects of the intensification on flood levels in surrounding areas. Several pipe network updates were made to the model to represent the surrounding flood hydraulics in a higher level of detail than the previous model.

This report describes the model updates and flood impact assessment results for the latest citywide plan change intensification modelling undertaken in July 2024. The previous model build report[1] issued to PNCC in 2018 summarises in more detail the full model build and assumptions for the citywide modelling previous to this. We recommend that this report is read in conjunction with the 2018 model build report.

Figure 1.1 shows the proposed intensification areas provided by PNCC.

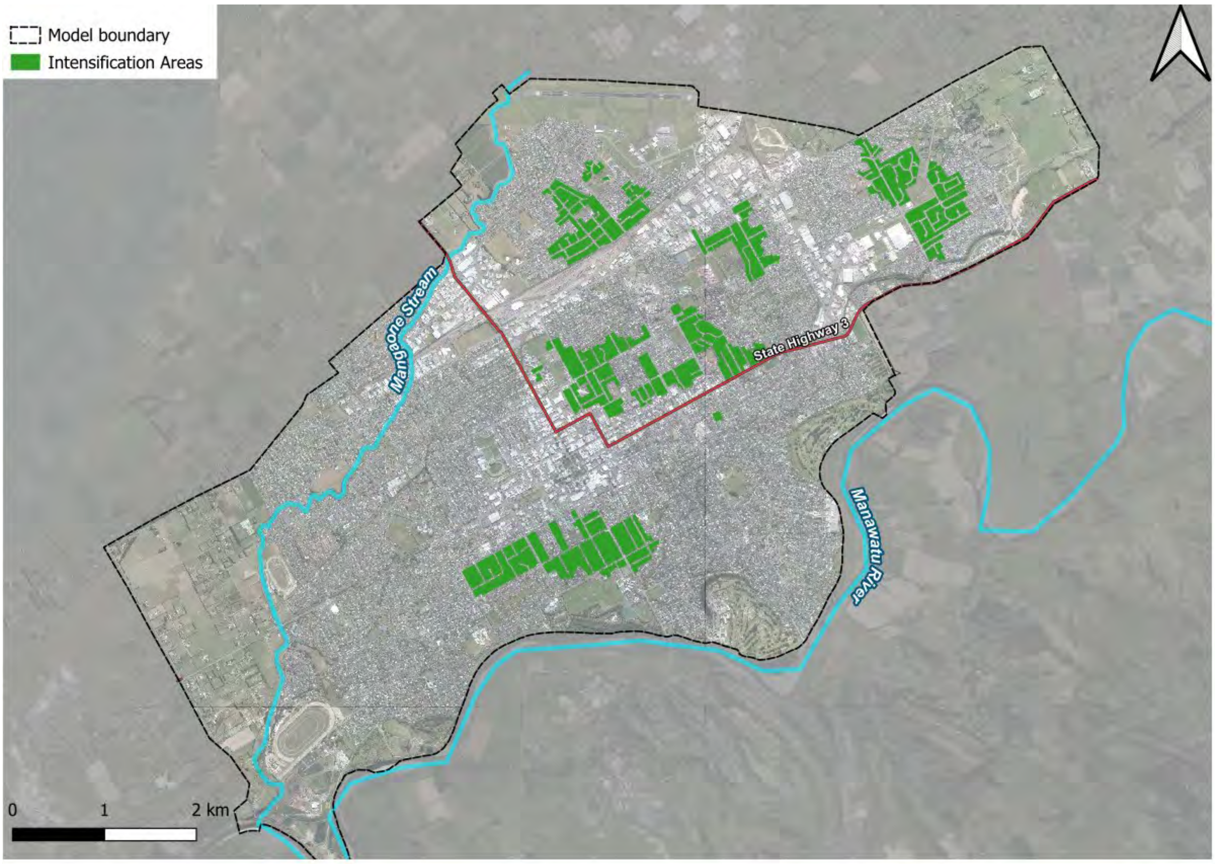

Figure 1.1: Intensification areas

[1] T+T (2017) TUFLOW model build report – final. Issued to PNCC as final June 2018. T+T internal reference 851994.

2 Existing flood model

In August 2023, T+T delivered the results of city-wide flood modelling to PNCC to inform initial plan change discussions. The model used for this assessment was developed at a city-wide scale, and T+T merged all model refinements that had been undertaken prior to August 2023 into a single model with varying levels of detail across the city.

Over time, parts of the citywide model extent have been refined where required to assess various development proposals or to address areas of uncertainty. Substantial model updates were carried out and reported in 2023 - 2024, and since then, the model has been extended in several locations. These refinements have all been developed in separate versions of the citywide model.

For the purposes of this assessment, we have merged all the refinements as part of separate modelling exercises into a single update of the citywide model, mainly involving the addition of stormwater pipes. Subsequent sections describe the model updates undertaken and their implications, and the model build is briefly summarised in Table 2.1.

Table 2.1: Model build summary

Model Element	Report Section	Description
Model Software	-	2023-03-AE TUFLOW HPC Solver
Time Step	-	The TUFLOW HPC model applies an adaptive time step, based on maintenance of a Courant condition.
Datums	-	Horizontal: New Zealand Transverse Mercator (NZTM) Vertical: New Zealand Vertical Datum 2016 (NZVD2016)
Model Extent	Section 2.1.1	The extent of the model was set based on the extents of the urban areas of Palmerston North but excludes the Manawatu River
Model Topography	Section 2.1.2	
Model Cell Size	-	A cell size of 4 m by 4 m (8 m2) was utilised in the Palmerston North City model.
Hydrology	-	Rainfall in the Palmerston North model is simulated using a 'rain on grid' methodology. Rainfall depths were generated using NIWA's High Intensity Rainfall Design System (HIRDS) V4 for a range of event durations and exceedance probabilities. This data was used to create a 24-hour nested rainfall event.
Model boundaries	-	An inflow hydrograph for the Mangaone Stream was applied at the model boundary, as per previous modelling. There have been no updates to this inflow hydrograph since 2017, and they account for a climate change allowance of RCP 6.0 projected to 2130 as per the rain on grid hydrology.
Land use and soil infiltration	-	Surface roughness values adopted in the model were based on land use as categorised in Landcare Research's Land Cover Database version 4.1 (LCDB4).
Hydraulic structures	Section 2.1.3	No hydraulic element information was able to be sourced from the local council, except for survey information for the Redmayne drop structure, which was not included in the model. There are still several pump stations included in the model, however it is important to note these have not been updated since 2018.

2.1 Updated flood model setup

2.1.1 Model extent

The model extent, as shown in Figure 2.1, has remained largely unchanged as part of the model update. The extent of the model was set based on the extents of the urban areas of Palmerston North but excludes Manawatū River. The Manawatū River was excluded, as it has been in all previous modelling, due to the lack of connectivity and to keep the number of wet cells in the model to a minimum, therefore reducing model run times.

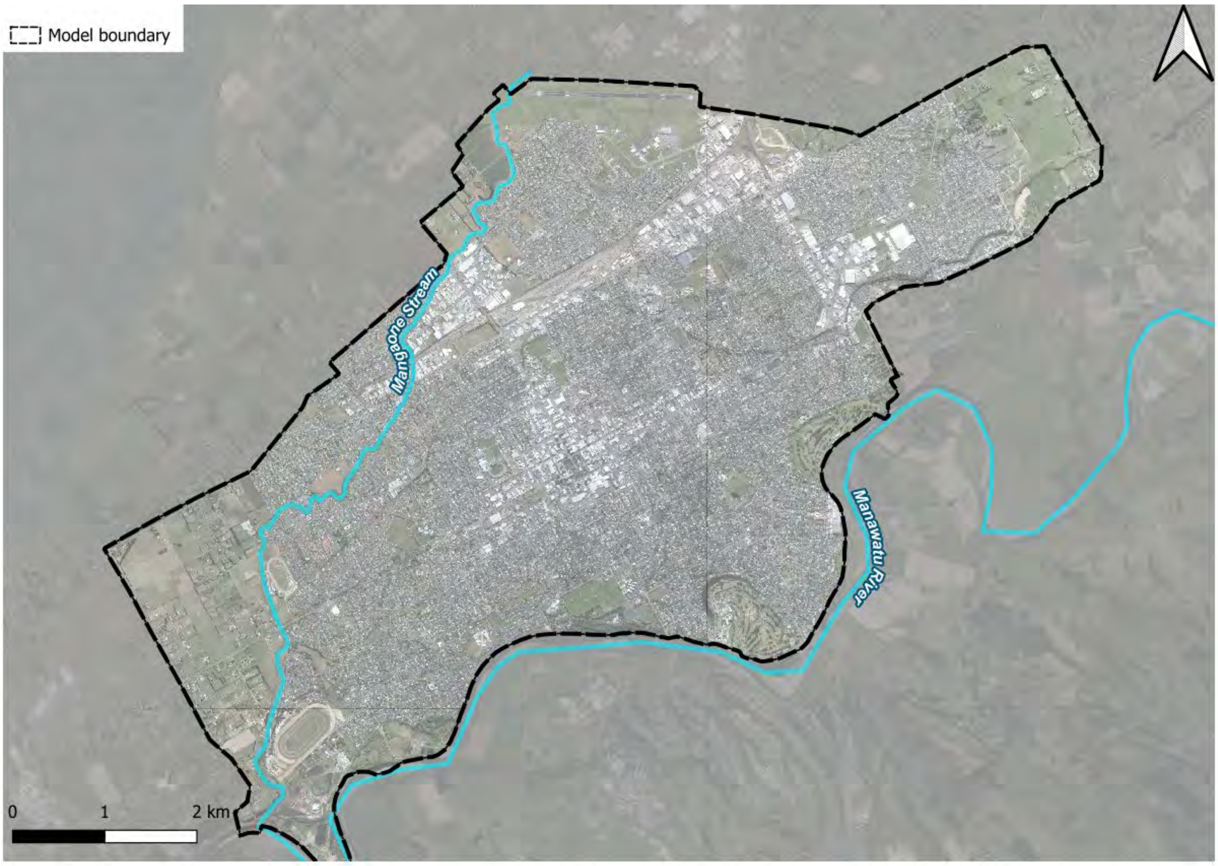

Figure 2.1: Model extent

2.1.2 Digital elevation model (DEM)

The model terrain has been derived from the Palmerston North 2018 LiDAR based DEM, which is unchanged from previous modelling as this is still the most recent dataset available. A previous limitation of the modelling was that the DEM represents a bare earth terrain, with all buildings and above-ground features detected having been removed. The most recent update includes the addition of building platforms as raised elements in the DEM at request of PNCC. The methodology applied to incorporate buildings is described in Section. 2.1.2.1 and the buildings modelled are shown in Figure 2.2.

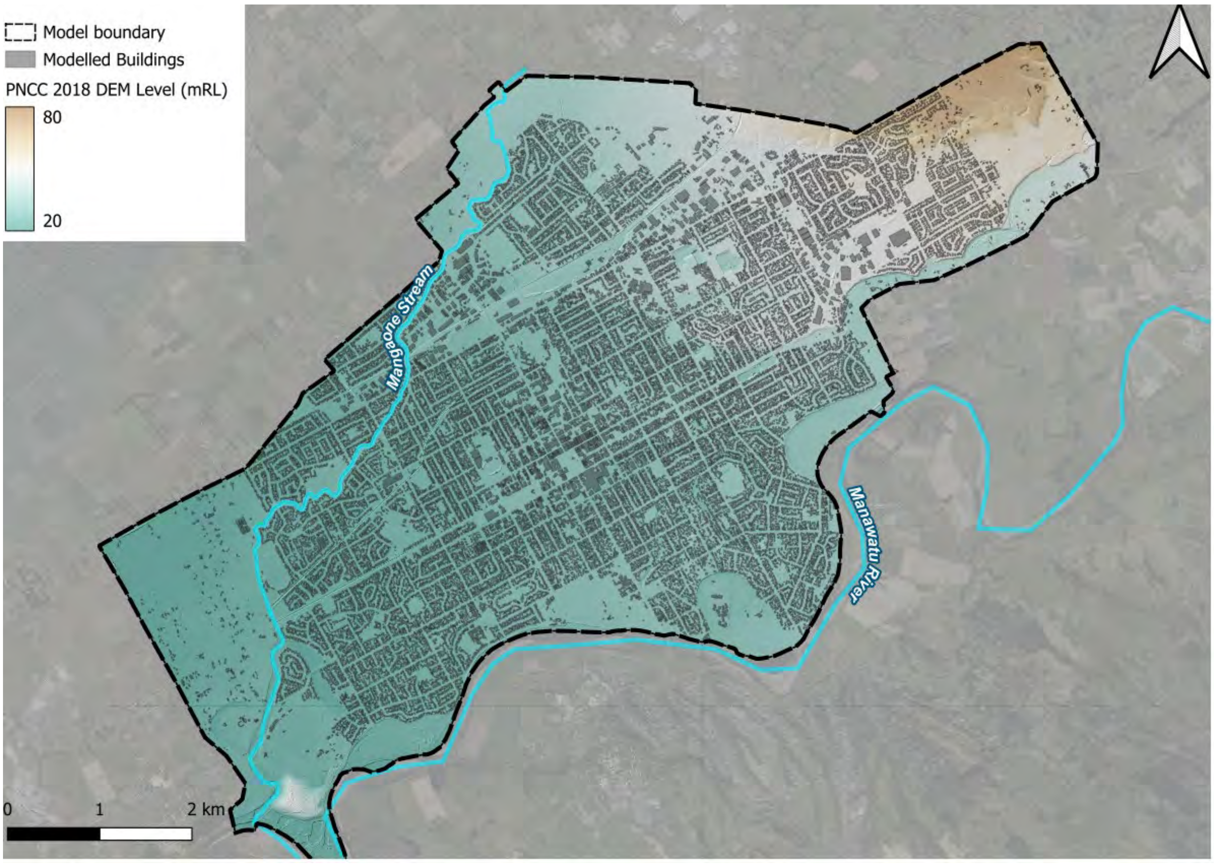

Figure 2.2: Model terrain with buildings

2.1.2.1 Buildings

There are several methods to represent buildings in flood modelling. An investigation by Australian Rainfall and Runoff[2] into different methods showed that removing computational grid points under the building footprint, or raising the grid points in the topography under the building footprint above the highest anticipated flood level gave the best match with flow behaviour observed in a physical model.

Building footprints were sourced from Land Information New Zealand (LINZ) which represents building footprints as of June 2024. The roof level (and thus the elevation) of each building footprint was defined as the maximum elevation value within the building footprint, plus 3 m. The centroid of the building was then raised an additional 1 m to avoid ponding on large roofs. A schematic is shown in Figure 2.3.

It is important to note where new buildings have been constructed between the period that the LiDAR was flown and when the building polygons were sourced (between 2018 and 2024) – the building footprints are included (i.e. with new developments) but the terrain surrounding these new buildings may not be properly represented.

[2] Australian Rainfall and Runoff (2012) – Revision Project 15: Two dimensional simulations in urban areas – representation of buildings in 2D numerical flood models.

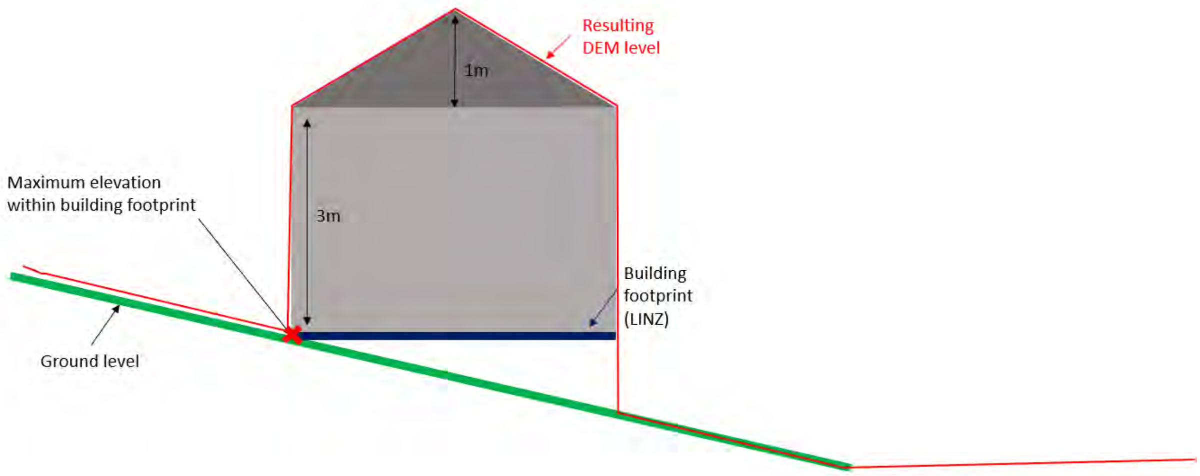

Figure 2.3: Modelling approach for buildings

2.1.3 Stormwater infrastructure

2.1.3.1 Stormwater pipe network

T+T have completed several previous modelling exercises to date using the model where some pipes, culverts, manholes and catchpits were represented in the model as 1-dimensional elements or "1d pipes" (instead of as 2D simulated pipes).

The inclusion of "1d pipes" represents a higher level of detail than the "2D pipes", therefore the areas in which these pipes are included instead of the "2d pipes" are considered to have a higher level of detail. An upgrade of the entire model to the "1d pipe" approach was not undertaken as the purpose of this assessment was for assessing relative effects. However, the "1d pipes" previously included in the model were included to ensure that reported flood depths are consistent across all previous reported flood depths provided to PNCC.

The locations of the "1d pipes" and "2d pipes" included in the updated model are shown in Figure 2.4.

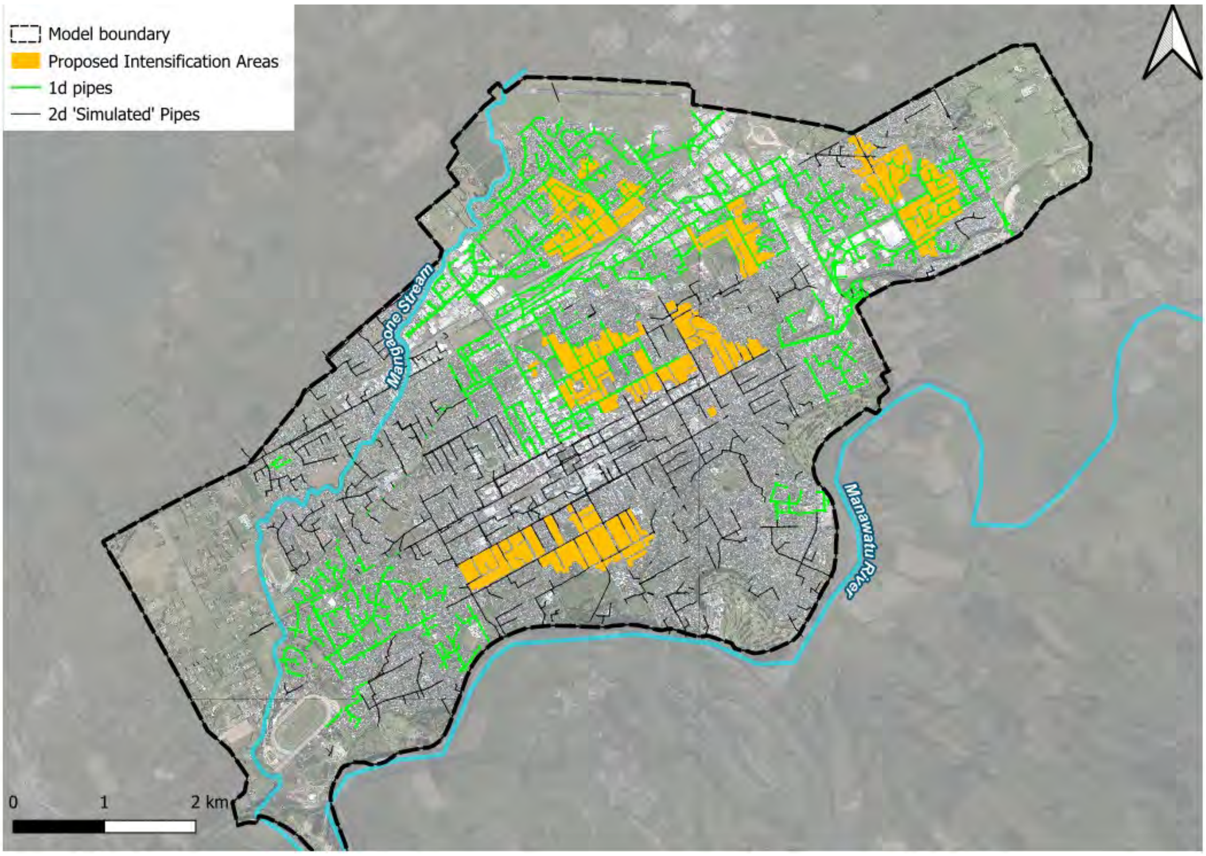

Figure 2.4: 1d and 2d pipe extents

The pipe and culvert information were supplied by PNCC for this modelling and was projected to NZVD2016, consistent with the LiDAR-based DEM. Prior to applying council data to the model, it was noted that a large portion of network data was missing invert level information, and as such, it was agreed with PNCC that an interpolation exercise would be undertaken to estimate invert levels where information was missing. This was done using a T+T in-house python script that interpolates values for unknown inverts based on the following general sequence of assumptions:

1 If a node invert level is known, use it.
2 If a node invert of a connecting pipe is known, use it.
3 If the node is a catchpit/sump, set invert level as the LiDAR DEM (ground level) minus the pipe diameter with the addition of 0.1 m (i.e. assumed 100 mm pipe cover).
4 If the node is a pipe inlet or outlet, use LiDAR DEM (ground level).
5 Following the above process, assign the remaining unknown inverts by 'searching' the upstream and downstream network for known inverts and linearly interpolating a value.

Most of the intensification areas largely sit within the refined '1d pipe' extent, with the exception of the intensification area to the south. As such, floodplain hydraulics may not be properly represented with this hybrid approach, especially in smaller events where there is more reliance on the stormwater network for flood conveyance.

3 Intensification assumptions

For the areas shown in Figure 3.1 below, an 80% impervious factor was applied (in most cases increasing from 60%) to represent the proposed intensification areas. This equates to approximately 53 ha in new impervious area over 267 ha.

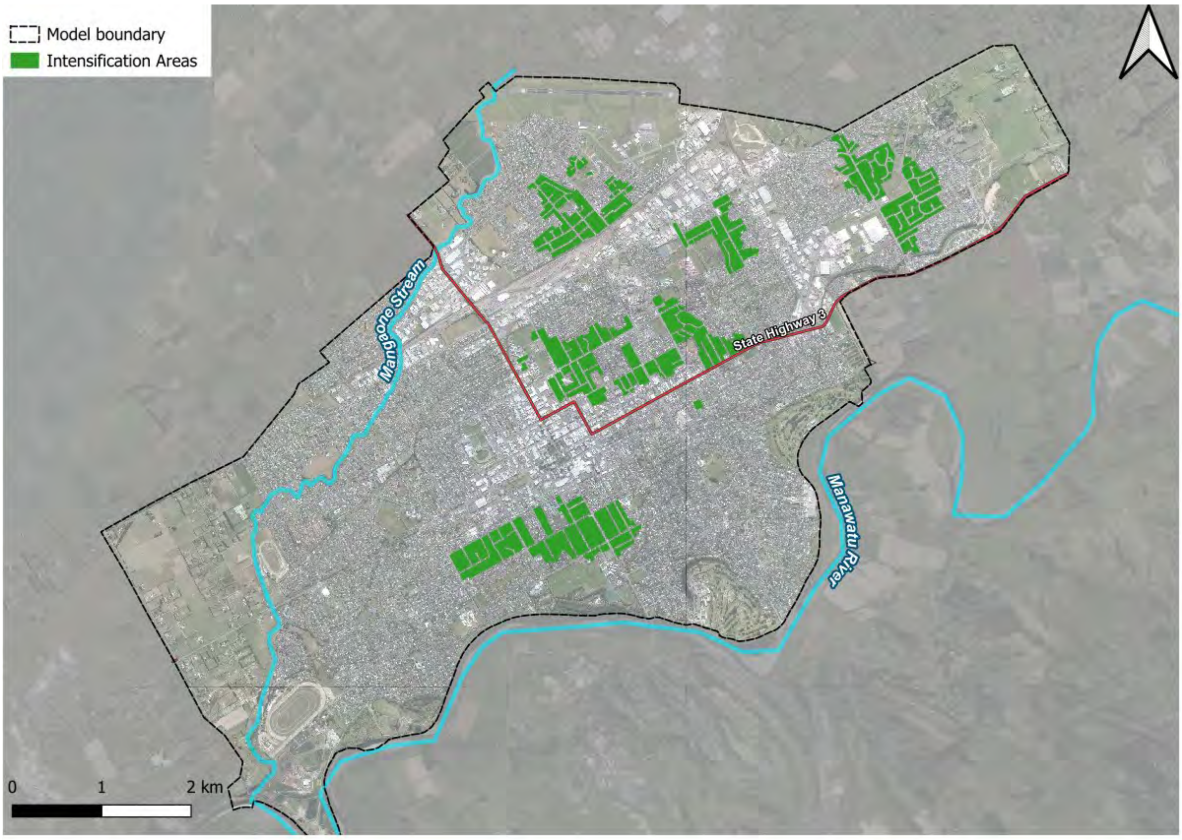

Figure 3.1:Modelled proposed intensification areas

4 Climate change

The climate change scenario that has been modelled is the representative concentration pathway (RCP) 6.0 to the year 2130 climate change projection from HIRDS, as directed by PNCC via email correspondence with Veni Demado dated 29 May 2024.

5 Model limitations

Some limitations of the intensification modelling are as follows. Note this does not encompass the limitations of the hydraulic modelling, that is detailed fully in the full model build reporting:

- All areas within the proposed intensification areas are assumed to be developed simultaneously (i.e. the full area is re-built as one project). In reality, individual parcels will be developed separately over time until the full area is re-developed. Where this intensification is occurring in areas that are currently providing flood plain storage, this will create individual effects from each parcel on the surrounding properties. These individual effects have not been assessed as part of this modelling exercise. This has implications for properties within the intensification extent and addressing this scenario will be a key factor in enabling intensification within these areas.

- The capacity of stormwater pipe network has not been assessed as part of this work. When intensification occurs, PNCC will need to determine if the pipe network has capacity for the increased runoff. No allowance has been made for new piped connections from the intensification areas.
- Intensification areas have been modelled as an increase in impervious area. No allowance for infilling has been assessed as a result of raising existing parcels above the floodplain (i.e. no loss of floodplain storage). In reality, the final layouts of intensified areas will be different to what has been modelled and thus the actual effects may be different. Therefore, the flood effects presented as a result of this work should be treated broadly.

6 Flood model results

Maps showing the predicted maximum flood extent and depth under existing conditions from the updated model are presented in Appendix A. Flood depth and level results for the model scenarios are shown in Table 6.1.

Flood depths less than 0.1 m have been removed from the maps as this is the threshold depth above which flooding has been considered with confidence as "real" and not potentially an artefact of inaccuracies in the DEM.

Table 6.1: Model run matrix

	Scenario average recurrence interval (ARI) RCP6.0 2130[1]			
Model Scenario	**2 Year**	**10 year**	**50 year**	**100 Year**
Existing development	✓	✓	✓	✓
With intensification[2]	✓	✓	✓	✓

1 All hydrology scenarios have been modelled as a 24 hour fully nested hyetograph

2 The intensification scenario contains all stormwater infrastructure as existing and not any future planned stormwater upgrades

Maps showing the predicted flood level difference are presented in Appendix A. Flood level difference is the maximum flood level with proposed intensification minus the maximum flood level without proposed intensification.

7 Discussion

The combined flood level difference as a result of the proposed intensification, for all ARI events modelled, is shown in Figure 7.1. This shows all the flood level differences from Appendix A, for all events modelled on a single map.

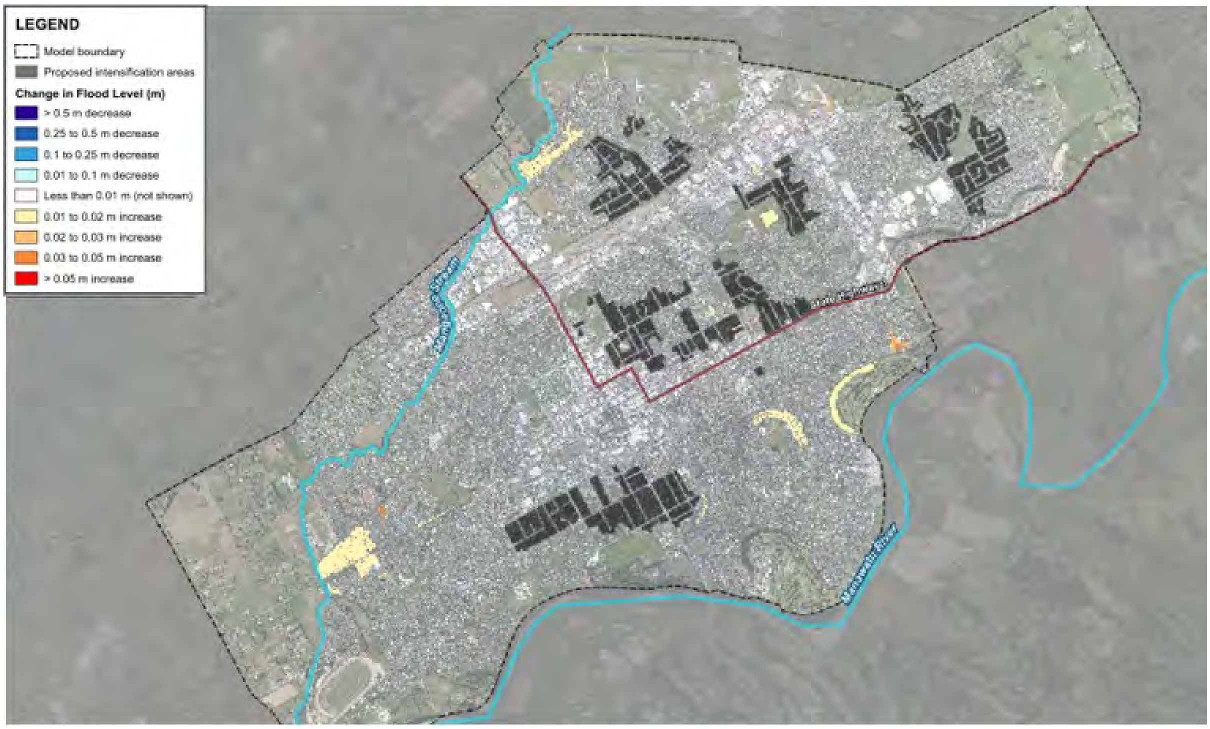

Figure 7.1: Combined flood level difference

As a result of intensification and the associated increase in impervious area from 60% to 80% in the areas defined in Figure 3.1 the model results show isolated increases in peak flood levels in the order of 10 - 20 mm in a for the 10, 50 and 100 year ARI events. In the 2-year ARI event, flood level effects are in the order of 10 – 50 mm are observed. In the scenarios assessed there are no new areas that flood as a result of the intensification, i.e. there is no observable increase in flood extent.

The areas that are impacted by increases in flood levels are generally concentrated in in areas that already experience inundation above 1 m in events greater than the 10 year ARI.

Some of these increases in flood level are within residential areas, including the following:

- Increases of 10 mm peak flood in a 10 year ARI event level north of Pioneer Highway, directly east of the Mangaone Stream. The increases in flood level are in areas with existing flood depths of 0.9 – 1.4 m.
- Increases of 10 mm peak flood level in a 10 year ARI event around Apollo Parade. This area experiences flood depths of 0.5 – 1 m in the existing 10 year ARI event.
- Increase of 10 mm peak flood level in a 10 year ARI event around Churchill Avenue. This area experiences flood depths of 0.8 – 1.5 m in the existing 10 year ARI event.
- In the 2 year ARI event, there are some localised flood level increases of 30 mm around Ruamahanga Crescent and the intersection of Pencarrow Street and Monrad Street. These increases are largely contained within the road corridors but do extend onto some private property.

For recreational areas which see a flood level increase:

- Increase of 10 - 20 mm peak flood level in a 2 and 10 year ARI event around Palmerston North Golf Club. This flood level increase is around the perimeter of the golf club which already experiences flooding of 1 - 1.5 m in the 2 year ARI event and 2 - 2.5 m in the 10 year ARI event.
- Increase of 10 – 20 mm peak flood level in all events modelled (2, 10, 50 and 100 year ARI event) in Edwards Pit Park. This park already experiences flood depths of >1.5 m in all events

For all areas, the increase in peak flood level is minor compared to the existing flood depths, and there is no increase in flood extent. Increases in peak flood levels are mainly concentrated in the lower parts of the sub-catchments within Palmerston North, and are mainly due to an increase in runoff volume that accumulates at the outlet points to the Mangaone Stream or towards the Manawatū River. We note that we have not assessed changes in peak flood levels against building outlines.

Due to the hybrid 1d/2d pipe approach, and the uncertainties of how intensification may occur over time catchment hydraulics have not been assessed during the intervening development period, which is especially important for the smaller events (i.e. 2 and 10 year) a greater proportion of stormwater conveyance is through the stormwater network. This assessment is intended to be a relative check based on the latest available information, and the conclusions should be treated as broad.

This assessment does not specifically consider whether the flood depths within the proposed intensification areas are acceptable or require any mitigation measures or infilling to raise floor levels above the floodplain, in order to be developed.

8 Recommendations

We have displayed the intensification effects ‘as is’ and have not done further investigation into determining the causes of these effects. If these effects are deemed to be unacceptable, we recommend that the model be specifically assessed in these areas to determine whether model refinements need to be carried out in order to determine the cause of these increases, and whether any mitigation needs to be applied to offset these effects.

As the majority of the flood effects are in the smaller events (2 and 10 year) and floodplain hydraulics may not be properly represented with the hybrid 1d-2d pipe approach, we recommend that if the flood effects presented in this report are deemed to be unacceptable, further site specific investigation into the appropriateness of assumptions made on this wider scale, model refinement if necessary and investigations into mitigation options should be undertaken.

9 Applicability

This report has been prepared for the exclusive use of our client Palmerston North City Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Alex White Water Resources Engineer	Simon Aiken Project Director

Technical review by Richard Brunton – Water Resource Engineer

ALWH
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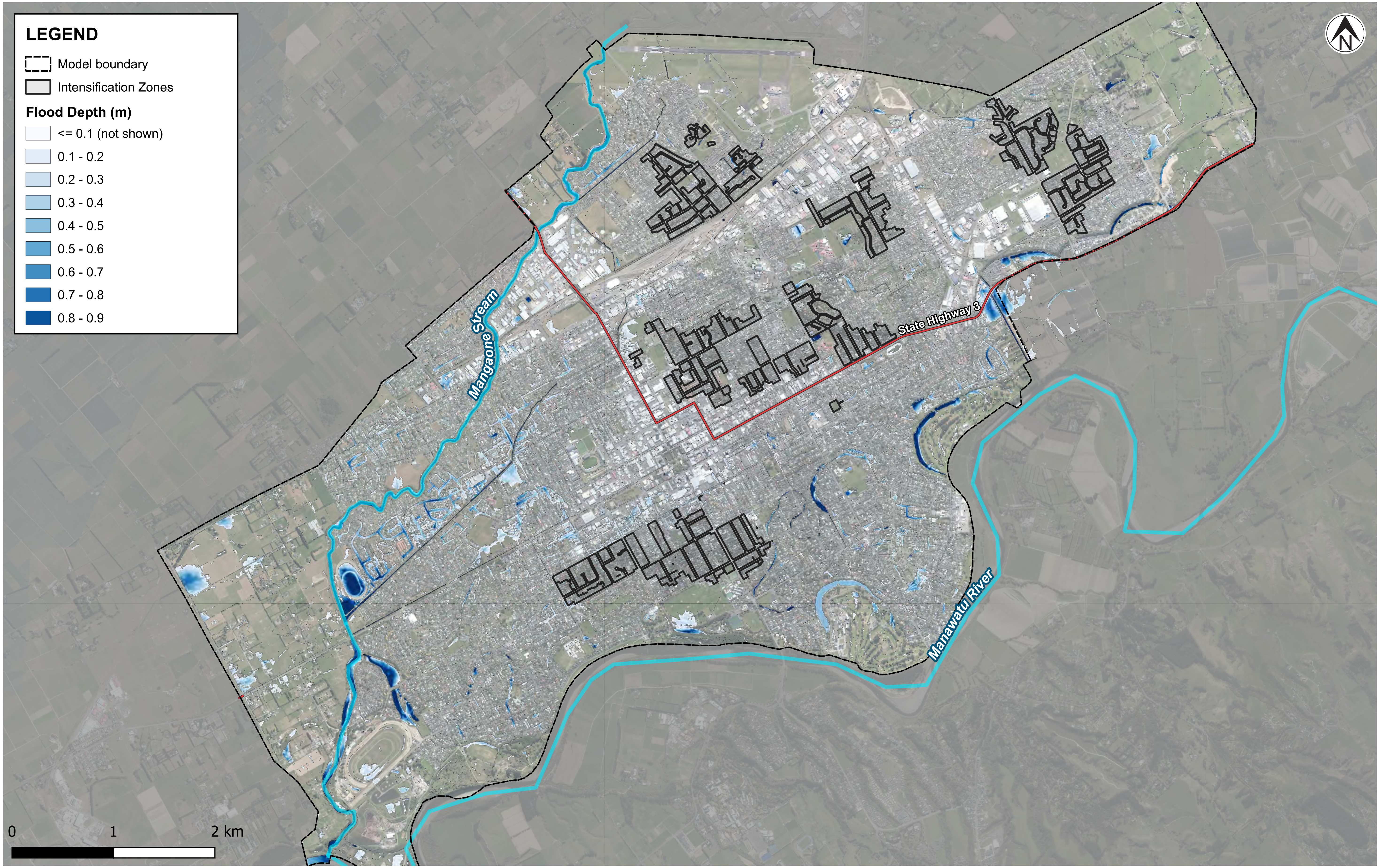
Appendix A Flood Maps

Layout: Drawn by ALWH



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NOTES:
Climate change factor has been applied as per RCP 6.0 Projected to 2130. Where Intensification has been applied, this is a blanket rate of 80% impervious

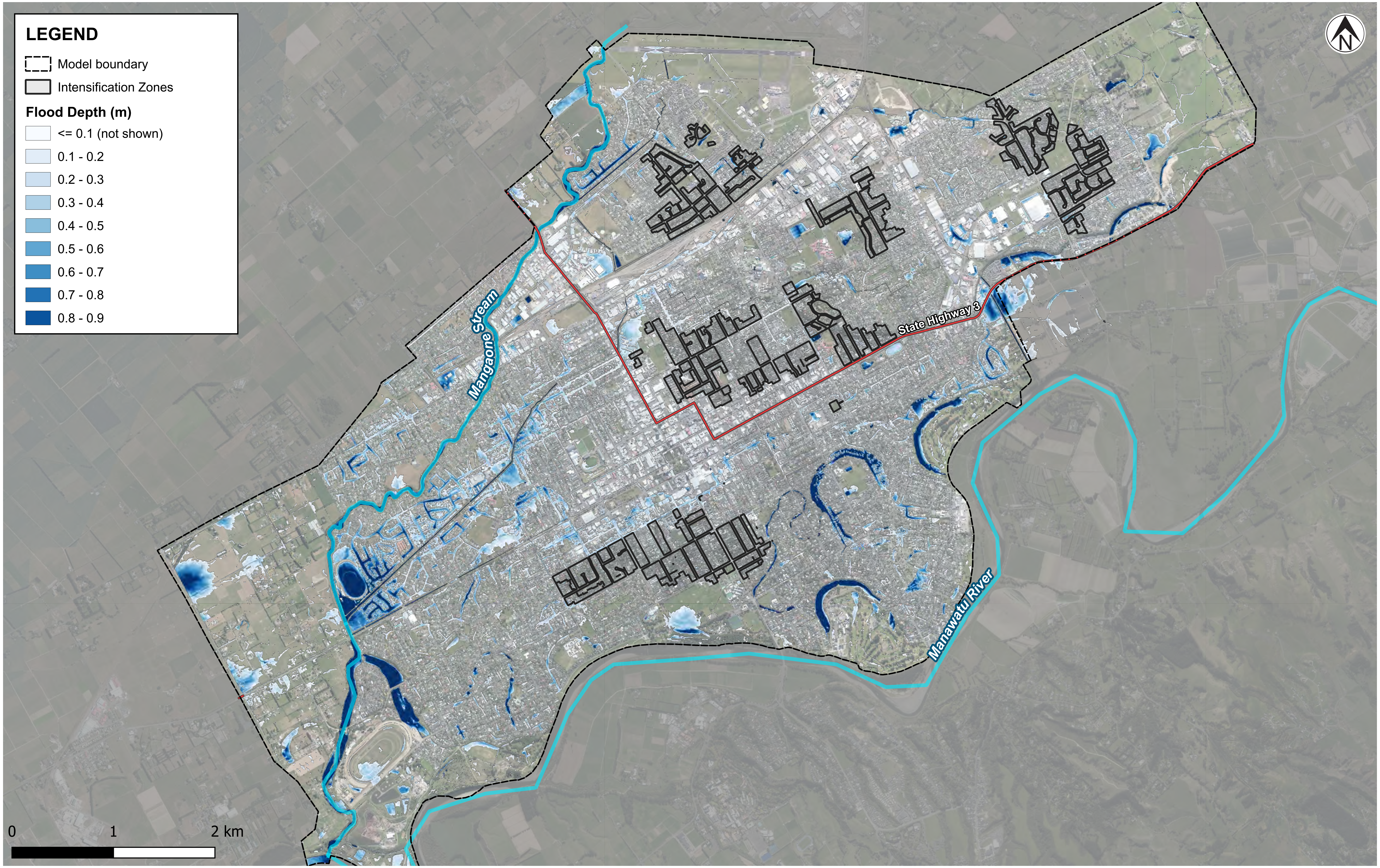
REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24
APPROVED	S Aiken	30/10/24

CLIENT Palmerston North City Council
PROJECT Plan Change Modelling, 2024
TITLE 2 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130
SCALE (A3) 1:35,000 FIG No. FIGURE 1. REV 0

Layout: Drawn by ALWH



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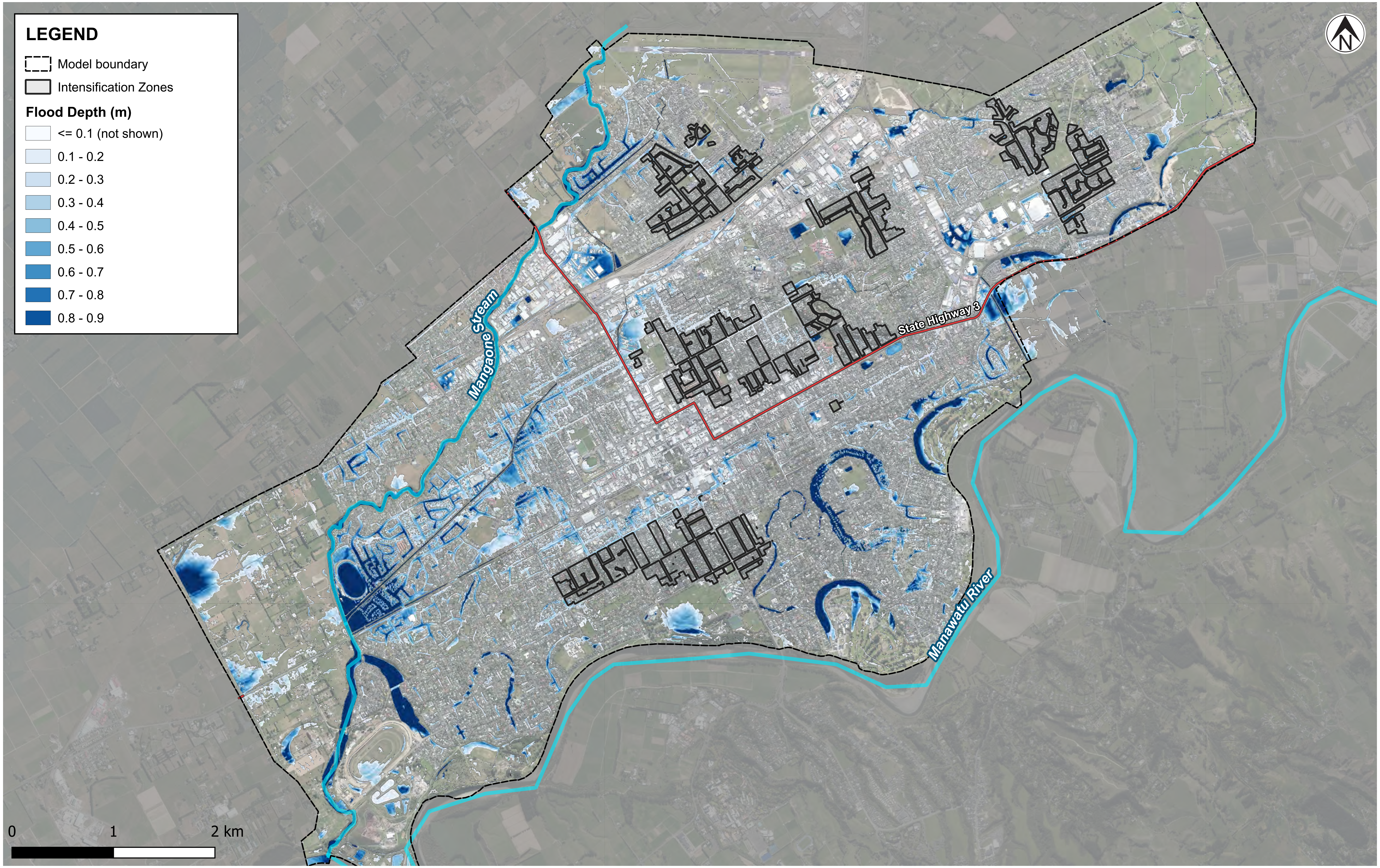
CLIENT **Palmerston North City Council**

PROJECT **Plan Change Modelling, 2024**

TITLE 10 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 2. REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED   DO NOT SCALE FROM THIS FIGURE   Layout: Drawn by ALWH



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LOCATION PLAN

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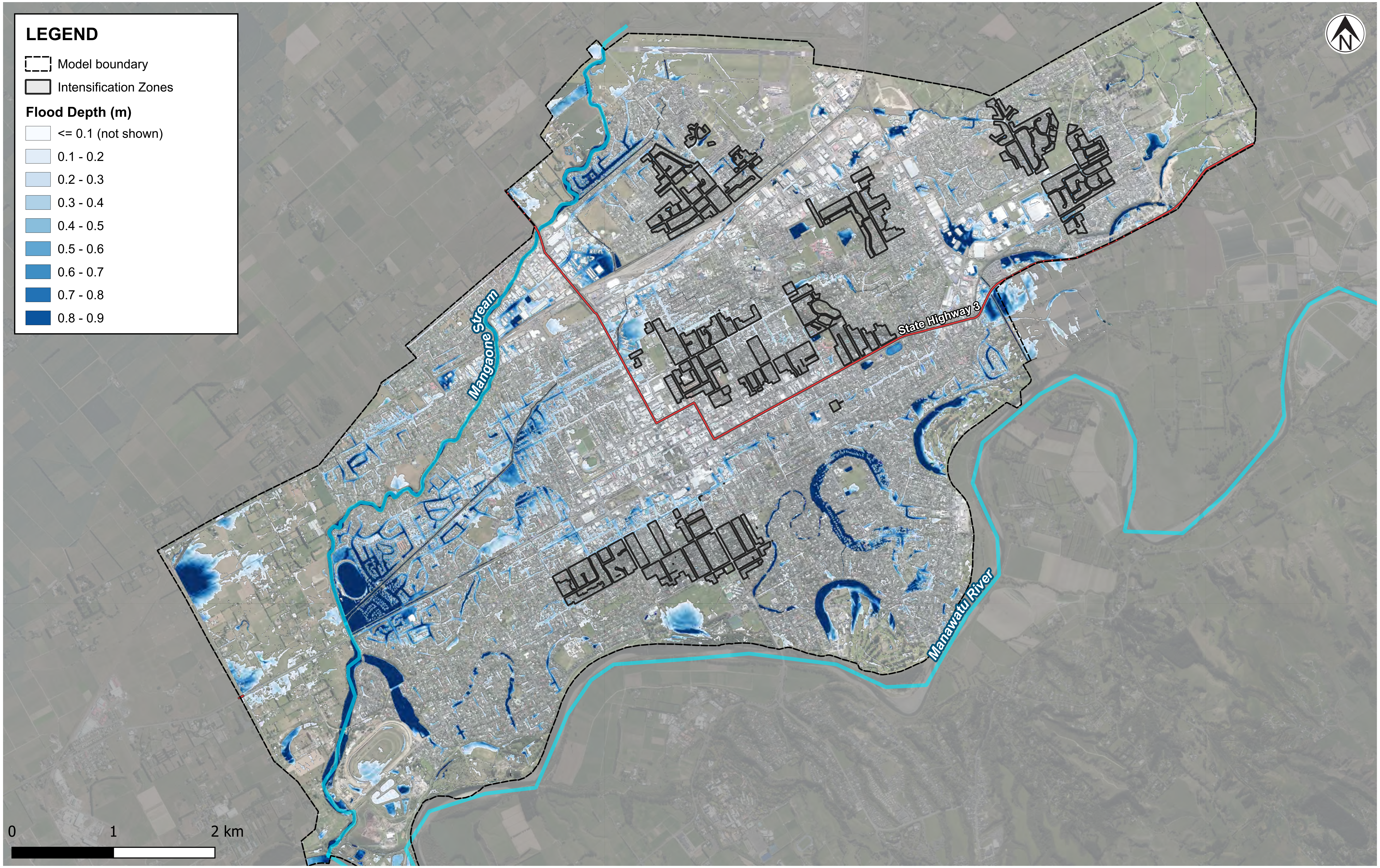
CLIENT **Palmerston North City Council**
PROJECT **Plan Change Modelling, 2024**
TITLE 50 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130
SCALE (A3) 1:35,000   FIG No. FIGURE 3.   REV 0

Layout: Drawn by ALWH



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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

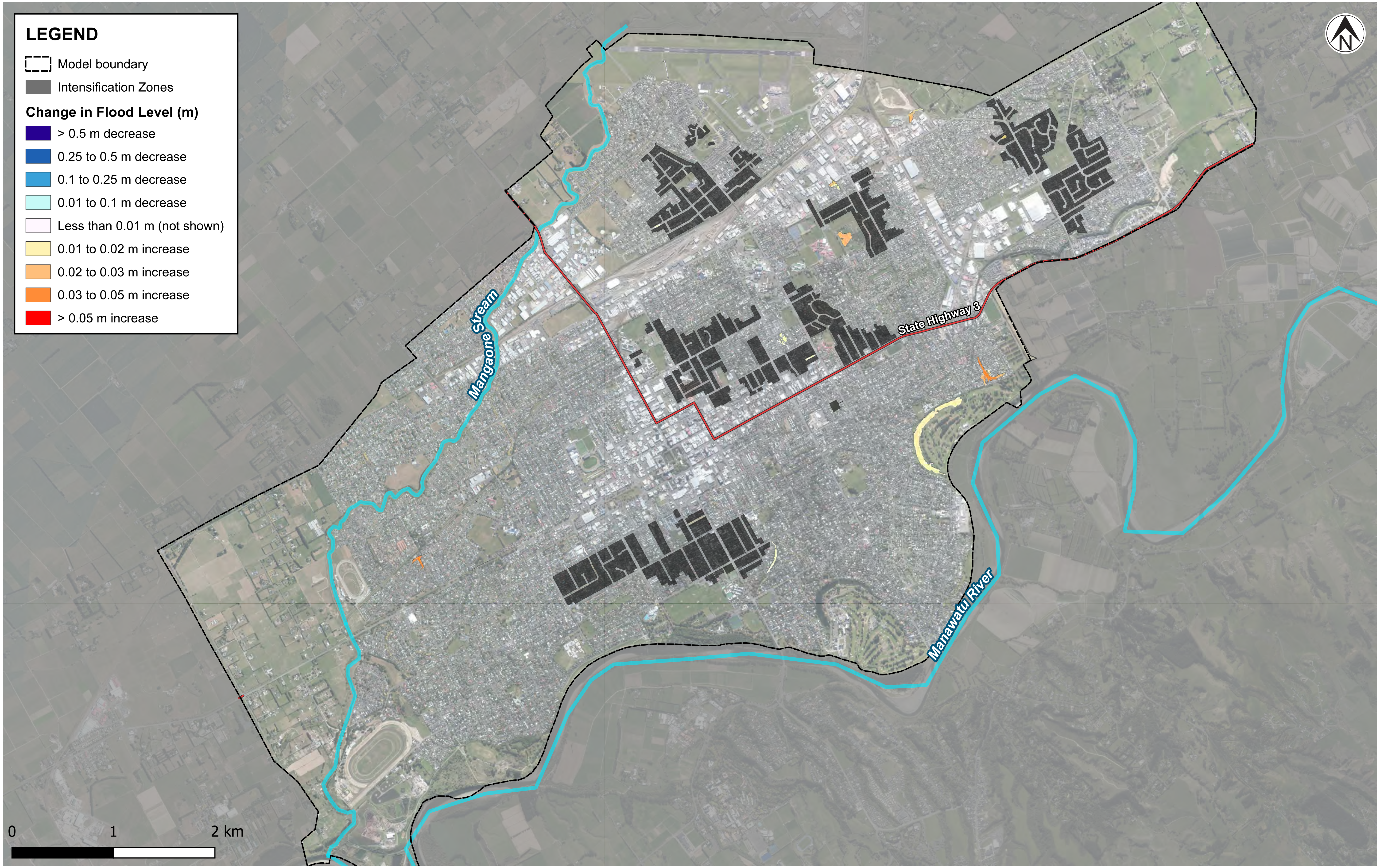
LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24
APPROVED	S Aiken	30/10/24

CLIENT **Palmerston North City Council**
PROJECT **Plan Change Modelling, 2024**
TITLE 100 Year Flood Depth (m) with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 4. REV 0

Layout: Drawn by ALWH



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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

LOCATION PLAN

PROJECT No. 851994.2300

DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24

S Aiken 30/10/24
APPROVED DATE

CLIENT Palmerston North City Council
PROJECT Plan Change Modelling, 2024
TITLE 2 Year Flood Level Difference with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 5. REV 0

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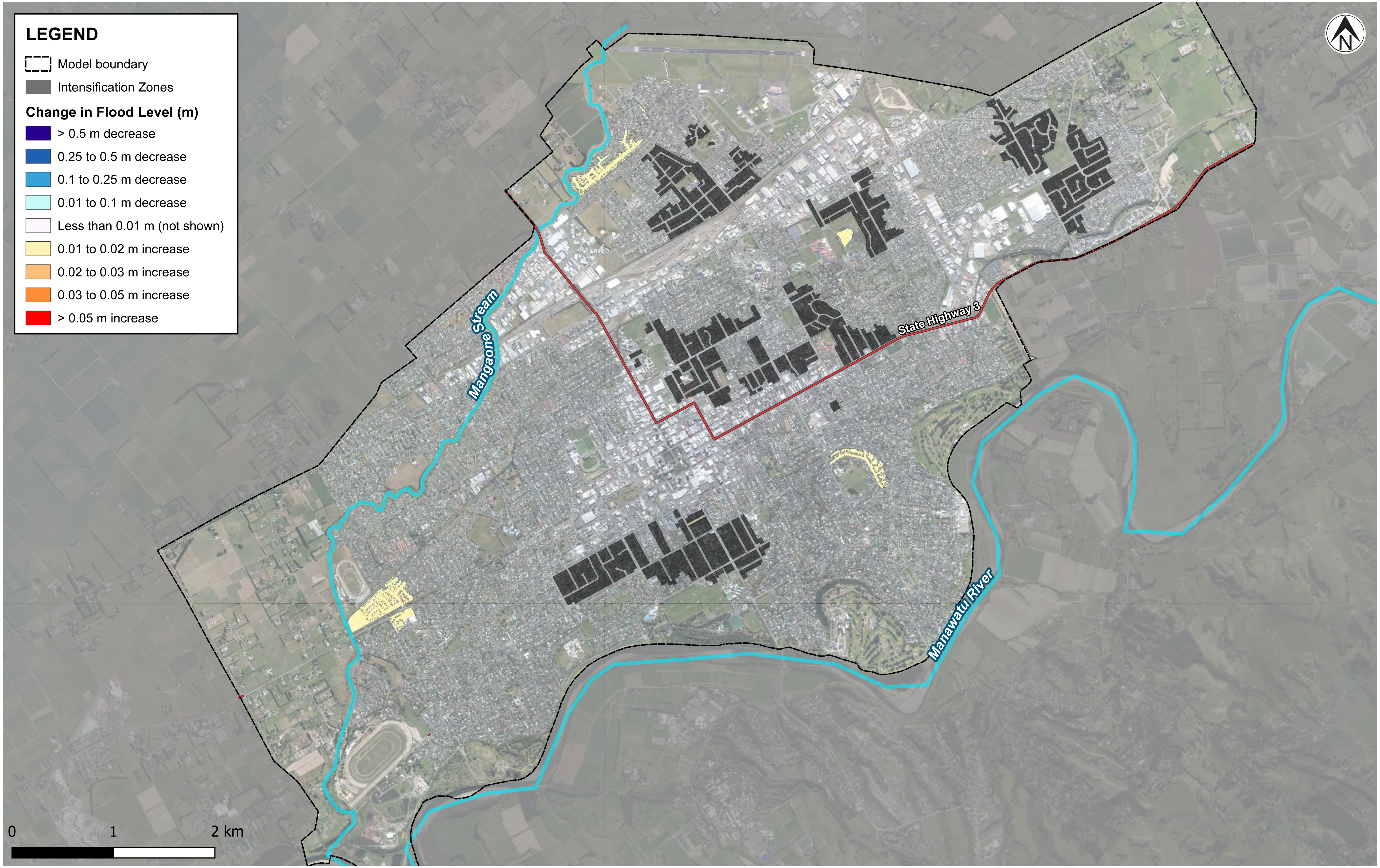
Layout: Drawn by ALWH



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REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24
S Aiken	30/10/24	
APPROVED	DATE	

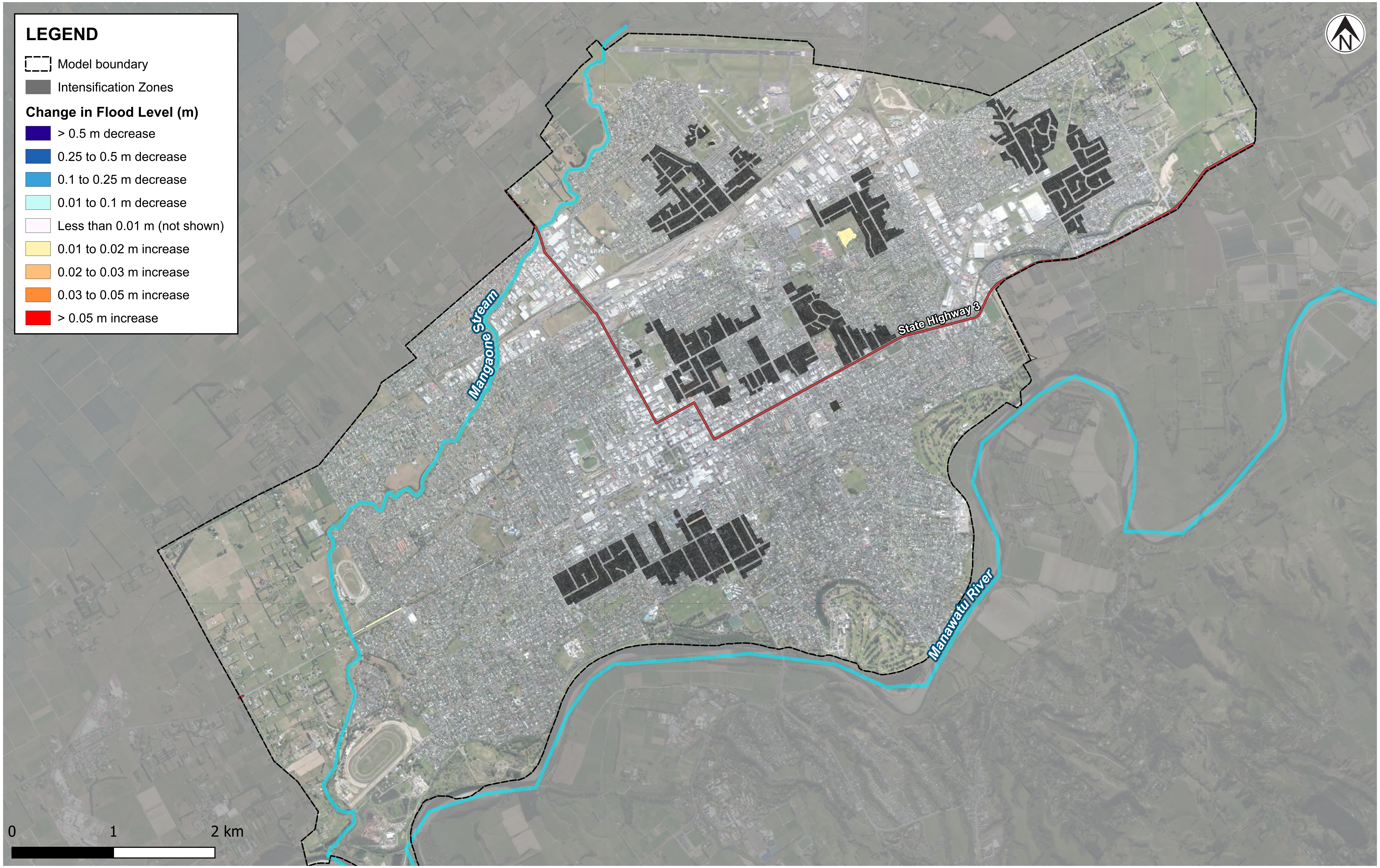
CLIENT **Palmerston North City Council**

PROJECT **Plan Change Modelling, 2024**

TITLE 10 Year Flood Level Difference with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 6. REV 0

Layout: Drawn by ALWH



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REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

LOCATION PLAN

PROJECT No. 851994.2300

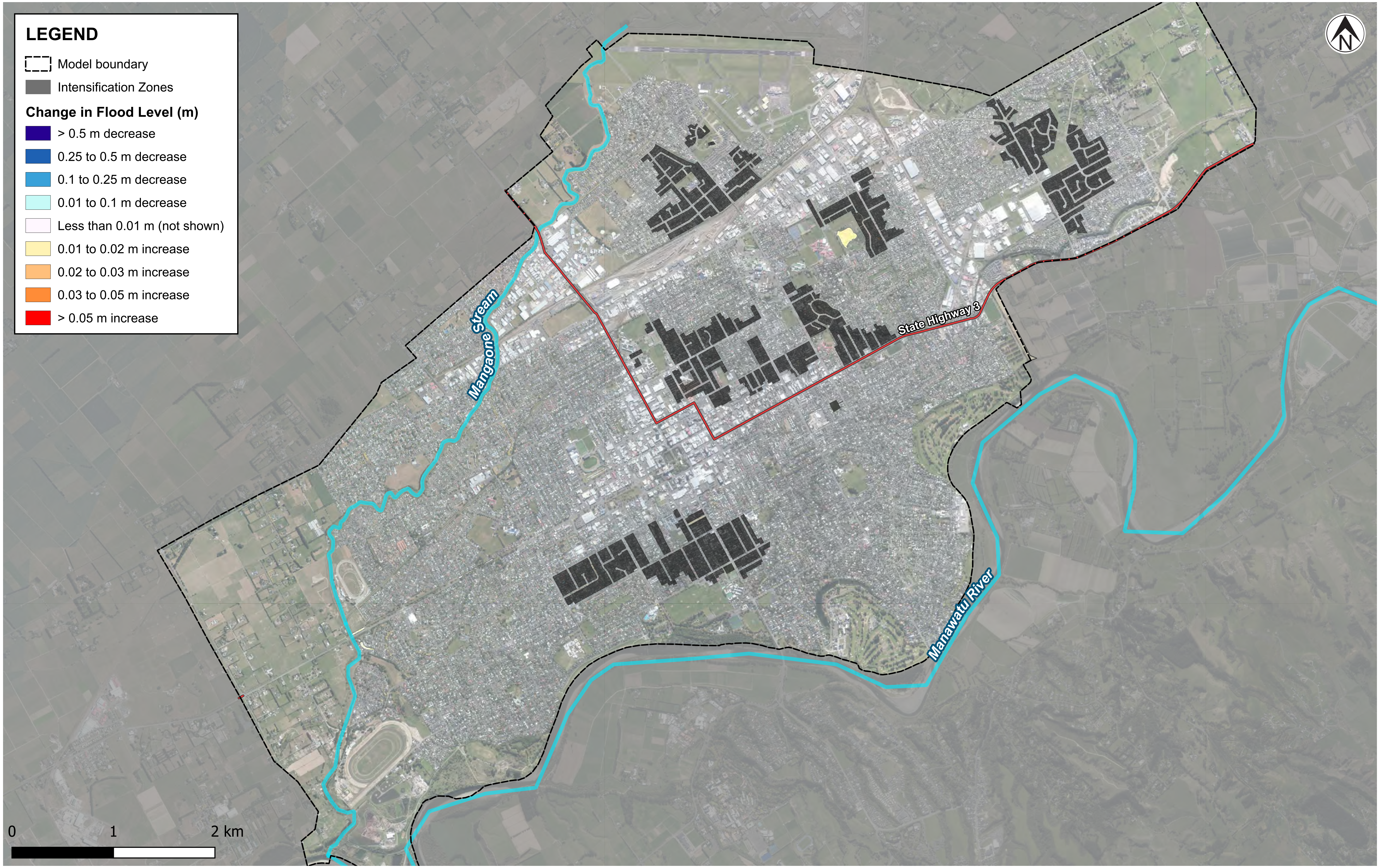
DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24

S Aiken 30/10/24
APPROVED DATE

CLIENT Palmerston North City Council
PROJECT Plan Change Modelling, 2024
TITLE 50 Year Flood Level Difference with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 7. REV 0

Layout: Drawn by ALWH



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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
1	FINAL	ALWH	RIBR	30/10/24

LOCATION PLAN

PROJECT No.	851994.2300	
DESIGNED	ALWH	OCT.24
DRAWN	ALWH	OCT.24
CHECKED	RIBR	OCT.24
APPROVED	S Aiken	30/10/24 (DATE)

CLIENT **Palmerston North City Council**

PROJECT **Plan Change Modelling, 2024**

TITLE 100 Year Flood Level Difference with RCP 6.0 Climate Change projected to 2130

SCALE (A3) 1:35,000 FIG No. FIGURE 8. REV 0

Appendix D. Blue-green Infrastructure Toolkit[11]

[11] GHD, 2023.

BGI MANAGEMENT DEVICES

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments: Sediment	Metals	Total petroleum hydrocarbon	Nutrients	Location in catchment	Location suitability	Suitable environment
Storage and detention systems		**Detention systems are used to capture, attenuate, and release stormwater in controlled volumes into receiving environments. The purpose of detention is to control peak flows and reduce runoff velocities. Reducing runoff velocities helps contaminants to settle and be treated naturally by vegetation, soil, and water before it is discharged into receiving environments.**							
Constructed wetlands	A constructed wetland mimics the treatment processes of natural wetlands. The wetland provides important functions, including detention, filtration of fine sediments and helping remove contaminants from stormwater runoff. Generally, wetlands and ponds require a large area to receive and treat stormwater.	Stormwater quality / Stormwater quantity	High	High	Medium	High	Base	Group residential Commercial Industrial	- Placed at the base of a catchment in natural gullies where hydrology will direct flow. - Suitable for large and low-density catchment areas with sufficient surface area - These are particularly effective at removing sediments, hydrocarbons, dissolved metals, and fine particles. - Used in brownfield and greenfield development
Constructed ponds *with extended detention*			High	Low	Low	Low	Base	Group residential Commercial Industrial	- Generally used for drainage of more than 2 ha - Used in brownfield and greenfield development
Dry pond *with extended detention*			Medium	Low	Low	Low	Base	Group residential Industrial	- Can be used in shared areas such as road corridors, pavement areas recreational areas. - Care should be taken to maintain shared spaces, particularly in road corridors where safety is a concern. - Used in brownfield and greenfield development
Dry pond *without extended detention*		Stormwater quantity	N/A				Base	Group residential Industrial	
Wet ponds *with extended detention*			N/A				Base	Group residential Industrial	

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments				Location in catchment	Location suitability	Suitable environment
			Sediment	Metals	Total petroleum hydrocarbon	Nutrients			
Bioretention (Biofilters)		**Raingardens, tree pits and planter boxes are the most common bioretention devices. Bioretention is a secondary treatment practice that can be integrated into landscapes or proposed planting schemes. Contaminants (including fine sediments) are removed from stormwater runoff through the uptake and water use of plants. Bioretention can be used both to attenuate peak runoff and to remove stormwater runoff pollutants. Water passes through soil media and is evaporated and infiltrated into the ground. Depending on design objectives, water can also slowly release into nearby surface water, stormwater, or combine sewer infrastructure. Retention accrues through subsurface trench components or soil soakage and evapotranspiration.**							
Raingardens and planter boxes	Contains plant species and grasses that can cope with waterlogged soil from rainstorms or dry soils during dry weather. They collect and slow surface water flow and provide treatment and attenuation through its infiltration through the ground with root and soil contact. Rain gardens provide amenities and can be integrated into the existing landscape, and are often used adjacent to footpaths, traffic triangles, islands in the centre of boulevards, school yards, carparks etc. It can also serve as a tool to promote pedestrian safety when implemented as bump-outs.	Stormwater quality / Stormwater quantity / Community level intervention	High	High	High	High	Source and base	All land use types	- Suitable for urban and high-density areas and adds amenity and ecological value to the landscape. - Can provide filtration through grassed/vegetated surfaces providing treatment for fine sediments and hydrocarbons. - Planter boxes is usually encapsulated to receive a point source of stormwater run-off (roof downpipe) - Stormwater run-off is directed into these areas to be taken up by the vegetation and infiltrate the soil. - Used in brownfield development
Tree pits / Storm trees (Urban tree canopy)	Tree pits are easily integrated into existing landscapes around high-density residential areas. It details, filtrate and reuse stormwater and can occur in footpaths, roadways, or courtyards.	Stormwater quality / Stormwater quantity / Community level intervention	High	High	High	High	Source	All land use types	- Suitable for higher density residential areas that retain fewer natural environments. It is important to note traffic visibility considerations should be considered when implementing. - Used in brownfield development
Riparian buffer	Riparian buffers balance, protect and promote environmental systems and biodiversity, alongside agricultural production. In areas adjacent to streams and rivers and acts as a buffer between land and water. Moderating and managing stormwater runoff and flood flow, while conserving both the aquatic ecosystem and urban habitat.	Stormwater quality / Stormwater quantity/ Community level intervention	High	High	NA	High	Mid catchment	Urban areas Rural agricultural land	- Suitable along stream edges, although factors such as property boundaries, slope, soils, and amount of vegetation must be considered for proper function.
Green roof	Green roofs (also referred to as vegetated roof covers, living roofs, nature roofs, and eco-roofs) are a thin layer of living plants growing on top of a roof. A green roof is not a collection of individual plants to beautify a roof space but rather an extension of a conventional roof that involves installing a layer of membrane, substrate, and plants.	Stormwater quality / Stormwater quantity	High	Low	Medium	High	Source	All land use types	- Used on rooftops of varying areas - Used in brownfield development. Roofs that are in good condition and extensive are the easiest to retrofit into green roofs.

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments				Location in catchment	Location suitability	Suitable environment
			Sediment	Metals	Total petroleum hydrocarbon	Nutrients			
Green walls	Green walls are described as a vegetated vertical surface or vertical gardens. It assists in the detention of stormwater capacity, by slowing and smoothing runoff along buildings.	Stormwater quantity	NA	NA	NA	NA	Source	Industrial Commercial developments	- Used on walls of varying industrial and commercial areas. - Includes a drip or irrigation system, a growing medium for plants and a support board at the base of the device. - Thorough irrigation systems, building codes and structural engineering requirements are important for proper stormwater collection and filtration, while also avoiding building leakage.
Hedgerows	Hedgerow plants retain and slow the rate of excess stormwater from entering waterways. Assisting in reducing the risks of flooding and erosion in the area. Plants catch and store stormwater through the leaves, branches, and root systems.	Stormwater quantity	NA	NA	NA	NA	Mid catchment	Urban areas Rural agricultural land	- Temperate environments – planting in the Fall season allows the roots to properly establish before the Winter rains. - Consistent supply of water (overhead irrigation/ drip irrigation or hand water) is crucial for the first few years post planting.
Filter strips / Green Gutters	Filter strips are gently sloping, vegetated areas adjacent to impervious surfaces. They are intended to reduce impacts of sheet flow, velocity of stormwater and help improve water quality. They are sometimes referred to as vegetated filter strips, grassed filter strips, grassed filters, or buffer strips. Pre- or post treatment systems would be necessary to treat hydrocarbons, high total suspended solids, or debris.	Stormwater quality / Stormwater quantity / Community level intervention	High	Medium	Medium	High	Mid catchment	All land use types	- Suitable to be implemented and used on a regional scale throughout high and low-density areas. - They are often located on property boundaries or adjacent to impervious surfaces to substitute for kerb and gutters. They can be man-made or natural. - Suitable for basic treatment of runoff from impervious urban areas. - Used in brownfield and greenfield development. In brown field development, filter strips are typically located along stream boundaries or next to impervious surfaces.
Planted / Vegetated swales	Vegetated swales help to slow runoff and allow infiltration. It captures and treats stormwater run-off through filtration, infiltration, adsorption, and biological uptake. Trees and plants intercept and slow runoff, increase permeability and provide shade and shelter.	Stormwater quality / Stormwater quantity	High	Medium	Medium	High	Mid catchment	Group residential Commercial	- It is not recommended for swales to be constructed if the land has a slope greater than 5% that cannot be terraced. - Suitable for urban and high-density areas. - Can add aesthetics and value to the landscape. - Used in brownfield development with typical locations being along stream boundaries or next to impervious surfaces.

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments				Location in catchment	Location suitability	Suitable environment
			Sediment	Metals	Total petroleum hydrocarbon	Nutrients			
Infiltration soakage		**Soakage is the disposal of stormwater by infiltration to the ground and is incorporated into a lot of the water sensitive urban design (WSUD) approaches. Stormwater from a site is discharged to specially designed soakage devices such as soak holes or soakage trenches, removing it from entering the stormwater network or discharging as overland flow. These devices can provide temporary storage allowing the stormwater time to soak away. Soakage and infiltration devices can provide benefits either at source or at the end of a catchment, especially when used in a treatment train. Soakage trenches provide pre-treatment before water enters an infiltration system to prevent clogging of the device (Lewis, et al., 2015).**							
Infiltration trench and basin	The device is a trench containing gravel and provides treatment and disposal of stormwater. Some treatment is provided by gravel in the trench, but most treatment is provided by adjoining soil. Filter strips usually accompany infiltration trenches providing pre-treatment. (SWCMP, 2021).	Stormwater quality / Stormwater quantity	High	High	High	Medium	Mid catchment	All land use types	- Suitable for a precinct sized catchment in urban environments. - Infiltration trenches are best when space to implement stormwater management are limited. It enhances the natural capacity of the ground to store and exfiltrate runoff into its surrounding environment, from its side and bottom. (Shaver, 2018) - Used in brownfield development, however careful planning is needed when implemented near sensitive structures in urban settings. Proper geotechnical soil testing should be conducted to ensure suitability before implementation of infiltration devices.
Permeable pavement	A pavement that is specifically designed to facilitate and maximize rainfall infiltration through the pavement for stormwater benefit. Beneath the paved surface area is an aggregate material that acts as a temporary reservoir, allowing for runoff to slowly infiltrate into the ground. Permeable pavements are more suited to road and parking lot surfaces, and in areas where there is low volume of traffic (Shaver, 2018).	Stormwater quality / Stormwater quantity	High	High	High	Low	Source	Individual residential Commercial	- Suitable for a lot or street sized catchment in urban environments - Generally used in private driveways and car parking areas - Drainage area generally < 1,000m2 - Used in brownfield and greenfield development. In brownfield development, permeable pavement is most suitable in areas where there is low sedimentation in stormwater
Water harvesting and reuse		**Water harvesting is the collection of rainwater or roof runoff via storage devices such as water tanks. This water can be used for potable or non-potable purposes. Storage tanks are usually installed above or below-ground.**							
Rainwater tanks **(Rain barrels)**	Rainwater tanks attenuation and re-use stormwater from rooftops in buildings and landscape areas. Rainwater collection reduces the need for water from suppliers. The tanks can be placed partially underground or underneath the eaves of buildings.	Stormwater quality / Stormwater quantity	High	Medium	NA	Medium	Source	All land use types	- May be used to capture flows from private rooftops of paved areas - Used in brownfield and greenfield development

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments				Location in catchment	Location suitability	Suitable environment
			Sediment	Metals	Total petroleum hydrocarbon	Nutrients			
Conveyance systems		**Conveyance systems treat stormwater runoff while it filters through the catchment. Filter strips and vegetated swales are the most common conveyance systems used for stormwater management. However, natural systems such as living streams and stream daylighting can also be considered as conveyance systems since they are located mid-catchment and are used to enhance receiving environments.**							
Living streams	Living streams are constructed or retrofitted waterways that mimic the characteristics of natural streams. These streams are different from a simple drain. There is usually riparian and aquatic vegetation that provides habitats for native animals.	Stormwater quality/ Stormwater quantity	*These major role of living streams is to convey runoff in highly urbanized areas and provide treatment. Healthy fringing and aquatic vegetation act as a biological filter.* *Organic and inorganic material can be filtered by living streams. For example, phosphorus and nitrogen can typically be filtered between 50-100%*[1]				Mid catchment	Areas with degraded natural streams or open drains with significant flows	- Suitable to be implemented at a regional scale or in areas of proposed development - Used in brownfield development
Stream daylighting	Stream daylighting is the process of restoring a stream which was once diverted underground to its original channel above-ground. These streams were channelled underground to accommodate for the development of an area. Obstructions that cover a river or creek is removed and the waterway is restored to its previous condition.	Stormwater quality/ Stormwater quantity / Community level intervention	*Stream daylighting increases the area available for water to pass through an area which increases storage capacity and reduces peak flows* *Daylighting buried streams is likely to enhance nutrient retention, improve channel habitation and restore floodplains*[2]				Mid catchment	Highly urbanised areas with remaining open space	- To determine whether daylighting is right for the community, thorough investigation of the area is required. For instance, daylighting a stream at a brownfield site will require a series of steps to assess its viability due to likely presence of hazardous substances, pollutant, or contaminants. - Used in brownfield development
Proprietary treatment devices		**Proprietary treatment devices are off-the-shelf and customised devices designed to provide stormwater treatment in various land uses and environments, including beneath trafficked areas and in high pollution risk activities, and for high rainfall events (e.g., first flush).**							
Gross pollutant traps (GPTs)	Treats stormwater prior to filtration devices or discharging points into wetlands and ponds. Designed to capture large diameter sediments, plastic, litter, leaves, and oils. Not suitable for removing fine sediment and dissolved pollutants.	Stormwater quality	Medium	Low	Medium	Low	Base	Group residential Commercial Industrial	- Stand alone or in a treatment train with ponds or bioretention systems. - Suitable for small to medium catchments - Relatively small footprint - Used in brownfield and greenfield development
Cartridge filters	Pass stormwater through a filter media to treat suspended solids, hydrocarbons, nutrients, and soluble heavy metals.	Stormwater quality	High	Medium	Medium	High	Mid catchment	Commercial Industrial	- Require a low driving head to operate and have a small footprint - Used in brownfield and greenfield development
Sand filters	Captures sediments, oils, and grease before solids before it is disposed to secure landfills. Appropriate controls (e.g., activated carbon filters) are needed to minimise disturbance.	Stormwater quality	High	High	High	Medium	Mid catchment	Commercial Industrial	- Require a low driving head to operate. - Significant site preparation may be needed to install the filter underneath trafficked areas - Used in brownfield and greenfield development

[1] Example of these removal rates are retrieved from *Section 4.3 Living Streams* in the Stormwater Management Manual for Western Australia: Structural Controls
[2] Trice, A. (2016). *Daylighting Streams: Breathing life into urban streams and communities*. American Rivers.

Treatment Device	Description	Function (Stormwater quality, Stormwater quantity or Community intervention)	Water quality treatments				Location in catchment	Location suitability	Suitable environment
			Sediment	Metals	Total petroleum hydrocarbon	Nutrients			
Oil/water separators	Designed to separate hydrocarbons, oil and grease from stormwater. Separators are part of a spill management system. Separated hydrocarbons must be disposed after a spill has occurred or during maintenance checks. Best used in combination with non-structural controls. This will include oxidation, volatilisation, or biological microbial decomposition mechanisms.	Stormwater quality	Low	Low	High	Low	Mid catchment	Commercial Industrial	- Often used in retrofit situations to provide water quality treatment at a small scale, especially in tight constraint areas - Implemented at the source in new developments and retrofitting applications - Used in brownfield and greenfield development