Assessment of Effects on Flooding for Proposed Whirinaki Stopbank

Prepared for

Hawkes Bay Regional Council

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Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Hawkes Bay Regional Council and others (not directly contracted by PDP for the work), including Land Information New Zealand, National Institute of Atmosphere and Water, Tonkin and Taylor, Transport Recovery East Coast and Landcare Research. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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Executive Summary

Pattle Delamore Partners (PDP) has been engaged to develop a hydraulic flood model for Hawke's Bay Regional Council (HBRC) to determine the design height of a proposed stopbank at Whirinaki. The proposed stopbank will be a mixed level of service stopbank with one section providing protection to Pohutukawa drive in events up to a 100-year ARI[1], and the other protecting Pan Pac from flooding of the Esk River for events up to and including the in the 500-year ARI event with the appropriate allowances for climate change. For the 100-year event, this equates to a design flow of 1442 m³/s whilst for the 500-year event, this equates to a design flow of around 3000 m³/s. For context, the recent Cyclone Gabrielle had an estimated flow of 2157 m³/s and an assigned return period of between 180 and 220-years (without climate change).

The proposed works (and assessment of effects on flooding) includes the stopbank along Whirinaki Drain, modifications to SH2 for stopbank crossing, and modifications to North Shore Road for stopbank crossing. This assessment of effects on flooding is based on results from a continuation of the "Esk River Hydraulic Model" described in our previous report (June 2025).

Model Runs

The primary assessment of effects on flooding has been completed using 14 model runs. This includes seven hydrological events"

- 50-year event with and without climate change;
- 100-year event with and without climate change;
- 500-year event with and without climate change; and,
- Cyclone Gabrielle.

For each of these seven hydrological events, a pre (existing environment) and post construction model has been run.

[1] ARI (Annual Recurrence Interval). For events with and ARI of ~5 to 10 or greater, the inverse of the ARI is equivalent to the AEP (Annual Exceedance Probability), the probability that a given event will be exceed in any year.

Effects on flooding

Reduced Flooding: The proposed works are projected to decrease the net flooded area by approximately 7% and the net number of flooded buildings by at least 12% across various flood events (from 50-year to 500-year, with and without climate change). This is a net difference, therefore some areas may increase and some may decrease but the net change is 12%.

Stopbank Performance: The 500-year stopbank protecting Pan Pac effectively prevents flooding of Pan Pac and residential houses on Whirinaki Road in both the design (500-year) event and the Cyclone Gabrielle event. The 100-year stopbank, protecting residential houses on Whirinaki Drain performs as intended with protection in events up to the 100-year and overtopping in larger events such as Cyclone Gabrielle or the 500-year events.

Flood Hazard Changes: The proposed works generally decrease flood hazard classifications. Impacts on buildings are primarily decreases in hazard, especially for Pan Pac, the substation, and some residential areas. Some increases to the flood hazard classifications occur within the LC3 (Land Categorisation 3) area, and along North Shore Road and Pohutukawa Drive in a 500-year event.

Effects on Buildings: The proposed works generally result in a decrease in flood hazard classification for buildings, particularly for Pan Pac, the substation, and some residential areas on North Shore Road and Pohutukawa Drive. While some localised increases in hazard are observed within the LC3 area and North Shore Road and Pohutukawa Drive in a 500-year event. There are minimal increases in the hazard classification for non-habitable dwellings, such as garages and garden sheds.

Cultural Sites: The proposed works have minimal impact on all cultural sites for the 50-year and 100 events. In the 500-year event, the hazard classification is unchanged although flood depths do increase by up to 40 mm.

Lifeline Utilities: No changes in hazard classification are expected for State Highway 2, the rail line, or SH5. The substation's hazard classification improves significantly as a result of the protection afforded by the proposed Whirinaki Stopbank.

Horticultural Land: 30ha of orchard between the Esk River and Whirinaki Drain stopbank experiences a localised increase in flood depth (up to 100 mm). However, given the land use and existing flood conditions, the impact is considered acceptable.

Flood Velocities: Flood velocities are largely unchanged at most locations. Some increases are observed at Whirinaki Drain @ SH2 and Upper Whirinaki Drain, but these are not expected to significantly increase scour or erosion risk.

Temporary works: The borrow pit has minimal negative flood impacts. Staged construction over two years was considered, with the 500-year stopbank constructed in the first construction season. For flood events less than the 50-year event, the impact will be minimal as the 500-year stopbank does not displace any significant amounts of water. Between the 50 and 500-year events. The effects are expected to be less than those predicted for the 500-year event. Given the probability of getting a 50-year event or larger over the two construction seasons is low – the risk of a slightly exacerbated flood effect is considered acceptable.

Conclusion

In conclusion, the proposed works provide a significant level of protection to critical infrastructure, several residential properties in Whirinaki and protection for the commercial Pan Pac operation whilst having limited adverse impacts on flooding.

Table of Contents

SECTION		PAGE
1.0	**Introduction**	**1**
2.0	**Proposed construction works**	**1**
3.0	**Changes and updates from October Model**	**2**
4.0	**Model scenarios**	**4**
5.0	**Flood Hazard**	**5**
6.0	**Effects on flooding and flood hazard**	**6**
6.1	**Overview (consequential flood effects assessment)**	**8**
6.2	**Flood levels and flood depths**	**17**
6.3	**Flood hazard**	**19**
6.4	**Flood velocities**	**31**
7.0	**Effects of temporary works on flooding**	**32**
7.1	**Construction of Stopbank and SH2 upgrade**	**33**
8.0	**Conclusions**	**33**
9.0	**References**	**34**

Table of Figures

Figure 1: Proposed stopbank location	2
Figure 2: Flood hazard curves (Smith et al., 2014)	5
Figure 3 Location of assessed areas, and significant/critical infrastructure.	8
Figure 4: Locations at which flood velocities and levels have been extracted	18
Figure 5: Flood levels at various locations for modelled events. See Figure 4 for locations of extraction points	19
Figure 6: Flood levels and hazard at cultural locations for climate change modelled events. See Figure 3 for locations of extraction points. Note change in vertical elevation between plots	25
Figure 7: Flood levels and hazard at 76 Taits Road for climate change modelled events. See Figure 3 for location.	26
Figure 8: Flood levels and hazard at 75 Taits Road for climate change modelled events. See Figure 3 for location.	27

D R A F T

Figure 9: Flood levels and hazard at 77 Taits Road for climate change modelled events. See Figure 4 for location. 27

Figure 10: Flood levels and hazard at 79 Taits Road for climate change modelled events. See Figure 3 for location. 28

Figure 11: Flood levels and hazard at 1023 SH2 for climate change modelled events. See Figure 3 for location. 29

Figure 7: Flood velocities at various locations for modelled events See Figure 4 for locations of extraction points 32

Table of Tables

Table 1: Model runs 4

Table 2: Change in area of flooding and number of buildings flooded across modelled area (pre and post) 9

Table 3: Changes in hazard area (ha) classification (pre and post) 11

Table 4: Post construction hazard classifications for buildings with change from pre in parentheses 12

Table 5: Hazard area (ha) classification for the post construction model (change from pre model in parentheses) 15

Appendices

Appendix A: Figures

Appendix B: Flood Hazard Figures

Appendix C: Detailed Figures (Bayview and Pan Pac)

Appendix D: Climate change memo

Appendix E: Memo on the effects of the Railway on flooding

Appendix F: Detailed consequential flooding tables

1.0 Introduction

Pattle Delamore Partners (PDP) has been engaged by Hawke's Bay Regional Council (HBRC) to prepare a hydraulic flood model for the purpose of determining the design height of the proposed Whirinaki stopbank. The proposed stopbank will be a mixed level of service stopbank with one portion providing protection to Pohutukawa drive in events up to a 100-year ARI[2], and the other protecting Pan Pac from flooding of the Esk River for events up to and including the in the 500-year ARI event with the appropriate allowances for climate change. For the 100-year event, this equates to a design flow of 1442 m^3/s whilst for the 500-year event, this equates to a design flow of around 3000 m^3/s (with climate change) which is in excess of most Gabrielle estimates. This report outlines the effects on flooding that will result from the construction of the proposed infrastructure which primarily consists of:

- A stopbank, adjacent to Pan Pac, sized to a 500-year event;
- A Stopbank, adjacent to Whirinaki Drain South East of SH2, sized to a 100-year event;
- Modifications to SH2 to ensure it can cross the new stopbank; and,
- Modification to North Shore Road to ensure it can cross the new stopbank.

The hydraulic model used to perform this assessment is a continuation of the model described in our October 2023 report titled "Esk River Hydraulic Model". For further information on assumptions and inputs of this model, refer to our 2025 report Esk River Hydraulic Model. This model has been constructed using Tuflow[3] for the specific purpose of stopbank design and assessing effects on flooding.

2.0 Proposed construction works

HBRC have stipulated that the Whirinaki stopbank should be designed to the 100-year event, however, Pan Pac desire a 500-year level of service and have agreed to fund the difference. Therefore, the stopbank has been designed to a mixed level of service to achieve a 500-year protection for Pan Pac and 100-year protection for Pohutukawa Drive climate change has been allowed for RCP 8.5 2044. Whilst the design uses a 20-year climate horizon, this effects assessment has been conducted using a 50-year climate horizon (out to 2074). The proposed

[2] ARI (Annual Recurrence Interval). For events with and ARI of ~5 to 10 or greater, the inverse of the ARI is equivalent to the AEP (Annual Exceedance Probability), the probability that a given event will be exceed in any year.
[3] Version 2023-03-AB-iSP

stopbank location and associated works and features of note are presented in Figure 1.

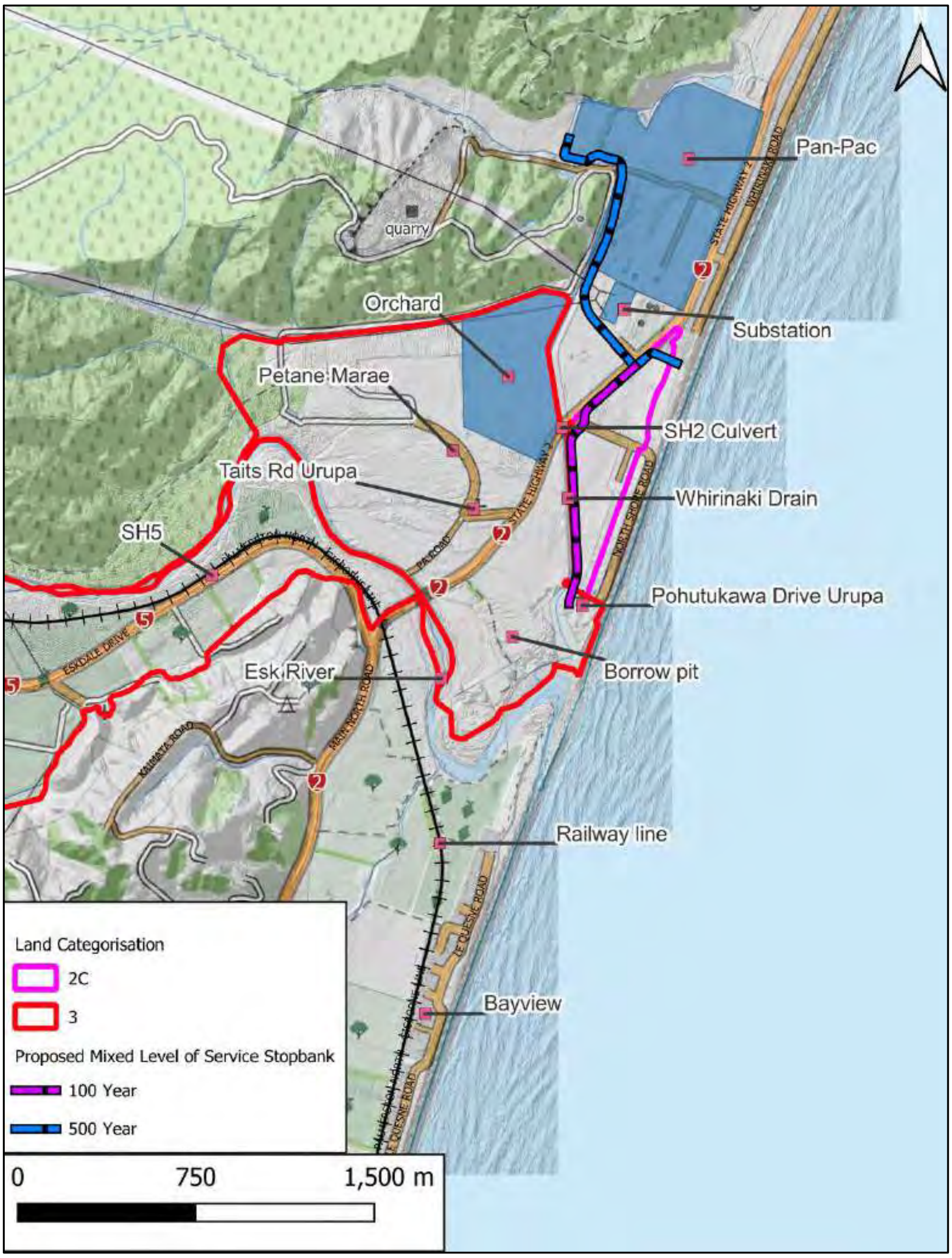

Figure 1: Proposed stopbank location

3.0 Changes and updates from October Model

The following changes have been applied to the hydraulic model:

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- The design specification stipulated by HBRC for the entire stopbank is mixed level of service stopbank (HBRC, 2024). Our October 2023 model used a 100-year plus 500 mm freeboard standard;
- The freeboard requirement has been determined for the entire stopbank by PDP (Pattle Delamore Partners, June 2025). In summary, we recommend the following freeboards:
  - 100-year level of service 700 mm;
  - 500-year level of service SH2 to gravel beach 900 mm;
  - 500-year level of service SH2 to haulage roads 700 mm; and,
  - 500-year level of service haulage roads 500 mm.
- Design flows for all events (10 to 500-year) have been provided by HBRC[4]. PDP has reviewed these flows and adopted them as fit for purpose despite some limitations. We note they are slightly different to our own estimates provided in the October report. The design flows are provided and discussed in Section 7.1.2 of our design report "Esk Valley: Design Model Build Report";
- Previously, we accounted for climate change out to 2120 by increasing peak flows by 40% (RCP8.5 2120). For this round of modelling, HBRC have instructed that we should use RCP8.5 2074 which is approximately a 25% increase in peak flow;
- We have included two minor culverts on Whirinaki Drain which are located in the upper reaches, adjacent to Pan Pac;
- Flows for the Whirinaki Catchment have been added to the model. These were derived by a regional characteristics assessment with a catchment exponent of 0.8. Design flows were also derived from a rainfall runoff model, but these were discarded in favour of the regional assessment because the flow estimates, whilst similar, were slightly lower for the rainfall runoff model. To be conservative, the peak flow from the Whirinaki Drain was assumed to coincide with the Esk River's peak flow. Early model iterations showed that the water levels in Whirinaki Drain were largely controlled by peak flow and culvert structures, therefore the event volume and shape were not considered critical factors to the design;
- The WSP survey was added to the model, this survey primarily covers the Whirinaki Drain area, replacing the 2023 LIDAR survey (where available); and,

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[4] Email from Craig Goodier to Ben Throssell on 23 April 2024

- Model roughness, downstream boundaries, base topography and other model parameters have not changed since the previous model iteration.

4.0 Model scenarios

The model scenarios that have been run for the flood effects assessment are presented in Table 1. The format of the model short ID is:

ModelNumber + catchment development + event ARI + climate change

The model tags are as follows:

- Development status:
  - pre: the pre development (existing environment) model state; and,
  - post: the post construction, developed catchment status.
- Flood event Average Recurrence Interval (ARI):
  - 50: a 50-year (2% AEP) event (peak flow of 1127 m^3/s);
  - 100: a 100-year (1% AEP) event (peak flow of 1442 m^3/s);
  - 500: a 500-year (0.2% AEP) event (peak flow of 2400 m^3/s); and,
  - CGB: the historic Cyclone Gabrielle Event (peak flow of 2175 m^3/s).
- Climate change assumption:
  - None: no climate change (current conditions); and,
  - RCP8.5 2074: The RCP8.5 climate projection for the year 2074. Further details on this climate assumption are provided in Appendix D but summarising, this climate change scenario adds 25% to the peak flow.

Table 1: Model runs

Model short ID	Development	ARI	Climate Change
M01+pre+50+NoCC	Pre	50-year	None
M02+pre+100+NoCC		100-year	
M03+pre+500+NoCC		500-year	
M04+pre+CGB+NoCC		Cyclone Gabrielle	
M05+pre+50+RCP8.5_2074		50-year	RCP8.5 2074
M06+pre+100+RCP8.5_2074		100-year	
M07+pre+500+RCP8.5_2074		500-year	

Table 1: Model runs

Model short ID	Development	ARI	Climate Change
M08+post+50+NoCC	Post Construction	50-year	None
M09+post+100+NoCC		100-year	
M10+post+500+NoCC		500-year	
M11+post+CGB+NoCC		Cyclone Gabrielle	
M12+post+50+RCP8.5_2074		50-year	RCP8.5 2074
M13+post+100+RCP8.5_2074		100-year	
M14+post+500+RCP8.5_2074		500-year	

5.0 Flood Hazard

The flood hazard classifications specified by the Australian Rainfall and Runoff Guidelines have been adopted for this assessment (Figure 2) which was adopted from Smith et al., (2014). These flood hazard curves are often employed in New Zealand and are the hazard curves recommended by the Greater Wellington Regional Council Flood Hazard Modelling Standard (GWRC, 2021).

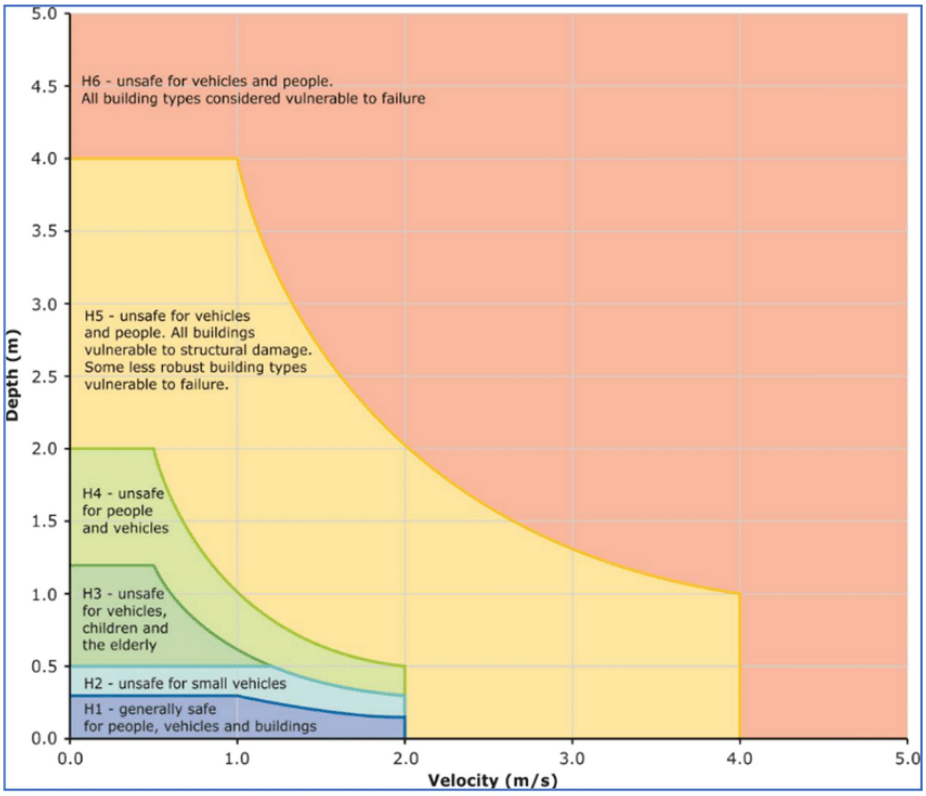

Figure 2: Flood hazard curves (Smith et al., 2014)

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There is no formal guidance available nationally or locally which can be applied as a framework for assessing effects on flooding and flood hazard. Therefore, when considering effects on flooding, we use the following framework:

- **Magnitude of Effect:** In this instance, the effect is quantified by changes to the flood depth/level and changes to the flood hazard classification.
- **Event Scale:** An effect for a smaller, more frequent, event is considered worse than the same effect for a larger, less frequent event.
- **Property Sensitivity:** Properties with existing flood vulnerabilities have a lower tolerance for additional flooding compared to those with low or no flood hazards.
- **Land use:** The land use of the affected property is also a consideration. Rural land used for grazing/cropping/horticulture is considered to have a greater tolerance to flood effects when compared to residential dwellings.
- **Scale of the proposal:** While less critical than the factors above, the size of the proposal generating the effect should be considered. A significant proposal, such as building the Whirinaki Stopbank which will protect regionally significant infrastructure and 100's of residential properties, generating an effect is more acceptable than a smaller proposal (for example a stopbank protecting ten houses) generating the same effect.

6.0 Effects on flooding and flood hazard

The flood depths for the Cyclone Gabrielle flood event (pre and post) are shown in Appendix A, Figures A1 and A2 respectively. Flood depths for the 100-year event (pre and post are presented in Figures A3 and A4 respectively and for the 500-year (pre and post) are presented in Figures A5 and A6 respectively.
A matching set of detailed figures are presented in Appendix C. These figures show:

- The model extent covers from the Esk Valley to the coast;
- The figure shows building footprints and the proposed stopbank delineation;
- For the 100-year event, both Pan Pak, residents along Whirinaki Road and Pohutukawa Drive are protected from flooding;
- For the Cyclone Gabrielle event and the 500-year even, Pan Pac and residents along Whirinkai Road are protected but the stopbank protecting Pohutukawa Drive is overtopped with some flooding of Pohutukawa Drive predicted; and,

- Flood depths of well over a metre are observed throughout the Esk Valley and river corridor. Flood depths are less towards the southern extent, but still significant and over a metre in some places.

Figure 3 shows the location of areas of interest in the model. Bayview, a residential area south of the railway line damaged by Cyclone Gabrielle, is a key area for flood impact assessment. KiwiRail has a designation which allows reinstatement of the railway, but currently has no plans to do so. This railway historically acted as a partial flood barrier, similar to a stopbank, by constraining the Esk River's flow and offering some protection to Bayview. However, its construction makes it more vulnerable to failure (compared to a stopbank) during floods. While the railway does influence flood hazard and water levels in some events, an investigation (Appendix E) found that its presence has a limited impact on the conclusions drawn about the flooding effects of the proposed construction works. The figures presented in Appendix A, B and C plus all flood results presented in the main body of this report, assume that the rail embankment is in its current, post-cyclone, unrepaired condition.

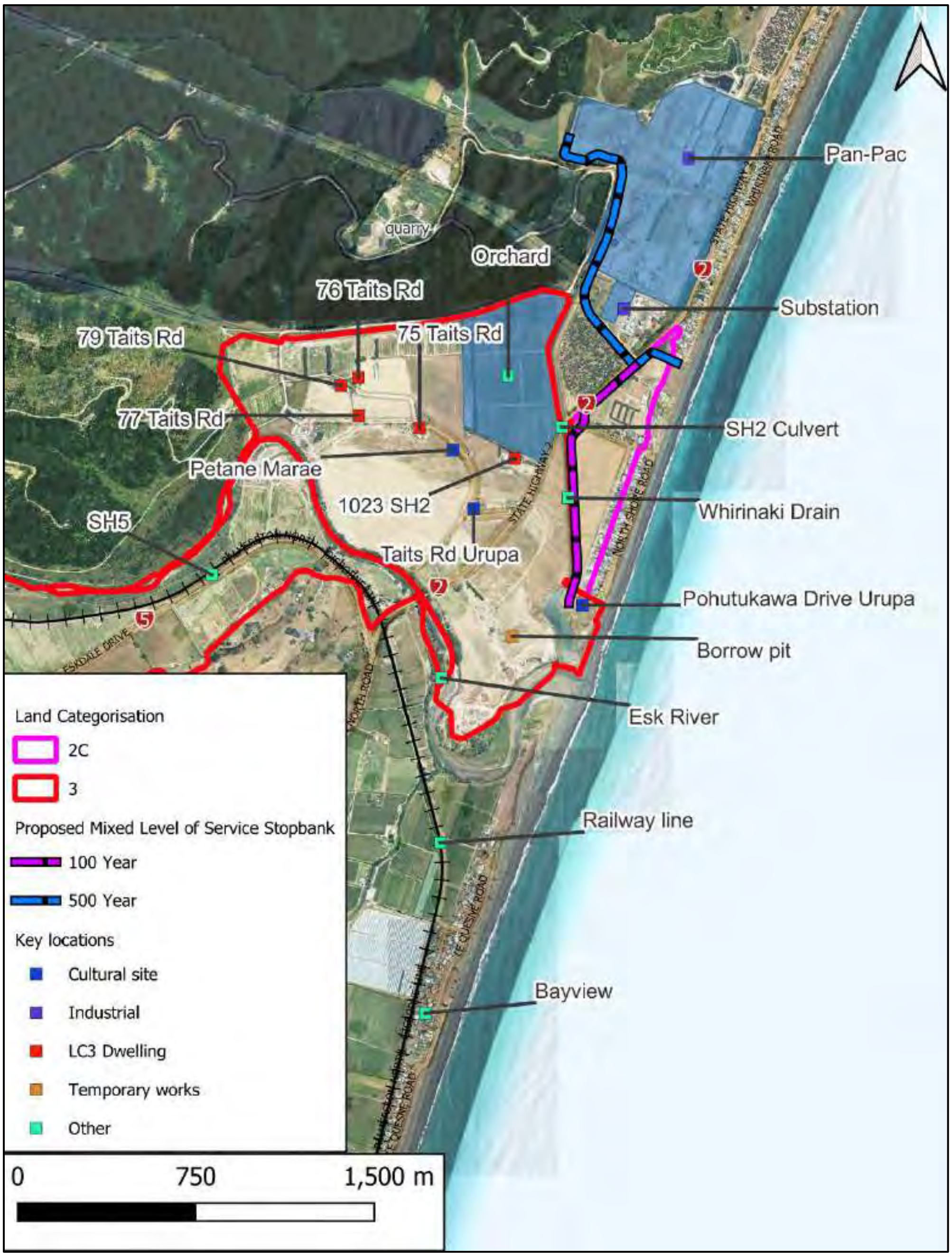

Figure 3 Location of assessed areas, and significant/critical infrastructure.

6.1 Overview (consequential flood effects assessment)

An overview of the effects on flooding due to the proposed work is provided in the following Tables.

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Table 2 shows the change in total area flooded and the number of buildings flooded. Across all events modelled (from a 50-year event without climate change to a 500-year event with climate change):

- The flooded area is expected to decrease by approximately 7% as a result of the proposed works; and,
- The number of buildings flooded is expected to decrease by at least 12% and up to 26%.

Table 2: Change in area of flooding and number of buildings flooded across modelled area (pre and post)

Modelled event	Area of flooding (ha)		No. buildings in flooded area	
Modelled event	Before proposed works (pre)	After proposed works (post)	Before proposed works (pre)	After proposed works (post)
50YR+NoCC	632	538 (↓ 11%)	226	168 (↓ 26%)
50YR+RCP8pt5_2074	721	610 (↓ 12%)	296	225 (↓ 24%)
100YR+NoCC	730	619 (↓ 12%)	308	236 (↓ 23%)
100YR+RCP8pt5_2074	885	788 (↓ 10%)	448	360 (↓ 20%)
500YR+NoCC	1,111	1199 (↓ 7%)	827	727 (↓ 12%)
500YR+RCP8pt5_2074	1,364	1282 (↓ 7%)	977	821 (↓ 16%)
CGB+NoCC	986	1070 (↓ 8%)	767	653 (↓ 15%)
Increase of more than 1% (except H1)				
Decrease of more than 1%				

Table 3 shows the change in flood hazard area classification (using the Australian Rainfall and Runoff hazard classification). The table breaks down the area of hazard classification for each flood model, pre and post construction. The table shows:

- H1 (generally safe): Decreases to this classification except for Cyclone Gabrielle with no change.
- H2 (unsafe for small cars): Decreases for this classification for the 50, and 100-year models of (15-20%) and for Cyclone Gabrielle and 500-year events (up to 3%) for the classification;
- Decreases across all models for the H3 (unsafe for vehicles, small children and elderly) and H4 (unsafe for people and vehicles) classification; and,

- Minimal changes for the 50, and 100-year, with decreases for the 500-year and Cyclone Gabrielle of (6-13%) to H5 (unsafe for vehicles and people, buildings vulnerable to damage and some may be vulnerable to failure) and H6 (unsafe for vehicles and people, all buildings vulnerable to failure) classifications.

Table 3: Changes in hazard area (ha) classification (pre and post)

Modelled event	Before proposed works (pre)					
	H1[1]	H2	H3	H4	H5	H6
50YR+NoCC	146	77	141	63	111	69
50YR+RCP8pt5_2074	129	87	139	107	155	78
100YR+NoCC	127	87	141	110	161	79
100YR+RCP8pt5_2074	142	95	201	126	220	96
500YR+NoCC	217	157	290	167	321	133
500YR+RCP8pt5_2074	135	137	344	178	411	174
CGB+NoCC	210	150	253	138	290	118
Modelled event	**After proposed works (post)**					
	H1	H2	H3	H4	H5	H6
50YR+NoCC	116 (-20%)	67 (-13%)	111 (-21%)	64 (0%)	111 (0%)	69 (0%)
50YR+RCP8pt5_2074	98 (-24%)	71 (-19%)	119 (-14%)	88 (-18%)	156 (0%)	78 (0%)
100YR+NoCC	99 (-23%)	70 (-20%)	120 (-15%)	90 (-19%)	161 (0%)	79 (0%)
100YR+RCP8pt5_2074	129 (-9%)	80 (-15%)	161 (-20%)	99 (-21%)	221 (1%)	97 (0%)
500YR+NoCC	213 (-2%)	153 (-2%)	268 (-8%)	138 (-17%)	294 (-8%)	133 (0%)
500YR+RCP8pt5_2074	129 (-4%)	134 (-3%)	336 (-2%)	151 (-15%)	358 (-13%)	175 (0%)
CGB+NoCC	210 (0%)	146 (-3%)	208 (-18%)	116 (-16%)	272 (-6%)	118 (0%)
Increase of more than 1% (except H1)						
Decrease of more than 1%						

Notes:

1. *Increases to category H1 (generally safe) are caused by reductions in H2-H6*

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Table 4 shows the number of buildings (split by commercial, open space, rural and residential) within each hazard classification for the post construction model scenarios. The change (increase/decrease) from the pre-development model is shown in parentheses. It should be noted that this table only shows the net change to the totals, it does not completely capture all changes. For example, if one building goes from H3 to H4 and another goes from H4 to H3, then no change will be identified as the net change is zero. More detailed tables which identify the change to hazard classifications are presented in Appendix F. Table 4 shows:

- **Commercial buildings:** Decreases across all events with and without climate change. These decreases are largely associated with buildings on Pan Pac and the substation which in the post development event, are protected from flooding.
- **Rural:** Generally decreases over most hazard categorisations. Some increases for individual events over the H1, H2, H3 and H4 classifications.
- **Open Space:** Minimal changes across all events modelled. Much of the LC3 land is categorised as open space.
- **Residential:** No changes for the H6 categorisation, decreases across the H1, H4 and H5 categorisations. Generally, decreases for H2 and H3 events although the 50-year sees a slight increase.

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Table 4: Post construction hazard classifications for buildings with change from pre in parentheses

Commercial						
Event	H1	H2	H3	H4	H5	H6
50YR_NOCC	0 (-28)	0 (-24)	0 (-4)	0	0	0
50YR_RCP8pt5_2074	0 (-26)	0 (-27)	0 (-7)	0	0	0
100YR_NOCC	0 (-26)	0 (-24)	0 (-10)	0	0	0
100YR_RCP8pt5_2074	0 (-10)	0 (-19)	0 (-36)	0	0	0
500YR_NOCC	0 (-1)	0 (-3)	0 (-27)	0 (-36)	0 (-1)	0
500YR_RCP8pt5_2074	0 (-1)	0 (-2)	0 (-9)	0 (-30)	0 (-34)	0
CGB_2023_NOCC	0 (-2)	0 (-3)	0 (-54)	0 (-7)	0 (-1)	0
Rural						
Event	H1	H2	H3	H4	H5	H6
50YR_NOCC	44	27	44 (-2)	17	11	0

Table 4: Post construction hazard classifications for buildings with change from pre in parentheses

50YR_RCP8pt5_2074	35 (+1)	25	60	32 (-2)	21	0
100YR_NOCC	39 (-1)	25 (+1)	61	33 (-2)	21	0
100YR_RCP8pt5_2074	60	42 (+1)	89 (-1)	40 (-2)	38	1
500YR_NOCC	65 (-2)	74 (+3)	147 (+1)	60 (-1)	62 (-2)	6
500YR_RCP8pt5_2074	49 (+2)	48	163 (-2)	93 (+3)	86 (-2)	10
CGB_2023_NOCC	86 (-6)	71 (-5)	116 (-1)	56	54 (-2)	3
Open Space						
	H1	H2	H3	H4	H5	H6
50YR_NOCC	1	0	0	1	0	0
50YR_RCP8pt5_2074	1	0	0	0	1	0
100YR_NOCC	1	0	0	0	1	0
100YR_RCP8pt5_2074	0	1	0	0	1	0
500YR_NOCC	0	2	8	0	1	0
500YR_RCP8pt5_2074	0	0	10	0	0	1
CGB_2023_NOCC	1	1 (-1)	8 (+1)	0	1	0
Residential						
	H1	H2	H3	H4	H5	H6
50YR_NOCC	9 (-1)	10 (+1)	5	0	0	0
50YR_RCP8pt5_2074	19 (-6)	11 (-4)	22 (+1)	0	0	0
100YR_NOCC	23 (-5)	10 (-5)	25	0	0	0
100YR_RCP8pt5_2074	36 (-8)	20 (-2)	33 (-11)	2	0	0
500YR_NOCC	96 (-10)	72 (-4)	81 (-10)	7 (-8)	0	0
500YR_RCP8pt5_2074	86 (-31)	75 (-8)	129 (-31)	18 (-9)	7 (-2)	0
CGB_2023_NOCC	95 (-8)	67 (-8)	47 (-16)	3 (-2)	0	0
Increase of more than 1%						
Decrease of more than 1%						

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Table 5 shows the hazard area classification for the post developed events with the change in area (from the pre-development event) in parentheses. More detailed tables which identify the change to hazard classifications are presented in Appendix F. The table defines the areas by categorisation, residential and commercial, rural and open space and the Land Categorisation Three zone. Most increases (greater than 1%) in this table are in the residential and commercial categories (H5 and H6).

Given that one of the primary purposes of this project is protection of residential and commercial areas, these apparent anomalies were further investigated through detailed inspection of the model results and zonings. This showed that these increases are primarily because part of the Whirinaki Drain appears to have a commercial zoning.

The effect of the stopbank is to increase the hazard classification for this drain which results in an increase in the hazard classifications (H5 and H6) for commercial areas. There are large reductions to the H2, H3 and H4 ratings which are reflected in the hazard maps (Appendix B) and Table 5 below.

Table 5: Hazard area (ha) classification for the post construction model (change from pre model in parentheses)

Residential + Commercial						
Modelled event	**H1[1]**	**H2**	**H3**	**H4**	**H5**	**H6**
50YR_NOCC	1.72 (-22.10)	0.82 (-8.03)	1.79 (-5.42)	0.75 (+0.15)	0.97 (+0.14)	0.02 (+0.01)
50YR_RCP8pt5_2074	1.84 (-19.36)	1.30 (-10.76)	2.79 (-9.48)	0.94 (+0.19)	1.24 (+0.26)	0.03 (+0.01)
100YR_NOCC	1.96 (-18.46)	1.28 (-11.59)	2.90 (-10.03)	0.95 (+0.17)	1.27 (+0.28)	0.03 (+0.01)
100YR_RCP8pt5_2074	2.78 (-9.75)	1.56 (-9.64)	3.69 (-25.71)	1.16 (-1.07)	1.56 (+0.36)	0.04 (+0.02)
500YR_NOCC	7.56 (-4.34)	5.48 (-2.49)	6.37 (-18.36)	1.81 (-26.17)	2.05 (-0.32)	0.12 (+0.06)
500YR_RCP8pt5_2074	7.02 (-4.01)	5.28 (-2.39)	9.75 (-6.76)	2.51 (-23.79)	2.73 (-21.17)	0.26 (+0.14)
CGB_2023_NOCC	7.55 (-5.17)	5.04 (-3.42)	4.36 (-32.39)	1.42 (-9.43)	1.87 (+0.45)	0.08 (+0.05)
Rural + Open Space						
Modelled event	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**
50YR_NOCC	112.74 (-7.52)	64.73 (-2.21)	108.44 (-24.37)	61.78 (+0.12)	99.94 (+0.04)	59.04 (+0.06)
50YR_RCP8pt5_2074	94.49 (-12.08)	68.39 (-5.68)	115.95 (-10.45)	85.50 (-19.79)	144.54 (+0.20)	67.64 (+0.15)
100YR_NOCC	95.14 (-10.25)	67.57 (-5.98)	116.64 (-10.62)	87.51 (-20.60)	149.82 (+0.27)	68.95 (+0.18)
100YR_RCP8pt5_2074	124.80 (-3.22)	77.94 (-4.66)	156.63 (-14.06)	96.48 (-25.75)	209.60 (+1.24)	86.34 (+0.37)
500YR_NOCC	123.90 (-0.30)	120.12 (-2.00)	215.71 (-4.88)	133.77 (-3.09)	281.21 (-26.87)	122.62 (+0.32)
500YR_RCP8pt5_2074	84.52 (-1.37)	84.98 (-1.10)	220.06 (-1.78)	141.49 (-2.53)	343.75 (-32.12)	164.05 (+0.48)
CGB_2023_NOCC	156.47 (-0.20)	121.25 (-1.94)	197.57 (-12.62)	112.92 (-12.66)	259.30 (-18.90)	107.96 (+0.52)

Table 5: Hazard area (ha) classification for the post construction model (change from pre model in parentheses)

Residential + Commercial						
LC3 Zone						
Modelled event	H1	H2	H3	H4	H5	H6
50YR_NOCC	96.61 (-2.38)	50.20 (+0.04)	85.24 (+1.28)	52.27 (+0.14)	79.73 (+0.03)	43.23 (+0.04)
50YR_RCP8pt5_2074	79.96 (-7.20)	56.13 (-3.43)	89.35 (-0.69)	70.71 (+0.55)	121.03 (+0.19)	50.12 (+0.11)
100YR_NOCC	77.42 (-6.66)	55.46 (-3.81)	89.95 (-1.22)	72.21 (+0.50)	125.78 (+0.24)	51.28 (+0.14)
100YR_RCP8pt5_2074	50.90 (-3.23)	44.69 (-2.97)	87.65 (-12.12)	74.10 (+0.17)	180.27 (+1.27)	67.01 (+0.29)
500YR_NOCC	19.13 (+0.67)	29.09 (-0.69)	69.68 (+0.22)	85.04 (+0.47)	237.24 (-1.79)	100.96 (+0.27)
500YR_RCP8pt5_2074	4.76 (-0.16)	10.19 (-0.29)	35.50 (-1.10)	72.91 (+1.11)	281.87 (-0.69)	140.17 (+0.35)
CGB_2023_NOCC	31.89 (+1.68)	36.29 (-1.33)	74.06 (-9.11)	73.99 (-5.78)	221.89 (+1.62)	86.93 (+0.37)

6.2 Flood levels and flood depths

Effects on flood depths have been assessed for the 100-year event. These effects are presented in Figure A7, Appendix A. Figure A7 shows:

- The greatest flood level increases are adjacent to the proposed stopbank with increases dissipating with distance from the stopbank;
- There are some increases in flooding for localised areas within Bayview. Further interrogation of the model results shows that these are localised depression areas which fill up over time. The current model only considers flooding from the Esk River and Whirinaki Drain, it does not consider localised rainfall on Bayview and the hill catchments surrounding Bayview. If this source of water was also included, these depressions would fill and the effects of flooding would be less; and,
- Building footprints with flood increases of greater than 50 mm are all located in the Esk Valley, north of SH2. This area of land has been categorised as LC3 as seen in Figure 3.

Detailed flood levels over time have been extracted at six locations (Figure 4). These flood levels are presented in Figure 5.

Figure 5 shows:

- **Esk River @ SH2,** flood depths are unchanged with no difference pre and post building of the proposed stopbank and associated infrastructure. This shows the model and infrastructure at this location are not sensitive to the proposed works;
- **Whirinaki Drain @ Coast**, Maximum flood depths are unchanged and flood depths generally are largely unchanged across all events modelled with the exception of a 200 mm increase in flood level on the rising limb for the 500-year event. These results indicate that water levels in this location are primarily controlled by tidal levels and we do not consider them sensitive to the implementation of the proposed works;
- **Whirinaki Drain @ SH2**, there are increases in the peak flood depths of up to 150 mm for the 500-year event (with climate change), reducing to 50 mm for the 100-year event (with climate change) and 50 mm for the 50-year event (with climate change). This increase is due to the constraining of the floodway by the stopbanks. These increases are entirely within a major drain designed for floodwater conveyance;
- **Upper Whirinaki Drain**, peak flood depths are very similar to the above and the same comments apply; and,

- **Esk River @ Taits Road and Thurley Place @ Railway Crossing**, peak flood depths for both locations are largely unchanged with no difference pre and post building of the proposed stopbank and associated infrastructure. This shows the model and infrastructure at this location are not sensitive to the proposed works.

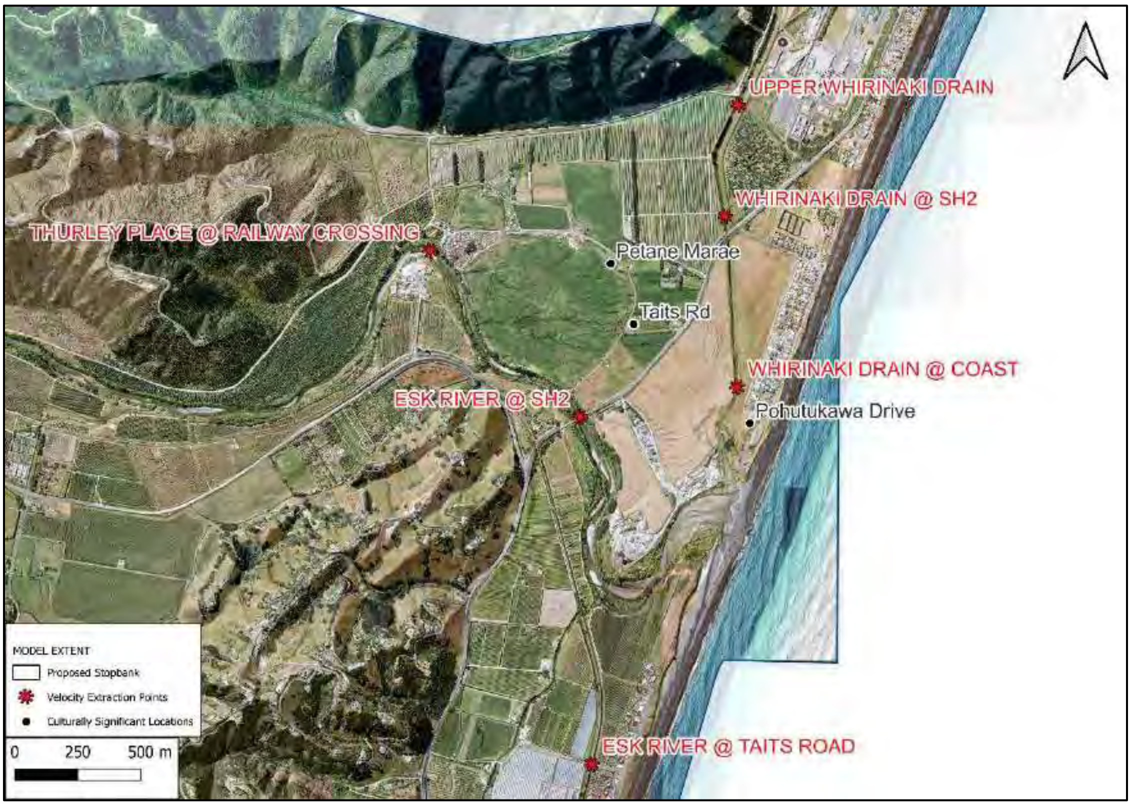

Figure 4: Locations at which flood velocities and levels have been extracted

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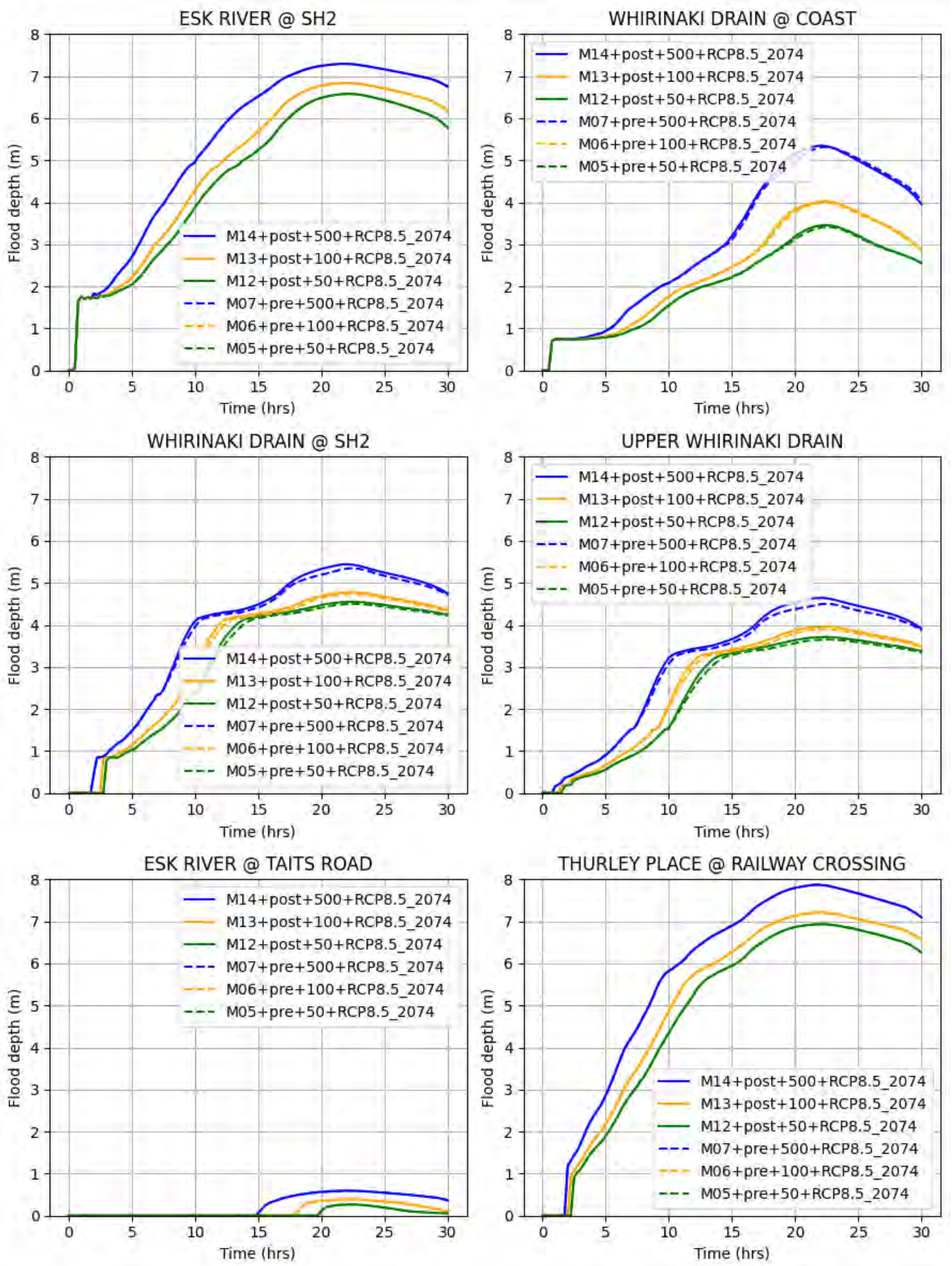

Figure 5: Flood levels at various locations for modelled events. See Figure 4 for locations of extraction points

6.3 Flood hazard

The proposed stopbank diverts flood flows and potentially effects the flood hazard. Assessments of flood hazard should identify potential consequences which include:

- Affected buildings;
- Critical buildings;
- Lifeline utilities and the population serviced by them; and,
- Buildings with social or cultural significance.

Given that risk is a product of consequence and likelihood, and the event likelihood is fixed, if the consequences do not increase as a result of the proposed stopbank, then the risk will not increase. To determine the change in consequences, flood hazard has been defined using the Australian Rainfall and Runoff Guidelines (2019) (Section 5.0).

The following methodology has been implemented to determine the flood hazard and changes in flood hazard for buildings.

- Calculate the flood hazard for the event (as per the hazard curves in Figure 2);
- Defined the building footprints as per the LINZ Building Outlines (Layer ID 101292);
- Take the maximum flood hazard classification contained within each building footprint for the pre and post development events; and,
- Compare the changes.

It is worth noting the following limitations with this approach:

- All buildings are considered, not just habitable dwellings. Whilst buildings that were not habitable dwellings could have been removed from this analysis. This would be a judgement call and therefore all buildings were left in;
- Floor levels are not included in this hazard assessment which could reduce the hazard classification of the building;
- The flood depths and velocities can change substantially within a single risk category and there will be no change in hazard classification. Conversely, a property or building that sits on the boundary of two risk categories can see a change in hazard classification from a relatively small change in depth and/or velocity; and,
- The maximum hazard value that intersects the building footprint is taken as the hazard value for the entire footprint. This is likely conservative, particularly in locations where the footprint may intersect a relatively small high hazard area.

Whilst there are some limitations with the approach, the key purpose of the model is to determine changes in the hazard classification as a result of the proposed stopbank rather than an absolute hazard classification for each building within the catchment. Therefore, the adopted approach is considered fit for purpose.

6.3.1 Buildings

Effects of flooding on buildings should primarily be assessed against the standard and level of protection they were constructed to with checks done for overdesign events to ensure the hazard is not significantly exacerbated.

There are several standards and codes for construction of buildings, many of which would not have been current at the time of construction.

New Zealand Building Code, Clause E1[5]. Clause E1.3.2 states that:

"Surface water, resulting from an event having a 2% probability of occurring annually, shall not enter buildings."

Given the age of many of the properties in the catchment, it is likely that the building code was the only relevant standard at the time of construction (and event this code may not have been in place).

NZS 4404, the Land Development and Subdivision Infrastructure standard recommends a freeboard of 500 mm above the 100-year event. This standard was issued in 2012 and may have been applied to some of the newer buildings within the study area.

We also evaluated the 500-year flood event. This is considered an extreme, or "overdesign," event in New Zealand, exceeding the standard level for which building freeboard and flood protection measures are normally implemented.

50-year event

Figures B2 and B3, Appendix B show the flood hazard (pre and post) for the 50-year event with and without climate change.

In the 50-year event, both with and without climate change, much of the flow is contained within the river and nearby floodplain with no significant flow over the existing Whirinaki Stopbank. Therefore, in the post construction model, the stopbank and proposed works do not divert significant volumes of floodwaters and there are minimal adverse (or beneficial?) effects on buildings.

For the 50-year event (without climate change):

- There are several decreases to the hazard classification for Pan Pac buildings and substation;
- There is one increase in hazard classification (H1 to H2) for a garage (3 Anthony Place, Bayview); and,

[5] https://www.building.govt.nz/assets/Uploads/building-code-compliance/e-moisture/e1-surface-water/asvm/e1-surface-water-1st-edition-amendment-12.pdf

- There are no increases in hazard classification for habitable dwellings anywhere within the modelled extent.

For the 50-year event (with climate change):

- There are several decreases to the hazard classification for Pan Pac buildings, substation and habitable dwellings on North Shore Road (Whirinaki);
- An increase in hazard classification (H2 to H3) over part of the property (at 15 Thurley Place); and,
- There are no other increases in hazard classification for buildings anywhere within the modelled extent.

100-year event

Figures B4 and B5, Appendix B show the flood hazard (pre and post) for the 100-year event with and without climate change.

In the 100-year event, both with and without climate change, similar to the 50-year event, there are limited effects due to minimal diversion of floodwater.

For the 100-year event (without climate change):

- There are several decreases to the hazard classification for Pan Pac buildings, substation and habitable dwellings on North Shore Road (Whirinaki);
- There are no increases in hazard classification for any buildings anywhere within the modelled extent.

For the 100-year event (with climate change):

- There are several decreases to the hazard classification for Pan Pac buildings, substation and habitable dwellings on North Shore Road (Whirinaki);
- There is an increase (H1 to H2) for a shed in 2 Bruce Place.
- There is an increase in hazard classification (H3 to H4) for a building at 1023 State Highway 2 which is within the LC3 area; and,
- There are no increases in hazard classification for habitable dwellings outside of LC3 anywhere within the modelled extent.

500-year event

Figures B6 and B7, Appendix B show the flood hazard (pre and post) for the 500-year event with and without climate change. The 500-year event is a significant over design event that exceeds the magnitude of Cyclone Gabrielle (a 180 to 220-year event, NIWA 2024). Therefore, some degree of effects is expected.

For the 500-year event (without climate change):

- There are several decreases to the hazard classification for Pan Pac buildings, substation;
- There is an increase in Hazard Classification (H2 to H3) for 39 Pohutukawa Drive;
- There is no change or a decrease in hazard classification for North Shore Road buildings;
- There is an increase in hazard classification (H4 to H5) for a building at 1023 State Highway 2 which is within the LC3 area; and,
- There is 1 house in Bayview (21 Sheehan Street) with an increase in Hazard Classification(H2 to H3);

For the 500-year event (with climate change):

- There are several decreases to the hazard classification for Pan Pac buildings, substation;
- There is an increase to flooding of habitable dwellings on North Shore Road and Pohutukawa Drive (Whirinaki) by up to 100mm. With an increase in Hazard classification for one residential dwelling (H4 to H5);
- There are no increases in hazard classification for habitable dwellings outside of LC3 anywhere within the modelled extent. There are some increases for non-habitable dwellings.
- Two residential buildings on Le Quesne Road Increasing in Hazard Classification (H2 to H3)

6.3.2 Sites of cultural significance

There are three sites of cultural significance (Figure 4) within the modelled area including two urupa (located near Taits Road and Pohutukawa Drive) and a marae (Petane). All three sites are located in the LC3 categorisation. Figure 6 shows temporal flood levels and hazard for each site. Figure 6 shows:

- The pre and post development flood levels are shown over three flood events, the 50-year, 100-year and 500-year all with climate change scenario RCP8.5 2074;

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- The increase in maximum flood level for each event;
- The range of terrain levels encompassed within the dwellings/urupa footprint; and,
- The temporal flood hazard classification.

Petane Marae, just north of SH2, Figure 6 shows:

- For the 50 and 100-year events with climate change the site generally has a hazard classification of H1 (generally safe) both with and without the proposed stopbank and no increase in flood levels; and,
- For the 500-year event with climate change the site has a hazard classification of H3 (unsafe for vehicles children and elderly) both with and without the proposed stopbank. The increase in flood level for this event is estimated at 17 mm and whilst there is no change in the maximum hazard classification (H3, unsafe for vehicles children and elderly), there is an increase in the temporal duration of this hazard classification meaning it is less safe for longer.

Taits Rd urupa is around 200 m south of the Petane Marae, Figure 6 shows:

- For the 100 and 50-year events with climate change the site generally has a hazard classification of H1 (generally safe) both with and without the proposed stopbank and no increase in flood levels; and,
- For the 500-year event with climate change the site is classified as H2 (unsafe for small vehicles) prior to the proposed works with an increase of flood levels of 36 mm after the proposed works with no change to hazard classification.

Pohutukawa Drive urupa adjacent to the Pohutukawa Drive residential area, Figure 6 shows no change in classification as a result of the proposed works across all events modelled (generally safe, H1).

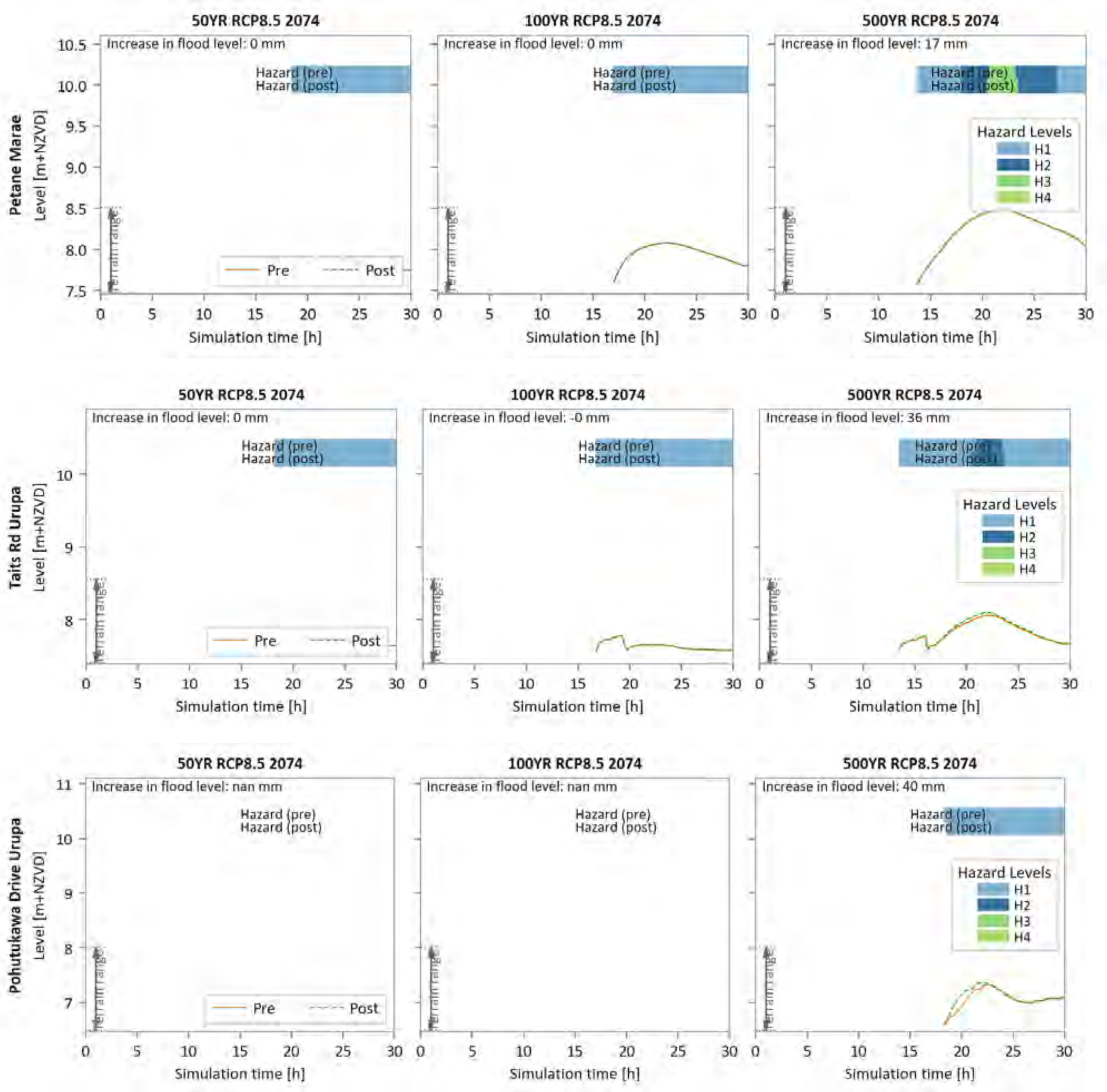

Figure 6: Flood levels and hazard at cultural locations for climate change modelled events. See Figure 3 for locations of extraction points. Note change in vertical elevation between plots

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6.3.3 LC3 Dwellings

Five LC3 dwellings have been identified as potentially impacted by the proposed works. The impacts are presented in Figure 7 to Figure 8 whilst the locations are presented in Figure 4.

76 Taits Road (Figure 7)

- For the 100 and 50-year events with climate change the dwelling generally has a hazard classification of H1 (generally safe) both with and without the proposed stopbank and no increase in flood levels; and,
- For the 500-year event, the expected increase in flood level is 6 mm. There is no change in the maximum hazard classification (H2, unsafe for small vehicles).

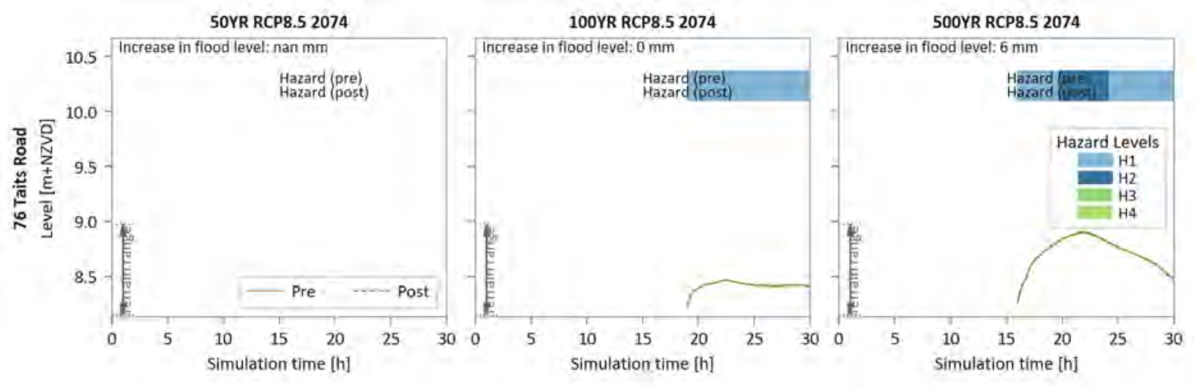

Figure 7: Flood levels and hazard at 76 Taits Road for climate change modelled events. See Figure 3 for location.

75 Taits Road (Figure 8)

- For the 100 and 50-year events with climate change the effects on the dwelling are similar to the above (76 Taits Road); and,

For the 500-year event, the expected flood level increase is 8 mm and will remain at hazard H3 (unsafe for vehicles children and elderly.

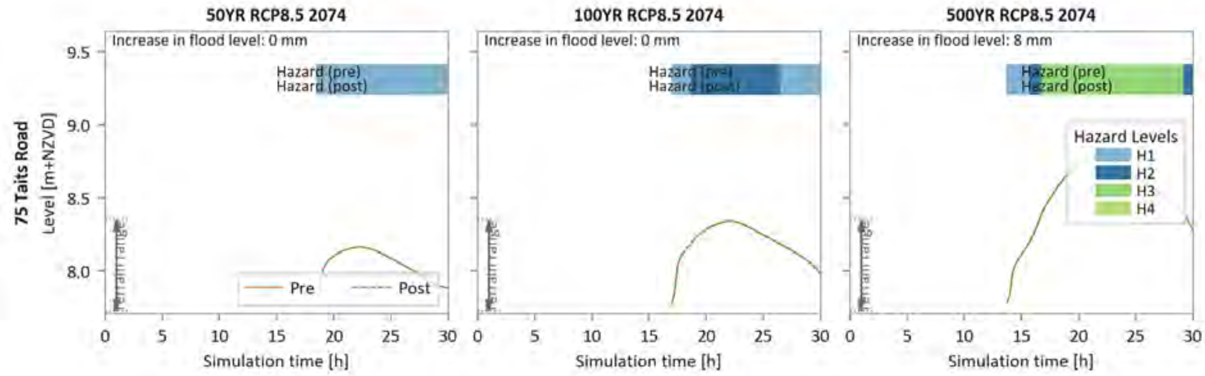

Figure 8: Flood levels and hazard at 75 Taits Road for climate change modelled events. See Figure 3 for location.

77 Taits Road (Figure 9)

- For the 100 and 50-year events with climate change the effects on the dwelling are similar to the above (76 Taits Road); and,
- For the 500-year event, the expected increase in flood level is 22 mm. There is no change in the maximum hazard classification (H2, unsafe for small vehicles) and no change to the duration of the H2 classification.

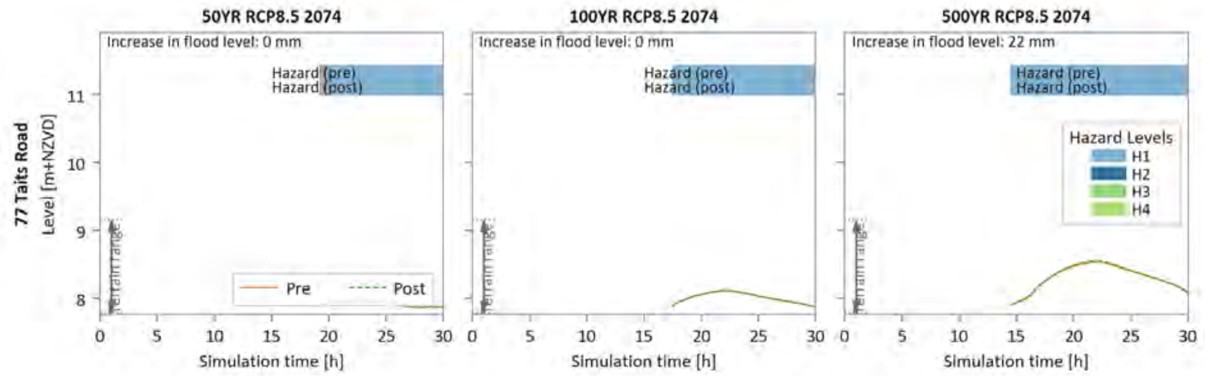

Figure 9: Flood levels and hazard at 77 Taits Road for climate change modelled events. See Figure 4 for location.

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79 Taits Road (Figure 10)

- For the 100 and 50-year events with climate change the effects on the dwelling are similar to the above (76 Taits Road); and,
- For the 500-year event, the expected increase in flood level is 2 mm. There is no change in the maximum hazard classification (H2, unsafe for small vehicles) however the duration of the H2 classification is extended.

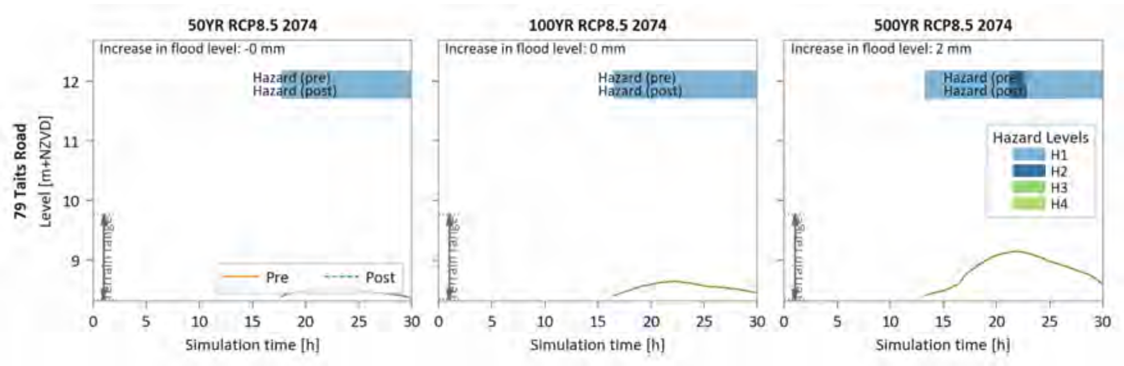

Figure 10: Flood levels and hazard at 79 Taits Road for climate change modelled events. See Figure 3 for location.

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1023 SH2 (Figure 11)

- For the 50-year event, the expected increase in flood level is 22 mm and the hazard classification is expected to remain at H1 (generally safe);
- For the 100-year event, the expected increase in flood level is 42 mm and the hazard classification is expected to remain at H2 (generally safe) with a slightly longer duration and,
- For the 500-year event, the expected increase in flood level is 86 mm and the hazard classification is expected to remain at H3 (unsafe for vehicles children and the elderly) with a slightly longer duration.

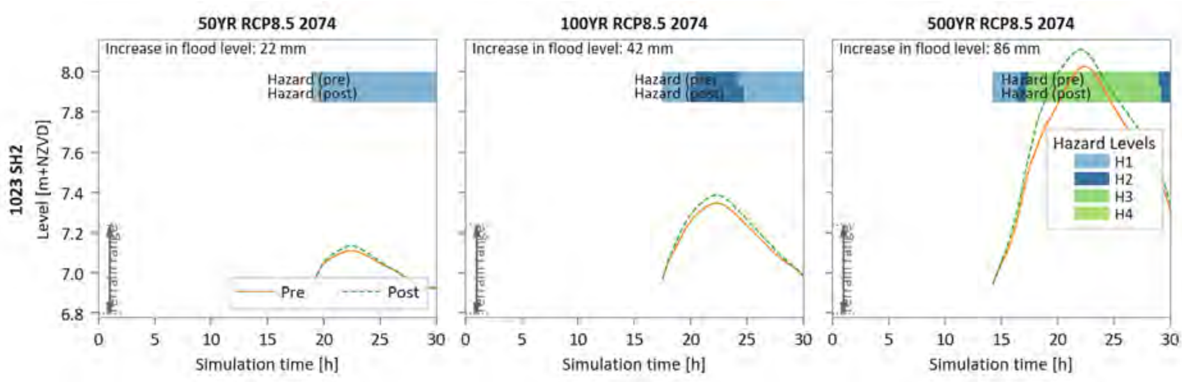

Figure 11: Flood levels and hazard at 1023 SH2 for climate change modelled events. See Figure 3 for location.

6.3.4 Lifeline utilities, State Highway 2, Rail and Substation

The effects on lifeline utilities are considered for the 500-year event. The operational status of State Highway 2 depends on the highest hazard classification present along the road. This stretch of SH2 is classified as H5 (buildings vulnerable to structural damage), a classification that remains constant regardless of the stopbank's status. Therefore, this event does not alter the road's operational status for the 500-year event.

Similarly, for the rail line and SH5, there is no change to the hazard classification.

For the substation, the hazard categorisation without the proposed stopbank is generally H3 (unsafe for vehicles children and elderly) and H4 (unsafe for people and vehicles). The hazard classification with the proposed stopbank decreases to H1 (generally safe).

6.3.5 Horticultural land

The effects on horticultural land are considered for the 100-year event with climate change. Figure A7 shows the 100-year flood level difference, this figure shows maximum depth increases of between 50 and 100 mm for an orchard (approximately 30 ha) adjacent to Whirinaki Drain (Figure 3). Elsewhere within the Esk Valley, effects are less than 10 mm, and the focus of this section is subsequently on the 30ha orchard block.

Figure B5 shows the flood hazard (pre and post) for the 100-year event with climate change. The maximum flood hazard within the orchard is H4 (unsafe for people and vehicles) both with and without the proposed stopbank with minimal change in the extent of the hazard. In summary:

- Limited Additional Depth Increase: The maximum depth increase within the orchard is less than 100 mm. However, existing flood depths in the area already range from 500 to 1500 mm;
- Land Use Context: This is an orchard, and it's highly unlikely that people or vehicles would be present during a significant flood event; and,
- Damage Factors: Damage to the orchard is more likely to result from debris and sediment carried by floodwaters rather than solely flood depths. In both scenarios (with and without the stopbank) velocities and depths are high enough to carry significant sediment and debris loads.

6.4 Flood velocities

Flood velocities have been extracted at six locations (Figure 4). These flood velocities are presented in Figure 7. Changes in flood velocities, coupled with flood depths, have the potential to increase scour and erosion.

Figure 7 shows:

- **Esk River @ SH2,** velocities are largely unchanged with no difference pre and post building of the proposed stopbank and associated infrastructure.
- **Whirinaki Drain @ Coast**, peak flow velocities are largely unchanged across all events modelled. There are some changes to the velocity profile over time although these are minimal and would not be expected to alter the scour/erosion potential of the flow;
- **Whirinaki Drain @ SH2**, there are increases in both the peak velocity and the velocity profile over time. However, both pre and post stopbank velocities are less than 0.8 m/s which is a relatively low velocity and unlikely to exacerbate scour or erosion. The increase in velocity is a result of higher headwater conditions due to the constriction of the overland flow;
- **Upper Whirinaki Drain**, there are only some increases (0.2 m/s) to the peak velocities and although these peaks are sustained for a longer period of time, up to five hours rather than one hour. The peak velocities, both pre and post construction, are less than 0.8 m/s which is a relatively low velocity and unlikely to exacerbate scour or erosion; and,
- **Esk River @ Taits Road and Thurley Place @ Railway Crossing**, peak flood velocities for both locations are largely unchanged with no difference pre and post building of the proposed stopbank and associated infrastructure. This shows the model and infrastructure at this location are not sensitive to the proposed works.

In conclusion, whilst there are some changes to the peak velocities and velocity profiles, at the locations interrogated, these changes would be unlikely to exacerbate or cause further scour and erosion, over and above what is already experienced in an extreme event.

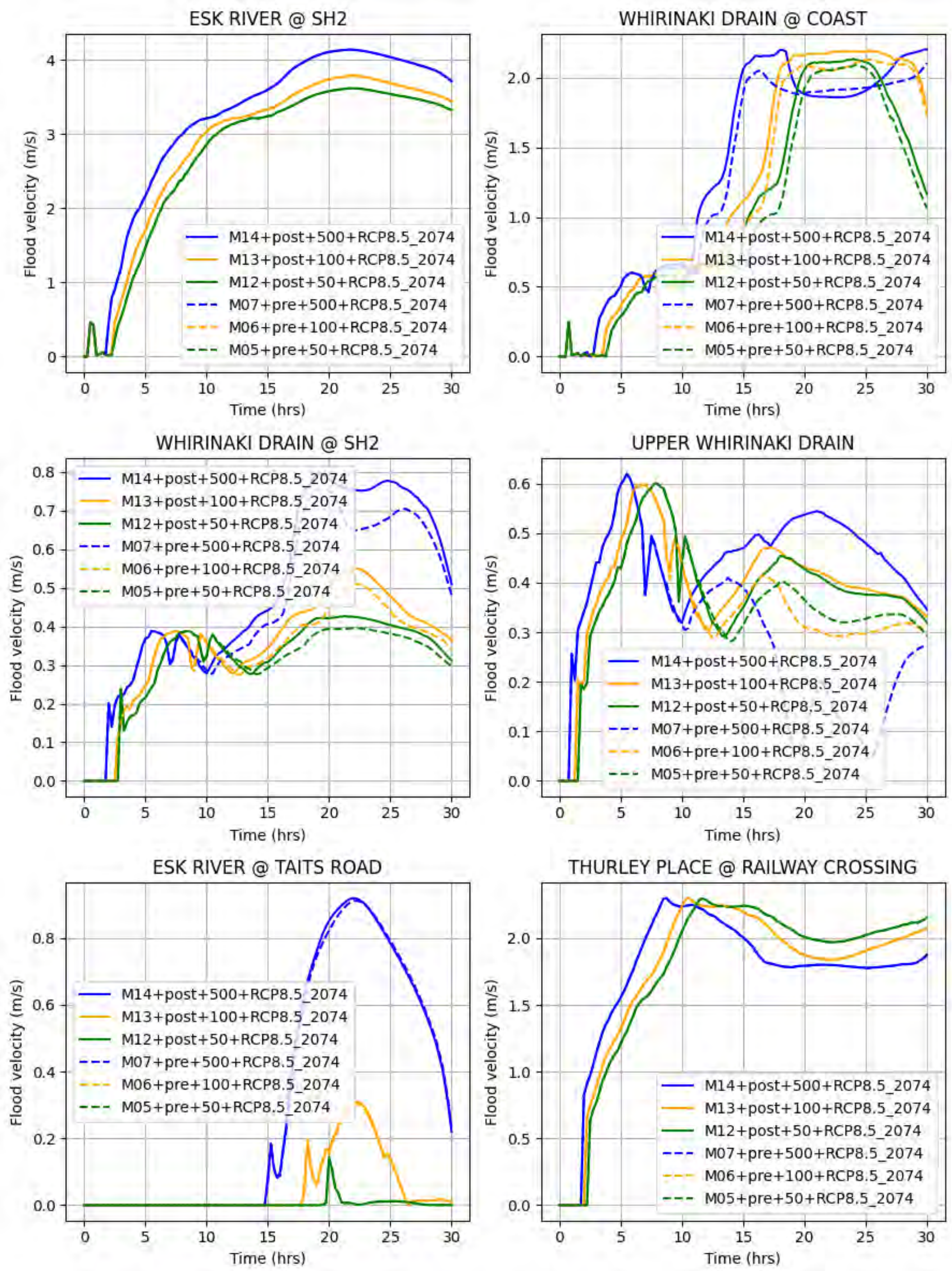

Figure 12: Flood velocities at various locations for modelled events See Figure 4 for locations of extraction points

7.0 Effects of temporary works on flooding

As part of the proposed works, there are some temporary activities for which consent is sought which could impact the effects on flooding.

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7.1 Construction of Stopbank and SH2 upgrade

The proposed stopbank construction may extend over two seasons. In such a scenario, the 500-year stopbank would likely be prioritised for construction, with the 100-year stopbank to follow next season. To evaluate the implications of this phased approach, the 500-year flood event, incorporating climate change projections, was assessed without the 100-year stopbank in situ. This model demonstrated that the exclusion of the 100-year stopbank generally results in reduced flood levels compared to its full implementation.

For flood events less than the 50-year event, the impact will be minimal as the 500-year stopbank does not displace any significant amounts of water. Between the 50 and 500-year events. The effects are expected to be less than those predicted for the 500-year event. Given the probability of getting a 50-year event or larger over the two construction seasons is low – the risk of a slightly exacerbated flood effect is considered acceptable.

8.0 Conclusions

We have assessed the effects on flooding for a suite of proposed construction works consisting of Whirinaki Stopbank and SH2 improvements. The proposed construction works provide a substantial level of protection (up to the 500-year event with climate change) for regionally significant infrastructure, including the Whirinaki Sub-station and Pan Pac plant. Flood protection is also provided for the currently zoned LC2c Pohutukawa Drive residential homes and several houses on North Shore Road and Whirinaki Road in events up to the 100-year. In conclusion, the proposed works:

- Significant Flood Reduction: reduce flooded areas and buildings by approximately 7% and at least 12%, respectively.
- Improved Flood Hazard Classification: The works generally decrease higher flood hazard classifications, with most buildings experiencing a decrease in hazard.
- Minimal Impact on Habitable Dwellings Outside LC3: No increases in hazard are expected for habitable dwellings outside the LC3 zone. Even within the LC3 zone, the quantifiable effects are constrained to 1 dwelling, 1023 SH2. On this dwelling, there is no change in the hazard classification although flood levels in the 50-year event (with climate change) are expected to increase by 20 mm whilst in the 500-year event, they are expected to increase by 80 mm.
- Limited Impact on Cultural Sites: The proposed works have minimal impact on cultural sites and provide protection for the Pohutukawa Drive urupa.

- Protected Lifeline Utilities: No changes in hazard are expected for key infrastructure; the substation's is fully protected up to a 500-year event with climate change.
- Manageable Impact on Horticultural Land: Impacts on the orchard are considered manageable given existing conditions and land use.
- Minimal Changes in Flood Velocities: Flood velocities are generally unchanged, with localised increases not expected to significantly increase scour.
- Manageable Temporary Construction Impacts: Temporary construction risks are low due to the low probability of a major flood during the construction period.
- Overall Positive Outcome: The works provide significant flood protection with limited adverse impacts.

9.0 References

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Smith, G. P., Davey, E. K., & Cox, R. J. (2014). *Flood Hazard* (WRL Technical Report 2014/07). University of New South Wales.

Appendix A: Figures

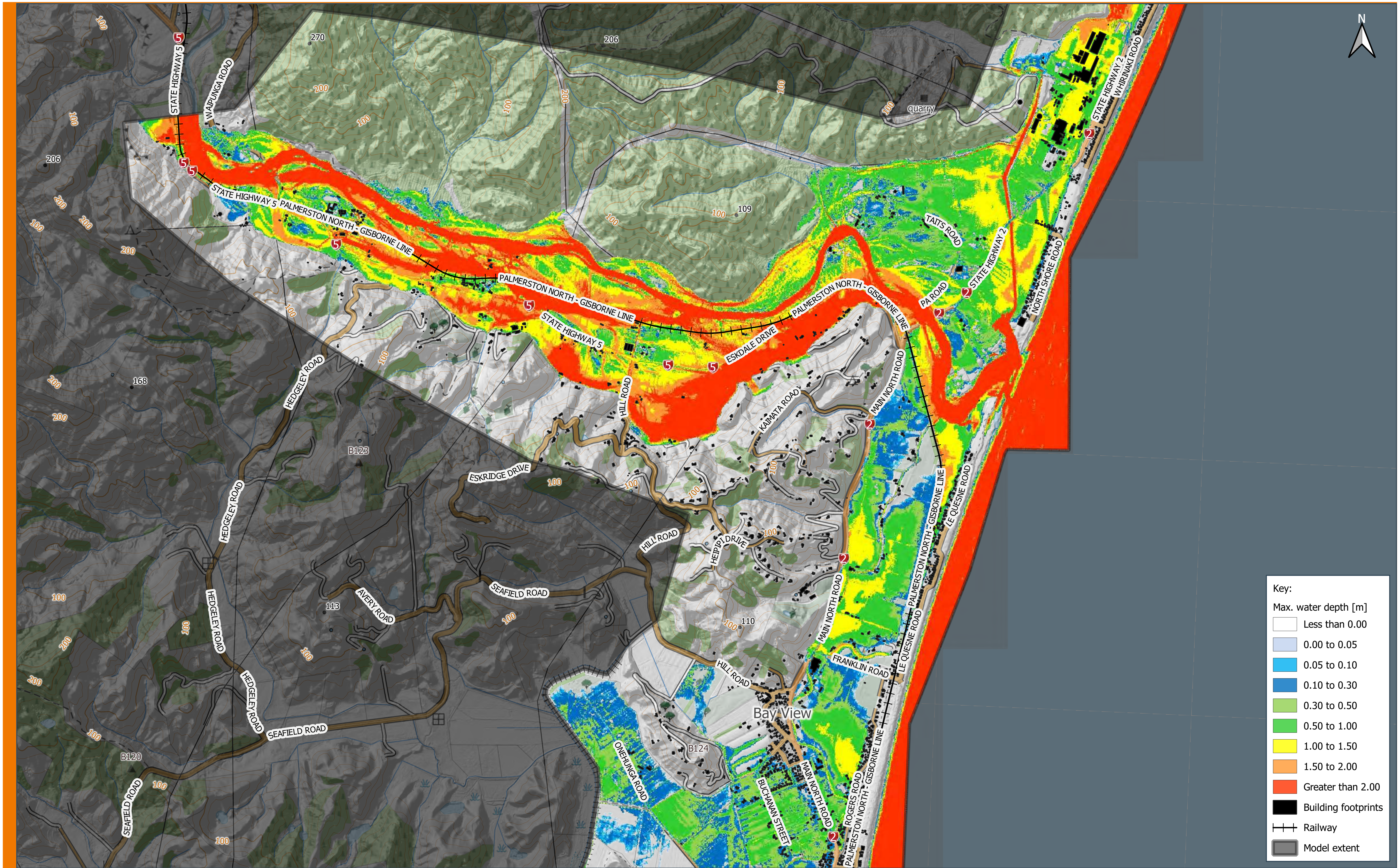


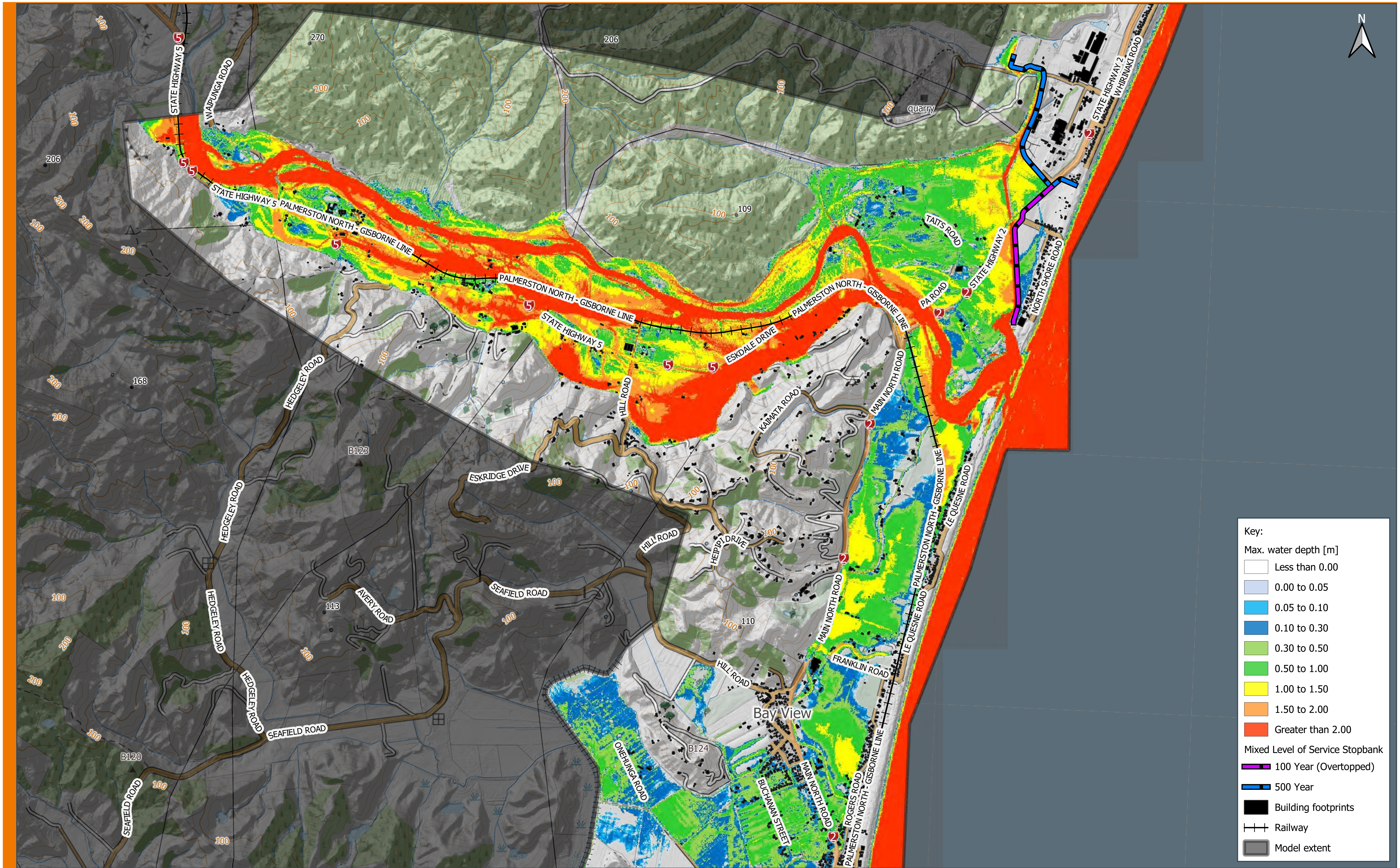
Figure A1, Existing flood depths, Cyclone Gabrielle. The model simulates flows exclusively from the Esk River and does not incorporate localised rainfall.

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

REVISION: 01 | DATE: 27 Jun 2025 | BY: TC
CLIENT: HBRC



pdp

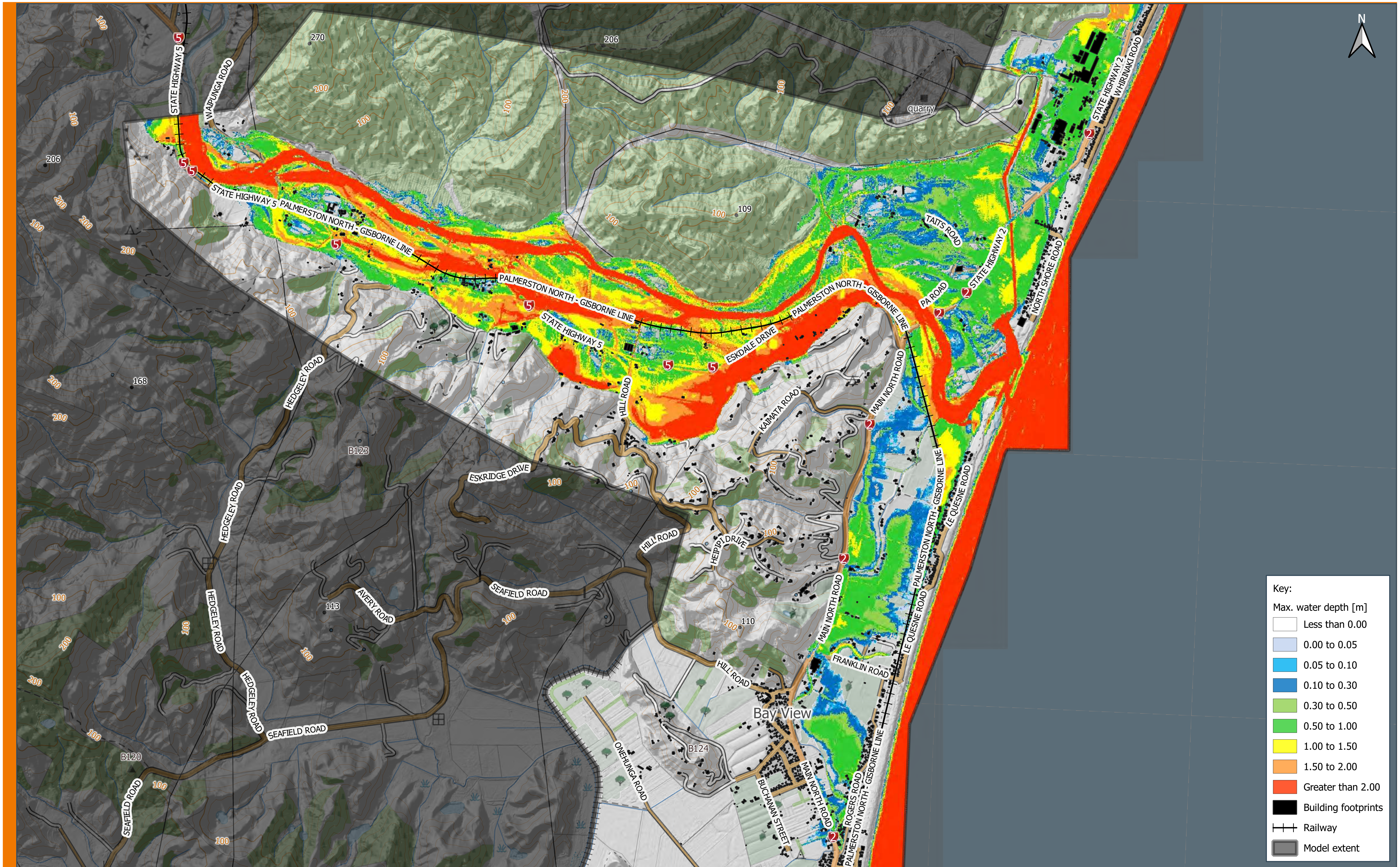
Figure A2, Post construction flood depths, Cyclone Gabrielle. The model simulates flows exclusively from the Esk River and does not incorporate localised rainfall.

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

REVISION: 01 | DATE: 27 Jun 2025 | BY: TC
CLIENT: HBRC



pdp

Figure A3, Existing flood depths (100-year ARI, with climate change)

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

REVISION: 01 | DATE: 27 Jun 2025 | BY: TC
CLIENT: HBRC

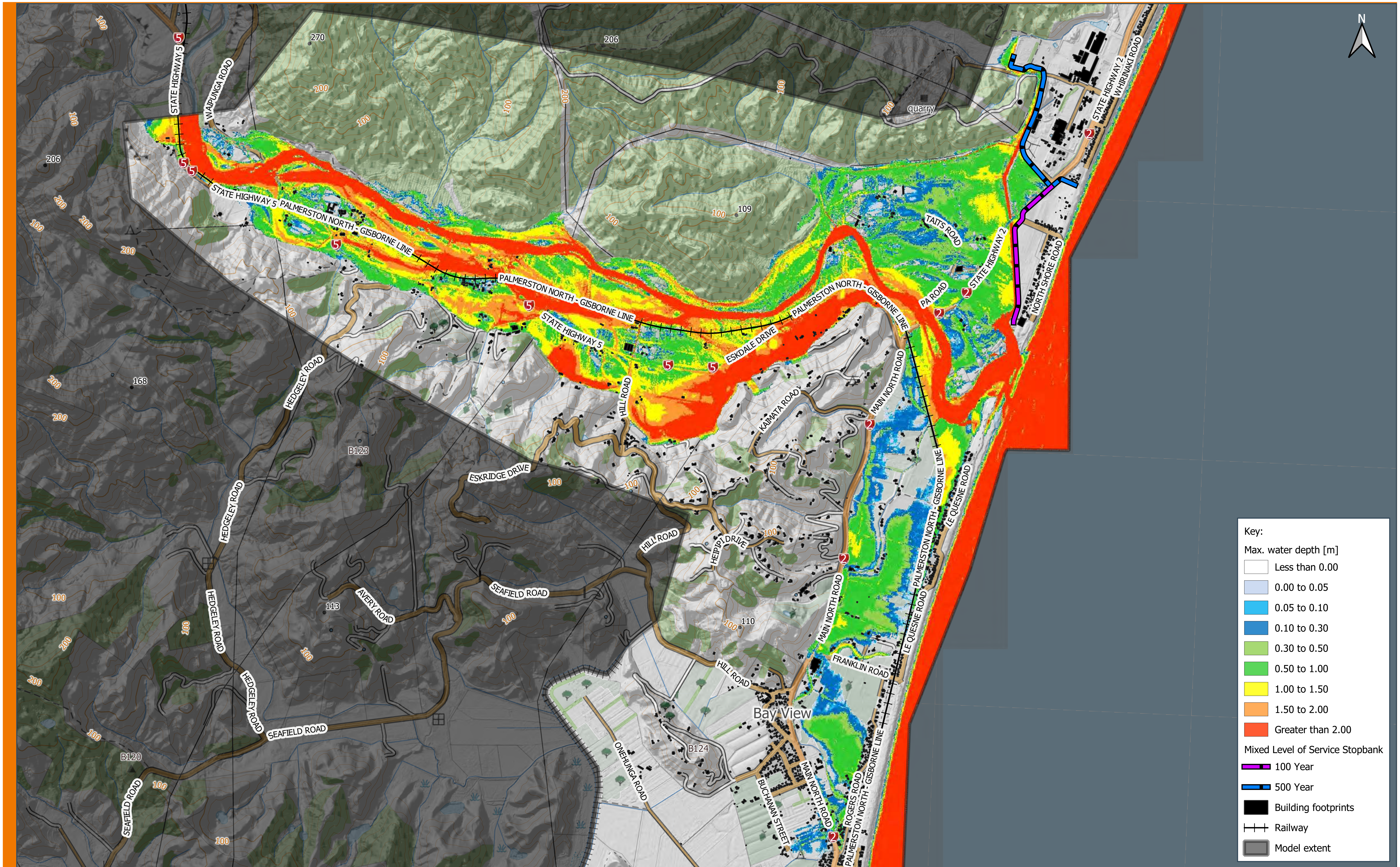


Figure A4, Post construction flood depths (100-year ARI, with climate change)

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

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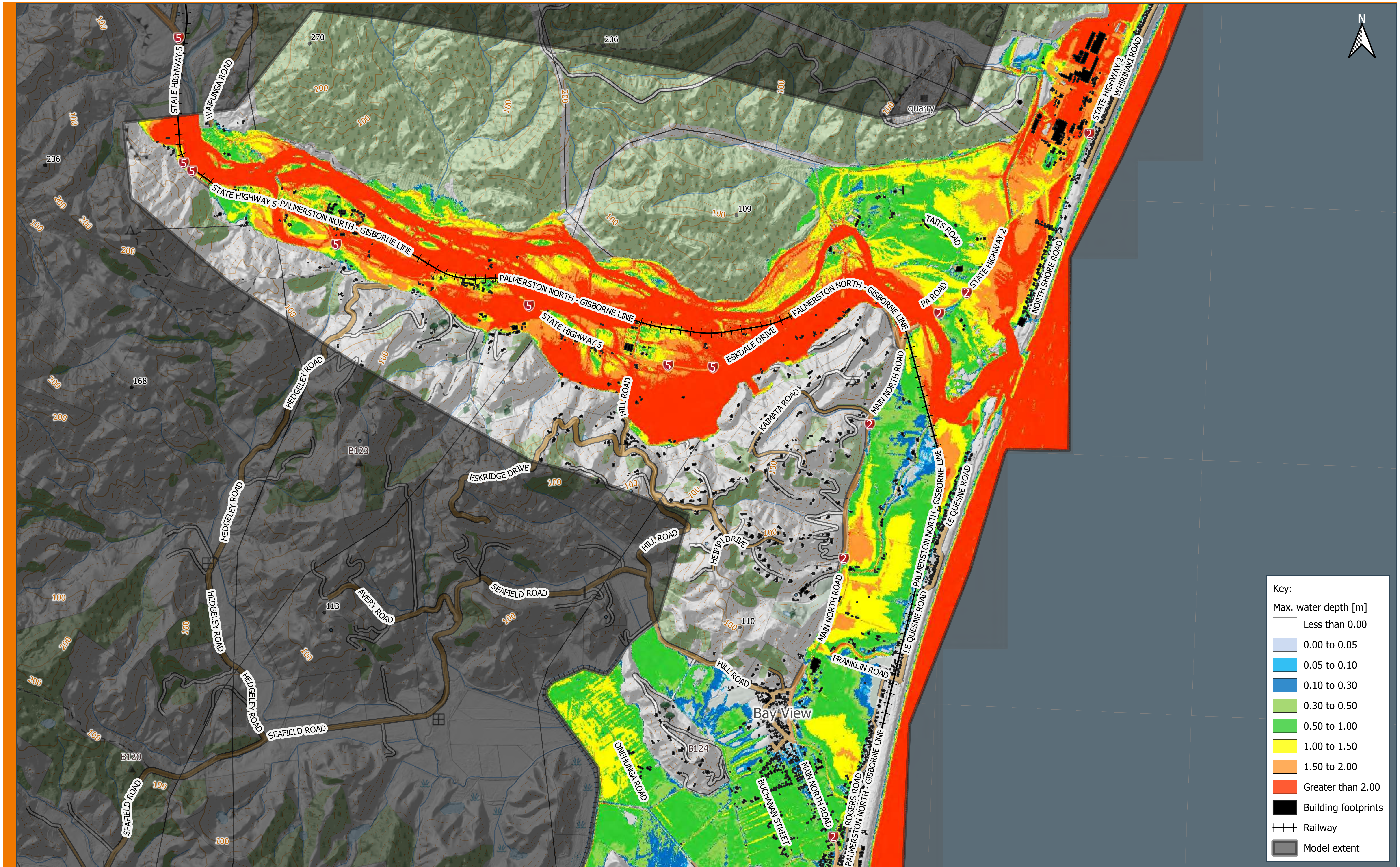

Figure A5, Existing flood depths, (500-year ARI, with climate change)

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

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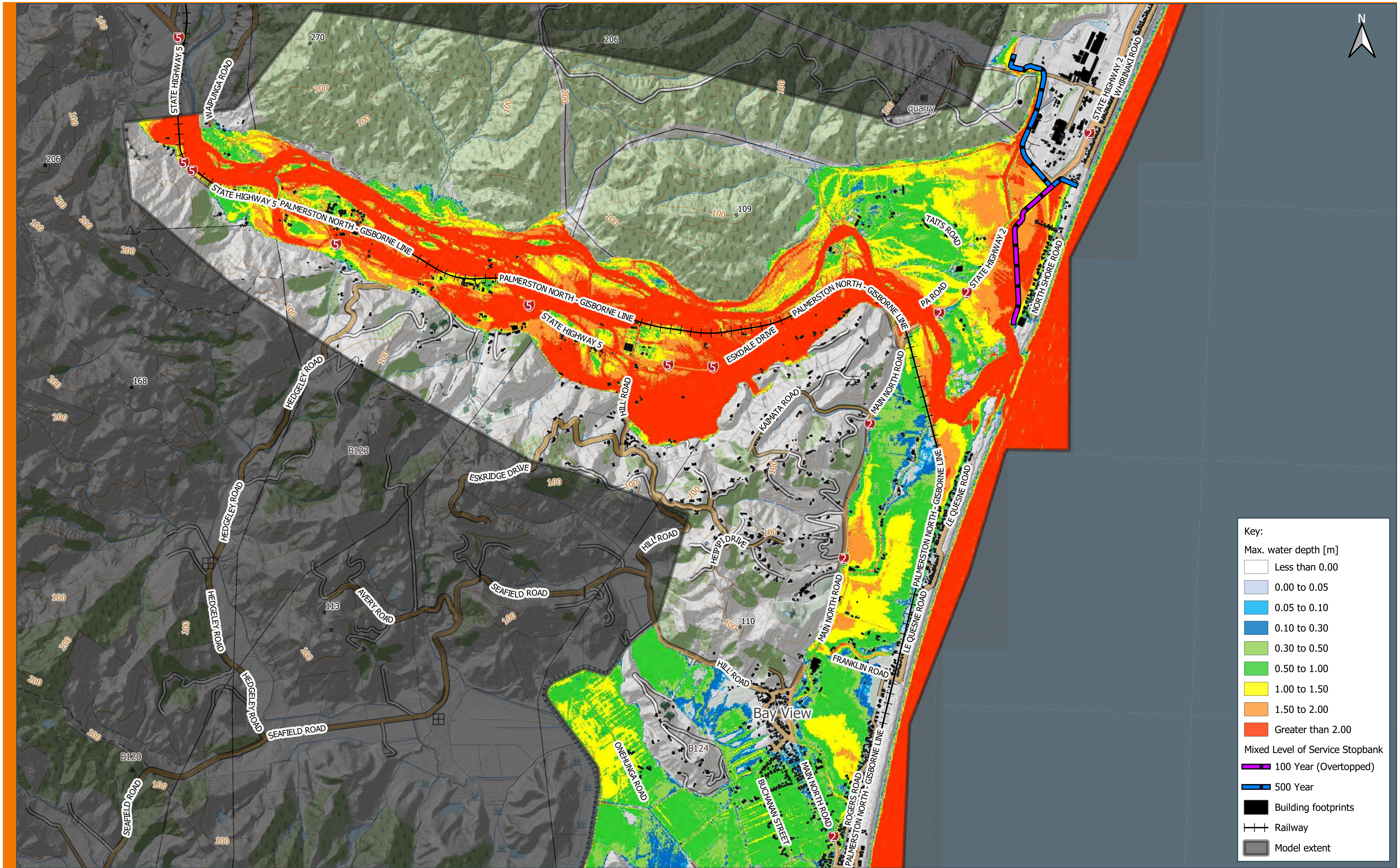

Figure A6, Post construction flood depths, 500-year ARI, with climate change

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

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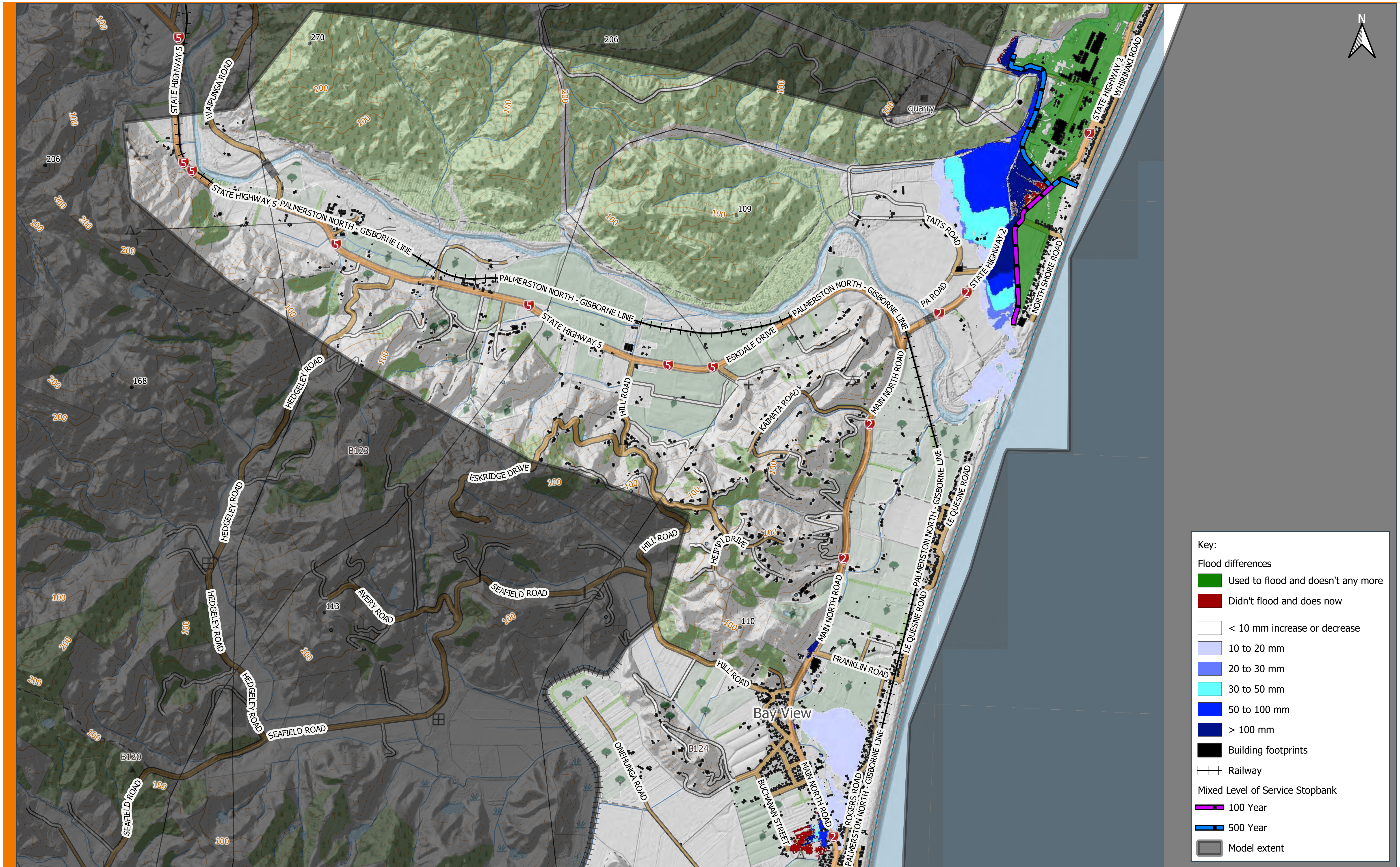

Figure A7, flood difference (post construction - existing) 100-year ARI, with climate change. Increases less than 10 mm are transparent

Esk Valley Hydraulic Model: Flood effects assessment

NOTES:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE [https://data.linz.govt.nz] AND LICENCED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

SCALE : 1:25,000 (A3)

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Appendix B: Flood Hazard Figures