Addendum to Short List Options Flood Modelling Report

To	Wairoa Flood Protection - Project Group
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Subject	Addendum to Short List Options Modelling Report

This is an addendum to the Short List Options Flood Modelling Report (WSP, Jan 2024). The addendum covers two matters as follows:

1. The modelling of a new Option (Option1 C);
2. Model changes following peer review by DHI.

1 Option 1C Modelling

At the Wairoa flood protection stakeholder meeting on the 9th February 2024, WSP was asked to test whether there was a floodway option that would work hydraulically and avoid Takitimu and Tawhiti a Maru marae and the urupa;

A 170m floodway option was modelled (called Option 1C). Option 1C was designed to avoid both the Takitimu and Tawhiti a Maru maraes by following an S-shaped curve as shown in Figure 1.

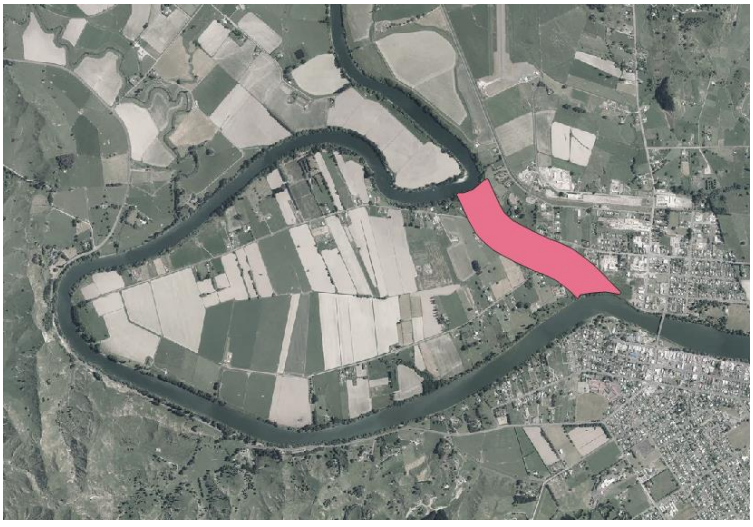

Figure 1. Option 1C

The Option 1C results have been compared to the predicted baseline (existing situation) scenario for the 1% AEP flow event. Spot comparisons of predicted velocity and depth values have been calculated at the points labelled in the maximum depth maps.

The maps below show the predicted flood extent for the option and a difference map indicating changes in the predicted flood surface for the proposed option versus the currently predicted baseline flooding to indicate expected change.

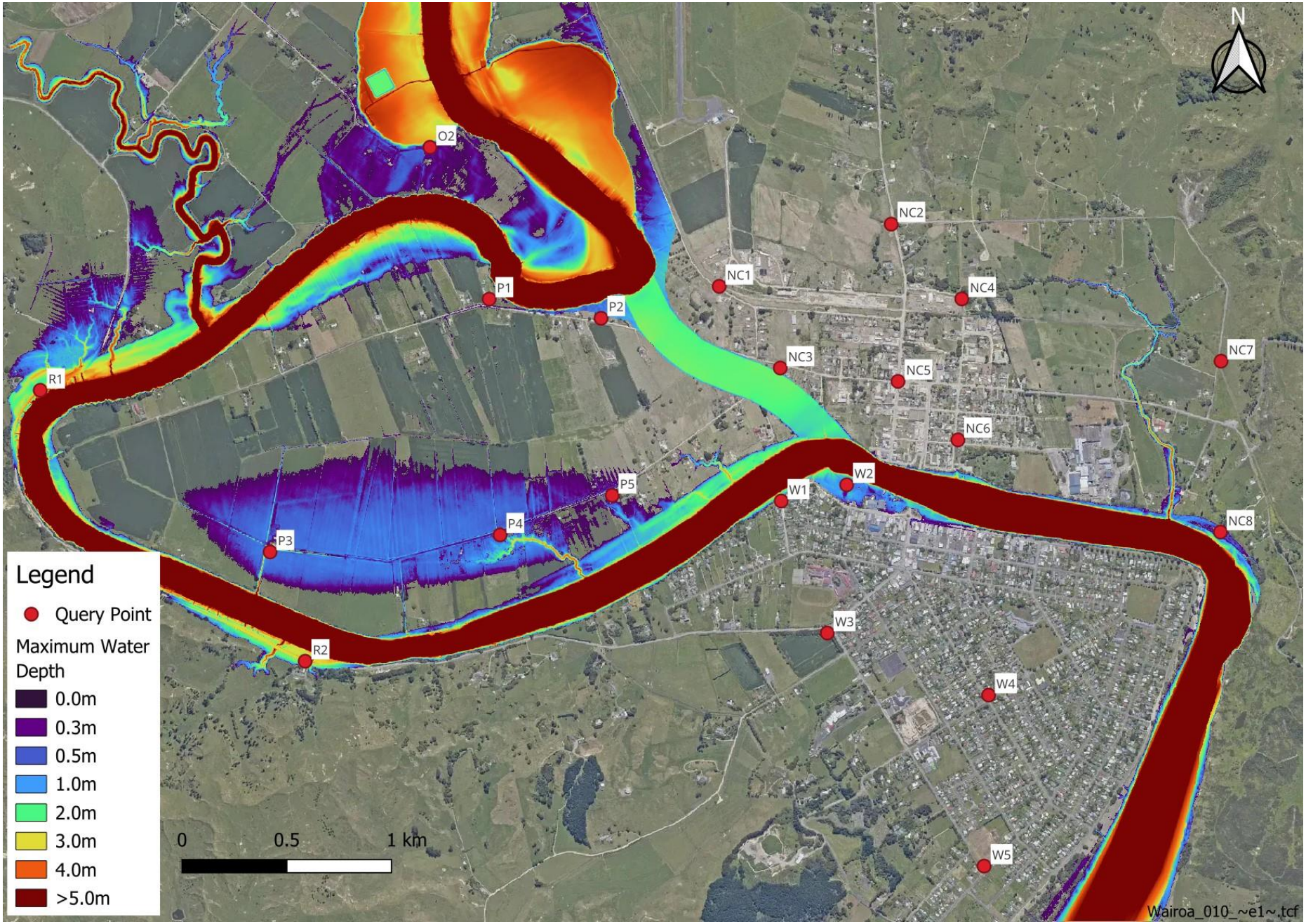

Figure 2. Predicted maximum water depths for short-listed Option 1C

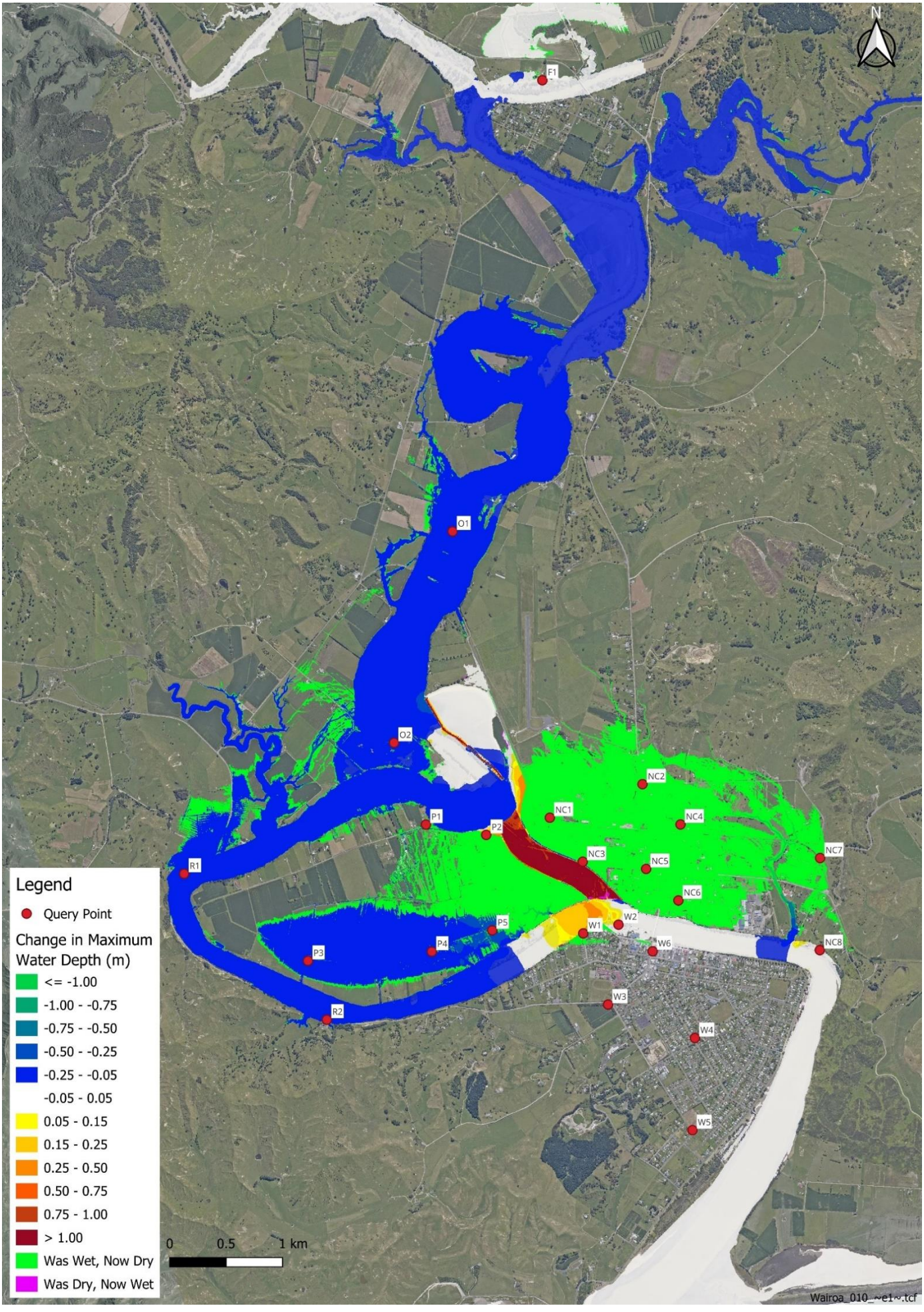

Figure 3. Change in predicted maximum water depth due to short-listed Option 1C

Depth Results at Option 1C Query Points

Spot / query depth points for the predicted 1% AEP event from the baseline and predicted flooding for Options 1A, 1B, and 1C are shown in Table 1. Changes in water depth are compared in Table 2.

Similarly, points for velocity are shown in Table 3. Changes in maximum water velocity are compared in Table 4.

Please note that the baseline hydraulic model has undergone revision since *Short List Modelling Report v0.8* has been published and some values may have changed. The numerical change is less important than the magnitude of change between baseline and optioneering scenarios. All options have been modelled for feasibility only and are not final.

Table 1. Predicted maximum water depths at query points for 1% AEP current climate scenarios.

Point	Description	Maximum Water Depth (m)			
		Baseline	Option 1A	Option 1B	Option 1C
F1	34 Pakowhai Road	2.12	1.95	2.00	2.07
F2	Near 673 Frasertown Road	0.49	0.21	0.28	0.42
NC1	Junction Railway Road and Airport Road	0.67	0.00	0.00	0.00
NC2	Junction Kiwi Road and SH38	0.78	0.00	0.00	0.00
NC3	Junction Ruataniwha Road and Waihirere Road	0.75	0.04	0.52	0.00
NC4	Junction Freyberg Street and MacDonald Street	0.64	0.00	0.00	0.00
NC5	Junction Crarer Street and SH38	0.40	0.00	0.00	0.00
NC6	Junction Freyberg Street and Hunter-Brown Street	0.35	0.00	0.00	0.00
NC7	Junction Kiwi Road and Rail	0.64	0.00	0.00	0.00
NC8	Left bank at bend near Ngamotu Road	0.21	0.24	0.24	0.23
O1	End of Railway Road	1.73	1.06	1.26	1.57
O2	End of Huramau Road East	0.27	0.00	0.00	0.10
P1	Ruataniwha Marae	0.01	0.00	0.00	0.00
P2	92 Ruataniwha Road	0.20	0.00	0.00	0.00
P3	Near 235 Waihirere Road	0.84	0.61	0.61	0.72
P4	Overland flow path near 150 Waihirere Road	1.71	1.39	1.32	1.48
P5	105 Waihirere Road	0.35	0.03	0.02	0.05
R1	Junction SH2 and Kiwi Valley Road	3.51	2.63	2.83	3.33
R2	287 State Highway 2	3.10	2.64	2.64	2.95
W1	Junction Churchill Avenue and Marine Parade	0.46	0.00	0.00	0.00
W2	Ski Club	1.02	0.98	1.11	1.06
W3	Junction Kitchener Street and Achilles Street	0.00	0.00	0.00	0.00
W4	Junction Lahore Street and Clyde Road	0.00	0.00	0.00	0.00
W5	Junction Kitchener Street and McLean Street	0.00	0.00	0.00	0.00

Table 2. *Change in maximum predicted water depth from Baseline 1% AEP current climate model with optioneering scenarios. (-) values indicate a decrease in water depth in option. (+) values indicate an increase in water depth in option.*
** denotes point is within a floodway where depth increase is intentional.*
Green indicates a water depth of zero in the optioned, orange indicates a partial reduction in water depth in the scenario, red indicates a water depth increase in the scenario.

Point	Description	Depth (m)	Change in Maximum Water Depth from Baseline Scenario (m)		
		Baseline	Option 1A	Option 1B	Option 1C
F1	34 Pakowhai Road	2.12	-0.17	-0.13	-0.05
F2	Near 673 Frasertown Road	0.49	-0.28	-0.21	-0.07
NC1	Junction Railway Road and Airport Road	0.67	-0.67	-0.67	-0.67
NC2	Junction Kiwi Road and SH38	0.78	-0.78	-0.78	-0.78
NC3	Junction Ruataniwha Road and Waihirere Road	0.75	-0.70	-0.23	-0.75
NC4	Junction Freyberg Street and MacDonald Street	0.64	-0.64	-0.64	-0.64
NC5	Junction Crarer Street and SH38	0.40	-0.40	-0.40	-0.40
NC6	Junction Freyberg Street and Hunter-Brown Street	0.35	-0.35	-0.35	-0.35
NC7	Junction Kiwi Road and Rail	0.64	-0.64	-0.64	-0.64
NC8	Left bank at bend near Ngamotu Road	0.21	+0.03	+0.02	+0.02
O1	End of Railway Road	1.73	-0.66	-0.47	-0.15
O2	End of Huramau Road East	0.27	-0.27	-0.27	-0.17
P1	Ruataniwha Marae	0.01	-0.01	-0.01	-0.01
P2	92 Ruataniwha Road	0.20	-0.20	-0.20	-0.20
P3	Near 235 Waihirere Road	0.84	-0.23	-0.23	-0.12
P4	Overland flow path near 150 Waihirere Road	1.71	-0.32	-0.39	-0.23
P5	105 Waihirere Road	0.35	-0.32	-0.33	-0.30
R1	Junction SH2 and Kiwi Valley Road	3.51	-0.88	-0.68	-0.18
R2	287 State Highway 2	3.10	-0.47	-0.46	-0.15
W1	Junction Churchill Avenue and Marine Parade	0.46	-0.46	-0.46	-0.46
W2	Ski Club	1.02	-0.04	+0.09	+0.04
W3	Junction Kitchener Street and Achilles Street	0.00	0.00	0.00	0.00
W4	Junction Lahore Street and Clyde Road	0.00	0.00	0.00	0.00
W5	Junction Kitchener Street and McLean Street	0.00	0.00	0.00	0.00

Velocity Results at Option 1C Query Points

Table 3. Predicted maximum water velocity at query points for 1% AEP current climate scenarios.

Point	Description	Maximum Water Velocity (m/s)			
		Baseline	Option 1A	Option 1B.170	Option 1C.200
F1	34 Pakowhai Road	0.90	0.88	0.89	0.89
F2	Near 673 Frasertown Road	0.01	0.01	0.01	0.01
NC1	Junction Railway Road and Airport Road	1.81	0.00	0.00	0.00
NC2	Junction Kiwi Road and SH38	0.44	0.00	0.00	0.00
NC3	Junction Ruataniwha Road and Waihirere Road	1.16	0.00	2.02	0.00
NC4	Junction Freyberg Street and MacDonald Street	0.69	0.00	0.00	0.00
NC5	Junction Crarer Street and SH38	1.05	0.00	0.00	0.00
NC6	Junction Freyberg Street and Hunter-Brown Street	0.77	0.00	0.00	0.00
NC7	Junction Kiwi Road and Rail	0.18	0.00	0.00	0.00
NC8	Left bank at bend near Ngamotu Road	0.16	0.16	0.16	0.16
O1	End of Railway Road	0.76	0.71	0.72	0.75
O2	End of Huramau Road East	0.71	0.00	0.00	0.51
P1	Ruataniwha Marae	0.00	0.00	0.00	0.00
P2	92 Ruataniwha Road	1.08	0.00	0.00	0.00
P3	Near 235 Waihirere Road	0.68	0.42	0.43	0.58
P4	Overland flow path near 150 Waihirere Road	1.50	0.83	1.05	1.19
P5	105 Waihirere Road	1.10	0.20	0.15	0.26
R1	Junction SH2 and Kiwi Valley Road	0.81	0.70	0.75	0.79
R2	287 State Highway 2	0.46	0.33	0.37	0.43
W1	Junction Churchill Avenue and Marine Parade	0.44	0.00	0.00	0.00
W2	Ski Club	0.91	0.95	0.53	0.69
W3	Junction Kitchener Street and Achilles Street	0.00	0.00	0.00	0.00
W4	Junction Lahore Street and Clyde Road	0.00	0.00	0.00	0.00
W5	Junction Kitchener Street and McLean Street	0.00	0.00	0.00	0.00

Table 4. *Change in predicted maximum water velocity from Baseline 1% AEP current climate model with additional optioneering scenarios. (-) values indicate a decrease in water depth in option. (+) values indicate an increase in water depth in option.*
Green indicates a water depth of zero in the optioned, orange indicates a partial reduction in water depth in the scenario, red indicates a water depth increase in the scenario.

Point	Description	Velocity (m/s)	Change in Maximum Water Velocity from Baseline Scenario (m/s)		
		Baseline	Option 1A	Option 1B.170	Option 1C.200
F1	34 Pakowhai Road	0.90	-0.01	-0.01	-0.00
F2	Near 673 Frasertown Road	0.01	-0.01	-0.01	-0.00
NC1	Junction Railway Road and Airport Road	1.81	-1.81	-1.81	-1.81
NC2	Junction Kiwi Road and SH38	0.44	-0.44	-0.44	-0.44
NC3	Junction Ruataniwha Road and Waihirere Road	1.16	-1.16	+0.85	-1.16
NC4	Junction Freyberg Street and MacDonald Street	0.69	-0.69	-0.69	-0.69
NC5	Junction Crarer Street and SH38	1.05	-1.05	-1.05	-1.05
NC6	Junction Freyberg Street and Hunter-Brown Street	0.77	-0.77	-0.77	-0.77
NC7	Junction Kiwi Road and Rail	0.18	-0.18	-0.18	-0.18
NC8	Left bank at bend near Ngamotu Road	0.16	+0.00	-0.00	-0.00
O1	End of Railway Road	0.76	-0.05	-0.03	-0.00
O2	End of Huramau Road East	0.71	-0.71	-0.71	-0.19
P1	Ruataniwha Marae	0.00	0.00	0.00	0.00
P2	92 Ruataniwha Road	1.08	-1.08	-1.08	-1.08
P3	Near 235 Waihirere Road	0.68	-0.26	-0.26	-0.10
P4	Overland flow path near 150 Waihirere Road	1.50	-0.67	-0.45	-0.31
P7	Te Ha te pe Lane	0.00	0.00	0.00	0.00
R1	Junction SH2 and Kiwi Valley Road	0.81	-0.11	-0.06	-0.02
R2	287 State Highway 2	0.46	-0.12	-0.08	-0.02
W1	Junction Churchill Avenue and Marine Parade	0.44	-0.44	-0.44	-0.44
W2	Ski Club	0.91	+0.04	-0.38	-0.21
W3	Junction Kitchener Street and Achilles Street	0.00	0.00	0.00	0.00
W4	Junction Lahore Street and Clyde Road	0.00	0.00	0.00	0.00
W5	Junction Kitchener Street and McLean Street	0.00	0.00	0.00	0.00

2 Model Roughness Changes

Following peer review by DHI in December 2023, some Wairoa model roughness parameters were revisited in January - February 2024. This addendum sets out what 'roughness' is, the reasoning behind the changes, and the implications of roughness modifications for the baseline and short-listed options modelling.

What is Roughness in a flood model?

Terrain roughness is a parameter used in hydraulic modelling that represents resistance water encounters as it flows over land and through water channels. This resistance represents an energy loss from the water and assists in calculating and balancing energy transfer in a hydraulic model. Roughness will vary based on many factors such as land use, vegetation, and urbanised areas. Examples of higher roughness include areas such as dense groups of trees and scrub, populated areas with buildings, fences,

cars, and other structures, and tilled crops and vineyards. Variations in roughness affect the waters velocity and depth in rivers, channels and in overland flow paths / flood plain.

Roughness's are based on extensive research and are standardised worldwide, with some minor adjustments based on model calibration (the Wairoa model has been calibrated to the Cyclone Gabrielle event.)

Change to the base model

Following peer review of the WSP Wairoa fluvial model by the Danish Hydraulic Institute (DHI) New Zealand in January 2024, an additional internal review of hydraulic model roughness was performed, and it was observed that trees and native bush were not represented appropriately along the banks of the Wairoa River in the land use data set used. Along the Wairoa River, trees and scrub are frequently present on the riverbanks, which will adversely affect the flow capacity of the channel during flood events.

Areas with dense trees and scrub were manually traced from pre- and post-Cyclone Gabrielle aerial imagery and have been subsequently included in the model. Figure 4 below shows the roughness zones for comparison before and after the model was updated (un-shaded areas utilise the default model roughness).

Figure 4. Roughness zones comparison - before incorporation of trees/ scrub (left). After incorporation of dense trees/ scrub (right).

Implications of roughness modification.

For the (baseline) and option scenarios, the adjustment of roughness values has some impact to the overall flooding within North Clyde and Wairoa township (0.0m to 0.18m increase). There are notable increases in the water level upstream of the Wairoa/ Waiau River junction and downstream of the horseshoe bend/ breakout at Ruataniwha Road. The changes near Pakowhai Road in Frasertown better

match the sediment deposition marks, while the changes near Ruataniwha Road and State Highway 2 appear to overestimate the sediment marks.

There is also some change in the total discharge across the floodplain through North Clyde (see Figure 6). While some of these differences may seem significant, comparison of sediment deposition from post-cyclone aerial photos shows that the increase in water level generally tends to better match debris lines than in prior modelling.

As the Wairoa riverbanks eroded significantly and lost vegetation during Gabrielle, it is likely that some of the areas of increased roughness may now overestimate existing post-cyclone conditions. However, it is likely that this vegetation will regrow before the next significant flood event.

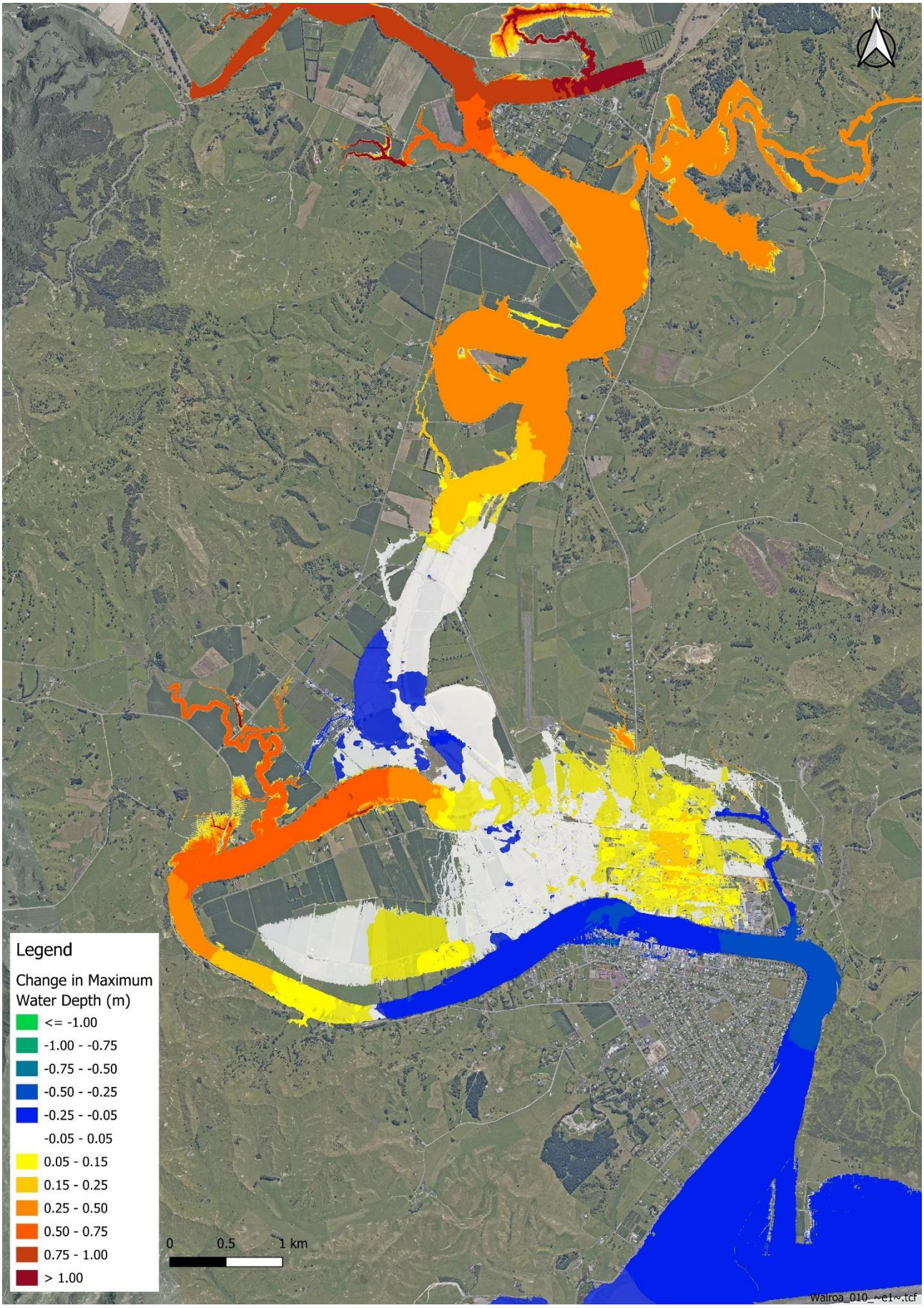

Figure 5. Change in predicted maximum water depth for Cyclone Gabrielle event between incorporation of trees/ scrub into model. (+) values indicate an increase in water depth due to trees/scrub. (-) values indicate a decrease in water depths due to trees/ scrub.

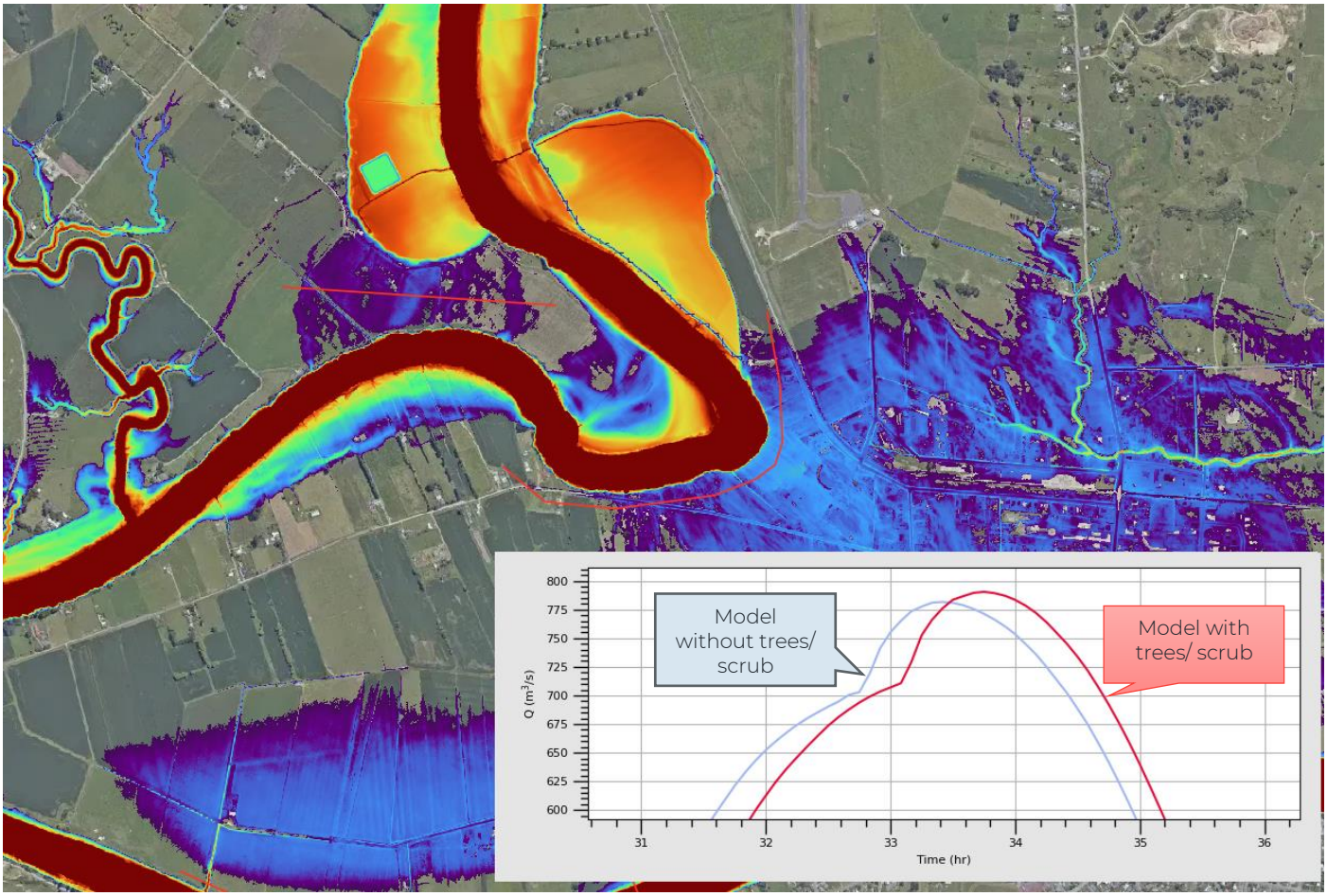

Figure 6. Predicted flow breakout comparison at horseshoe bend. Peak flows are delayed ~15min, and there is an additional 9m³/s of flow discharged across the North Clyde floodplain in the model with trees/ scrub.

For the Option 5 stopbanks, there are notable implications due to the roughness adjustments. This is due to the removal of the overland flow path through North Clyde and an increase in water levels near Ruataniwha Road. Figure 77 and Figure 88 show the difference in flooding near Ruataniwha Road due to vegetation incorporation into the Wairoa model.

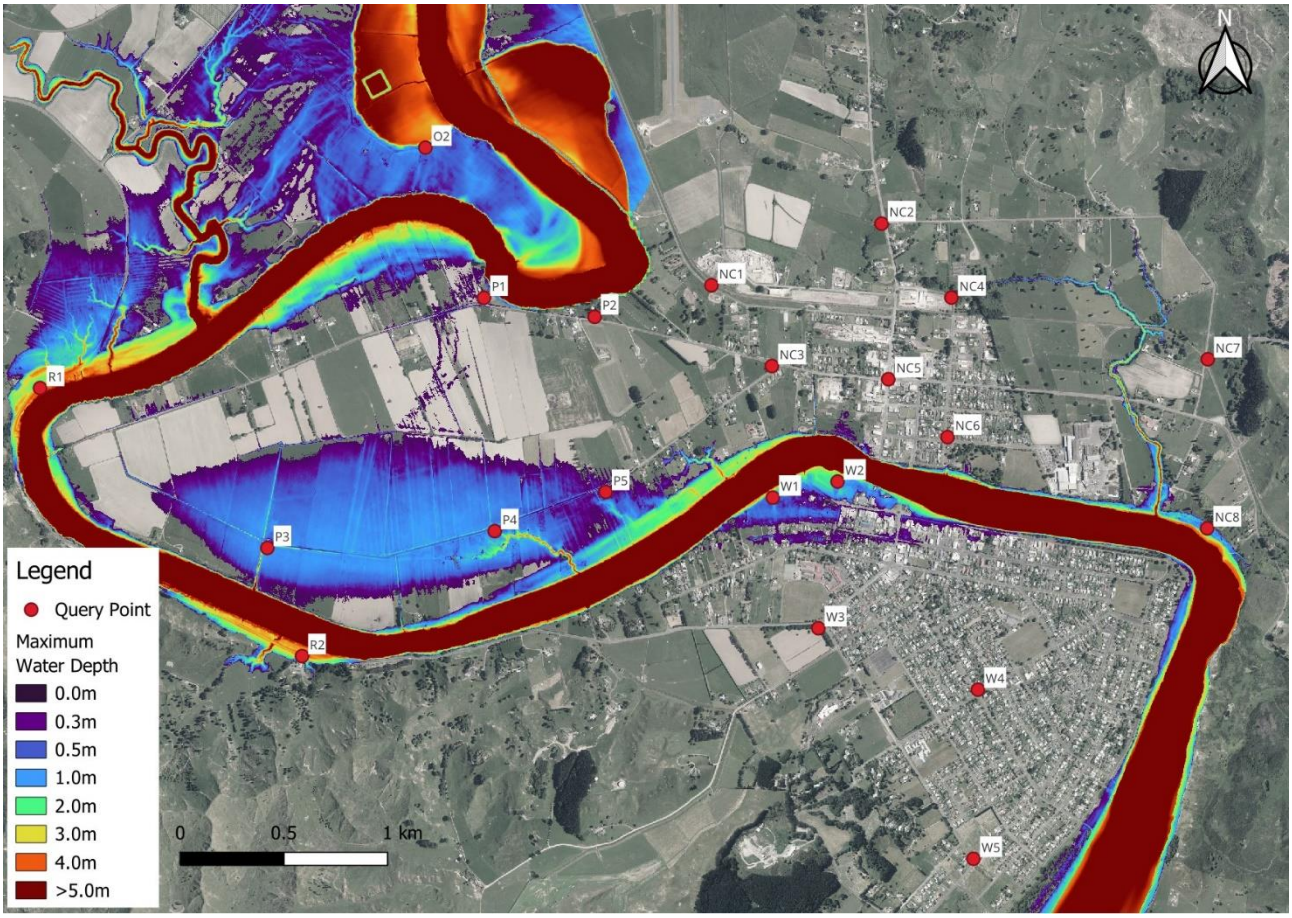

Figure 7. *Option 5A predicted maximum water depths without incorporation of trees/ scrub (1% AEP)*

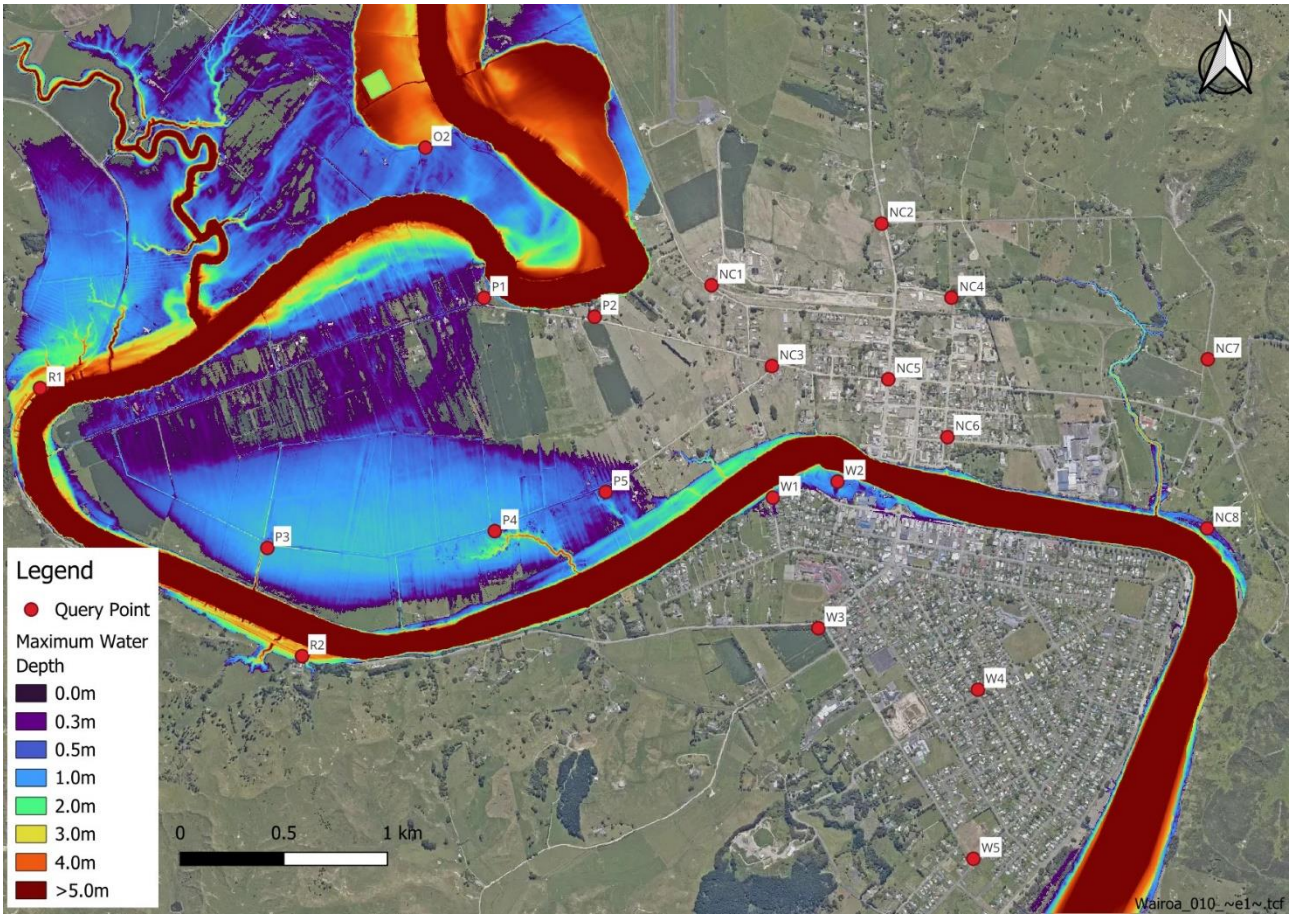

Figure 8. *Option 5A predicted maximum water depths after incorporation of trees/ scrub (1% AEP). Note that the decreased flooding in Wairoa near the esplanade, is due to addition of low bunds near point W1.*