APPENDIX 7

Ruakākā Flood Modelling

Ruakākā Energy Park Solar Farm Consent Design

Prepared for Meridian Energy Ltd
Prepared by Beca Limited

7 July 2023

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Contents

Appendices

Revision History

Revision Nº	Prepared By	Description	Date
1	Cameron Oliver	Draft for client review	01/06/2023
2	Cameron Oliver	First Issue	07/07/2023

Document Acceptance

Action	Name	Signed	Date
Prepared by	Cameron Oliver		07/07/2023
Reviewed by	Elliot Tuck		07/07/2023
Approved by	Brent Meekan		07/07/2023
on behalf of	Beca Limited		

Executive Summary

This report describes a flood model built to test the relative effects of the proposed solar farm on surrounding water levels. Two events were tested: 50 year average recurrence interval (ARI) with climate change and the 100 year ARI with climate change.

The model was built in HEC-RAS and based on a LiDAR surface. Rainfall estimates were taken from HIRDS, while curve numbers and roughness values were based on New Zealand Fundamental Soil Layer and the New Zealand Land Cover Database. Flood events were modelled to coincide paired with a 20 year sea level with allowance for sea level rise.

Post-development scenarios incorporated a concept earthworks surface and an adjustment to roughness due to the presence of solar array support poles. A bund with outlet structures was included on the north-eastern side of Site 1 to attenuate flows, preventing downstream water levels from being higher than pre-development levels.

Modelling demonstrated that the development will generally reduce maximum water levels on adjacent properties in the 50 year with climate change and 100 year with climate change events. Water levels will increase by about 1 mm upstream of Site 1; a difference that is within the margin of modelling error. Increases were also modelled within a drain alongside Mair Rd (downstream of Site 1); however this was contained within the drain. Velocity differences are likewise minor. The model shows that the proposed development will have a negligible effect on flooding.

The proposed development has a minimal, and generally positive, effect on flood levels for the following reasons:

- Site 1: while earthworks make it easier for water to reach the central drain, the bund with outlet structures along the downstream (north-eastern) boundary attenuates flow such that downstream water levels do not exceed pre-development levels.
- Site 2: earthworks are a mixture of cut and fill, and do not substantially change flow paths or storage.
- Site 3: earthworks across the site are predominantly in cut, and particularly so for the wetland on the southern side. This means that there is there is more volume available for water to pond in during a flood. That is, the proposed development increases the available flood attenuation storage available.

1 Context

Ruakākā Energy Park Solar Farm is to be split over three sites. Sites 2 and 3 lie within the catchment of Ruakākā River, which is situated approximately 20 km south-west of Whangārei and drains to Bream Bay. The catchment is approximately 9,600 ha and is predominantly farmland (Figure 1-1). Site 1 drains into a channel running north-east, before turning along Mair Road and then discharging to the ocean.

This report describes a flood model built to test the relative effects of the proposed solar farm on surrounding water levels. Two events were tested: 50 year average recurrence interval (ARI) with climate change and the 100 year ARI with climate change.

Figure 1-1 River catchment (red dashed line), model extent (white line) and site boundaries (blue polygons)

2 Hydrology

2.1 Rainfall

Rainfall estimates were obtained from HIRDS v4 (https://hirds.niwa.co.nz/) at the centre of the river catchment. Spatial variability of HIRDS estimates across the catchment was checked and found to be minimal at the 6 hour duration[1].

RCP 6.0 to 2090 was used for climate change estimates. RCP 6.0 represents a medium-high scenario and the design life for the solar farm is 60 years. The HIRDSv4 areal reduction factor method was used across the full model extent, giving factors of 0.83 at the 2 hour duration and 0.91 at the 6 hour duration.

HIRDS depths were used to generate 24-hour nested storms, with the peak rainfall occurring at 12 hours.

Rainfall was applied directly to the 2D surface as rain-on-grid and losses were modelled using the SCS loss method (SCS,1986). Initial abstraction was set to 0.2 S, as per SCS (1986).

Hydrologic soil groups were assigned based on soil drainage class from the New Zealand Fundamental Soil Layer[2] (see 22 in Appendix A). Curve numbers were assigned based on New Zealand Land Cover Database (LCDB)[3] classes (Table 7-2) and are plotted in Figure 2-1.

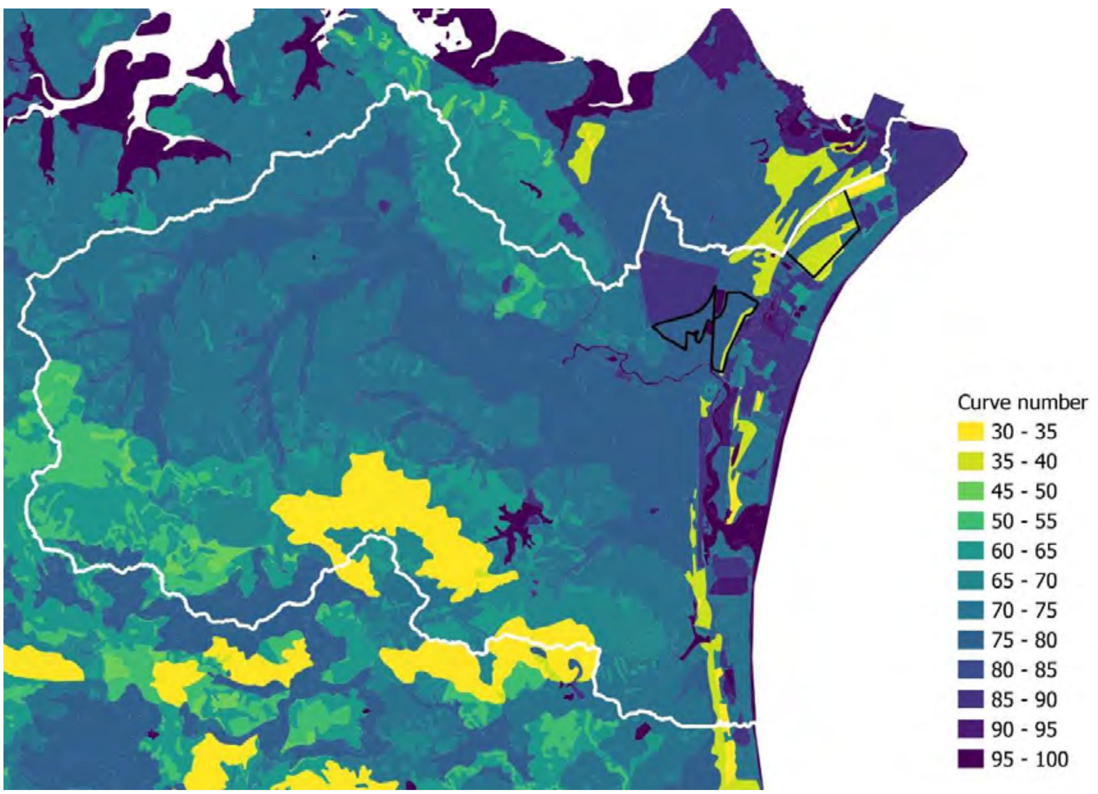

Figure 2-1 Assigned curve numbers with model extent (white line)

[1] This was chosen because the peak modelled flow in Ruakākā River adjacent to site 3 occurred 5 hours and 30 minutes after the peak rainfall

[2] https://lris.scinfo.org.nz/layer/48104-fsl-soil-drainage-class/

[3] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

3 Hydraulic Model

A two-dimensional hydraulic model was developed in HEC-RAS v6.2. Northland 1m LIDAR[4] (New Zealand Vertical Datum 2016) was used as the pre-development terrain, while post-development terrain included concept earthworks surfaces on sites 1, 2 and 3. The model extent is depicted in Figure 1-1. A rectangular mesh with 25 m grid cells was used, with refinements along break lines[5] and within the sites.

Rain on grid was applied using SCS losses as per Table 7-2. 50 year climate change (CC) and 100 year CC events were run for both pre- and post-development conditions.

The LiDAR surface did not include bridge decks and as such represented the channel only at these locations. As a conservative approach, bridge decks and culverts were not included in the model. The exception was a 3-meter diameter ocean outfall pipe from the drain alongside Mair Road which was included because of its linkage to the coast. Reservoirs (including Wilson's Dam, a water supply reservoir) were included with the level seen in the LiDAR, i.e. at typical/full level.

The post-development model included a bund on the north-eastern side of Site 1 with a vertical slot for up to 50 year CC flows and a weir for 100 year CC flows. This attenuated flows, preventing downstream water levels from being higher than pre-development levels in the 50 year CC and 100 year CC events.

The model was run for 48 hours.

3.1 Roughness

Pre-development Mannings' n roughness categories were assigned to LCDB categories (see Table 7-3 in Appendix A) and are plotted in Figure 3-1. Pre-development Mannings' n roughness categories were assigned to LCDB categories (see Table 7-3 in Appendix A) and are plotted in Figure 3-1. For post-development, roughness was modified for the presence of solar panel support poles within each site using the Luhar and Nepf (2013) method[6]:

$$n_{poles} = \left(\frac{C_d a h}{2g}\right)^{1/2} h^{1/6}$$

where:

- C_d is the drag coefficient. Isolated, rigid cylinders have a drag coefficient of approximately 1.0 (Shields et al., 2017)
- *a* is the frontal area of vegetation per volume (1/m)
- *h* is the height of vegetation (m)
- *g* is acceleration due to gravity (m/s^2)

Total roughness within each site was therefore equal to roughness of the ground (0.035) plus the roughness due to poles calculated using the above equation.

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[4] https://data.linz.govt.nz/layer/110757-northland-lidar-1m-dem-2018-2020/

[5] Break lines were used along key roads, bunds and channels

[6] Originally developed in the context of emergent vegetation, i.e. vegetation that isn't fully submerged

Table 3-1 Roughness due to support poles

	Nominal depth (m)	Mannings roughness due to poles	Bed roughness	Total roughness
Site 3	1.5	0.016	0.035	0.051
Site 2	0.05	0.002	0.035	0.037
Site 1	0.5	0.008	0.035	0.043

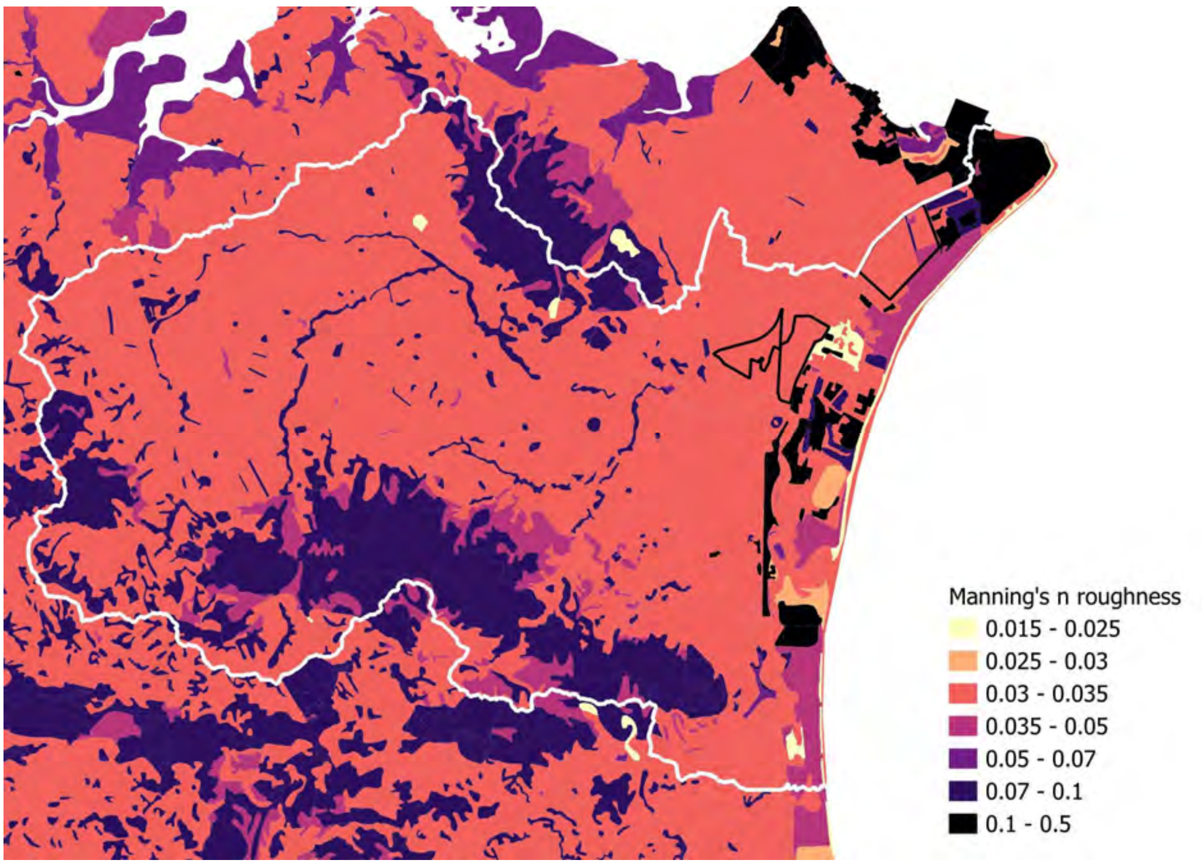

Figure 3-1 Pre-development roughness with model extent (white line)

3.2 Tidal boundary

Extreme sea levels were taken from Table 2.4 of Tonkin & Taylor (2021), reproduced below in Table 3-2. Sea level rise for RCP 6.0 2090 was interpolated from Table 3.3 of Tonkin & Taylor (2021) (reproduced below in Table 3-3) at 0.55 meters; this was added to all extreme water levels in Table 3-2.

Table 3-2 Extreme water levels (m NZVD2016) for Northland tide gauges. Extract from Table 2.4 of Tonkin & Taylor (2021)

Site	Record length (years)	5-year ARI	10-year ARI	20-year ARI	50-year ARI	100-year ARI	200-year ARI	500-year ARI
Marsden Point	57	1.42	1.46	1.52	1.60	1.67	1.71	1.84

Table 3-3 Median projections of sea level rise based on MfE (2017) with respect to a 1985-2005 baseline level. Extract from Table 3.3 of Tonkin & Taylor (2021)

Year	RCP2.6	RCP4.5	RCP8.5
2090	0.42	0.49	0.67

In lieu of a detailed joint-probability study, the flood and sea level rise combinations from Table 4.4 of BOPRC (2012) were used. This meant that both the 100 year CC flood and the 50 year CC flood were modelled with a 20 year CC sea level.

A sea level time series was applied to the model as a downstream boundary condition, as described below and plotted in Figure 3-2:

- A tidal cycle starting at MLWN (mean low water neaps, i.e. a high low-tide) and rising to reach the target sea level (20 yr CC) at the same time as the peak Ruakākā River flow (17:30 hrs).
- One tidal cycle before and two after that start at MLWN and rise to MHWS (mean high water springs); i.e. from a high low-tide to a high high-tide.

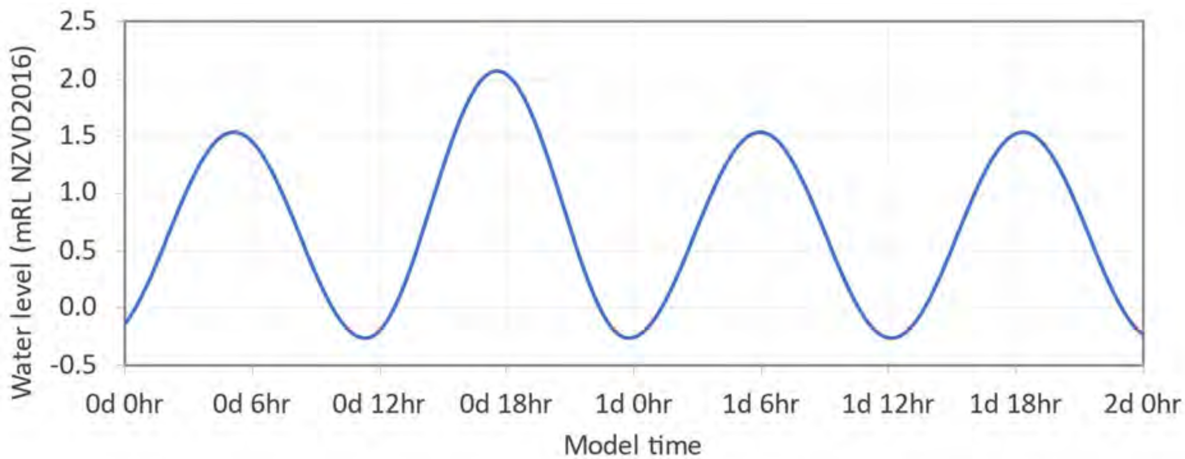

Figure 3-2 Modelled 20 year CC sea level (boundary condition)

4 Results

Modelled changes to maximum water level adjacent to each site caused by the development are listed in Table 4-1. While levels upstream of Site 1 are about 1 mm higher than currently in the 50 yr CC and 100 yr CC events, this difference is below the margin of modelling error and regardless would be imperceptible during such an event. All other post-development levels are lower than in pre-development.

Table 4-1 Post-development maximum depths relative to pre-development maximum depths

	100 yr CC	50 yr CC
Site 1 upstream (south-west)	1 mm increase	1.5 mm increase
Site 1 downstream (north-east)	0.5 mm decrease	10 mm decrease
Site 2 upstream (north-west, Marsden City subdivision)	69 mm decrease	69 mm decrease
Site 2 downstream (eastwards, between sites 2 and 3)	5 mm decrease	5 mm decrease
Site 3 upstream (north)	5 mm decrease	5 mm decrease
Site 3 downstream (south, within Ruakākā River)	3 mm decrease	4 mm decrease

Appendix B contains maps illustrating the following:

- Pre-development maximum depth
- Post-development maximum depth
- Maximum elevation difference
- Velocity difference at time of maximum depth

The following maps are included:

- 2318415-CY-0001: Site 1, 100 year CC
- 2318415-CY-0002: Site 1, 50 year CC
- 2318415-CY-0003: Sites 2 and 3, 100 year CC
- 2318415-CY-0004: Sites 2 and 3, 50 year CC

These maps illustrate that outside the proposed development there are only very minor effects on depth and velocity. Of note:

- Downstream of Site 1, water levels in the drain running alongside Mair Rd are somewhat higher, but this is contained within the drain.
- Culverts—such as from the Marsden City subdivision into two attenuation basins, located between sites 2 and 3—have not been included in the model. This was a conservative approach as part of a study that focussed on relative effects, not absolute levels. We recommend that these culvert pipes be surveyed and included in flood modelling for concept and/or detailed design of the project.

The proposed development has a minimal, and generally positive, effect on flood levels for the following reasons:

- Site 1: while earthworks make it easier for water to reach the central drain, a bund with outlet structures along the downstream (north-eastern) boundary attenuates flow such that downstream water levels do not exceed pre-development levels.
- Site 2: earthworks are a mixture of cut and fill, and do not substantially change flow paths or storage.

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5 Conclusion

This report describes a flood model built to test the relative effects of the proposed solar farm on surrounding water levels. Two events were tested: 50 year average recurrence interval (ARI) with climate change and the 100 year ARI with climate change.

Modelling demonstrated that the development will generally reduce maximum water levels on adjacent properties in the 50 year with climate change and 100 year with climate change events. Water levels will increase by about 1 mm upstream of Site 1; a difference that is within the margin of modelling error. Increases were also modelled within a drain alongside Mair Rd (downstream of Site 1); however this was contained within the drain. Velocity differences are likewise minor. Therefore the model shows that the proposed development will have a negligible effect on flooding.

6 Limitations

This modelling is intended to demonstrate the relative effect of the proposed Ruakākā Solar Farm on flood levels. It should not be used for any other purpose. The model is non-calibrated and represents catchment scale effects. It is based on LiDAR and does not include structure details or topographical survey.

7 References

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A

Appendix A – Tables

Table 7-1 Hydrologic soil group mapping

Soil drainage class	Description	Assumed hydrologic soil group
1	Very poor	D
2	Poor	D
3	Imperfect	C
4	Moderately well	B
5	Well	A

Table 7-2 Curve number mapping

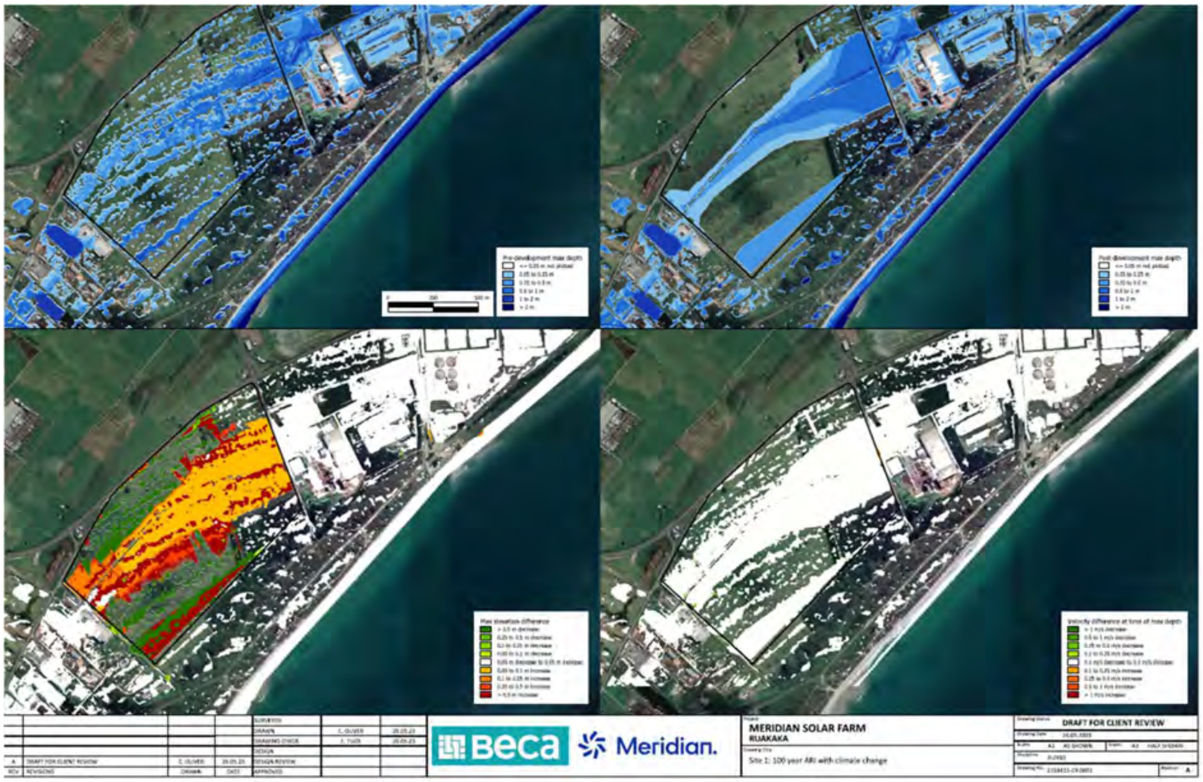
LCDB class	Assigned SCS class	A	B	C	D
Gorse and/or Broom	Brush - good condition	30	48	65	73
Manuka and/or Kanuka	Brush - good condition	30	48	65	73
Mixed Exotic Shrubland	Brush - good condition	30	48	65	73
Landslide	Fallow - Bare soil	77	86	91	94
Flaxland	Herbaceous - good condition	50	62	74	85
Lake or Pond	Impervious	100	100	100	100
River	Impervious	100	100	100	100
Estuarine Open Water	Impervious	100	100	100	100
Herbaceous Freshwater Vegetation	Impervious	100	100	100	100
Herbaceous Saline Vegetation	Impervious	100	100	100	100
Mangrove	Impervious	100	100	100	100
Urban Parkland/Open Space	Open space - good condition	39	61	74	80
High Producing Exotic Grassland	Pasture - good condition	39	61	74	80
Low Producing Grassland	Pasture - poor condition	68	79	86	89
Built-up Area (settlement)	Residential districts, 1/8 acre or less (town houses)	77	85	90	92
Short-rotation Cropland	Row crops - straight row - good condition	67	78	85	89
Surface Mine or Dump	Streets and roads - Gravel	76	85	89	91
Sand or Gravel	Streets and roads - Gravel	76	85	89	91
Transport Infrastructure	Streets and roads - Paved	98	98	98	98
Broadleaved Indigenous Hardwoods	Woods - good condition	30	55	70	77
Forest - Harvested	Woods - good condition	30	55	70	77
Deciduous Hardwoods	Woods - good condition	30	55	70	77
Indigenous Forest	Woods - good condition	30	55	70	77
Exotic Forest	Woods - good condition	30	55	70	77
Orchard, Vineyard or Other Perennial Crop	Woods—grass combination (orchard or tree farm) - good condition	32	58	72	79

Table 7-3 Roughness mapping

LCDB class	Assigned Chow (1959) category	Manning's n
Gorse and/or Broom	Light brush	0.050
Manuka and/or Kanuka	Light brush	0.050
Mixed Exotic Shrubland	Light brush	0.050
Flaxland	Light brush	0.050
Broadleaved Indigenous Hardwoods	Light brush	0.050
Forest - Harvested	Heavy stand of timber	0.100
Deciduous Hardwoods	Heavy stand of timber	0.100
Indigenous Forest	Heavy stand of timber	0.100
Exotic Forest	Heavy stand of timber	0.100
Orchard, Vineyard or Other Perennial Crop	Heavy stand of timber	0.100
Lake or Pond	Main channels, more stones and weeds	0.035
River	Main channels, more stones and weeds	0.035
Estuarine Open Water	Main channels, more stones and weeds	0.035
Herbaceous Freshwater Vegetation	Medium to dense brush	0.070
Herbaceous Saline Vegetation	Medium to dense brush	0.070
Mangrove	Medium to dense brush	0.070
Urban Parkland/Open Space	Pasture, short grass	0.030
High Producing Exotic Grassland	Pasture, high grass	0.035
Low Producing Grassland	Pasture, high grass	0.035
Built-up Area (settlement)	N/A	0.500
Short-rotation Cropland	Cultivated areas, mature row crops	0.035
Surface Mine or Dump	Gravel, uniform section, clean	0.025
Sand or Gravel	Gravel, uniform section, clean	0.025
Transport Infrastructure	Asphalt	0.015

B

Appendix B – Maps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RUAKAKA
Site 1: 100 year ARI with climate change
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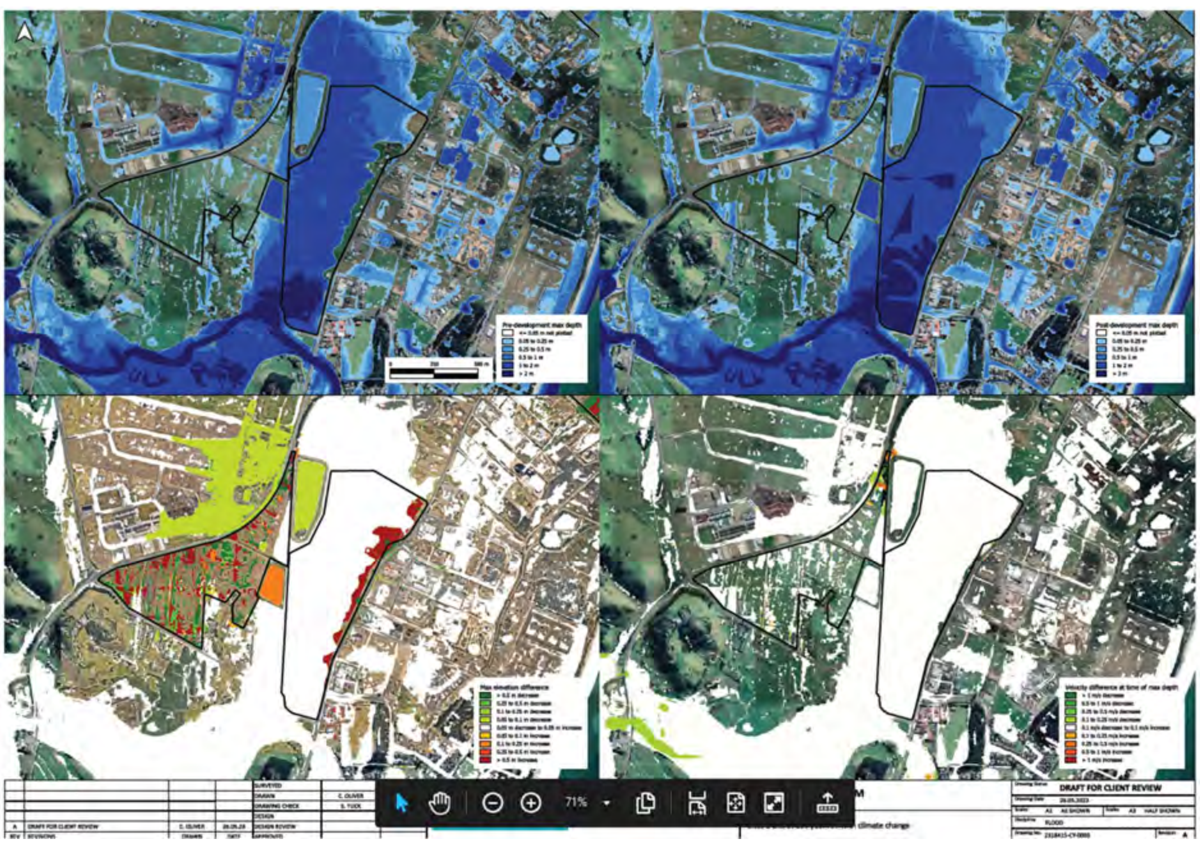
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Client: Meridian.

Project: RUAKĀKĀ SOLAR FARM

Title: 50 YEAR ARI WITH CLIMATE CHANGE: ELEVATION AND VELOCITY

Discipline: FLOOD

Drawing No. 2318415-CY-0005

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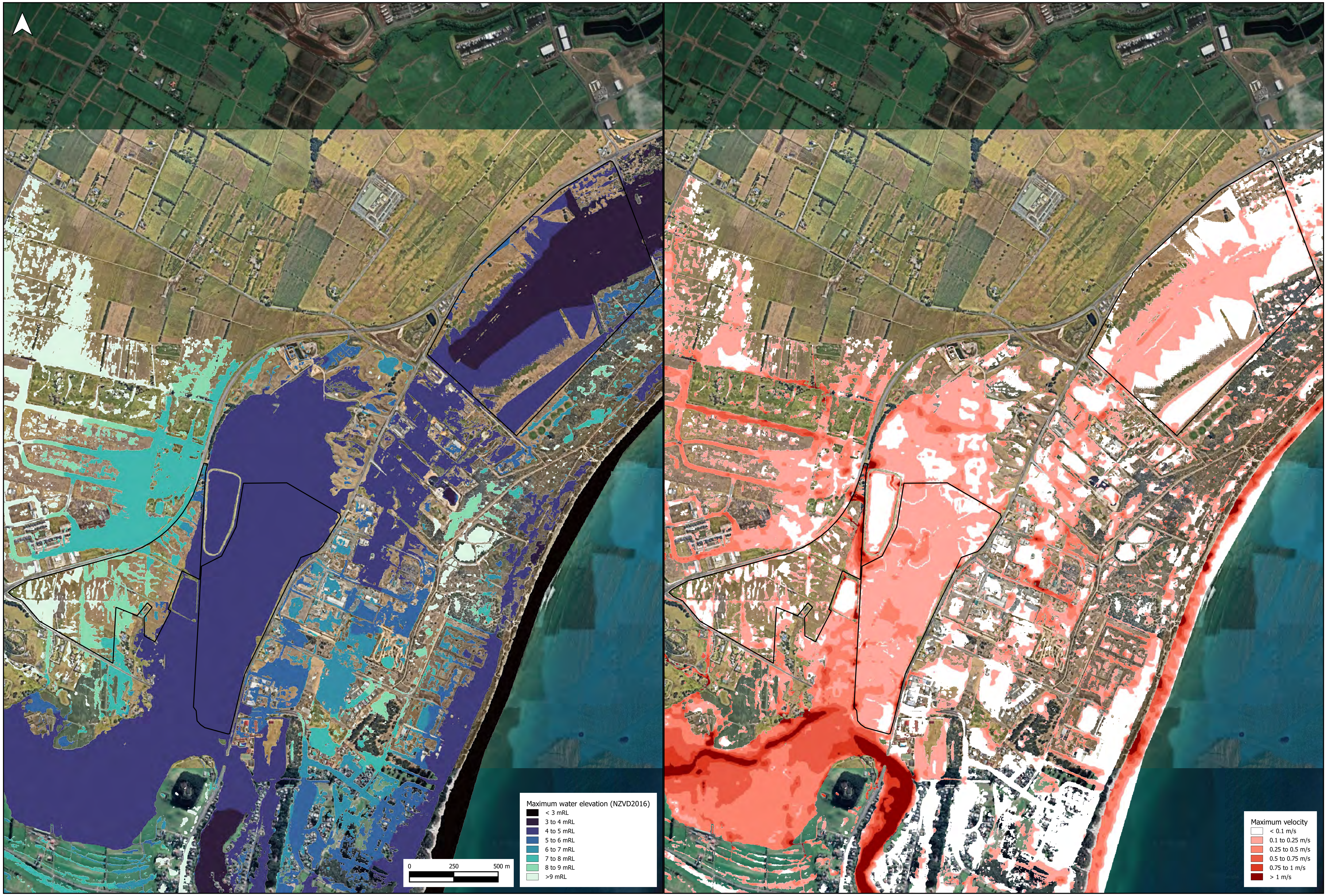

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