

Flood Effects – 531 and 535 Mill Road, Ōhoka

✦ Prepared for

Carter Group Limited (CGL)

✦ 9 September 2026



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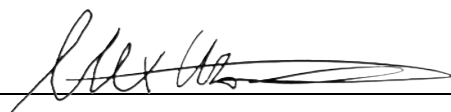
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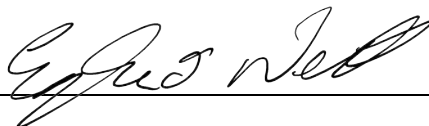
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Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Carter Group Limited [and] [others (not directly contracted by PDP for the work)], including National Institute of Water and Atmosphere, Land Information New Zealand, Environment Canterbury 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.

This report has been prepared by PDP on the specific instructions of Carter Group Limited for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

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Executive Summary

Pattle Delamore Partners Ltd (PDP) was engaged by Carter Group Limited to assess the flood effects associated with the proposed development at 531 and 535 Mill Road, Ōhoka. The site comprises approximately 156 ha of rural land southwest of Ōhoka township and is proposed to be developed for residential housing, business/commercial activities, a polo field and a retirement village. A site-specific two-dimensional TUFLOW hydraulic model has been developed to assess existing flood behaviour, represent the proposed development landform and drainage features, and quantify likely changes in flood levels resulting from the development.

This report supersedes the previous version of the report with the same title (PDP, May 2026), with the following updates made to this report following feedback from Environment Canterbury and Waimakariri District Council on the previous version;

- ⋆ A further re-calibration of the model undertaken using additional data, resulting in a closer match to observed conditions than was achieved previously.
- ⋆ Inclusion of the 100-year ARI/1% AEP event in accordance with the updated Waimakariri Engineering Code of Practice (September 2025)
- ⋆ Inclusion of a risk-based assessment under the National Policy Statement for Natural Hazards (December 2025)
- ⋆ Update of the post-development design based on the latest design surface produced by Inovo, dated 19 August 2026.

The baseline model has been developed using a direct rainfall approach with HIRDS design rainfall, climate change allowance to RCP8.5 2130, LiDAR-derived topography, spatially varied infiltration, calibrated roughness values and key hydraulic structures along Bradleys Road and Whites Road. The model has been calibrated against recorded flows in the Cust Main Drain for the 2014, 2022 and 2023 flood events, with the 2022 event providing the closest match to observed flows. Site validation using flood photographs also indicates general agreement between observed and modelled flood behaviour around the site. On this basis, the model is considered suitable for assessing relative changes in flooding between pre- and post-development conditions.

Existing model results show that the site and surrounding area are already subject to notable surface water flooding during design flood events, with flows generally conveyed from west to east through several overland flow paths and existing drainage features. The proposed development model includes the proposed landform, revised roughness zones, stormwater management areas and proposed culverts. These elements have been represented to preserve the

broad overland flow pattern across the site while providing sufficient conveyance and flood storage within the development area.

Model results for the 50-year, 100-year and 200-year ARI events show that the proposed development does not result in adverse increases in peak flood level at existing dwellings assessed in the vicinity of the site. The assessment indicates no existing dwellings with peak flood level increases greater than 20 mm, while a number of dwellings experience reduced flooding or removal of flooding within 2 m of the dwelling. Across the modelled events, 24, 23 and 18 dwellings are shown to have either reduced flooding or flooding removed in the 50-year, 100-year and 200-year ARI events respectively.

The wider assessment of off-site effects shows that peak flood level changes are generally small and dissipate with distance downstream of the site. Modelled increases are generally confined to established watercourses and their immediate surrounds, with the maximum increase in peak flood level of the order of 60 mm within an existing watercourse. A broader downstream area is shown to experience reduced peak flood levels, with reductions of up to approximately 100 mm. The modelling also indicates no appreciable effect on peak flood levels upstream of the site, demonstrating that suitable conveyance has been provided through the post-development landform.

Flood risk has also been assessed with reference to the National Policy Statement for Natural Hazards 2025 and Waimakariri District Council hazard categories. The assessment indicates that the majority of the site is subject to low or negligible flood risk, with isolated areas of medium risk on roads and part of the polo field. Areas of high or very high risk are generally contained within existing and proposed watercourses and stormwater management features.

Overall, the modelling indicates that the proposed development can be progressed without causing significant adverse flood effects, provided the development remains generally consistent with the landform, drainage and stormwater management assumptions assessed in this report subject to detailed design refinements. Further detailed design will be required to refine local drainage, road levels, stormwater management areas, culvert arrangements and any isolated medium-risk road areas. The model results should be interpreted at a catchment and development-scale level, and not as property-specific predictions, due to the inherent limitations associated with LiDAR topography, design rainfall assumptions, hydraulic roughness, infiltration and large-scale flood modelling.

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1.0 Background

Pattle Delamore Partners (PDP) has been engaged by Carter Group Limited (CGL) (the Client) to undertake a flood assessment to quantify the likely surface water effects of the proposed development located at 531 and 535 Mill Road, Ohoka. The site extent is shown in Figure 1 below relative to the Ohoka township. The site is located to the southwest of Ōhoka township, within the Waimakariri District, and is bordered by Bradleys Road and Whites Road. The site consists of approximately 155 ha of rural land. The proposed development will consist of residential housing, business/commercial area, a polo field, and a retirement village area.

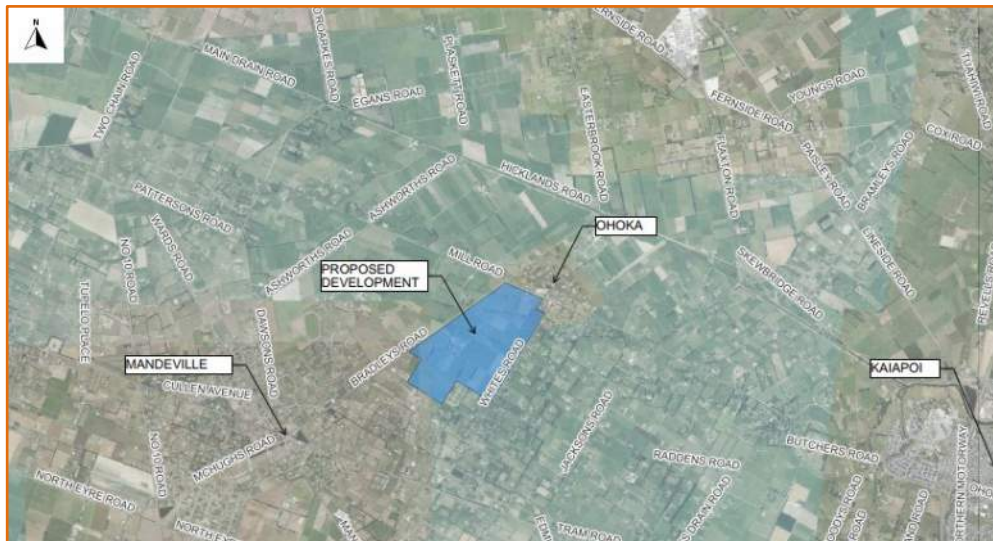


Figure 1: Site location

A 2D flood model using TUFLOW software has been built to understand the existing flooding in and around the site, and to understand the likely changes in surface water effects as a result of the proposed development being built. The purpose of this report is to summarise the model build, calibration and pre-and post- flooding on site as a result of the development.

This report has been updated since the previous issue in May 2026, in response to technical feedback from Environment Canterbury and Waimakariri District Council. This version of the report supersedes the previous version, and is intended to be a complete document summarising the modelling done to date as part of the Fast Track application.

2.0 Hydrological setting

2.1 Waimakariri district wide flood modelling

Some existing flooding information is available via Waimakariri District Natural Hazard website (<https://waimakariri.maps.arcgis.com/>) and Figure 2 below shows

the modelled extents and depths of the flooding for the 200-year event. Model results show several overland flow paths running through the site from west to east, and a notable amount of surface flooding on the site.

The district wide model was constructed by DHI on behalf of Waimakariri District Council. This flood model aims to provide flood hazard predictions for the entire Waimakariri District for the 100-year, 200-year and 500-year flood events.

The district wide model employs a rain on grid approach which is influenced by rainfall depth, infiltration, roughness and terrain assumptions. DHI report that there is limited opportunity for validation or calibration of this district wide model. DHI report:

- ∴ *“The MIKE 21 model results for a 1 in 100 year event give a peak flow of 910m³/s at the Fox Creek Okuku gauge, Figure 3-6. This is around double the flow estimated using frequency analysis, indicating that the infiltration rates may be too conservative in the hillside areas. However, given the uncertainties involved in the flood frequency analysis, it is difficult to determine by how much”*
- ∴ Further, *“Despite the potential overestimation of flow, it is believed that the model is still performing better in this area than in the earlier modelling”.*

Whilst the hill catchments are not of particular relevance to our area of interest (Ohoka), this validation shows that district wide model appears to be conservative in its uncertainty. That is, runoff is likely overestimated rather than underestimated for hill catchments.

While we have aimed for some general agreement with the available flood modelling information, we have not aimed to exactly replicate the existing flood modelling available. Rather, we have undertaken independent model calibration and validation relative to the site, and we note that the flood modelling information available online has been developed at a region wide scale. Our model has been developed for the specific purposes of understanding existing and potential future flooding for the site and immediate surrounding area.

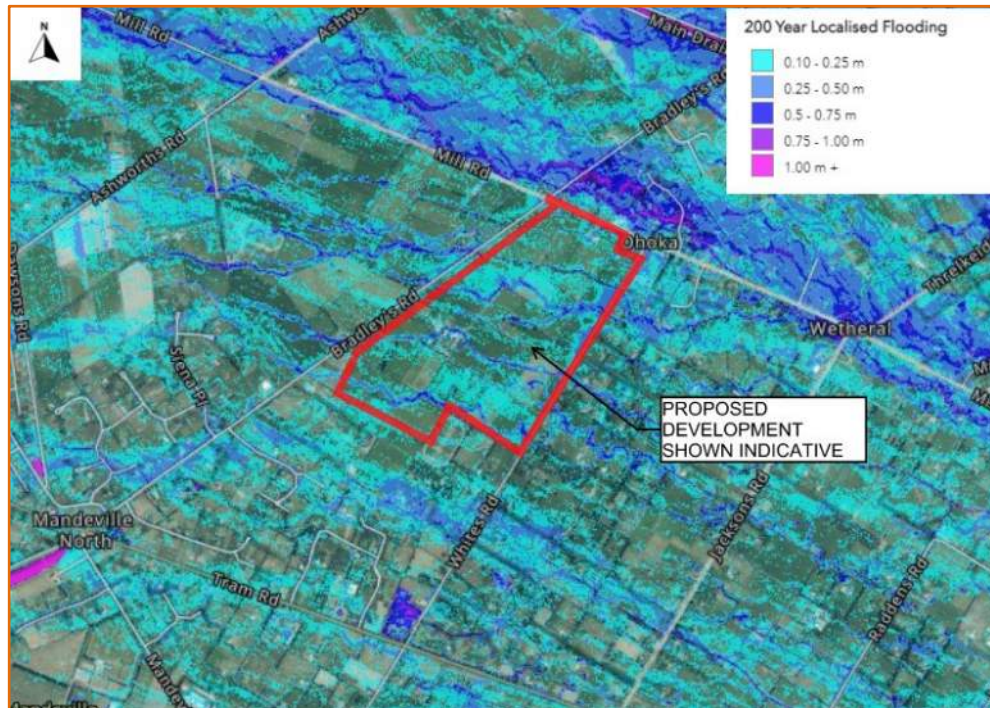


Figure 2: 200-year flood event localised flood depth.

2.2 Site specific stormwater

In terms of site-specific drainage and stormwater infrastructure, this consists of the following:

- ✧ *Upstream Catchments (Bradleys Road):*
Two culverts under Bradleys Road convey the majority of the upstream contributing catchment flows into the site. During significant storm events, runoff from the upstream contributing catchment breaches over Bradleys Road and discharges onto the proposed development area.

A portion of the upstream contributing catchment flow enters the site via overland flow from areas to the south of the site.
- ✧ *Site*
The site has limited formal stormwater infrastructure. Existing land drains collect stormwater and high groundwater from the site as well as convey upstream contributing catchment flows, directing flow downstream towards Whites Road.
- ✧ *Downstream Catchments (Whites Road):*
Three culverts under Whites Road convey the majority of the site flow through to the downstream environment (entering either Ōhoka tributary, South Ōhoka, or unnamed drain 1). A portion of the site flow enters into the Mill Road drain at the north of the site.

Figure 3 below shows indicatively the existing drainage and stormwater infrastructure at the site.



Figure 3. Site overview and existing watercourses

2.3 Large river systems

The site is in close proximity to the Ashley River to the north. Environment Canterbury (ECan) has undertaken flood modelling¹ of the river which also included assessment of likely stopbank breach scenarios. We have checked the model reporting to determine the potential influence on the site. It appears from that the breakout scenarios do not affect the site.

3.0 Guidance and standards

We have utilised and followed the below standards in the development of the hydraulic model;

- ✧ Waimakariri District Council (2025). *Engineering Code of Practice*. Updated February 2025, including Part 5: Stormwater and land drainage.
- ✧ Ministry for the Environment (December 2025). *National Policy Statement for Natural Hazards*
- ✧ Christchurch City Council (2003, with subsequent online updates). *Waterways, Wetlands and Drainage Guide: Ko Te Anga Whakaora mō Ngā Arawai Rēpō*.

¹ Oliver, T., & Wild, M. (2016). *Ashley River floodplain investigation: 2016 update* (Report No. R16/36). Environment Canterbury.
https://www.waimakariri.govt.nz/__data/assets/pdf_file/0008/71000/R16_36-Ashley_2016_floodplain_investigation.pdf

4.0 Baseline flood model

In order to understand the potential surface water effects of the site being developed, we first developed a baseline model of suitable accuracy in which post development effects can be reliably assessed. A hydraulic model has been built with TUFLOW software, using the latest quadtree and sub-grid sampling technology, with the following;

- ✧ A direct rainfall hydrological approach with the use of design rainfall
- ✧ Soil infiltration losses using Horton loss method, as recommended by CCC Waterways, wetland and drainage guide.
- ✧ A digital elevation model (DEM) derived from LiDAR sources, applied to TUFLOW as a 1 m x 1 m (1m²) computational grid referenced to NZVD 2016.

Model build details for the TUFLOW model are summarised in **Table 1** below.

Table 1: Model build summary		
Model element	Report Section	Description
Model software	4.0	TUFLOW HPC 2026
Datums and Projections	4.0	NZVD2016 for the vertical datum and; NZTM2000 (EPSG 2193) for the horizontal datum.
Model Extent	4.1	The model extent covers the site catchment and the Cust main drain catchment.
Model Topography	4.2	The base LiDAR is primarily the 2022 1m x 1 m Canterbury Digital Elevation model (DEM)
Model cell size	4.3	The model cell size has been chosen to be 8 m over the wider catchment, 4 m near-site and 2 m over the site itself.
Hydrology	4.4.1	The model uses a nested 24-hour hyetograph over the entire site catchment applied to every grid cell.
Climate Change	N/A	Climate change has been applied to the total rainfall depth in accordance with Representative Concentration Pathway (RCP) 8.5 projected to 2130
Downstream boundary	4.4.2	A landward edge waterfall boundary is applied around the model perimeter to prevent artificial edge ponding, with a downstream static tailwater level of 4 mRL.

Table 1: Model build summary

Model element	Report Section	Description
Land use and roughness	4.6	Land cover was sourced primarily from LCDBv5, with manual refinements for roads, the Cust Main Drain corridor, site drains and proposed development land use where more detailed hydraulic representation was required.
Soil infiltration	4.5	Horton infiltration losses have been applied based on soil drainage classifications from the Iris data dictionary, with adopted parameters adjusted through model calibration.
Hydraulic structures	4.7	Key culverts along Bradleys Road and Whites Road have been included based on PDP survey information, with minor farm culverts smaller than 600 mm diameter excluded where they are not expected to notably influence major-event hydraulics.

4.1 Computational solver and base parameters

The TUFLOW HPC software used for the hydraulic modelling contains several default or base parameters in the computational solver. We have opted to keep the majority of these settings at default or recommended settings, which pertain to the following;

- ✧ Single precision solver: Single precision (rather than double) is the recommended configuration for TUFLOW HPC due to its explicit, depth-based numerical formulation, which generally does not require the increased numerical precision offered by double precision calculations. The use of single precision provides improved computational performance and reduced memory requirements.
- ✧ Wu turbulence model: This model adopts the default Wu turbulence formulation to represent sub-grid scale turbulence and momentum diffusion. The Wu formulation is the current recommended turbulence model within TUFLOW HPC as it is significantly less sensitive to computational cell size than previous approaches, resulting in more consistent hydraulic behaviour across varying mesh resolutions, and removes the need for specific turbulence calibration.
- ✧ Adaptive timestep: This was adopted for all model simulations, with a recommended upper timestep bound of 5 seconds and lower bound of 0.1 seconds. The adaptive timestep algorithm automatically varies the simulation timestep according to prevailing hydraulic conditions, reducing the timestep during periods of rapidly changing flow and

increasing it during more stable conditions. This maximises computational efficiency while maintaining numerical stability and solution accuracy, and is the recommended approach for TUFLOW HPC modelling. The average timestep for the model is around 0.4 seconds at the peak of the simulation.

4.2 Model extent

The model extent covers the subject catchment that the site sits within, and the Cust Main Drain catchment which was the subject of model calibration. The extent is shown in Figure 4 below. The site catchment has been buffered to include additional area outside of the delineated catchment to ensure that the entire site catchment was captured, removing potential error in the catchment delineation process (explaining the hard model boundary edges).

The model extent terminates approximately along State Highway 1 at the downstream end, which is suitably far downstream for tailwater effects at the model downstream edge to have no effect on flood levels at the site nor effects on the calibration.



Figure 4: Model extent

4.3 Model topography

LiDAR used for the model was the Canterbury LiDAR 1m DEM (2020-2025) sourced from LINZ² and shown in Figure 5. The majority of the LiDAR in this area is dated 2022. This surface was considered to be an appropriate resolution for the purposes of this model. Representation of key hydraulic controls was improved by incorporating breaklines as 'ridges' and 'gullies' into the DEM.

² <https://data.linz.govt.nz/layer/111133-canterbury-lidar-1m-dem-2020-2025/>

These defined the crests of stopbanks along the Cust Main Drain and the crests of significant roads within the model domain, and lowering of perimeter drains where the LiDAR was showing obstructions due to the coarse resolution and/or vegetation cover.



Figure 5: Model topography

4.4 Cell size

TUFLOW's sub-grid sampling technology, which has been applied in this model, is well documented in its ability to yield hydraulically reasonable results for broad-scale overland flow behaviour for a larger cell size. Therefore, a large cell size is justifiable especially in areas where detailed resolution is not required in the model outputs and just the overland flow behaviour needs to be represented (i.e. in upper catchments). This also has the added benefit of speeding up model run times due to the reduction in the number of wet model cells. Therefore, we have applied a large cell size (8 m) over most of the model domain, where mapped outputs are not shown and therefore do not need high resolution.

Where resolution is critical to understanding on-site behaviour and to increase mapping resolution (i.e. on the site and surrounding waterways), or where detailed model resolution is required to achieve model calibration, a finer cell size (2 m) has been chosen. We have also included a 'buffer' zone where the cell size is 4 m over the area surrounding the high-resolution zone to smooth the transition in cell size.

Given that the underlying DEM is at 1 m resolution, we have tested a scenario in which the cell size is reduced to 1 m over the site and key areas, and 4 m elsewhere. The model results did not show any greater detail than the 2 m

results, however the run times quadrupled, therefore we have not used this as the chosen cell size.

4.5 Model boundaries

4.5.1 Hydrology

The model uses a fully nested 24-hour rainfall profile in its analysis, with rainfall intensities sourced from HIRDSv4. This allows multiple flood durations (10 minute to 24 hour) to be assessed in a single model run. This method has been chosen as it removes the need to undertake critical duration analysis in the catchment, and allows an ‘enveloped’ approach to assess likely effects of flooding (i.e. depth and duration) in one singular results set. Given that the purpose of this work is to compare predicted pre- and post- flooding and assess likely changes in peak flood depth, we suggest that this method is suitable.

Rainfall hyetographs are shown in Figure 6 below for the 50-year ARI, 100-year ARI and 200-year ARI events.

It is important to note that the WDC code of practice specifies assessment of up to a 72-hour event in its analysis. We have undertaken a sensitivity test in which a 72-hour nested event was tested in the model, however there were no discernible differences in the model results when comparing to the 24-hour storm profile, which was the expected result as the critical duration in the catchment is around 6 hours. The shorter duration was adopted in the design runs due to the number of model iterations being completed in the design development and will be tested again at the detailed design stage.

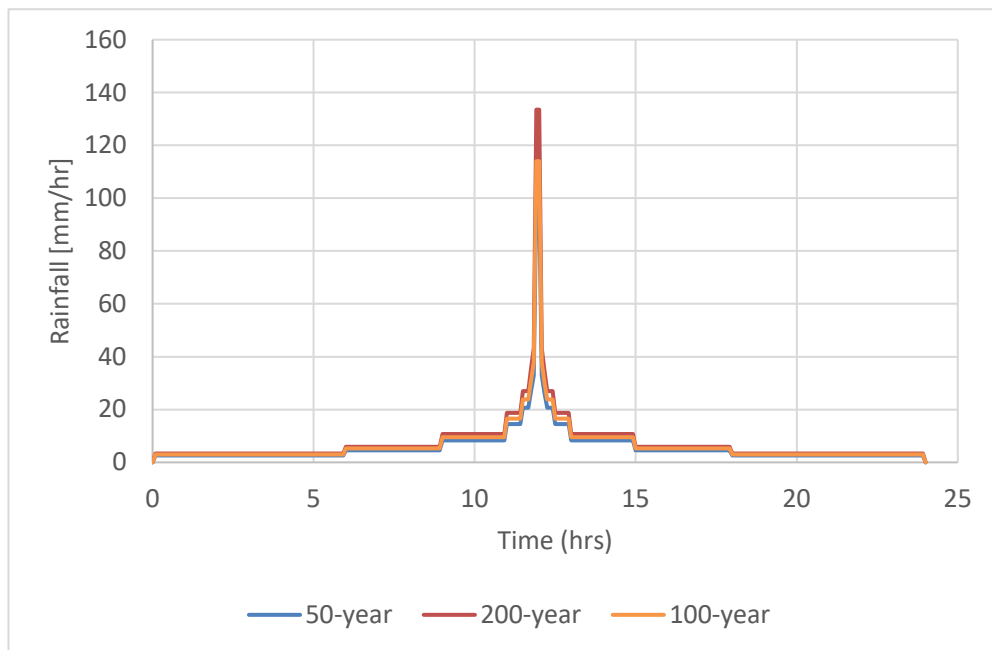


Figure 6: Design rainfall

4.5.2 External boundaries

External model boundaries consist of the following;

- ✧ A model edge 'waterfall' boundary which covers all landward edges of the model. This has been done to prevent artificial ponding on the edges of the model.
- ✧ A downstream boundary with a static tailwater level set at the downstream end of the model. The static tailwater level has been set at 4 mRL to be conservatively high to account for any backwater effects from the Kaiapoi River.

4.6 Soils

4.6.1 Infiltration rate

There are several supported methods to support soil infiltration in TUFLOW. The Horton loss method has been adopted as it is recommended by the Christchurch City Council Waterways, Wetlands and Drainage Guide for representing infiltration losses in direct-rainfall hydraulic models. The method allows infiltration capacity to reduce through the duration of a storm, from an initial rate toward a lower final rate, reflecting the progressive wetting and saturation of soils during rainfall.

In this model, Horton parameters have been assigned based on soil classifications derived from the LRIS data dictionary V3 (Landcare Research), with no infiltration applied to impervious or otherwise non-infiltrating areas. Infiltration rates have been set by using the recommended CCC values as a starting point, then changing them proportionally throughout the model calibration to determine the values that gave a best-fit in the calibration. The spatially varying soil classifications are shown in Figure 7 below and adopted values are shown in Table 2.

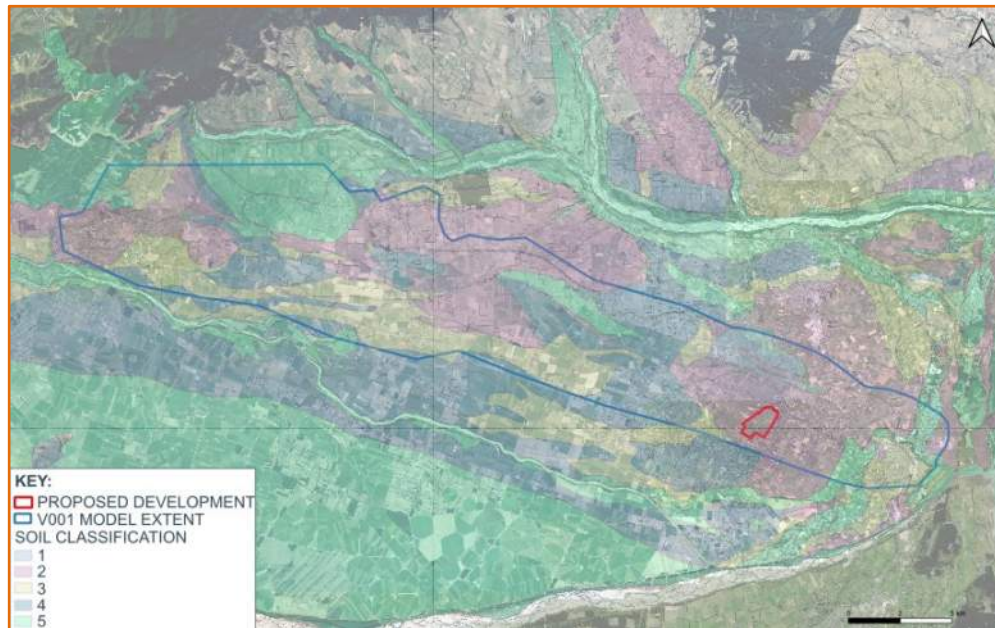


Figure 7: Soil types

Table 2: Soil infiltration parameters						
Soil drainage class	Soil ID	Method	Initial loss (mm)	Initial loss rate (mm/hr)	Final loss rate (mm/hr)	Decay rate (h-1)
Well drained	5	Horton	0.0	3.75	1.5	0.108
Moderately well drained	4	Horton	0.0	3.0	1.125	0.234
Imperfectly drained	3	Horton	0.0	2.25	0.75	0.360
Poorly drained	2	Horton	0.0	1.5	0.525	2.880
Very poorly drained	1	Horton	0.0	0.75	0.3	5.4

4.7 Land use and roughness

The spatial distribution of land cover across the model extent was sourced primarily from Land Cover Database Version 5 (LCDBv5), sourced from Landcare Research. Where detailed land use distinction is required above the level of detail that LCDBv5 provides, i.e. detailed land use distinction to represent existing site drainage, we have made manual edits to form the baseline scenario for roughness. This includes;

- ✧ Updating roughness zone around Cust Main Drain.

- ✧ Adding in roads from the LINZ road addresses layer³ and buffered 6 m.
- ✧ Manual changes on site to distinguish between site drains and surrounding pasture.

The resulting spatial land use is shown in Figure 8 below.

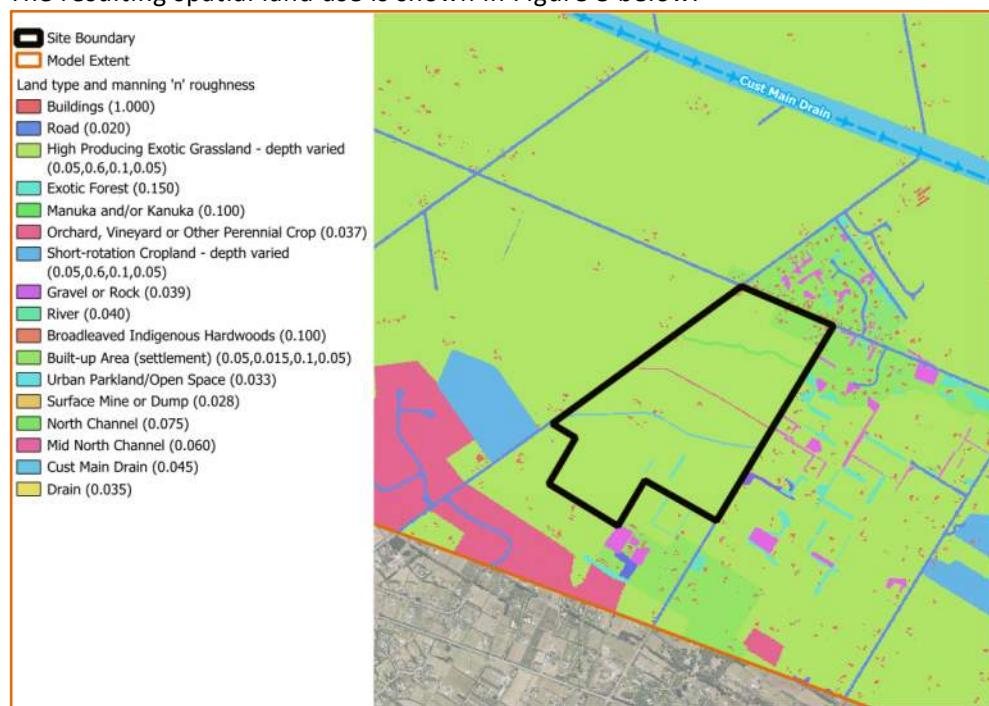


Figure 8: Roughness zones

Roughness values have been first estimated using “look-up” tables that document ranges of calibrated roughness that have been found on other surface water systems. These “look-up” values were applied as a starting point throughout the model calibration process to provide a calibration to gauged flood events.

In order to achieve a calibration to gauged flood events (refer Section 5.0), Manning's n values applied to land use zones were increased beyond “look-up” 2D roughness values, such as those published in Australian Rainfall and Runoff ARR5 (2019). Furthermore, it was found that applying depth varying roughness also improved model calibration, mainly to achieve goodness-of-fit with hydrograph shape and total runoff volume. The values adopted following calibration are shown in Table 3 below.

Table 3: Adopted roughness and imperviousness values by land use type

Land use type	Manning's roughness	Imperviousness (%)
Building	1	100
Roads	0.02	100

³ [NZ Addresses: Roads | LINZ Data Service](#)

Table 3: Adopted roughness and imperviousness values by land use type		
Land use type	Manning's roughness	Imperviousness (%)
High Producing Exotic Grassland - depth varied	Depth <0.05 n = 0.6, Depth >0.05 n = 0.05	-
Lake or Pond	0.02	100
Exotic Forest	0.15	-
Forest - Harvested	0.16	-
Deciduous Hardwoods	0.125	-
Manuka and/or Kanuka	0.1	-
Orchard, Vineyard or Other Perennial Crop	0.037	-
Short-rotation Cropland - depth varied	Depth <0.05 n = 0.6, Depth >0.05 n = 0.05	-
Gorse and/or Broom	0.125	-
Gravel or Rock	0.039	-
River	0.04	100
Broadleaved Indigenous Hardwoods	0.1	-
Low Producing Grassland	0.033	-
Built-up Area (settlement)	Depth <0.05 n = 0.015, Depth >0.05 n = 0.05	-
Herbaceous Freshwater Vegetation	0.1	-
Urban Parkland/Open Space	0.033	-
Surface Mine or Dump	0.028	-
Indigenous Forest	0.15	-
Fernland	0.16	-
Transport Infrastructure	0.016	-
Estuarine Open Water	0.015	-
Mixed Exotic Shrubland	0.08	-
Medium Dense Bush (connecting southern channels)	0.07	-

Table 3: Adopted roughness and imperviousness values by land use type		
Land use type	Manning's roughness	Imperviousness (%)
Dense Bush (connecting southern channels)	0.11	-
High Producing Exotic Grassland (Old Model)	0.035	-
Swale	0.07	-
North Channel	0.075	-
Mid North Channel	0.06	-
Mid South Channel	0.06	-
Drain	0.035	-
Developed lot	0.08	70
Developed large lot	0.08	30
Wetland	0.08	-

Where no fraction impervious value was specified, the land use type has been treated as pervious for the purposes of this summary table.

4.8 Hydraulic structures

Several existing hydraulic structures were surveyed and inputted into the model. Key hydraulic structures, specifically culverts along Bradleys Road and Whites Road, were incorporated into the model. These were mainly defined based on survey information collected by PDP in 2022, however Culv_06 was only recently constructed so was added into the model in September 2026. The location of these structures is shown in Figure 9 below and the details are summarised in Table 4.



Figure 9: Modelled existing culverts

Table 4: Model Culvert Parameters					
ID	Type	Culvert Width (m)	Culvert Height (m)	Upstream Invert (m RL NZVD2016)	Downstream Invert (m RL NZDV2016)
CULV_1	Box	1.5	1.5	27.11	27.11
CULV_2	Box	4.0	1.5	19.81	19.81
CULV_3	Box	3.7	1.5	19.01	19.01
CULV_4	Box	1.5	0.9	21.51	21.51
CULV_5	Box	4.0	1.5	24.11	23.81
CULV_6	Circular	0.6	n/a	19.3	19.3
CULV_7	Circular	1.00	n/a	19.4	18.9

We have only included structures that are considered to notably influence hydraulics in a major flood event, thus minor farm culverts (i.e. smaller than 600 mm diameter) have not been included in this model.

5.0 Model calibration

Model calibration has been done in two stages;

- ✧ Catchment calibration: the closest gauged watercourse is the Cust Main Drain (also referred to as the Cust River), therefore baseline model parameters (roughness, infiltration) have been set by matching flow hydrographs at the gauge.
- ✧ Site validation: photographs of recent flooding were provided to determine whether the model was suitably replicating on-site and near-site flooding. While the data is more qualitative, the site validation gives confidence that the model is adequately representing specific site flood conditions.

With these two methods, we deem that the model is suitably calibrated to replicate observed flooding and to represent severe event and future conditions.

5.1 Available information

The location of the flow and rainfall gauges relative to the site is shown in Figure 10 below. The periods of record are around 30-50 years.

For the rainfall, all five rainfall gauges were used to represent the spatial variation in rainfall across the catchment. Rather than applying a single rainfall record uniformly across the whole model, the recorded rainfall totals from each gauge were interpolated to create a continuous total rainfall grid. This approach provides a spatially varied representation of observed storm patterns across the catchment while still using measured rainfall data as the basis for the model input.

The model results were compared to gauged flows at a single location, Cust Main Drain at Threlkelds Road.



Figure 10: Flow and Rainfall Gauge Locations

5.2 Catchment calibration

Three rainfall events were chosen in order to undertake model calibration. Detailed summaries of the three calibration events and the associated event ARIs are summarised in Appendix A: Detailed calibration summary. These events are;

- ✧ **June 2014:** A prolonged rainfall event produced widespread flooding in North Canterbury, including impacts in Rangiora. Around **144 mm** of rainfall was recorded at Threlkelds Road, with the longer-duration rainfall and Cust Main Drain response indicating an event in the order of a **20 to 50-year ARI**.
- ✧ **July 2022:** An atmospheric river brought widespread heavy rain across Canterbury, with relatively consistent rainfall totals of around **70 to 80 mm** across the district. The Cust Main Drain peak flow was approximately a **20-year ARI**, while the overall Ōhoka flood response was likely around a **10 to 20-year ARI** due to wet antecedent conditions.
- ✧ **July 2023:** Persistent heavy rain caused flooding across eastern Canterbury, with the event more locally intense around Ōhoka and Rangiora. Threlkelds Road recorded around **117 mm over 24 hours**, with the critical shorter-duration rainfall indicating approximately a **20 to 50-year ARI** event for Ōhoka.

The 2022 event has been chosen as the main event where calibrated parameters have been chosen, with the other two events being used to supplement the calibration and to gain confidence in the chosen model parameters for a wider range of events. The 2022 event has been chosen because;

- ✧ It is a single hyetograph-peak flood event, which aligns with the chosen design rainfall approach
- ✧ There was a much closer match with recorded rainfall across all five gauges, which meant that a relatively uniform rainfall profile was applied across the whole catchment.
- ✧ It is the closest event to when the underlying LiDAR was flown (also in 2022)

Model calibration was undertaken by applying the recorded rainfall spatially across the model extent, and comparing results to the gauge. Model roughness and infiltration parameters were varied within $\pm 50\%$ of the recommended or textbook values, in order to match peak flows. The model parameters that yielded the best calibration match are summarised in Section 4.0. Recorded vs modelled flows are shown in Figure 11, Figure 12 and Figure 13 below.

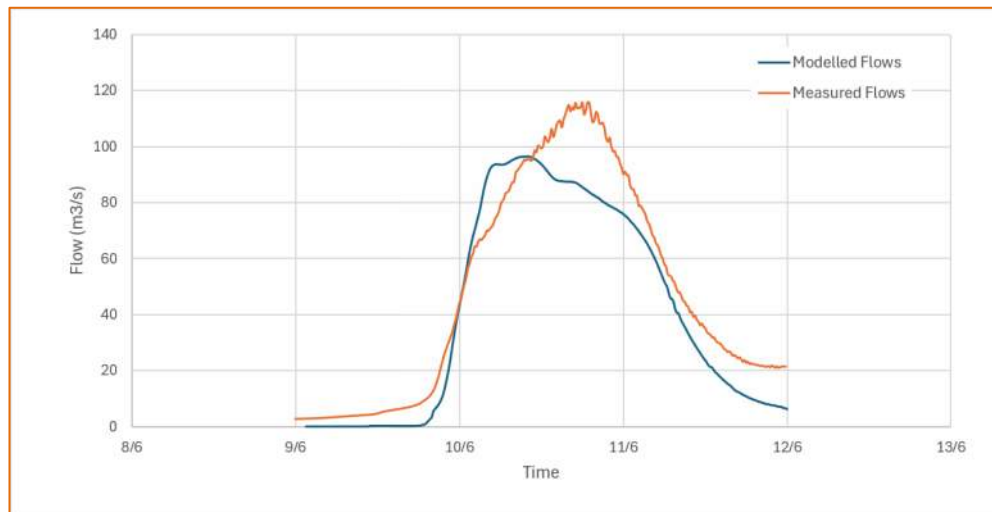


Figure 11: 2014 recorded vs modelled flows

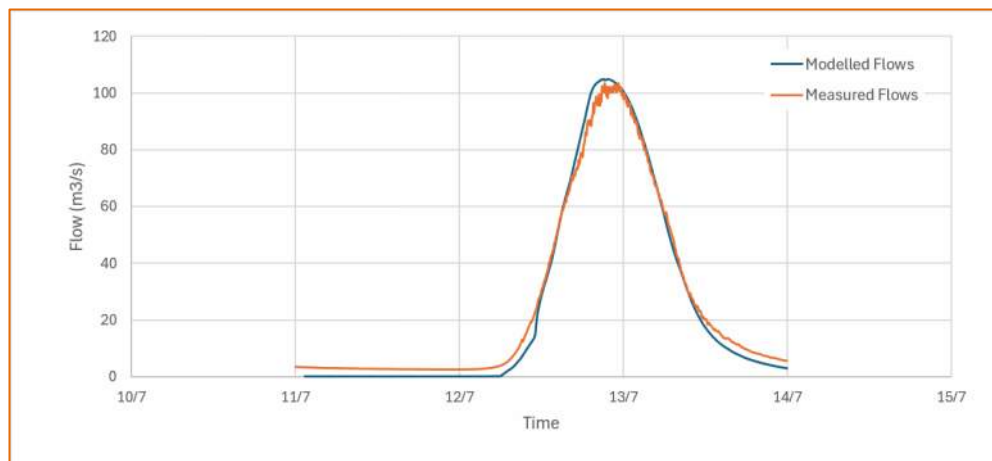


Figure 12: 2022 recorded vs modelled flows

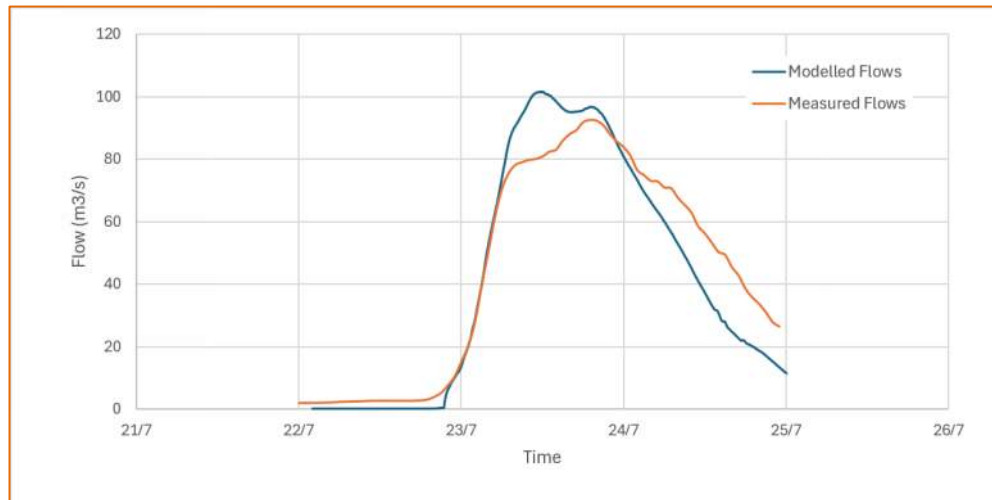


Figure 13: 2023 recorded vs modelled flows

The best calibration match was the 2022 event, with the recorded and observed flows matching closely. The 2014 and 2023 events showed reasonable matches especially on the rising limb of the flood. However, the hydrograph shapes are quite different implying that the recorded rainfall may have been different from what was observed, which may have been due to misrepresentation of spatially varied rainfall by the interpolation method.

5.3 Site validation

While catchment calibration was achieved by matching inflows to a single hydrograph, this does not allow for full spatial confidence in the model results, especially around the site of interest. To account for this, we have also carried out site specific validation where flood model results for the same calibration events were compared to site photographs. This has the following limitations;

- ∴ Photographs may not have been taken at the peak of the flood, therefore they may underestimate actual flooding.
- ∴ Approximate measurements have been taken from photographs, which is clearly going to have accuracy deficiencies.

Given the above, this exercise has been done to gain general confidence in model outputs around the site, and to highlight any clear deficiencies in the modelling, if any.

Comparisons to site photographs are shown in Appendix B: Model Validation Photos. There is general agreement with the model results and the site photographs, the photos either match the model or the model results show greater ponding, given the limitation that the photographs might not have been taken at the peak of the flood this result has been deemed reasonable.

6.0 Post-development flood model

The baseline model was modified to represent the developed site conditions. In this case, all other model parameters have been kept the same, but the post-development model contains the following changes within the site boundary;

- ✧ Proposed landform provided by Inovo dated 19 August 2026. This is shown in Figure 14 below.
- ✧ Delineated roughness zones (shown in Figure 15). All areas not manually defined in this figure are set to default baseline roughness, which mainly pertains to the polo field which maintains the baseline roughness values corresponding with grassland.
- ✧ Proposed stormwater culverts and network (locations shown in Figure 16 and details in **Table 5**) based off the latest site plans dated 9 June 2026 (ref 16013000-RC-440-4413).



Figure 14: Proposed ground levels



Figure 15: Land use roughness zones applied to model

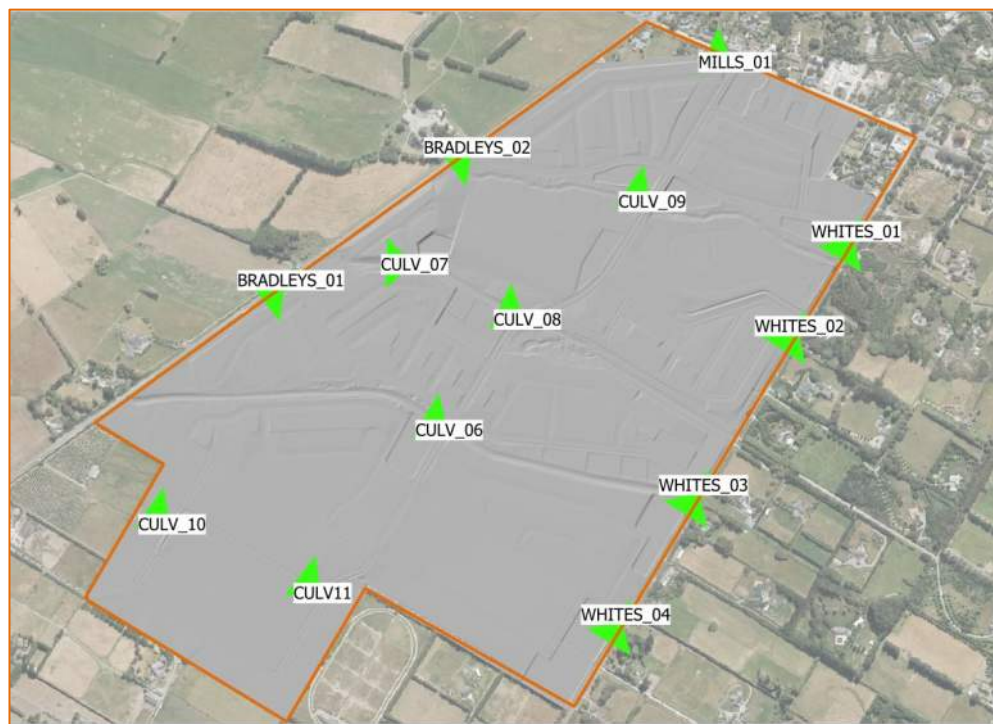


Figure 16: Locations of proposed stormwater culverts

Table 5: Proposed culvert parameters					
ID	Type	Culvert Width (m)	Culvert Height (m)	Upstream Invert (m RL)	Downstream Invert (m RL)
BRADLEYS_01	Circular	0.9	N/A	25.68	25.64
BRADLEYS_02	Circular (x2)	0.6	N/A	24.27	24.24
CULV_06	Box	1.5	1	22.93	22.82
CULV_07	Box	1.5	1	23.66	23.52
CULV_08	Circular	0.9	N/A	22.37	22.3
CULV_09	Box (x2)	4	2.5	20.99	20.83
CULV_10	Circular (x3)	0.6	N/A	27.03	27
CULV11	Circular (x3)	0.6	N/A	24.61	24.52
MILLS_01	Circular	0.9	N/A	20.8	20.79
WHITES_01	Box (x1)	1.5	0.8	19.2	19.23
WHITES_02	Circular (x2)	0.9	N/A	19.41	19.4
WHITES_03	Circular (x2)	0.9	N/A	20.09	20.07
WHITES_04	Circular	0.9	N/A	20.88	20.7

6.1 Stormwater management areas (SMAs)

The proposed stormwater management areas (SMAs) have been included in the design surface. The primary function of these areas is to provide peak flow attenuation for events up to 100 year ARI.

We have conservatively assumed that the SMAs will be full up to the freeboard level for all modelled events. The SMAs will be incorporated into the model at the detailed design stage.

7.0 Model runs

The Waimakariri Engineering Code of Practice (COP) states the following to assess the flood performance of the proposed development;

- ✧ Consideration of off-site effects for a range of design events and durations. As we have used a nested storm profile as the hydrological design input, we have assessed a single design storm for all ARI events.

- ∴ Proposed lots to be designed to accommodate a 200-year ARI flood.

The model has been designed to assess the site performance under extreme flood conditions (i.e. >50 year ARI). In events smaller than this, the primary stormwater network and SMAs have a greater bearing on site hydraulics, and therefore the model is currently not at a suitable level of detail to assess this. Therefore, we have modelled the events and scenarios as per **Table 6** below.

Table 6: Model run matrix

ARI event	Climate change projection	Pre-development	Post-development
50-year ARI	RCP8.5 2130	✓	✓
100-year ARI	RCP8.5 2130	✓	✓
200-year ARI	RCP8.5 2130	✓	✓

Flood maps showing peak flood depth, level, velocity, and changes in peak flood level are shown in Appendix C.

8.0 Discussion

8.1 Pre-development flooding

In the existing scenario, the site experiences notable surface water flooding and overland flow in all modelled scenarios. The flood water is conveyed through four main overland flow paths which travel in a north west to south east direction across the site. Peak flood depths as modelled for a 100 year ARI event are shown in Figure 17 below.

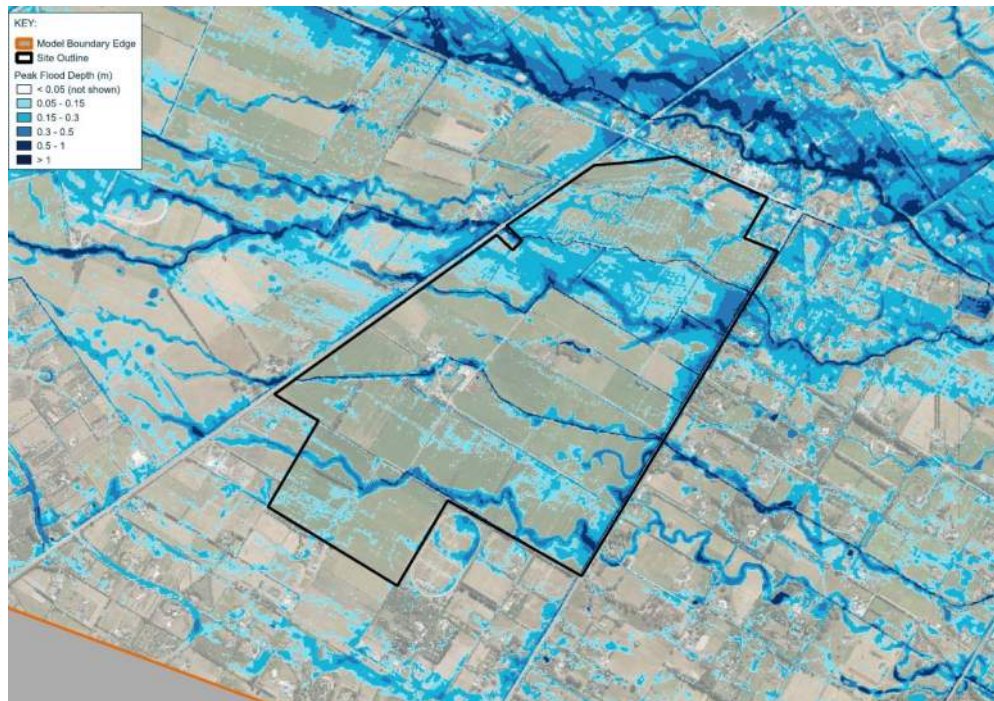


Figure 17: Pre-development flooding for the 100 year ARI event

8.2 Proposed development

The proposed site layout has been designed as to preserve the natural flow direction across the site, and thus is intended to be hydraulically neutral (i.e. no changes in peak flood level) to the surrounding area. On-site storage has also been included to offset the increases in impervious area associated with the proposed developed area. Peak flood depths and velocity for the proposed development for the same 100 year ARI event have been shown in Figure 18 below, demonstrating these elements.

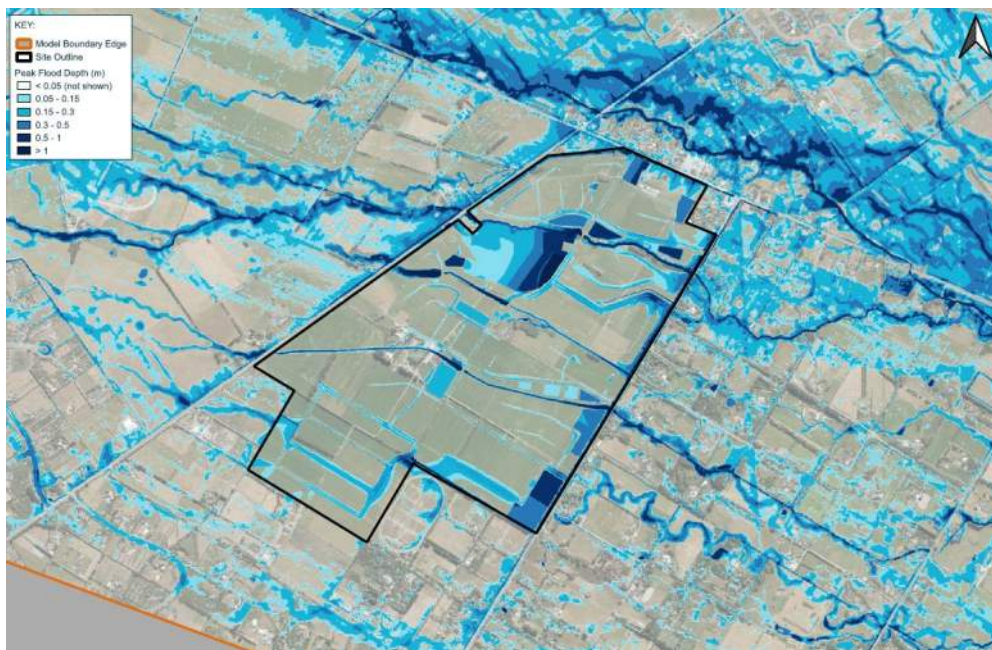


Figure 18: Post-development flooding for the 100 year ARI event

8.2.1 Minimum Floor Levels Within Site

NH-S1 of the Partially Operative Waimakariri District Plan requires minimum finished floor levels to be determined relative to the 0.5% AEP (200-year) flood event, including allowances for climate change, with a 400 mm freeboard applying in low hazard areas and a 500 mm freeboard applying in medium and high hazard areas. As portions of the site are subject to modelled flood hazards exceeding the low hazard threshold, and to provide a consistent and conservative design approach across the development, we recommend adopting a minimum finished floor level of 500 mm above the modelled 0.5% AEP flood level unless a site-specific Flood Assessment Certificate issued by Council specifies otherwise.

Final minimum floor levels for future development should be confirmed through the detailed design and consent process, having regard to the relevant flood hazard classification and any requirements specified by Council.

8.2.2 Flood risk

Peak flood depths, levels and velocities have been the primary focus of the flood modelling, however we have also assessed flood risk in line with the National Policy Statement - Natural Hazards 2025 (NPS-NH). The NPS-NH recommends a risk matrix based approach to hazards, following the matrix in Figure 19 below.

		Likelihood Level						
		Almost Certain	Very Likely	Likely	Possible	Unlikely	Rare	Very Rare
ARI (years)		up to 10	10-20	20-50	50-100	100-500	500-5000	> 5000
AEP		10% or more	10% to 5%	5% to 2%	2% to 1%	1% to 0.2%	0.2% to 0.02%	< 0.02%
Consequence Level	Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
	Major	Very High	Very High	High	High	Medium	Medium	Medium
	Moderate	High	High	High	Medium	Medium	Low	Low
	Minor	Medium	Medium	Medium	Medium	Low	Low	Low
	Negligible	Low	Low	Low	Low	Low	Low	Low

Figure 19: NPS-NH risk matrix

In terms of likelihood, we have related these to the event ARIs modelled and described in Section 7.0. For consequence, WDC have a hazard matrix which is adopted from assessing depth x velocity product for a given event as shown in Figure 20 below, which has been post processed and mapped in Appendix C.

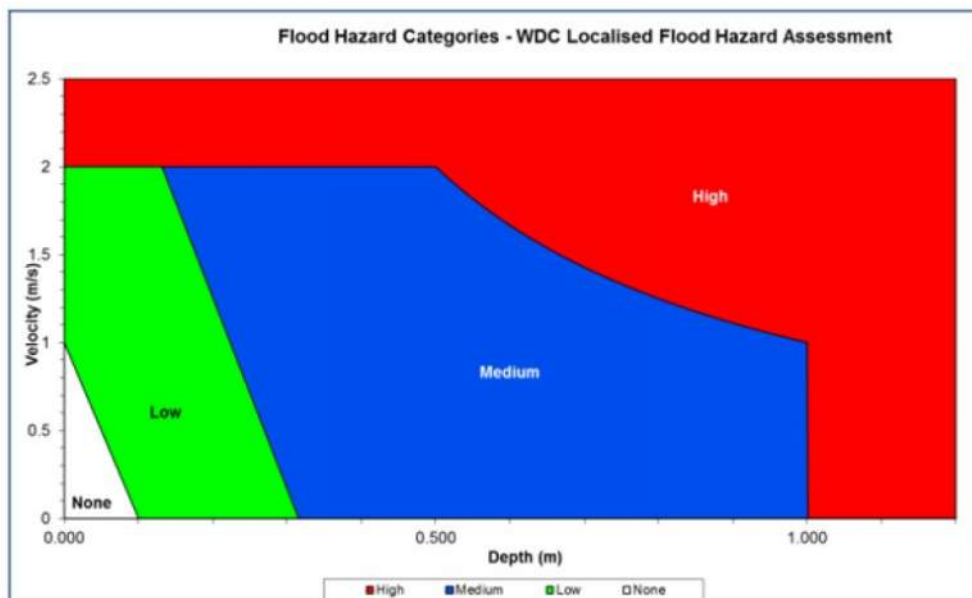


Figure 20: WDC Hazard Categories

In the case of the natural hazards we have translated the results into the following. In cases where there is not a directly equivalent category, we have conservatively adopted the highest of the two;

- ✧ Negligible: None

- ✧ Minor: Low
- ✧ Moderate: Medium
- ✧ High: Major to catastrophic

We have used the risk matrix to develop a combined risk map as shown in Figure 21 below. The map shows that;

- ✧ Across the vast majority of the site, the risk is either 'low' or 'negligible'.
- ✧ Most roads are shown as 'low' risk, with some isolated portions of 'medium' risk.
- ✧ A small portion of the polo field is shown to be 'medium' risk.
- ✧ The locations of high or very high risk are contained within the existing and proposed waterways.

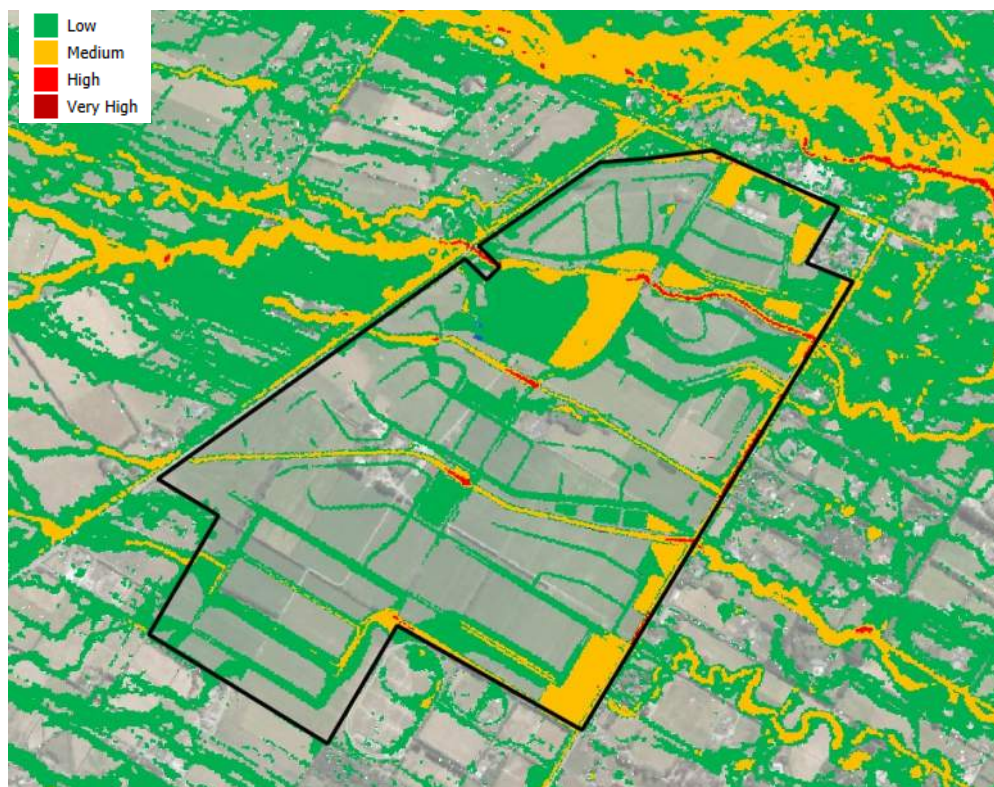


Figure 21: NPS-NH Risk Categories

In summary, the site is generally safe with areas of 'medium' and above hazard contained within stormwater and flood management features. There are isolated areas where the roads are shown to be at 'medium' risk. It is also important to note that the development does not cause any new hazard zones outside of the development extent.

8.2.2.1 Access and egress

As there are some portions of the proposed roads that show some inundation in extreme events, we have checked the likely duration of access and egress restrictions as a metric to assess potential consequences for human safety. There is no formal guidance on acceptable durations in which access and egress in the Canterbury region is considered 'acceptable', however guidance in other areas of the country such as Tauranga City Council⁴ state that access should not be cut off or inhibited for more than 24 hours during a standard 100-year ARI event. We have mapped the total time (hrs) in a 24-hour model simulation where the depth is predicted to be above 300 mm, shown in Figure 22, which is generally regarded as not being driveable. The model results show that the majority of ponding on the roads only exists for up to an hour, and in some isolated cases up to 5 hours. In the cases where the inundation lasts more than 1 hour, there is either an alternative access route, or the prolonged ponding only affects one side of the road.

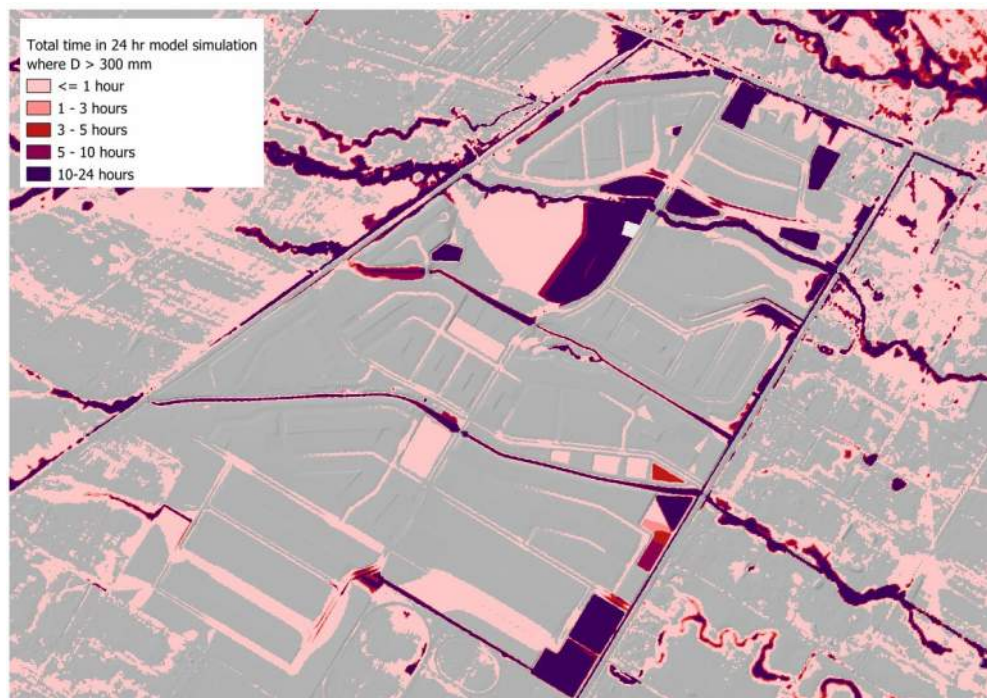


Figure 22: Flood duration in a 100 year ARI event

8.2.3 Assessment of effects downstream

Flood effects have been assessed by differencing peak flood levels attained between pre- and post-development scenarios. As the model has been set up to use a direct rainfall ("rain-on-grid") approach, all grid cells are considered by this assessment. Notable changes to peak flood level within the proposed

⁴ TCC. (2016). Flooding From Intense Rainfall Guideline.

development site are generally due to the changes in landform that will occur as a result of the development, and do not reflect a change in flood potential.

Outside of the proposed development, landform is kept constant between pre- and post-development scenarios. Any changes in peak flood level outside of the development are indicative of a flood effect of the development.

Much of the area adjacent to the proposed development site has been shown to be flood-prone to varying degrees across a range of different flood events. The pre-development flood performance (assessed by modelling) shows widespread flooding with peaks at relatively shallow depth (generally less than 300mm). There are several notable “watercourses” where runoff concentrates in flowing generally from west to east. Within these “watercourses” peak flood depths can exceed one metre.

Given that the proposed development will change the rainfall-runoff performance within the development area, an assessment of the effect of those changes on downstream has been carried out. As mentioned above, this assessment has focussed only on change to modelled peak flood level. Other effects, including velocity and flood duration have not been considered. The reason for this is it is peak flood level that determines flood extent and also indicates whether or not buildings will be inundated (i.e. if modelled peak flood level exceeds building floor level, the building may be considered “flood prone” in the event modelled).

Model results for pre- and post-development landforms have been compared for events of 50, 100 and 200 Year ARI's. These comparisons are shown in Appendix C. Evident from these are the following:

- ✧ While the absolute peak flood levels change for the events considered, the magnitude of the change that results from the proposed development is similar across all events.
- ✧ There is no effect on peak flood levels upstream of the site. This indicates that adequate conveyance has been provided in the post-development landform to allow passage of flows.
- ✧ The effects on modelled peak flood level dissipate with distance downstream. The most significant downstream effect (which is small) occurs immediately adjacent to the site.
- ✧ A reasonably large area downstream of the site is shown to experience slightly lower peak flood levels across the events considered. Peak flood levels have been shown to reduce by up to 100mm.

Modelling of the entire catchment has been used to assess flood effects from the proposed development. At this scale, models comprise numerous assumptions and generalisations such that the results should not be assessed at individual property scale level of detail – the section in this report that follows outlines model limitations.

While this modelling work cannot be considered to be accurate to the pixel, it demonstrates the overall behaviour of this large scale proposed land use change. The effects of this have been shown to be able to be mitigated such that the development will not change the flood performance to any significant degree. It is usual that more detailed analyses will be undertaken through the development process that “iron out” any small-scale flood effects. At this stage there is adequate confidence that the development, if progressed in general alignment with what has been modelled, will not cause adverse flood effects across the series of events considered.

8.2.3.1 Remaining increases in flood levels

Appendix C shows minor increases in flood levels directly east of the development, as shown in the screenshot in Figure 23 below.

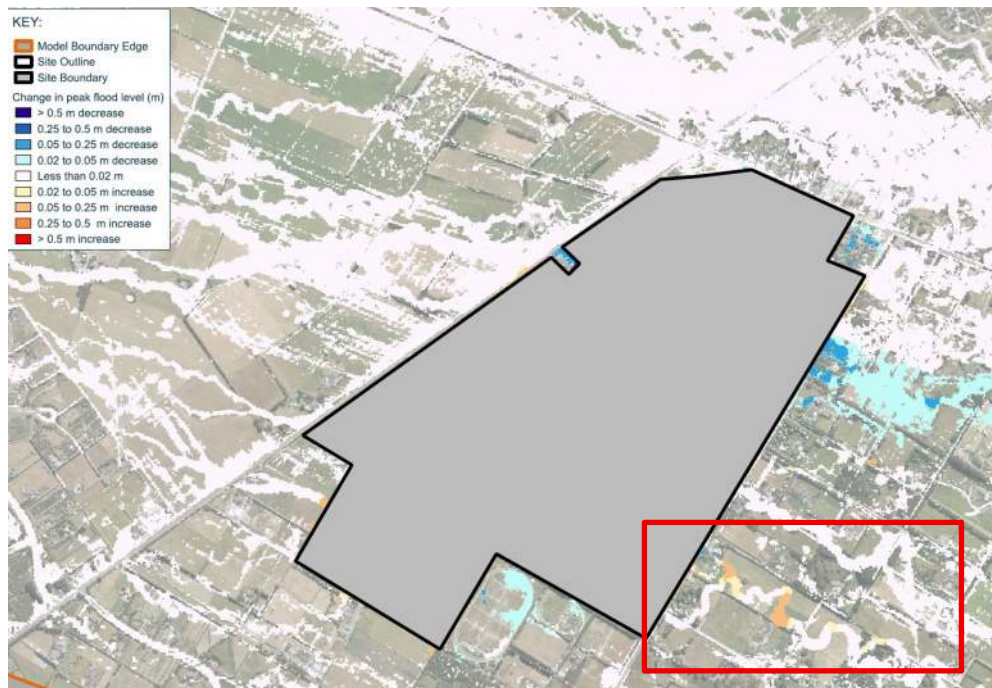


Figure 23: Changes in flood level in a 100 year ARI event, with the subject increases shown in a red outline

These increases are because the Stormwater Management Areas (SMAs) are not explicitly represented in the model, i.e. they are set as full to top of freeboard at the beginning of the model run. Therefore, there is slightly more water leaving the site at the start of the flood that would have otherwise been attenuated in the SMAs. Figure 24 below shows the flow hydrograph pre- and post-development for existing CULV_05, which discharges water from the site into this area. There is no spill over Whites Road into this area (i.e. drainage is solely via the culvert). The hydrograph shows a slight increase in flow at the start of the model simulation, but overall less flow (and thus less volume) discharging into the area in the post development scenario. We anticipate that due to the progression of the model into the detailed design stage (i.e. incorporating the SMAs), this effect will be removed. Given that without the SMAs these particular catchments are unattenuated, the increases are expected and will likely be removed as the model is updated at the detailed design stage.

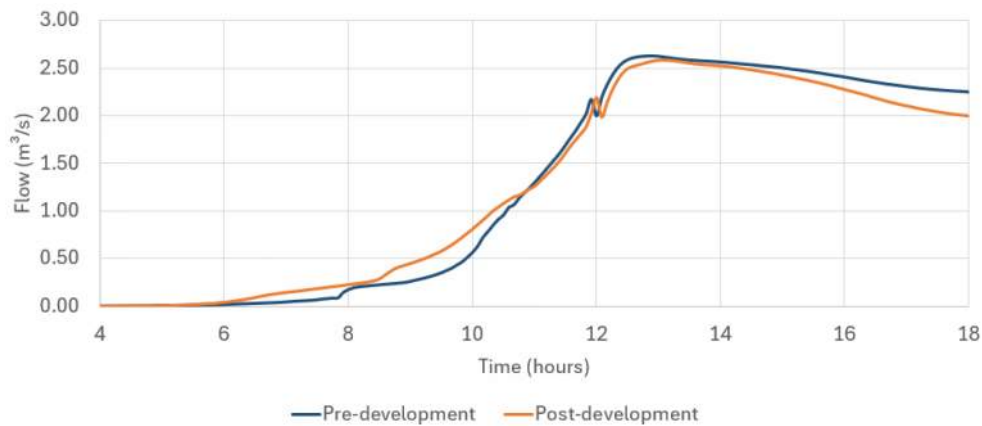


Figure 24: Flow hydrograph of Culv 05 for the 100 year ARI event, pre- and post-development

8.2.4 Affected buildings

In the vicinity of the site are a number of buildings, many of which are located in existing flooding areas. While the primary focus has been on ensuring that there are no increases in peak flood levels outside of the developed area associated with the proposed development, particular focus has been made on ensuring that there are no increases in peak flood level particularly around existing dwellings. The locations of all assessed buildings is shown in Figure 25 below. A visual comparison of the layer against the latest aerial imagery from LINZ shows general agreement, however several missing buildings were manually added in as shown in Figure 26.

It is important to note that we have not used surveyed floor levels in this assessment and are only assessing relative changes in flooding around the buildings.

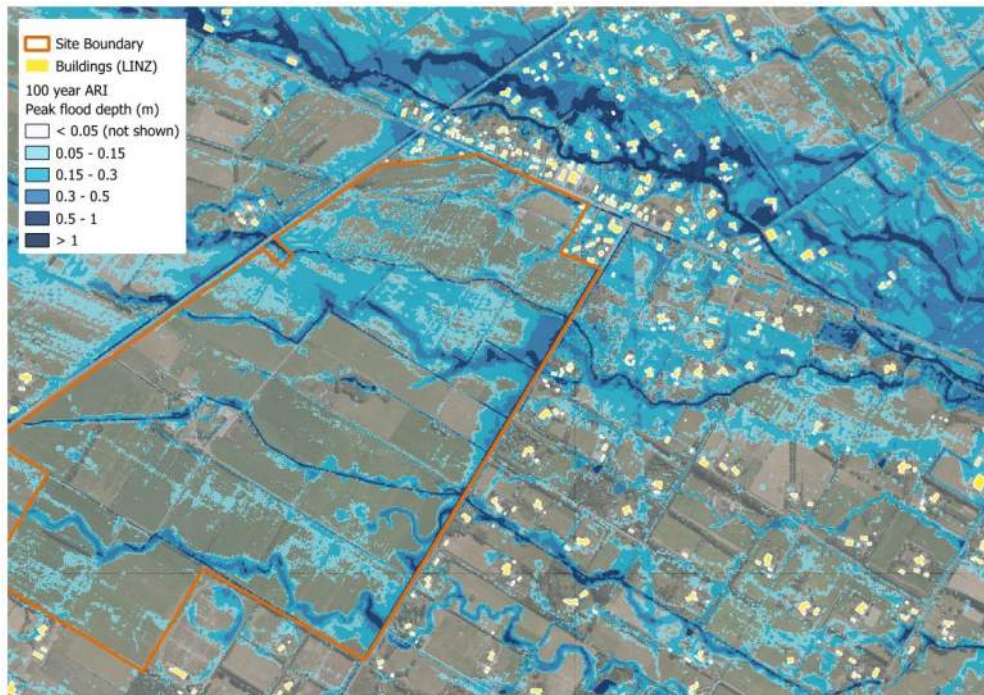


Figure 25: Building footprints near the proposed development



Figure 26: Location where the LINZ building outlines needed to be updated

The model results have been analysed for the 50-year, 100-year and 200-year ARI events to determine the changes in peak flood level within the vicinity (i.e. within a 2 m buffer) of each dwelling. We have reported 'counts' of dwellings where:

- ✧ The peak flood level has increased > 20 mm from existing.
- ✧ The peak flood level has decreased > 20 mm from existing.

It is important to note that maximum peak flood level change has been analysed, when previously we analysed average peak flood level change. The new methodology is considered more conservative. The summary of dwelling counts that fall under this criteria are shown in **Table 7** below. The model results show that there are no existing dwellings that see increases in peak flood level as a result of the development, and a total of 24, 23 and 18 buildings that see either the flooding decreases around the vicinity of the dwelling in the 50, 100 and 200 year events.

It is important to note that we have taken the LINZ building layer and only added in visible structures, and have not discriminated by type of structure in this analysis. Due to the relatively coarse nature of the model, these numbers should be treated as general conclusions as the model is not suitable for property level detail (described in more detail below).

Table 7: Dwelling counts		
Event ARI	Peak flood level increased	Peak flood level decreased
50-year	0	24
100-year	0	23
200-year	0	18

8.2.5 Potential effects on flooding in Silverstream

During previous conferencing matters, concerns were raised regarding potential flood effects downstream of the development near the lower Mill Road / Silverstream area. The location relative to the site is shown in Figure 27 below.

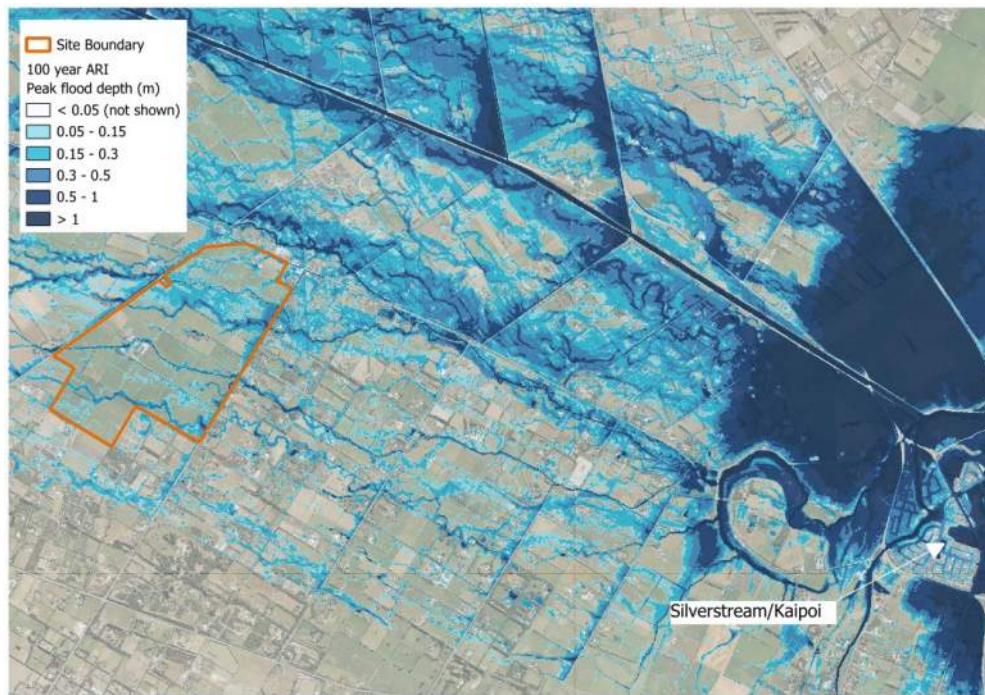


Figure 27: Silverstream/Kaipoi area relative to the site location

This assessment was completed in advance of the Waimakariri Engineering COP updates, and thus was only done on a 50 Year ARI event. The previous assessment has been provided in Appendix D.

The assessment was based on the 50-year event, for an additional discharge volume of 26,000 m³ (the total volume of the storage basins). The analysis indicated that to accommodate an additional 26,000 m³ of storage without exceeding a 20 mm rise in water level, a minimum elevation of 3.96 mRL is required.

The revised discharge volume (see the Stormwater report) is approximately 35,000 m³, assessing for a 100 year ARI event. Repeating the 'bathtub' analysis completed in Appendix D, to accommodate this storage, a minimum elevation of approximately 4.3 mRL would be required. The memo quotes a maximum flood level of 4.55 mRL for the 100 year ARI event, therefore using this analysis there wouldn't be an increase in peak flood level greater than 20 mm. The re-derived hypsometric curve is shown in Figure 28.

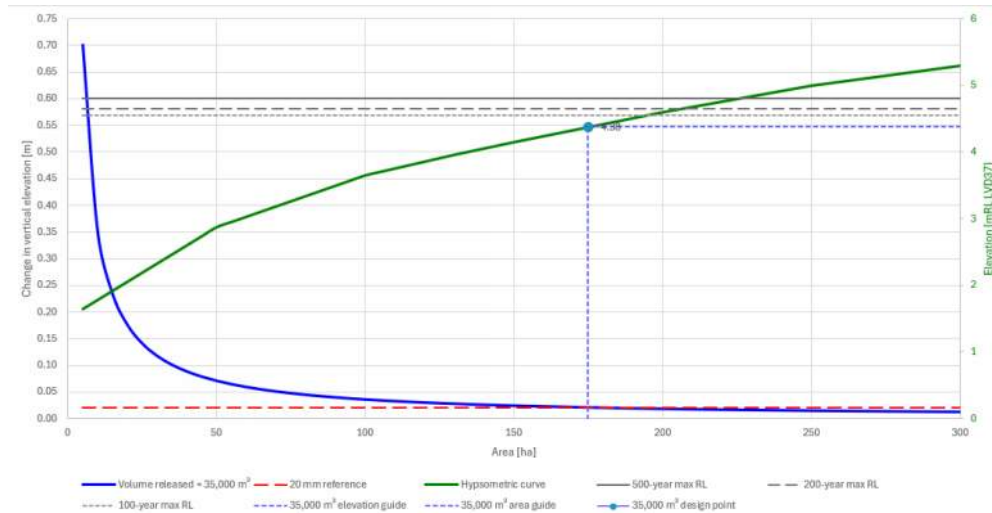


Figure 28: Hypsometric curve

It is important to note that the flood model results do not show any increases in peak flood level in the Silverstream area, in addition to the analysis conducted above. We have repeated the analysis as previous, however we note that the model results are a more suitable means to assess this.

8.2.6 Peak flows

In addition to assessing offsite effects, we have also checked the total outflow from the site in the pre-and post- development scenario to check the overall change in flow characteristics (outside of peaks). The pre- and post-development flows are shown in Figure 29. It is important to note that inflows have not been plotted, and are consistent between pre- and post- for all events. The flow hydrographs show that;

- ✧ Flows are generally higher at the start of the flood event. This is due to the fact that the SMA storage has not been represented in the model.
- ✧ Peak flows are in total lower in the post- vs the pre- in all modelled events.
- ✧ After the recession limb of the flood, the flow characteristics are generally the same.

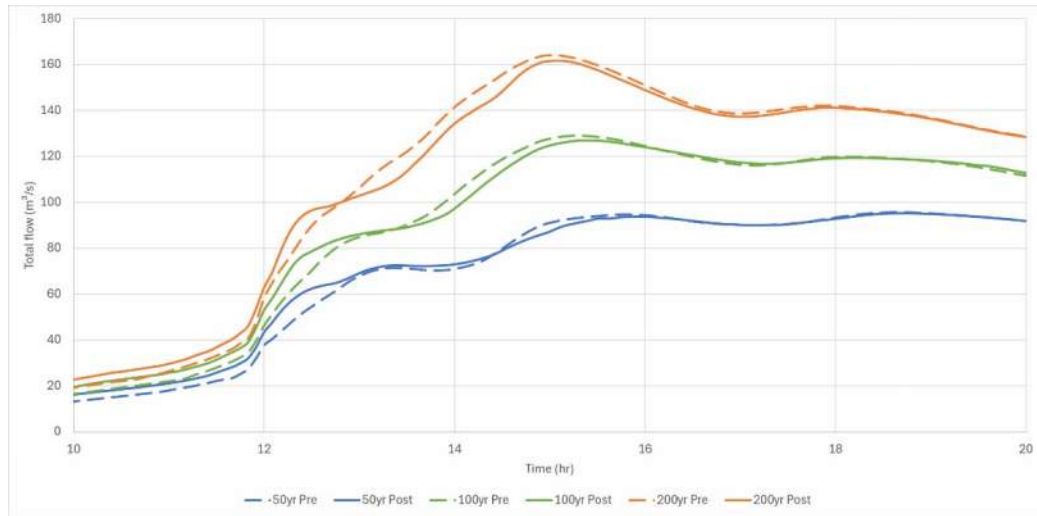


Figure 29: Total pre- and post- development flows leaving the site

9.0 Model sensitivity

Due to the fact that the model was suitably calibrated to determine model parameters such as roughness and infiltration, sensitivity tests were not carried out on these. The model calibration has reduced uncertainty in the base model parameters, but there is still inherent uncertainty in the design assumptions such as rainfall applied to the calibrated model.

Therefore, we have run the post- development model with the CCC WWDG temporal profile for the 100 year ARI 6-hour (critical) event to check the sensitivity of the rainfall temporal pattern on the proposed design, and to check the performance of the design against the rainfall used in in the development of the stormwater management plan⁵. The design 'nested' profile is shown in Figure 30 below.

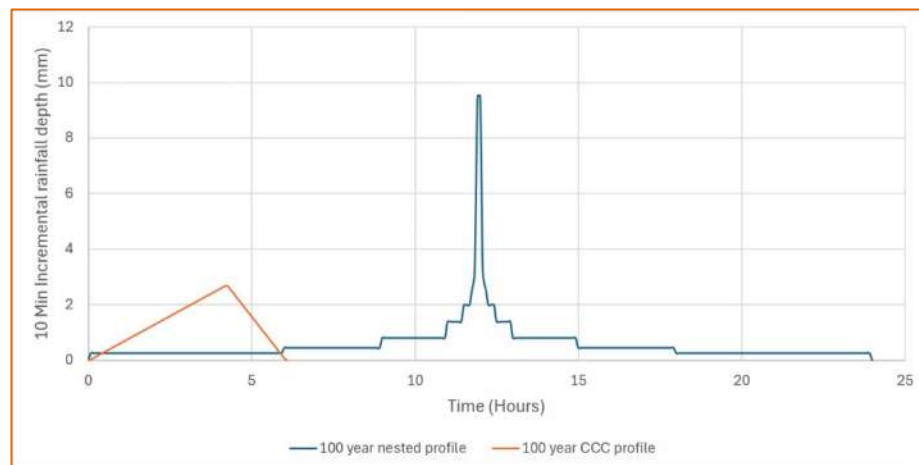


Figure 30: CCC Temporal profile vs design nested rainfall profile

⁵ PDP (September 2026) Fast Track Application – Stormwater Management for 531 & 535 Mill Road, Ohoka

Peak flood depths are shown in Figure 31 below. Model results showed that flood depths are generally lower using this temporal profile than the nested, and that there is not any new areas of likely flooding on the development site that are different from the nested profile runs.

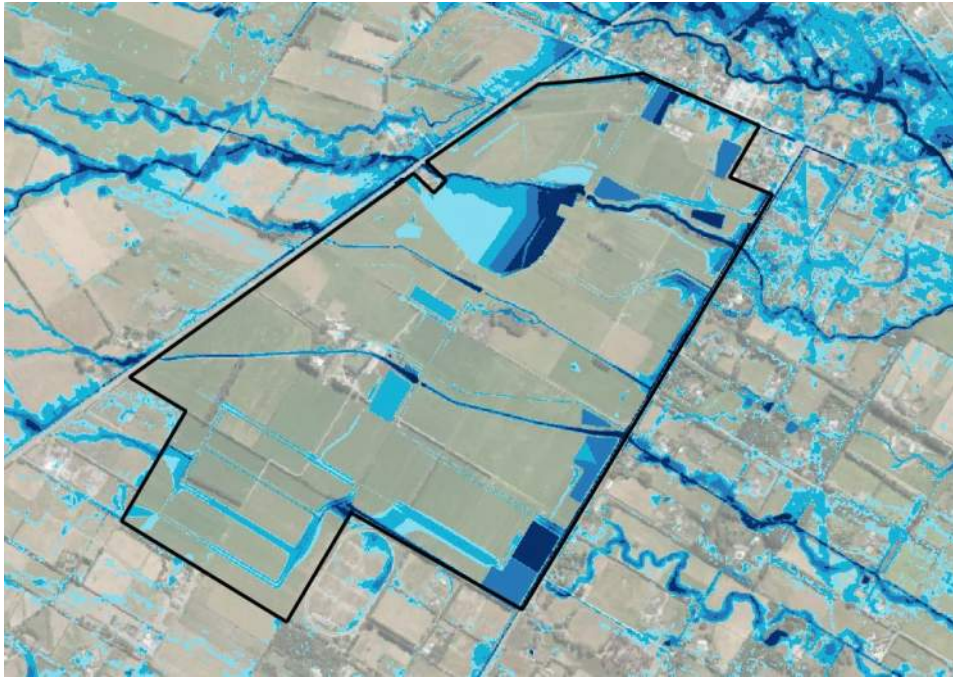


Figure 31: Peak flood depths, 100 year RCP8.5 with CCC Hyetograph

10.0 Model limitations

The modelling has the following limitations;

- ✧ Digital Elevation Model (DEM) derived from remote sensed LiDAR survey data. The limitations of accuracy of LiDAR data are well understood, and these limitations will apply to the model results. In particular, LiDAR survey data and the resulting DEM will have lower accuracy in areas such as incised waterways, heavily vegetated areas and water bodies. Where ground levels have changed since the LiDAR survey was captured, the DEM and hence the model will not recognise these changes and be out of date.
- ✧ A direct rainfall approach has been applied to the model, which can highlight accuracy deficiencies in input data by showing small 'puddles' in predicted flooding.
- ✧ Comparative plots have been shown for changes in peak flood level between two different scenarios. These plots are intended to show absolute difference between physical states, and imply that the model results themselves are absolute in nature. In reality, the uncertain nature of the modelling means that there is a 'confidence interval' in the model results themselves. As such, small differences in peak flood levels less than 15 mm have not been shown to account for this uncertainty.
- ✧ Modelling undertaken simulates the likely surface water flooding effects of an extreme 100 year ARI event that is based on future climate predictions (RCP8.5 projected to 2130). The severity of such event has not been experienced in living memory, as such these predictions have been extrapolated. The results presented may appear severe and are intended to represent a possible future extreme event that may occur.
- ✧ For the modelling undertaken, manning 'n' is the roughness parameter that has been selected. It is recognised that the manning equation gives reliable results in fully developed, rough, turbulent flow (which generally occurs at a high Reynolds number). This means that modelled behaviour may be closer to reality under high Reynolds number conditions (high combination of velocity and depth) and may be less accurate at lower Reynolds number. In this way, calibration is able to be achieved to peak flows (during conditions when Reynolds number is high), but is more challenging if using constant roughness at lower Reynolds number. Thus, if calibration seeks to match peaks only, then constant Manning n is a reasonable approximation. However, if calibration seeks to match an entire recorded hydrograph, there may be deviation in modelled performance at lower Reynolds number if constant Manning n was used. At lower Reynolds number, effective roughness will be higher than at high Reynolds number.

- ∴ We are aware that the results of Waimakariri district wide model exist and overlap with this area, and that the results differ marginally. The catchment/district wide modelling was built to understand flooding at a large scale, and thus lacks site specific detail and finer scale inputs used to develop the model used in our analysis. The results are thus expected to differ as the two models have been developed for entirely different purposes. The site-specific model detailed in this report is more reflective of flood conditions on the site as specific flood mechanisms relating to the site have been carefully considered.

11.0 Conclusion

The site-specific TUFLOW model has been developed and calibrated to provide a suitable basis for assessing changes in flood behaviour associated with the proposed development at 531 and 535 Mill Road, Ōhoka. The modelling indicates that the proposed landform, stormwater management areas and culvert arrangement generally maintain existing overland flow paths across the site and provide sufficient conveyance through the development area.

The assessment shows no adverse increase in peak flood level at existing dwellings assessed around the site for the modelled 50-year, 100-year and 200 - year ARI events. Off-site increases in flood level are generally small, dissipate downstream, and are mostly confined to established watercourses and their immediate surrounds, and are due to increases in the rising limb of the flood due to the SMAs not being explicitly represented. Therefore, we expect these effects to be removed as we progress into detailed design. The modelling also shows areas downstream of the site where peak flood levels are reduced.

The flood risk assessment indicates that most of the site is subject to low or negligible flood risk, with higher risk areas generally contained within watercourses and stormwater management features. Overall, provided the development remains generally consistent with the assumptions modelled in this report, it is expected to avoid significant adverse flood effects.

Detailed calibration summary

There are several rainfall stations located within the Waimakariri District, two of these (Ōhoka and Threlkelds Road) are within 5 km of the proposed subdivision. ECan also maintain a rated flow recorder at the nearby Cust Main Drain (Threlkelds Road). Rated flow and gauging data provided by Tony Gray (ECan)⁶ shows that:

- ✧ The recorder has 37 full years of data, from 1981 to 1986 and 1992 to the present day. There is a gap in the data from 1986 to 1992; and,
- ✧ The largest rated flow is 117.009 m³/s on 6 August 1995, very similar to the recorded peak for the 10 June 2014 event (115.634 m³/s) and the 12 July 2022 event (103.501 m³/s).

To help estimate the return period of historic events, a standard flood frequency analysis was conducted by fitting a Gumbel distribution to the annual maxima recorded for the Cust Main Drain.

2014 flood event

The NIWA weather catalogue⁷ reports that the 9-10 June 2014 event was due to a slow-moving high which pushed cold air onto the south-island. This column air clashed with a warmer north-easterly over north canterbury resulting in heavy rain. The NIWA weather catalogue reports that:

“23 elderly dementia patients were evacuated from their rest home after it was flooded. Rangiora High School was closed due to flooding”

Figure 32 shows the recorded rainfall and flow data. The Cust Main Drain recorded a peak flow of around 115 m³/s and a flood frequency analysis shows that this flow has a return period of somewhere between 20 years (102 m³/s) and 50 years (125 m³/s).

A total rainfall depth of 144 mm and maximum intensity of 7.5 mm/hr was recorded. The Cust recorder⁸ (at Threlkelds Rd) provides sub-hourly rainfall data:

- ✧ 40.0 mm was recorded over a six-hour duration, between a 5-year (36.6 mm) and 10-year (44.6 mm) event according to HIRDS V4;
- ✧ a maximum depth of 72.0 mm was recorded over a 12-hour duration, about a 20-year event (73.4 mm) according to HIRDS V4, and,
- ✧ a maximum depth of 114.0 mm was recorded over a 24-hour duration, exactly a 40-year (114 mm) event according to HIRDS V4.

⁶ Email from Tony Gray (ECan) to Ben Throssell (PDP) on 23 May 2023

⁷ https://hwe.niwa.co.nz/event/June_2014_New_Zealand_Storm

⁸ Supplied by Tony Gray (ECan) to Ben Throssell (PDP) on 15 June 2023

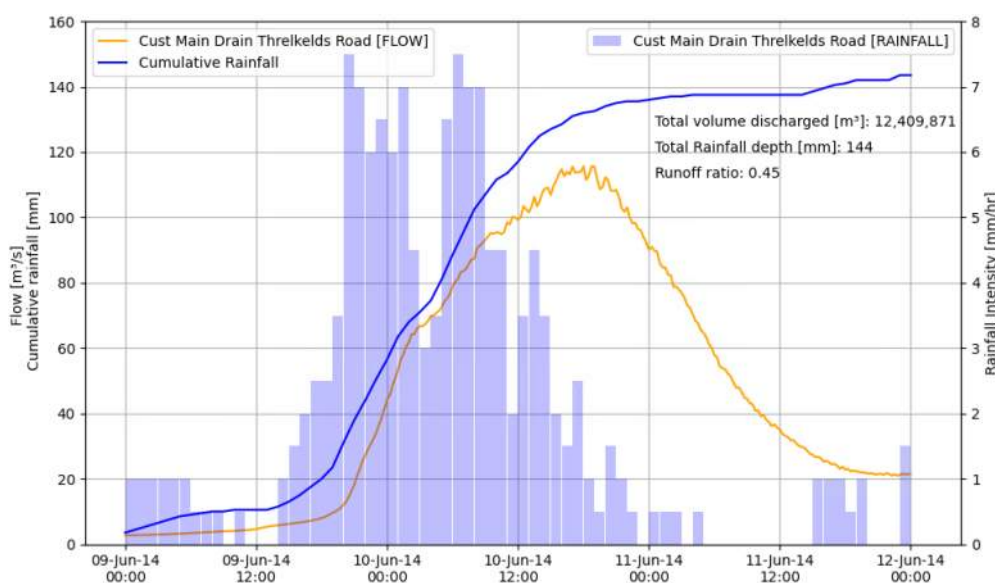


Figure 32. Recorded flows and depths for Cust Main Drain at Threlkelds Road for 9 June to 12 June 2014

2022 flood event

NIWA, in their monthly climate summary, reported⁹:

“On 11-12 July an atmospheric river of moisture brought heavy rain and strong winds large parts of the North Island and northern and eastern parts of the South Island.”

NIWA also reported in the same monthly climate summary that Christchurch in July 2022:

“was the wettest month (of any month) on record. The 310 mm of rain recorded there was the first time that more than 300 mm of rain was observed in one month since records began in 1863. This represents around half of the rain that Christchurch typically receives over the course of one year.”

Closer to Ohoka, rainfall depths for the 12 July event were remarkably consistent across the district, around 70 to 80 mm of total rainfall for recorders across the Waimakariri District. The Cust Main Drain recorded a peak flow of just over 100 m³/s, a total rainfall depth of 70 mm and maximum intensity of 7.5 mm/hr.

Analysis of the Ōhoka Rainfall recorder which has sub-daily rainfall data shows a maximum depth of:

- ∴ 34.8 mm was recorded over a six-hour duration, about a 5-year event (36.6 mm) according to HIRDS V4;

⁹ https://niwa.co.nz/sites/niwa.co.nz/files/Climate_Summary_July_2022_Final-v3.pdf

- ∴ a maximum depth of 61.8 mm was recorded over a 12-hour duration, about a 10-year event (62 mm) according to HIRDS V4; and,
- ∴ a maximum depth of 76.4 mm was recorded over a 24-hour duration, between a 5-year (69.5 mm) to 10-year (83.5 mm) event according to HIRDS V4.

For context, the flood frequency curve predicts a 10-year flow of 84 m³/s and 20-year flow of 102 m³/s. ECan report¹⁰ a 10-year flow of 90 m³/s for the same recorder. The flow recorded in Cust Main Drain for the July 2022 peaked at 103.501 m³/s. The flood frequency analysis shows that this flow has a return period of 20 years (102 m³/s).

The return period of flood elevations are a function of both rainfall and the antecedent conditions. This event occurred in winter and there was rainfall in the preceding days. Over the preceding four days, the Ōhoka recorder shows 13.5 mm, Threlkelds Rd shows 13.5 mm and Poyntzs Rd shows 30.5 mm. Therefore, the return period of this flood event, for Ohoka, was likely between 10 and 20 years.

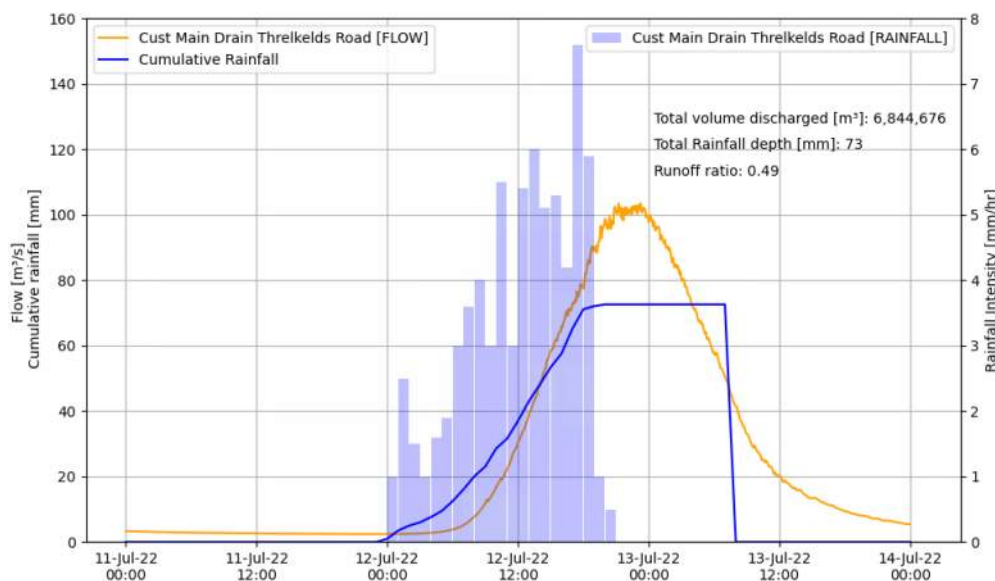


Figure 33. Recorded flows and depths for Cust Main Drain at Threlkelds Road for 11 July to 14 July 2022

¹⁰ <https://www.ecan.govt.nz/data/riverflow/>

2023 flood event

Niwa report¹¹:

“From 23-24 July, persistent heavy rain caused flooding in eastern parts of Canterbury. The SH1 bridge over the Ashburton River was closed due to build-up of flood debris, with a number of other roads around the region closed due to surface flooding. A man was rescued from the roof of his vehicle after being trapped in Hawkins River floodwaters.”

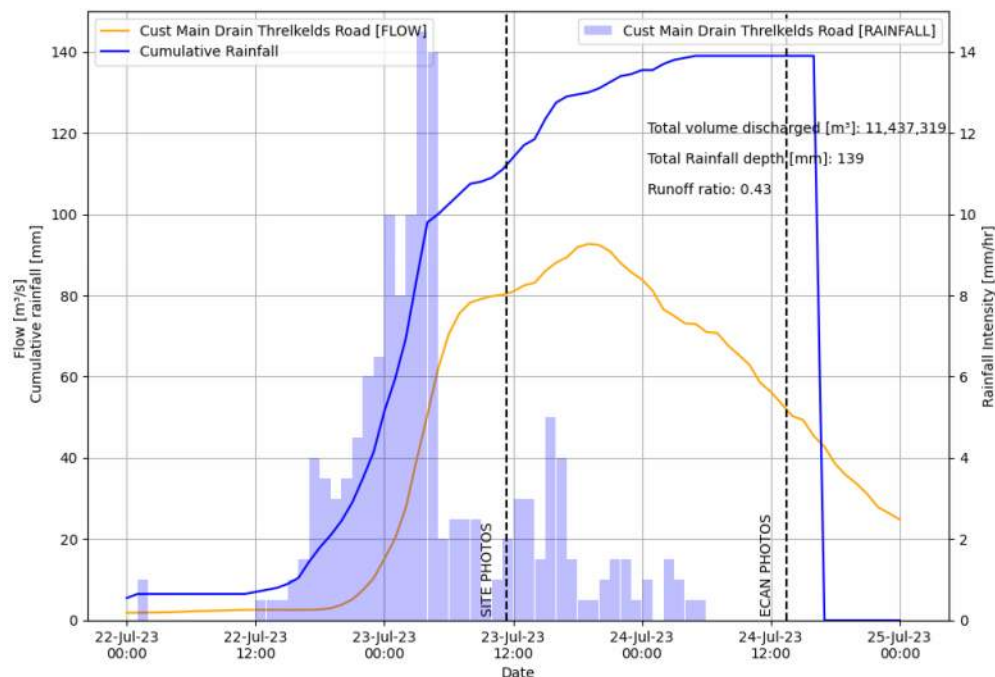


Figure 34. Recorded flows and depths for Cust Main Drain at Threlkelds Road for 22 July to 26 July 2023

Analysis of the nearby (2.5 km from Ohoka) Threlkelds Road Rainfall recorder shows the sub-daily rainfall data as follows:

- ✧ Maximum rainfall intensities were 14 mm/hr, this is around twice the maximum intensity recorded at Threlkelds Road for the 2014 and 2022 events.
- ✧ a maximum depth of 63.0 mm recorded over a six-hour duration, about a 40-year event (62.1 mm) according to HIRDS V4;
- ✧ a maximum depth of 87.5 mm was recorded over a 12-hour duration, about a 40 (85.5 mm) to 50-year (89.5 mm) event according to HIRDS V4, and,

¹¹ https://niwa.co.nz/sites/default/files/Climate_Summary_July_2023_Final.pdf

- ∴ a maximum depth of 117.0 mm was recorded over a 24-hour hour duration, about a 50-year (119 mm) event according to HIRDS V4.

For the 6-hour event, which is approximately the critical duration for Ōhoka (and the proposed development site) flood levels, the largest rainfall depths were recorded at the Threlkelds Road recorder (63 mm) and the Rangiora recorder (56 mm). All other recorders assessed showed lower rainfall depths meaning the 2023 event appears to have been centred over or close to Ohoka.

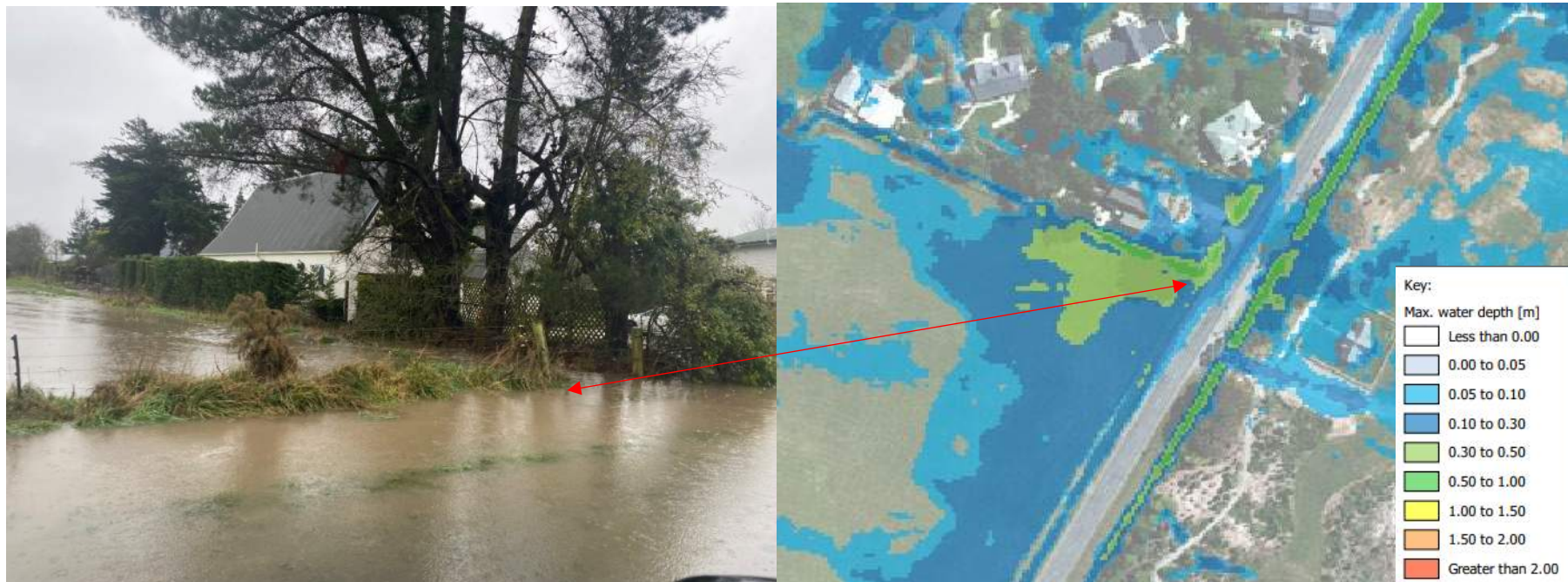
For the 24-hour event, maximum rainfall depths (117 mm) were recorded at the Threlkelds Road recorder. Again, all other recorders assessed showed lower rainfall depths.

Therefore, the most intense rainfall for this event was likely located over Ōhoka and Rangiora, and intensities for this event appear to decrease in the north, south and west directions. Therefore, rainfall intensities within the upper catchment of Ōhoka may have been lower.

The flow recorded in Cust Main Drain peaked at 92.677 m³/s. Flood frequency analysis (prepared prior to this event) shows that this flow has a return period of somewhere between 10-years (84 m³/s) and 20-years (102 m³/s).

Critical rainfall duration for Ōhoka is likely to be around 6-hours, therefore the rainfall event for the Ōhoka catchment was likely between a 20-year and 50-year event. Similarly, for flood levels in Ohoka, this event was likely between a 20-year and 50-year event.

VALIDATION PHOTO 1: WHITES ROAD LOOKING NORTH TOWARDS 401 WHITES ROAD, TAKEN AT 11:24AM 23 JULY 2023



The model shows a good match to the photo at this location. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 2: WHITES ROAD LOOKING SOUTHWEST, TAKEN AT 11:24AM 23 JULY 2023



The model shows depths that are higher than the photo within the paddock. Modelled depths are approx. 180mm. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 3: WHITES ROAD LOOKING NORTHEAST, TAKEN AT 11:25AM 23 JULY 2023



This was considered to be the critical validation location for the model. A good match has been achieved for the ponding across the road. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 4: WHITES ROAD LOOKING NORTH ACROSS Paddock TOWARDS 401 WHITES ROAD, TAKEN AT 11:29AM 23 JULY 2023



The model shows depths that are higher than the photo within the paddock. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 5: WHITES ROAD LOOKING NORTHWEST ACROSS PADDOCK TOWARDS 507 MILL ROAD, TAKEN AT 11:29AM 23 JULY 2023



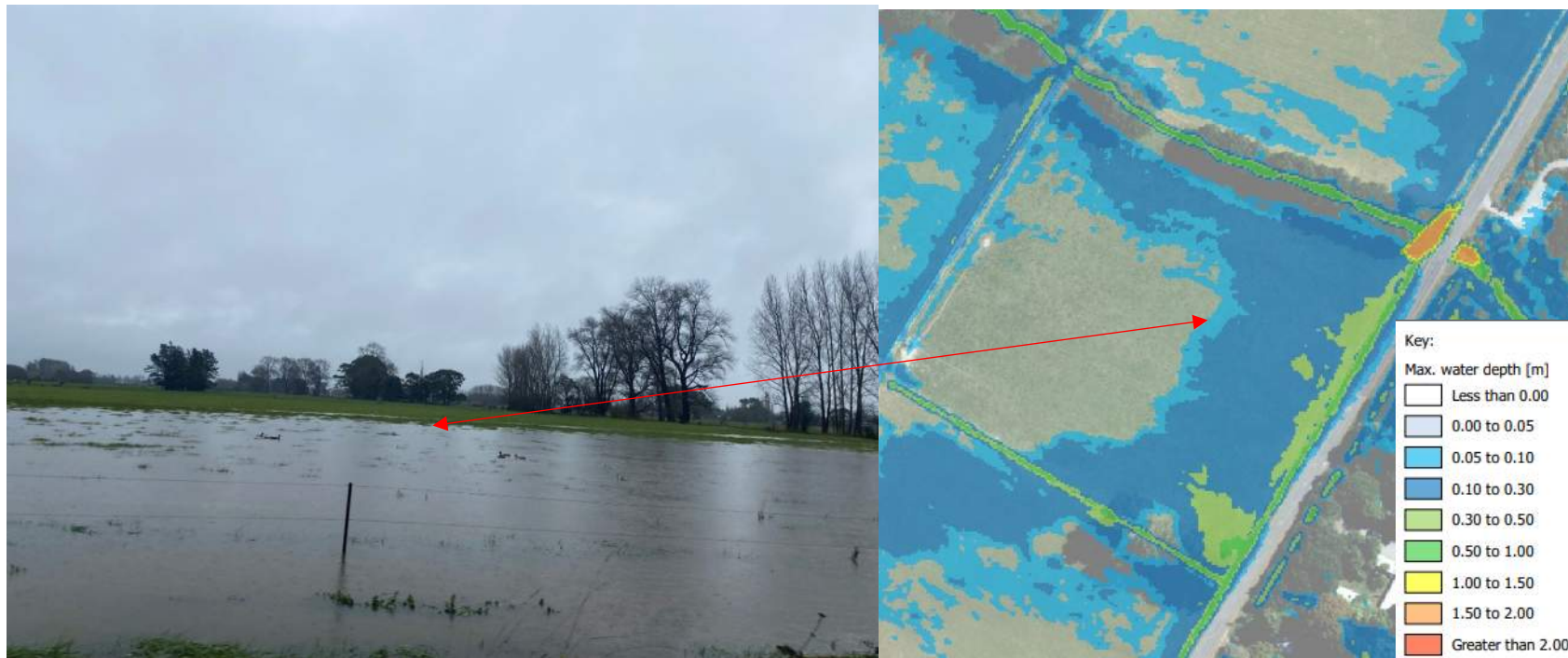
The model shows depths that are higher than the photo within the paddock. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 6: WHITES ROAD LOOKING WEST ALONG OHOKA STREAM, TAKEN AT 11:29AM 23 JULY 2023



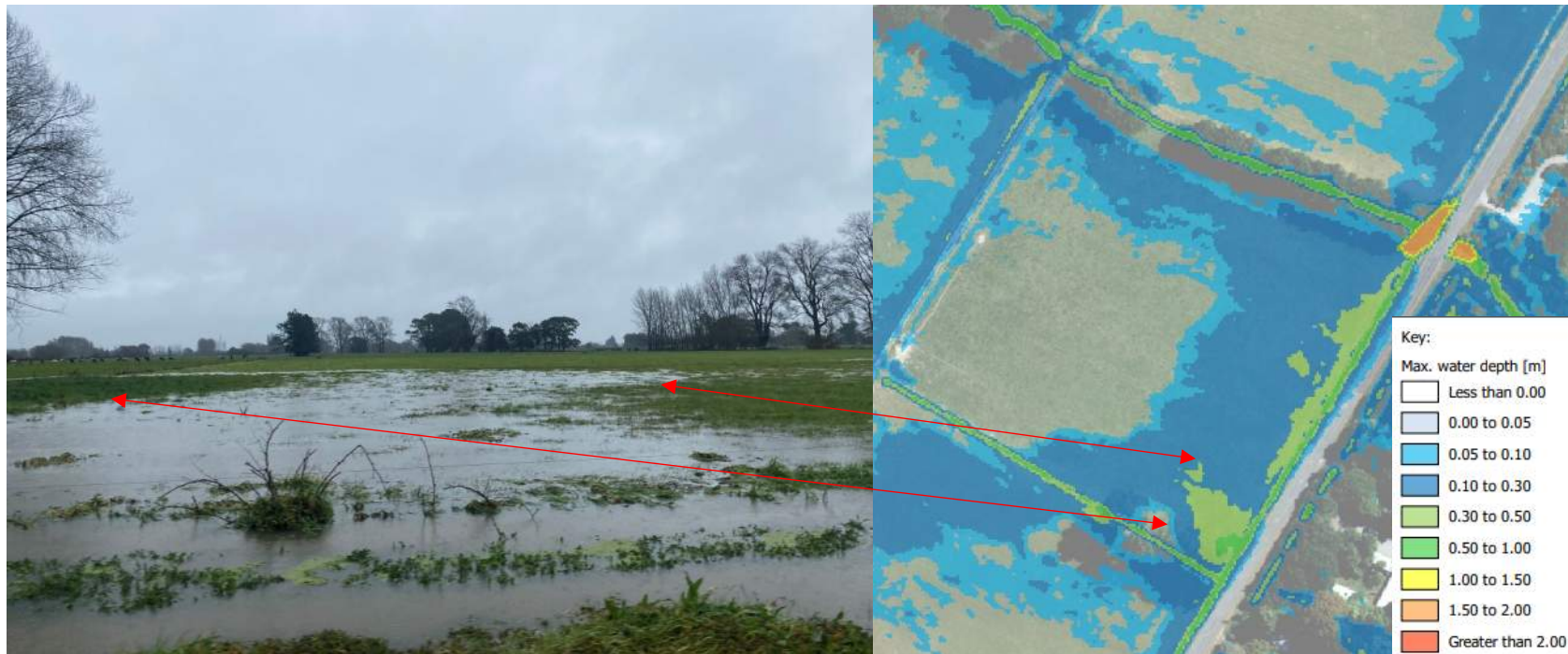
Ohoka Stream is flowing below bank full height for both the photo and model depths. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 7: WHITES ROAD LOOKING WEST ACROSS Paddock DIRECTLY SOUTH OF OHOKA STREAM, TAKEN AT 11:29AM 23 JULY 2023



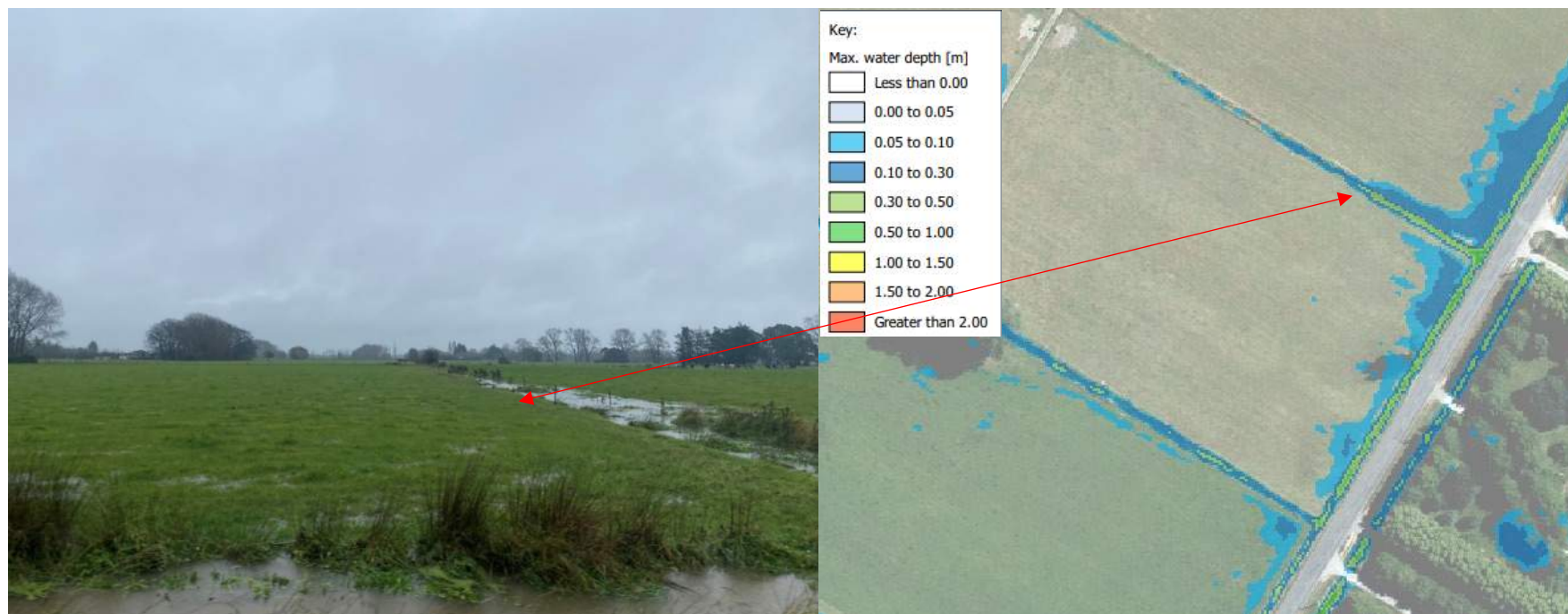
The model shows a good match to the photo at this location. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 8: WHITES ROAD LOOKING WEST ACROSS Paddock, TAKEN AT 11:29AM 23 JULY 2023



The model shows depths that are higher than the photo. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 9: WHITES ROAD LOOKING WEST ACROSS Paddock, TAKEN AT 11:29AM 23 JULY 2023



The model shows a good match to the photo at this location. (Depths less than 0.05 m not shown)

VALIDATION PHOTO 10: WHITES ROAD LOOKING WEST ACROSS Paddock AT THE SOUTHERN END OF THE SITE, TAKEN AT 11:28AM 23 JULY 2023



The model shows depths that are higher than the photo. The ponding depth in the photo may be masked by the height of the grass and the shape of the ponding matches. (Depths less than 0.05 m not shown)

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)

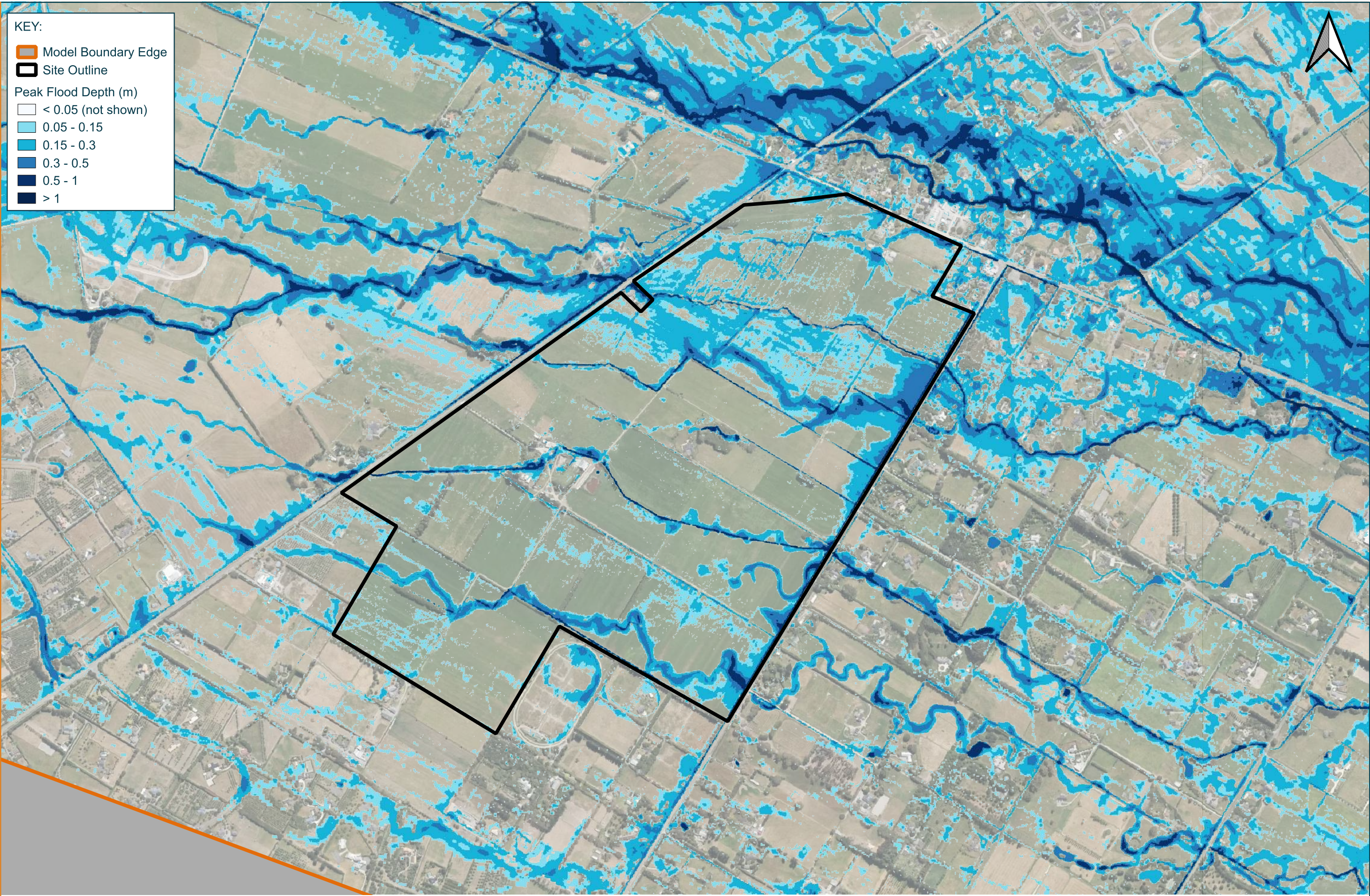
0.05 - 0.15

0.15 - 0.3

0.3 - 0.5

0.5 - 1

> 1



0 100 200 300 m

SCALE 1:10,000 (A3)

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1	FINAL	Sep. 26
NO.	REVISION	DATE
		AW
		BY

SOURCE:

1. Base aerial imagery sourced from Land Information New Zealand (LINZ)

2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'

3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT

CARTER GROUP

FIGURE

Figure 1 - 50 Year ARI Peak Flood Depth, Pre Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

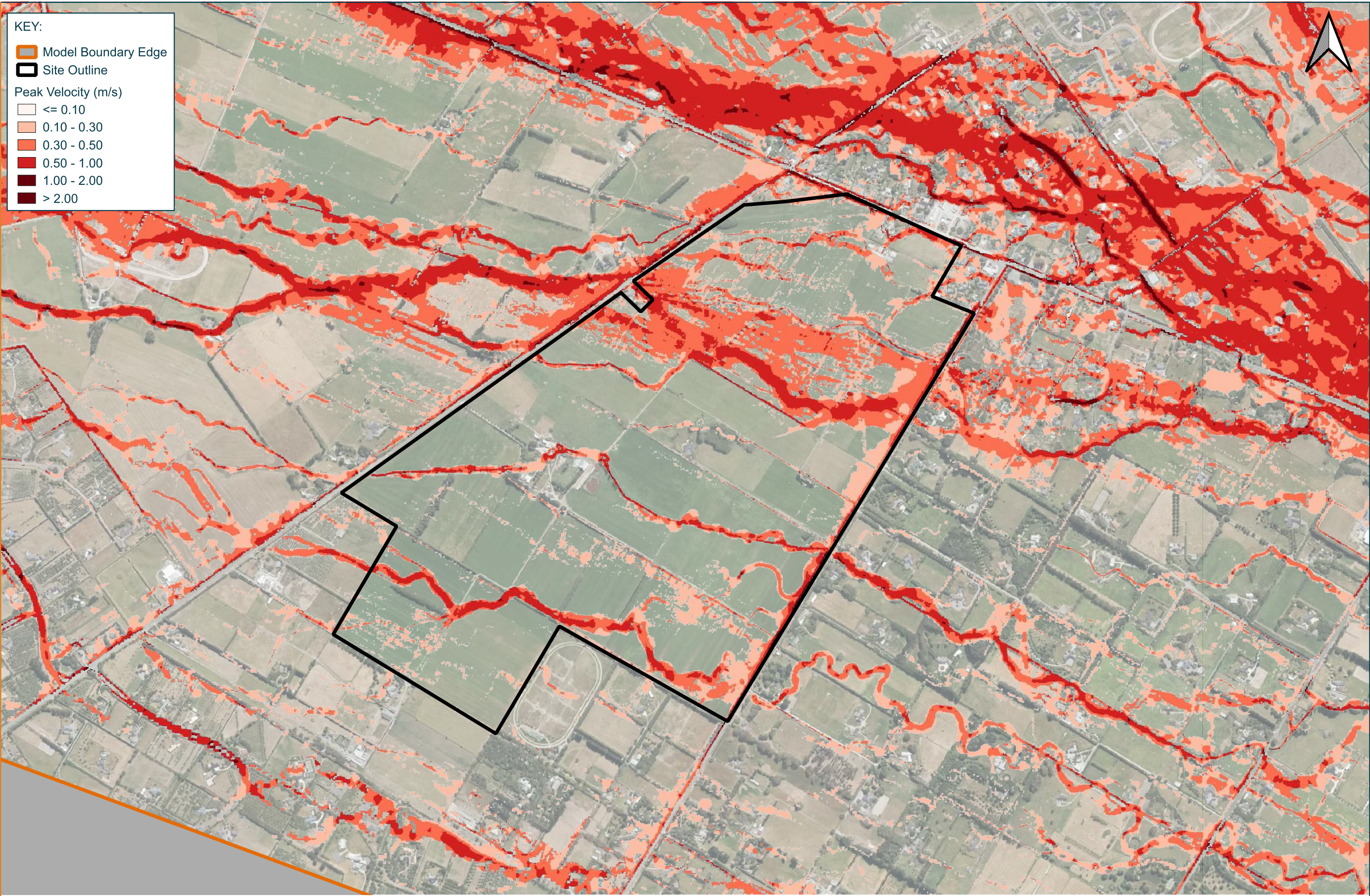
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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CLIENT



CARTER GROUP

FIGURE

Figure 2 - 50 Year ARI Peak Velocity, Pre Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

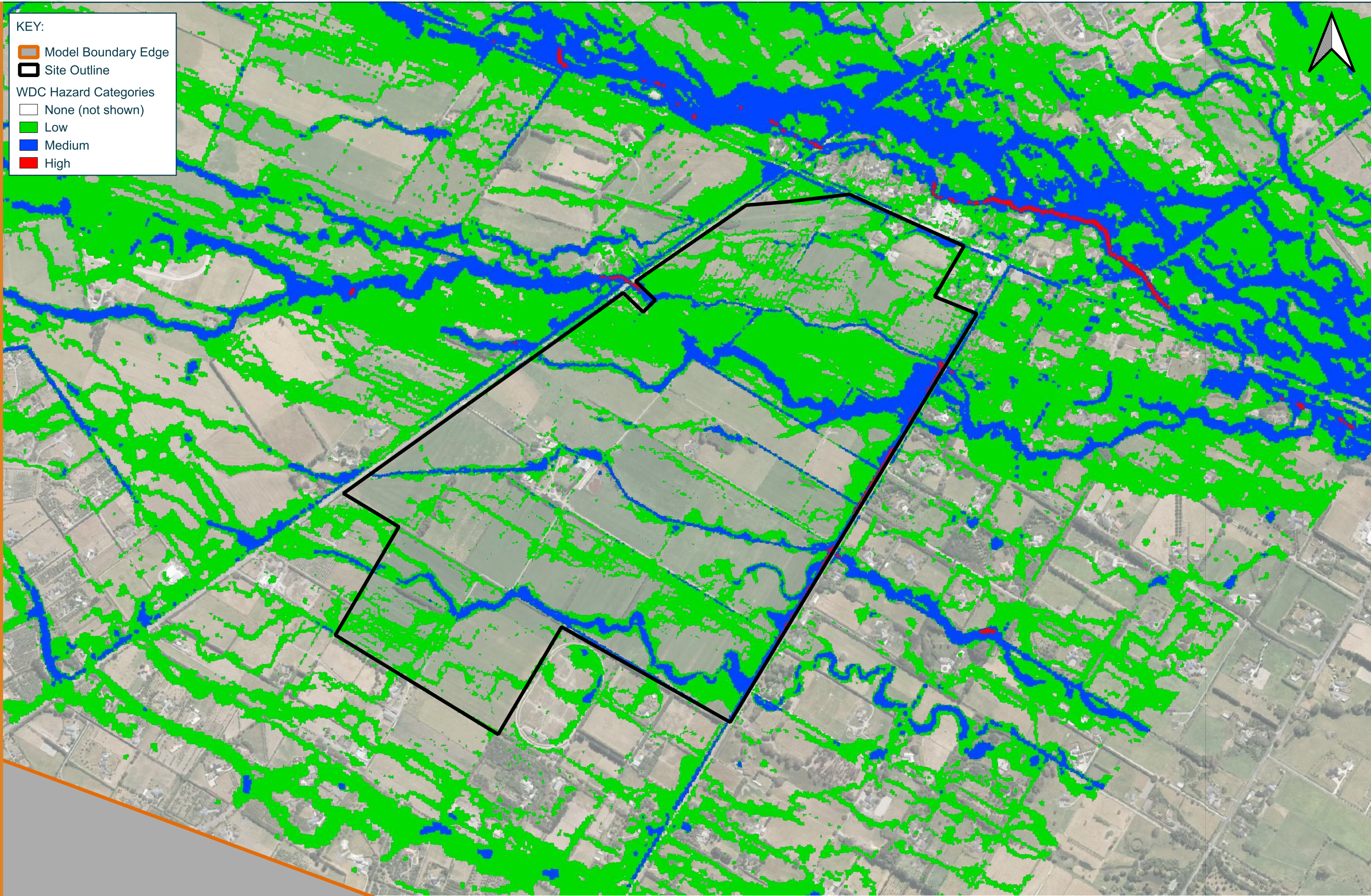
WDC Hazard Categories

None (not shown)

Low

Medium

High



0100200300 m
SCALE 1:10,000 (A3)
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CLIENT
 CARTER GROUP

FIGURE
Figure 3 - 50 Year ARI WDC Hazard Category, Pre Development

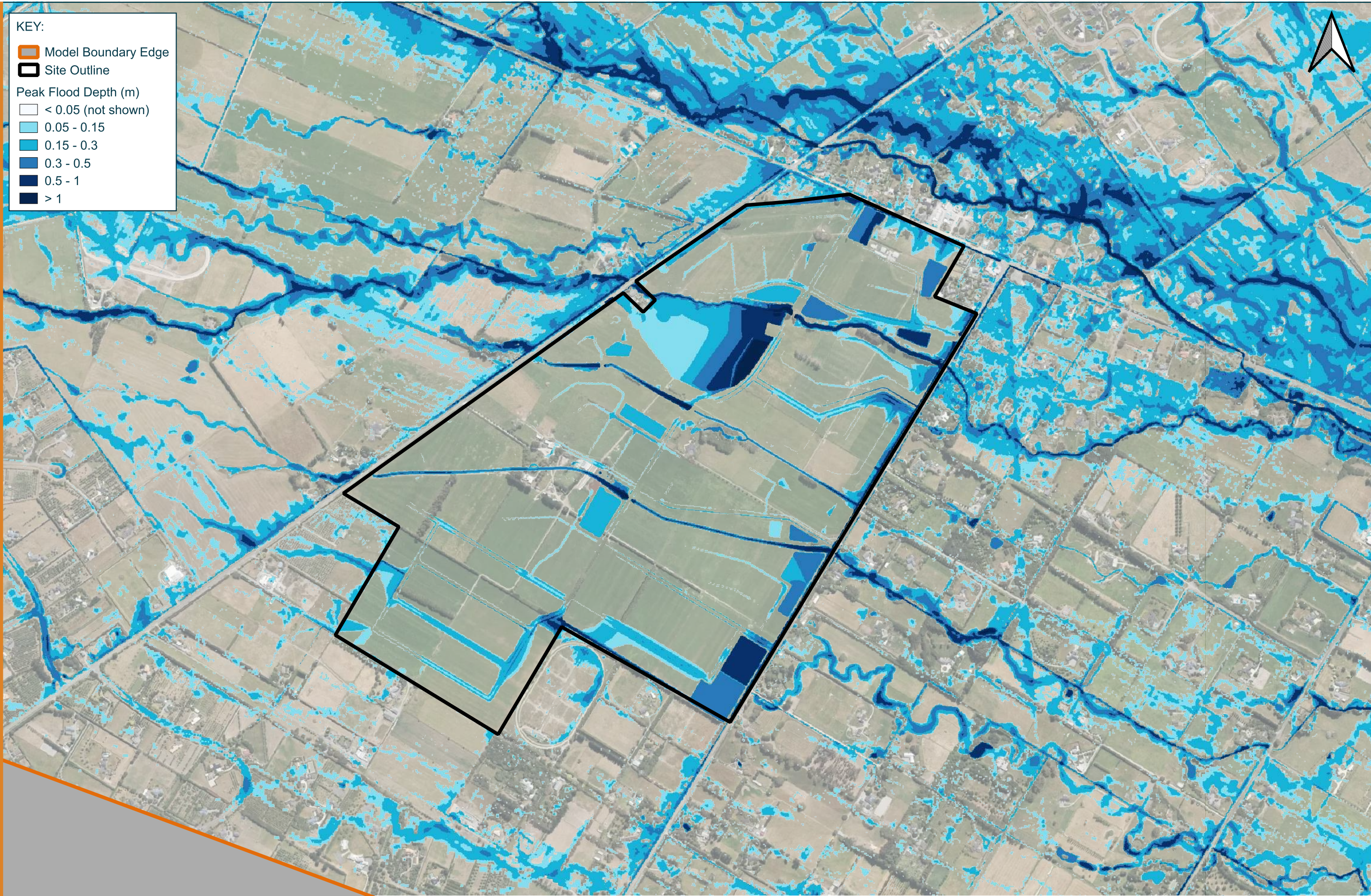
PROJECT
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)0.05 - 0.150.15 - 0.30.3 - 0.50.5 - 1> 1

0 100 200 300 m

SCALE 1:10,000 (A3)

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SOURCE:

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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

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FIGURE

Figure 4 - 50 Year ARI Peak Flood Depth, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

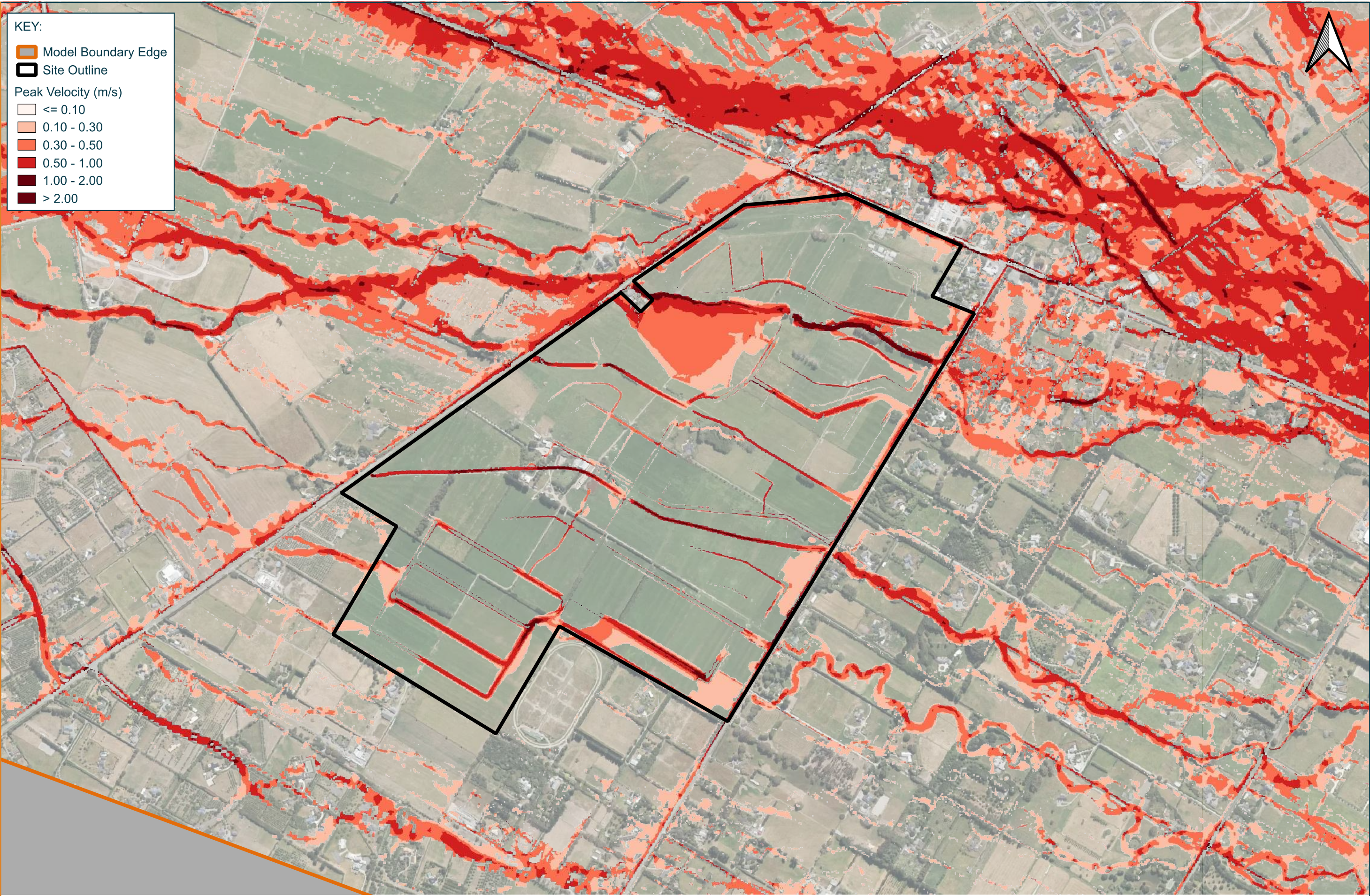
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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NO.	REVISION	DATE	BY

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2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT



CARTER GROUP

FIGURE

Figure 5 - 50 Year ARI Peak Velocity, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

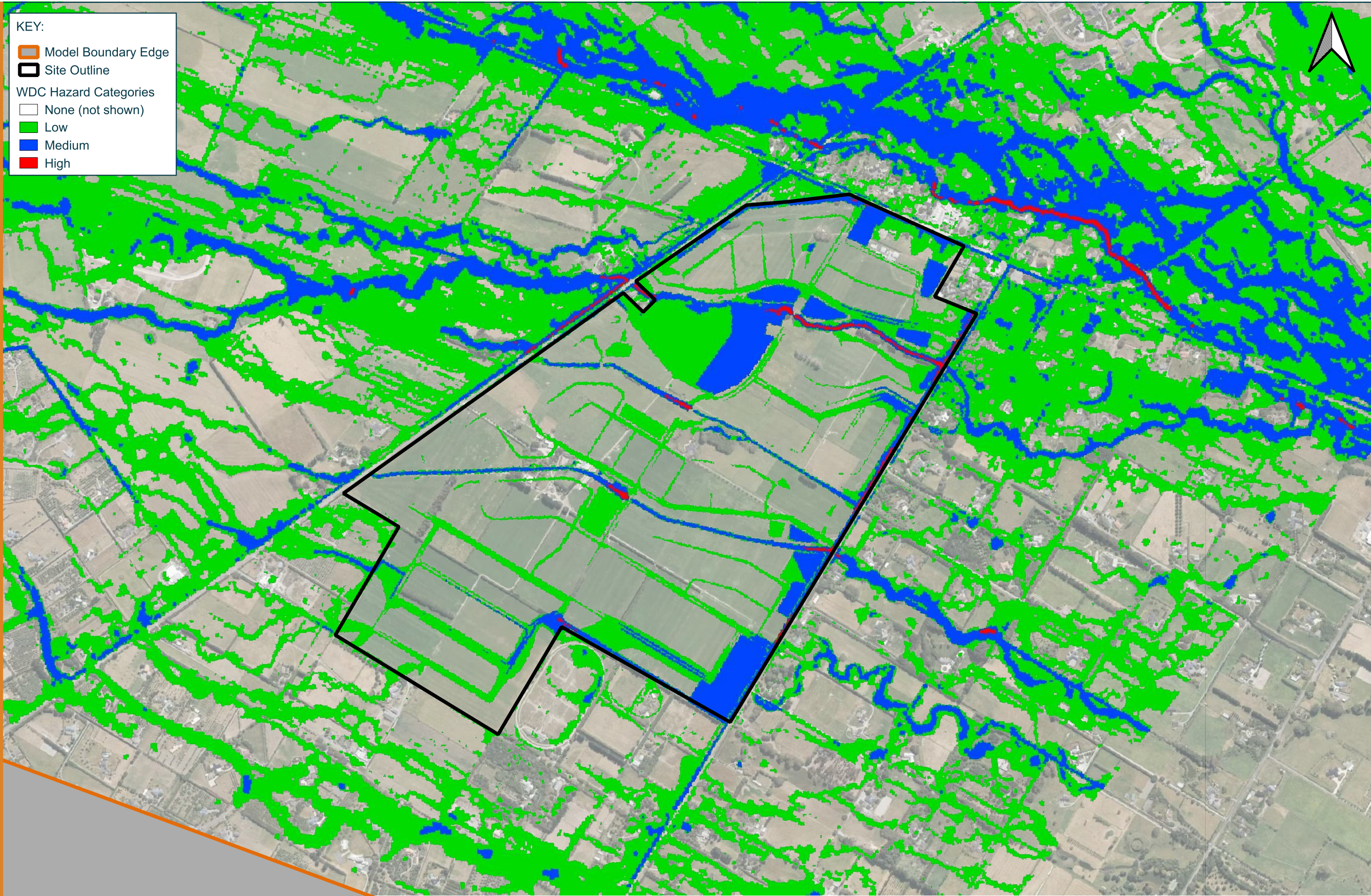
WDC Hazard Categories

None (not shown)

Low

Medium

High



0 100 200 300 m

SCALE 1:10,000 (A3)

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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 6 - 50 Year ARI WDC Hazard Category, Post Development

PROJECT

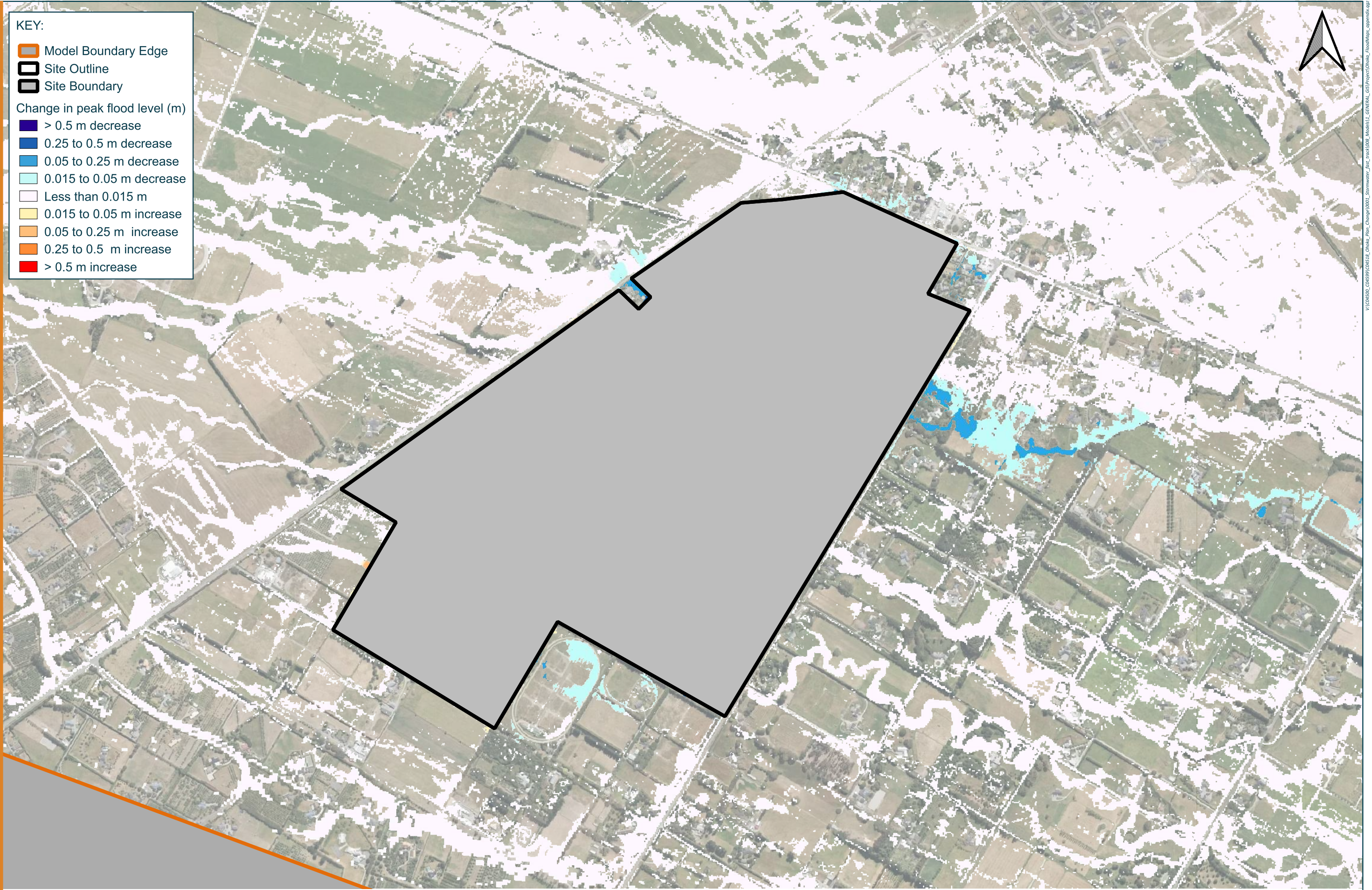
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

- Model Boundary Edge
- Site Outline
- Site Boundary

Change in peak flood level (m)

- > 0.5 m decrease
- 0.25 to 0.5 m decrease
- 0.05 to 0.25 m decrease
- 0.015 to 0.05 m decrease
- Less than 0.015 m
- 0.015 to 0.05 m increase
- 0.05 to 0.25 m increase
- 0.25 to 0.5 m increase
- > 0.5 m increase



0 100 200 300 m
SCALE 1:10,000 (A3)

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CLIENT



FIGURE

Figure 7 - 50 Year ARI Flood Level Difference, Post-Pre Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)

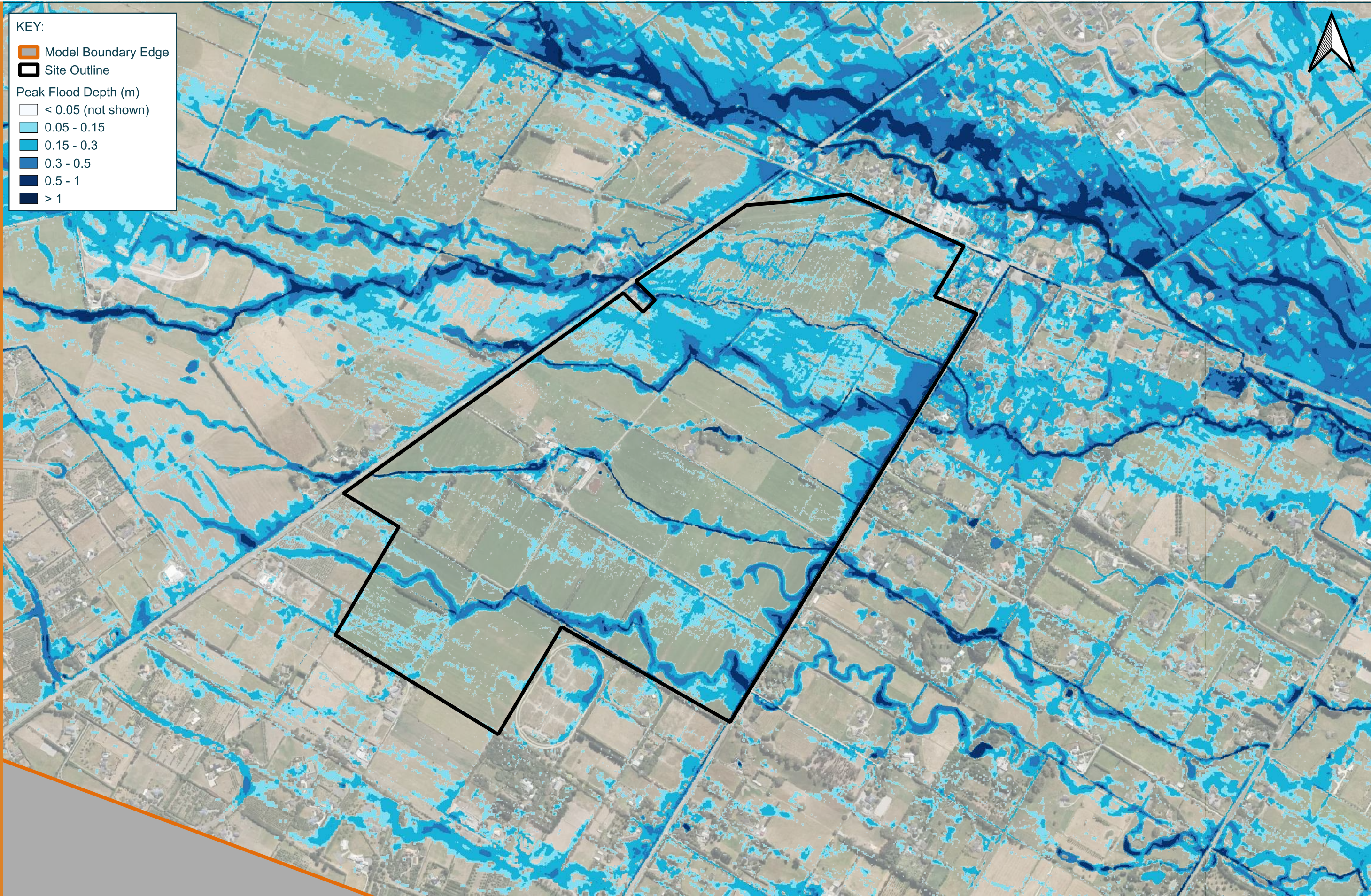
0.05 - 0.15

0.15 - 0.3

0.3 - 0.5

0.5 - 1

> 1



SCALE 1:10,000 (A3)

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CLIENT



FIGURE

Figure 8 - 100 Year ARI Peak Flood Depth, Pre Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

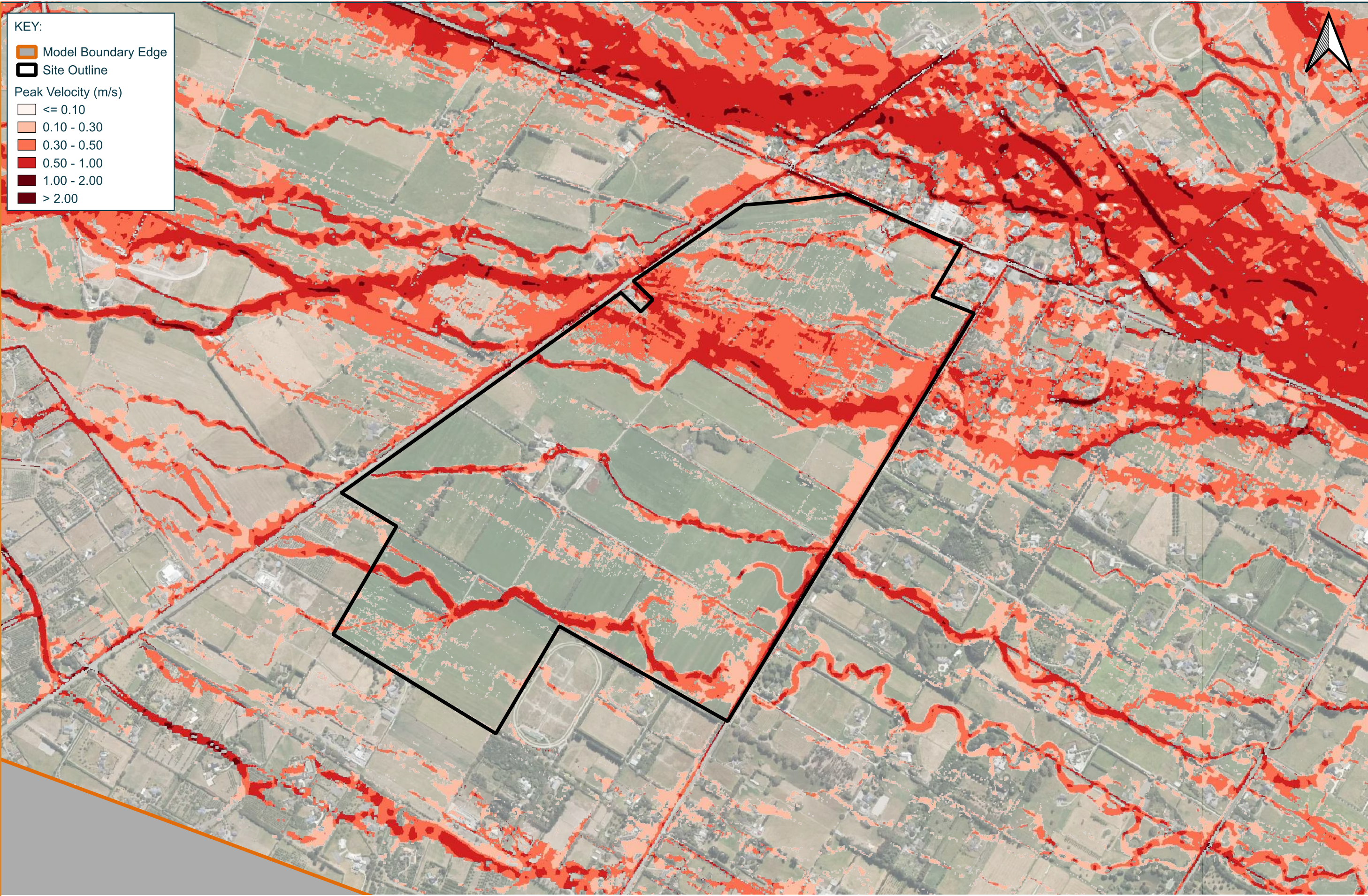
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT

CARTER GROUP

FIGURE
Figure 9 - 100 Year ARI Peak Velocity, Pre Development

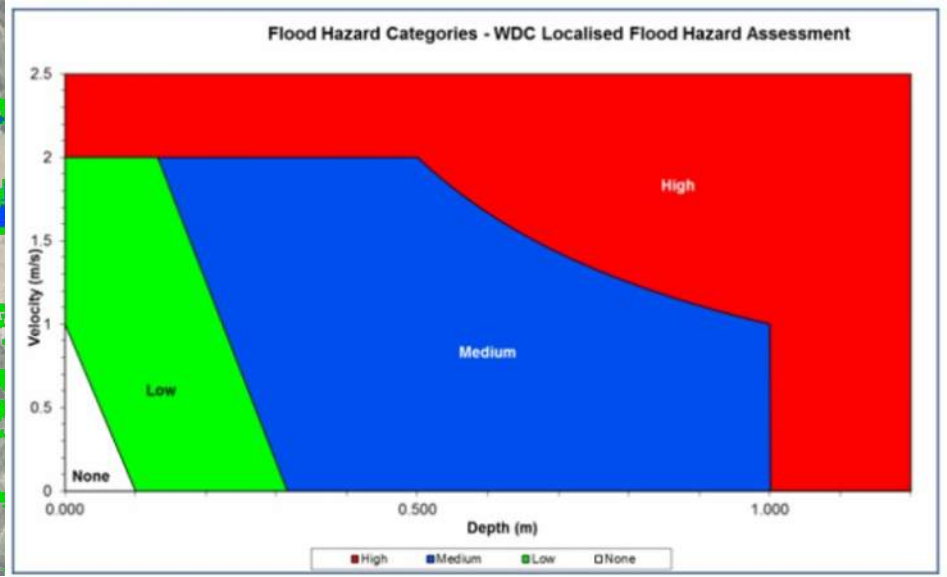
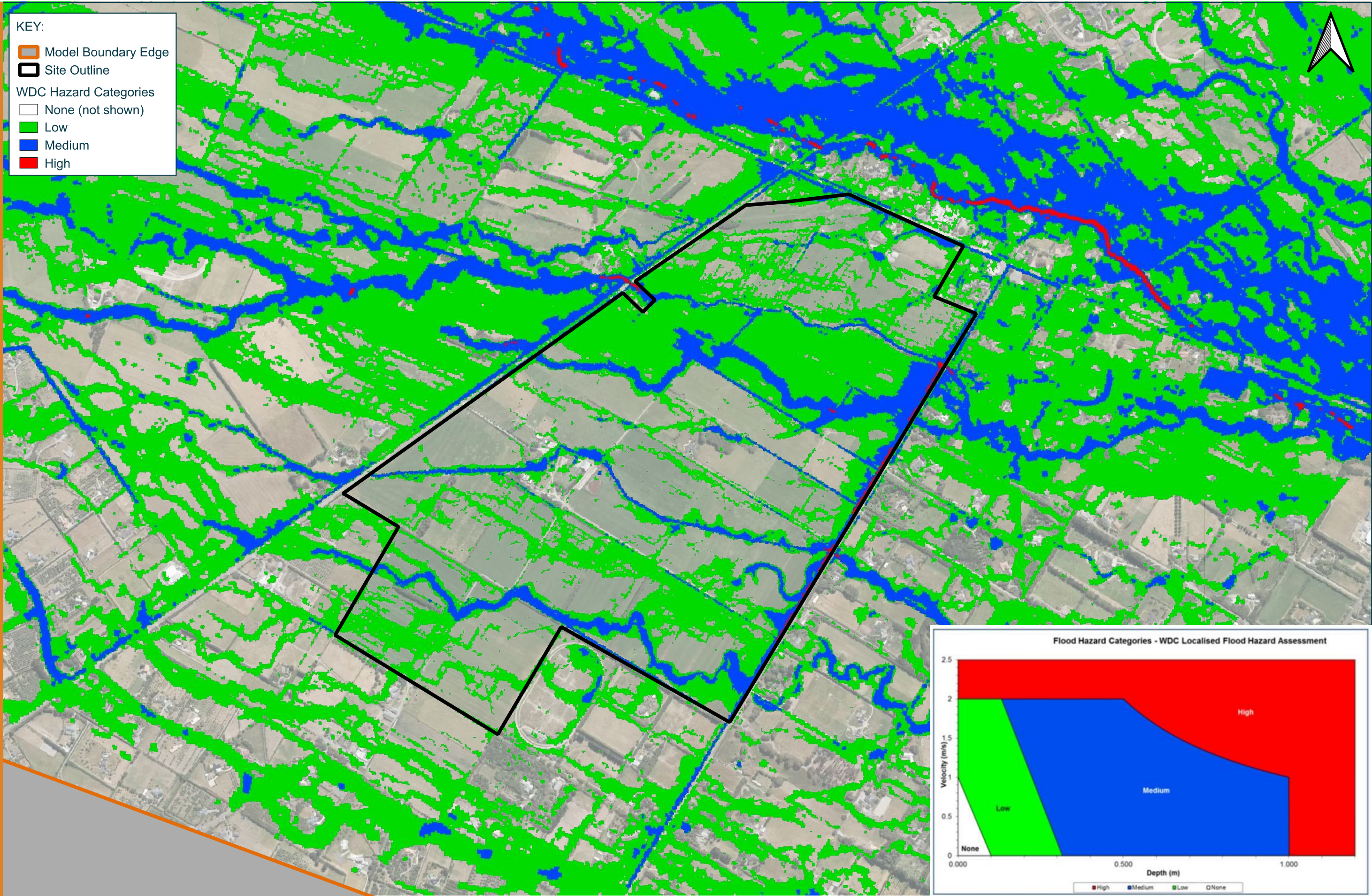
PROJECT
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

WDC Hazard Categories



0 100 200 300 m

SCALE 1:10,000 (A3)

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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 10 - 100 Year ARI WDC Hazard Category, Pre Development

PROJECT

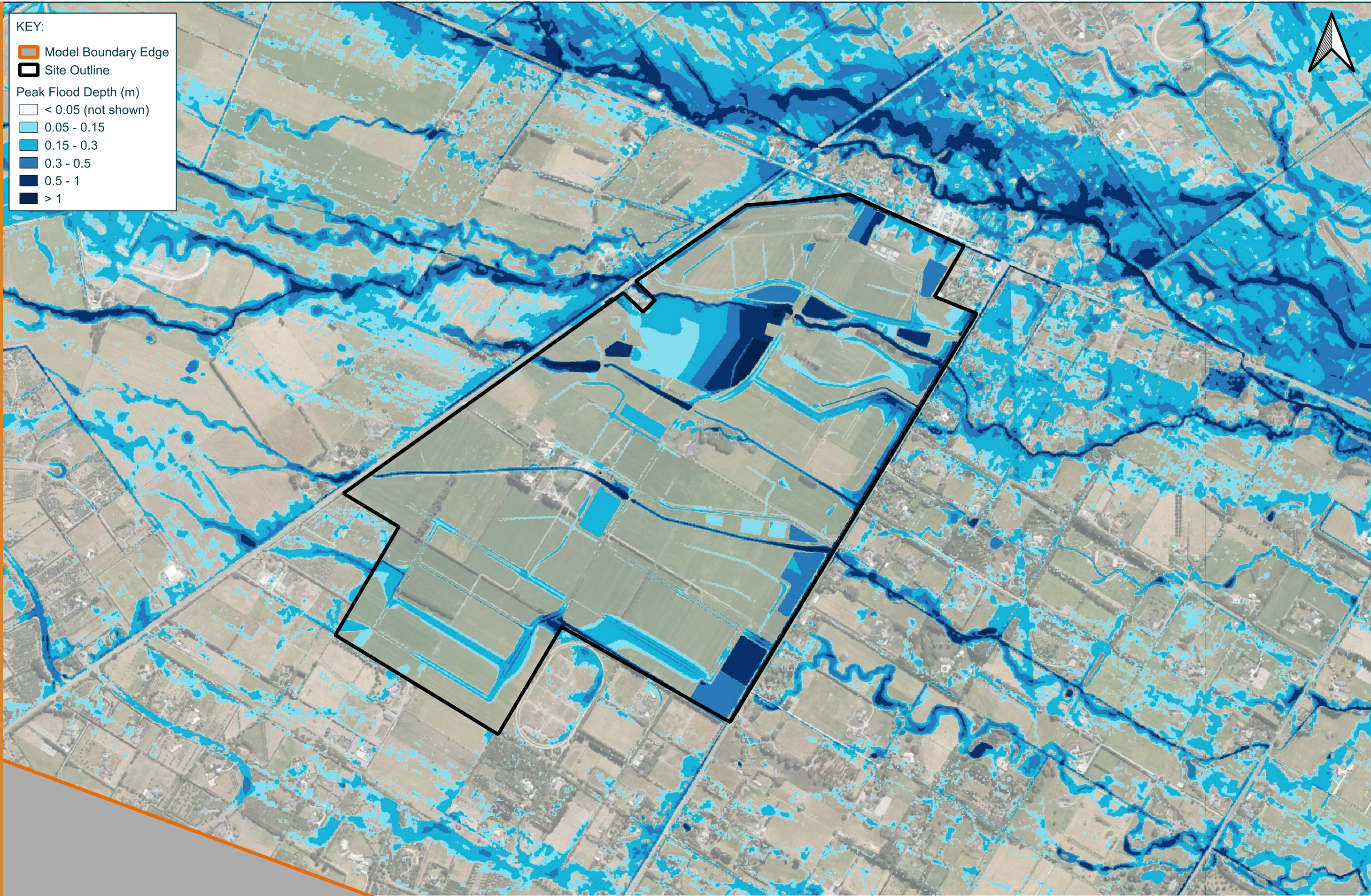
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)0.05 - 0.150.15 - 0.30.3 - 0.50.5 - 1> 1

0100200300m

SCALE 1:10,000 (A3)

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NO.	REVISION	DATE
		AW
		BY

SOURCE:

1. Base aerial imagery sourced from Land Information New Zealand (LINZ)

2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'

3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT

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FIGURE

Figure 11 - 100 Year ARI Peak Flood Depth, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

TEMPLATE FILE VERSION NUMBER V.1.4 - Last Updated 2 May 2025.

PATTLE DELAMORE PARTNERS LTD

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

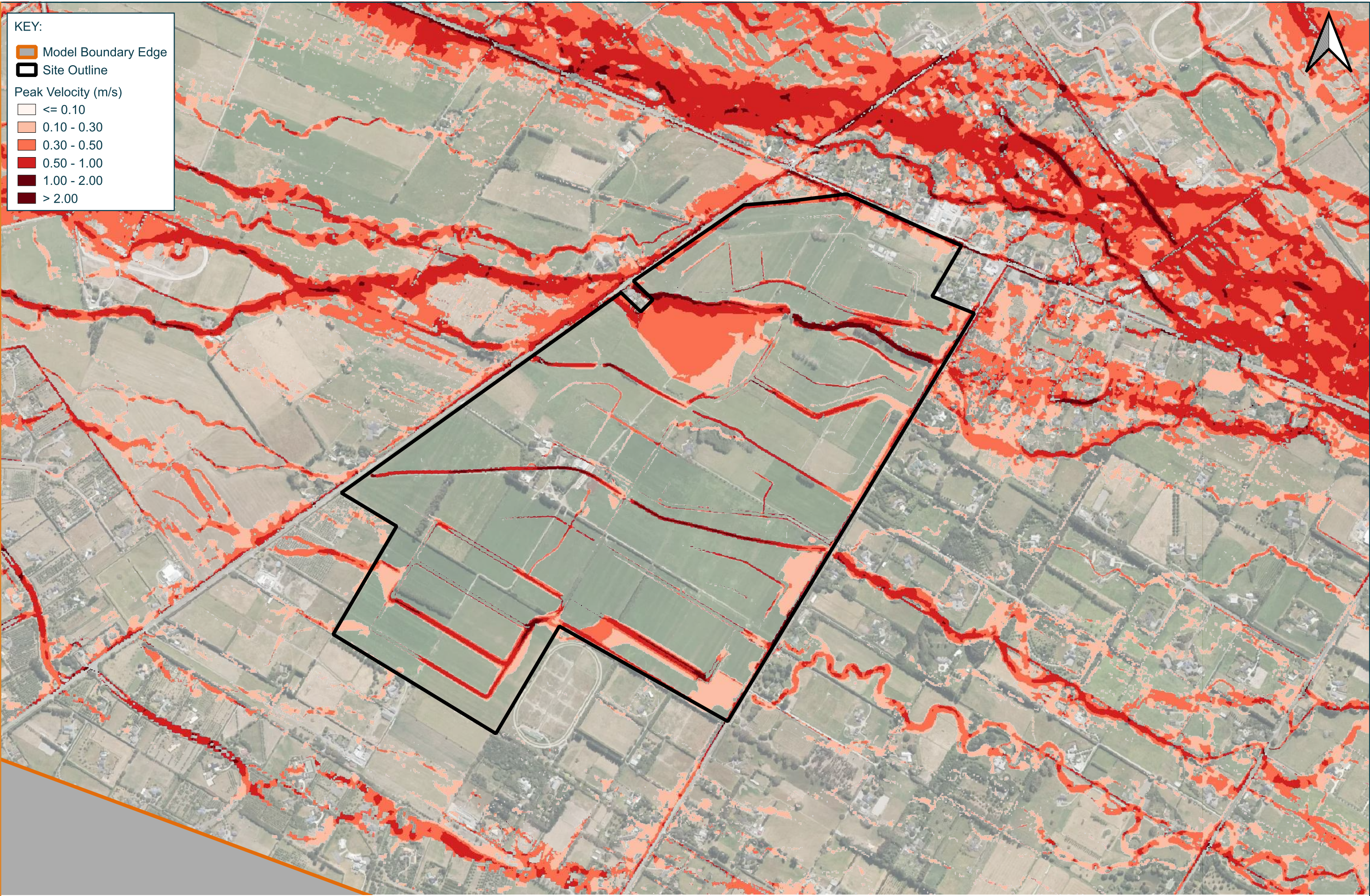
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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SOURCE:
1. Base aerial imagery sourced from Land Information New Zealand (LINZ)
2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT



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FIGURE

Figure 12 - 100 Year ARI Peak Velocity, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

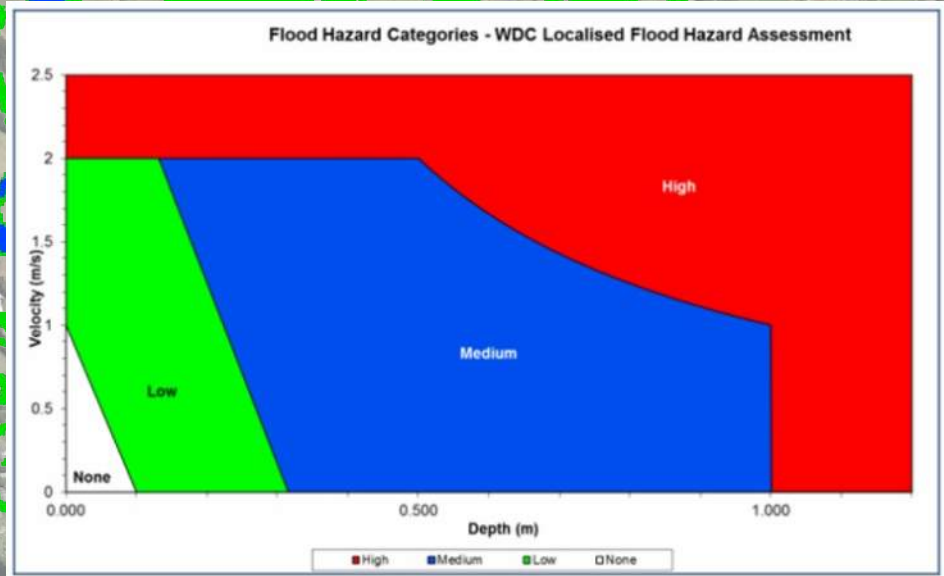
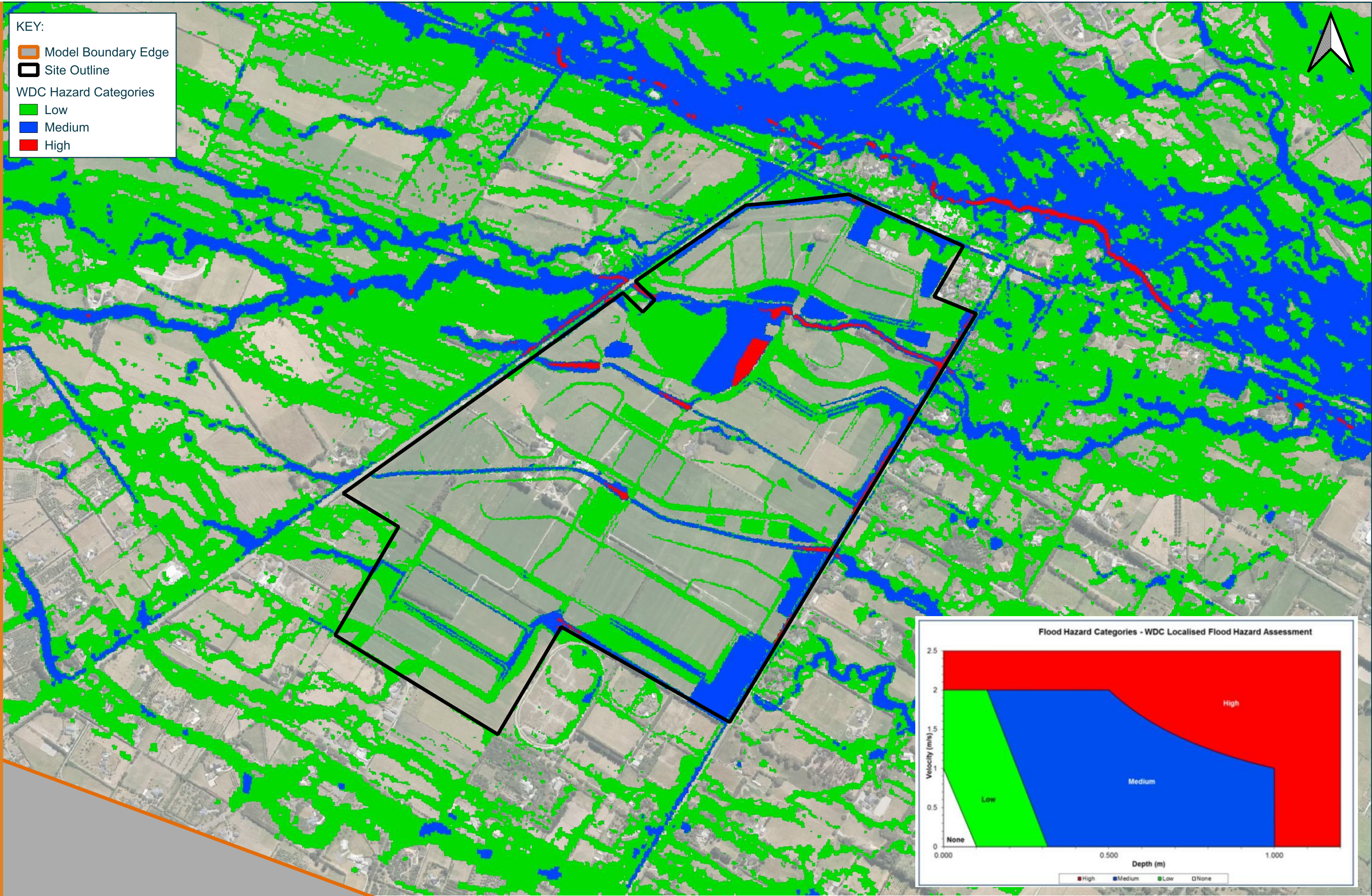
Site Outline

WDC Hazard Categories

Low

Medium

High



0 100 200 300 m

SCALE 1:10,000 (A3)

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2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 13 - 100 Year ARI WDC Hazard Category, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Site Boundary

Change in peak flood level (m)

> 0.5 m decrease

0.25 to 0.5 m decrease

0.05 to 0.25 m decrease

0.02 to 0.05 m decrease

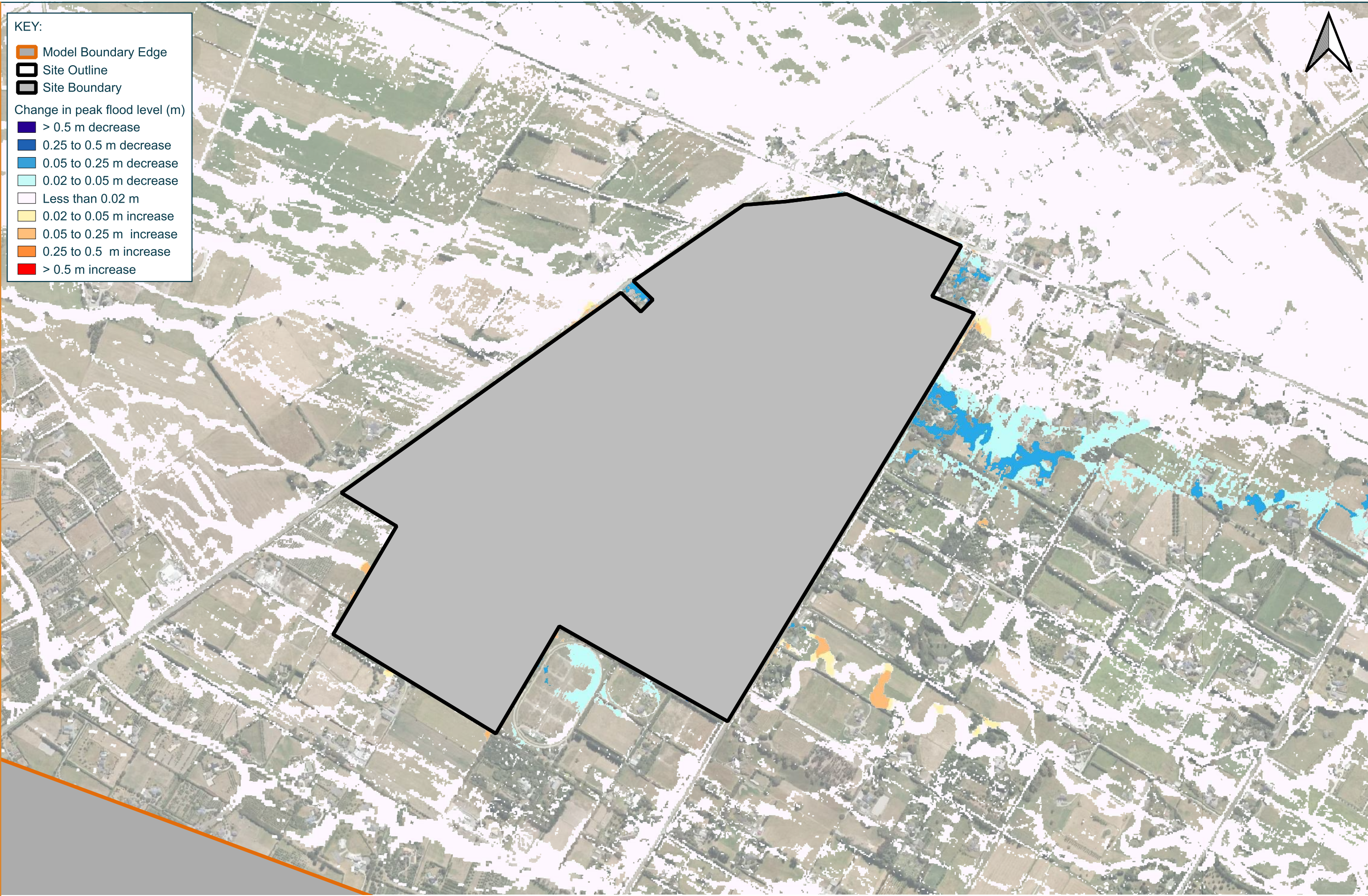
Less than 0.02 m

0.02 to 0.05 m increase

0.05 to 0.25 m increase

0.25 to 0.5 m increase

> 0.5 m increase



SCALE 1:10,000 (A3)

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NO.	REVISION	DATE
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SOURCE:
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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

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FIGURE
Figure 14 - 100 Year ARI Flood Level Difference, Post-Pre Development

PROJECT
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)

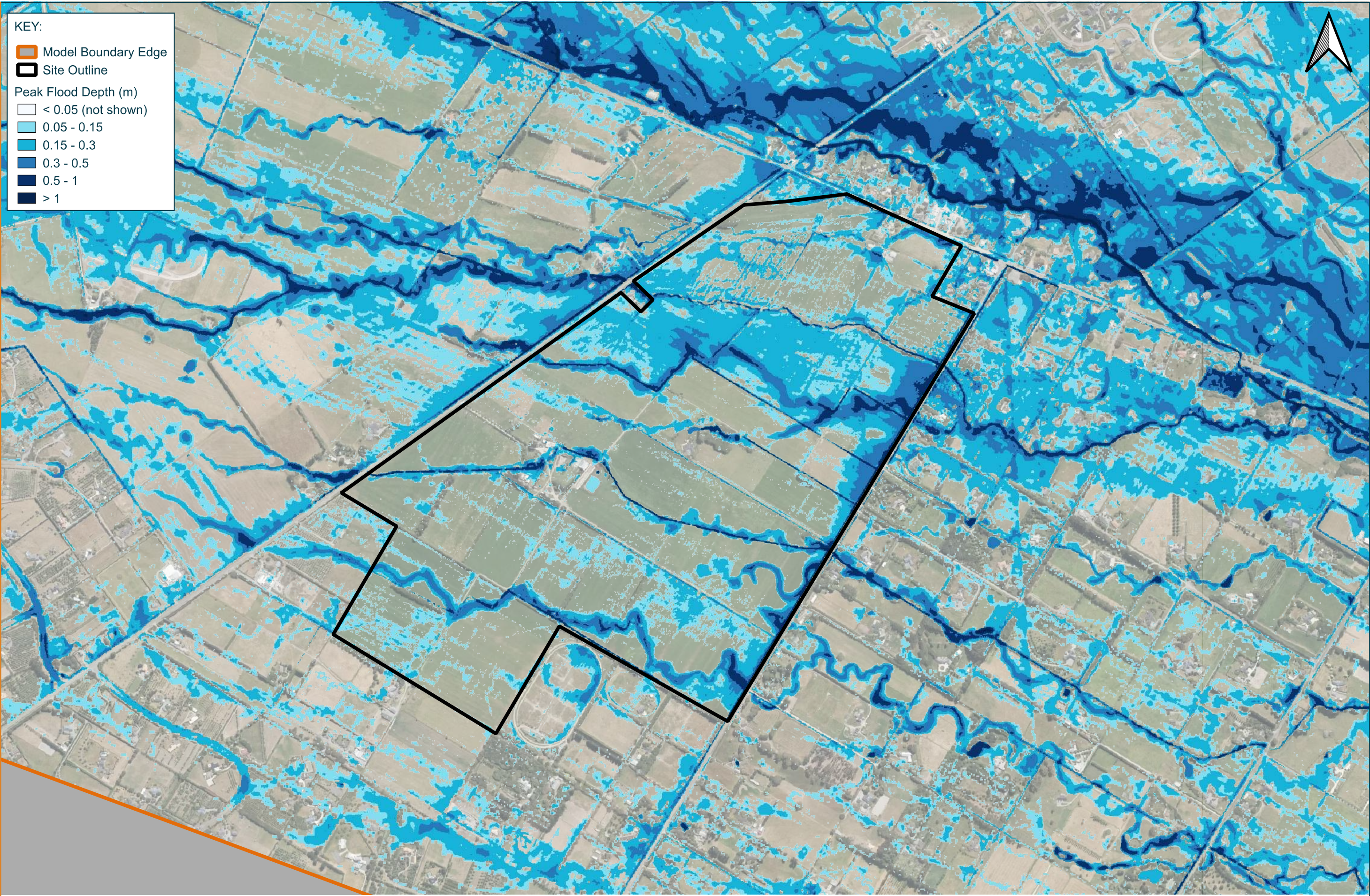
0.05 - 0.15

0.15 - 0.3

0.3 - 0.5

0.5 - 1

> 1



SCALE 1:10,000 (A3)

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NO.	REVISION	DATE	BY

SOURCE:
1. Base aerial imagery sourced from Land Information New Zealand (LINZ)
2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE
Figure 15 - 200 Year ARI Peak Flood Depth, Pre Development

PROJECT
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

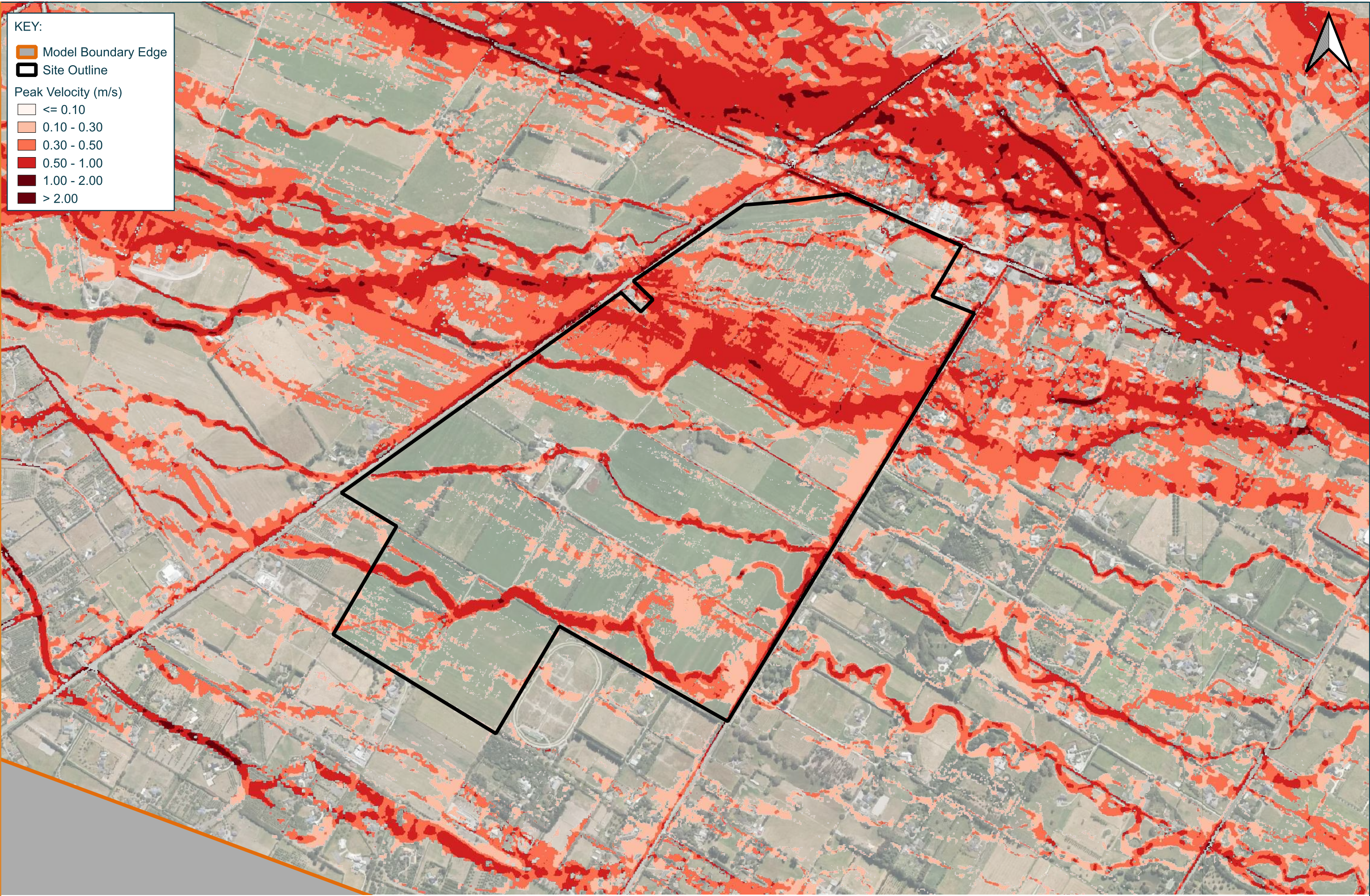
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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SOURCE:
1. Base aerial imagery sourced from Land Information New Zealand (LINZ)
2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE
Figure 16 - 200 Year ARI Peak Velocity, Pre Development

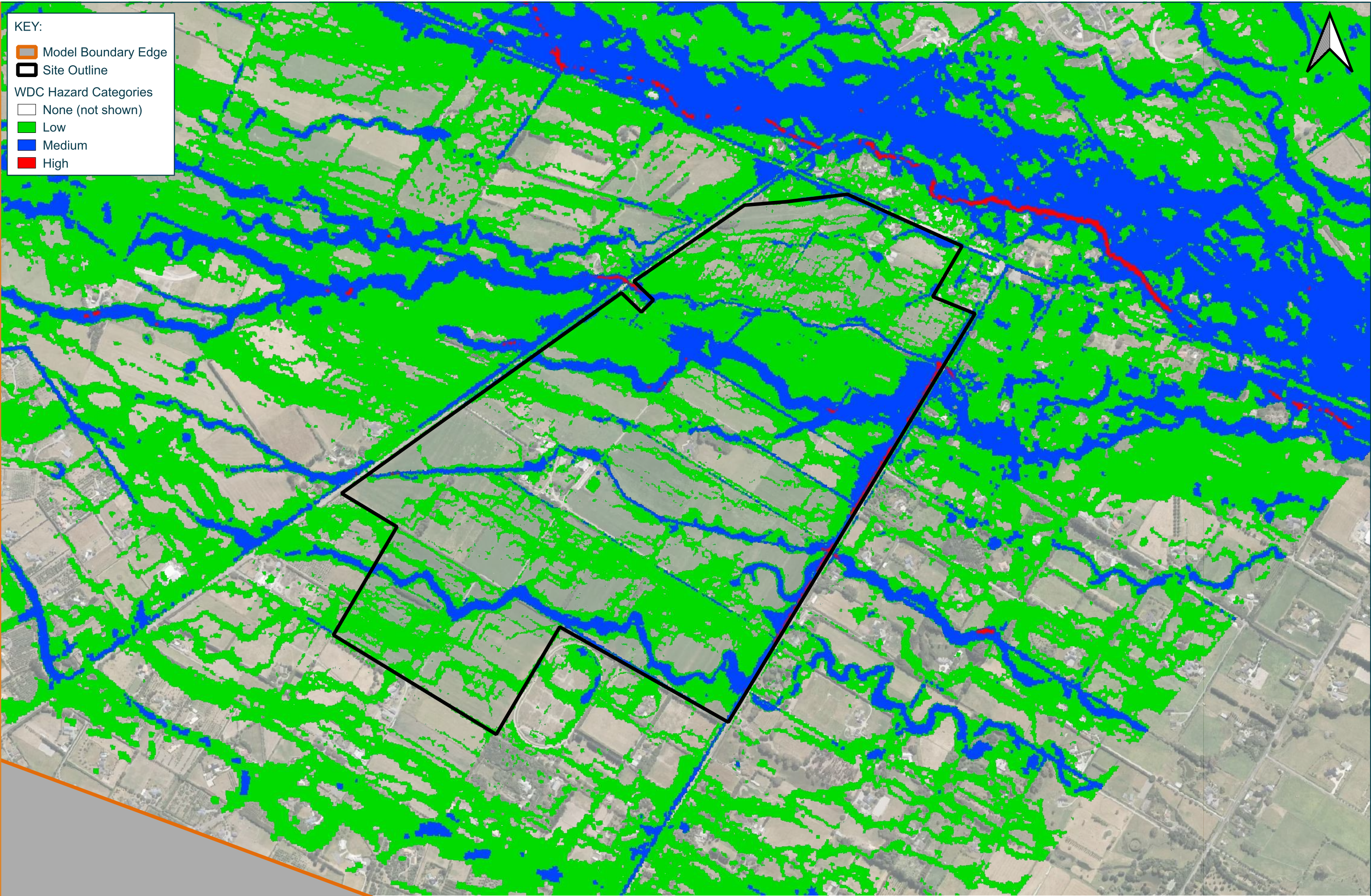
PROJECT
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

WDC Hazard Categories



0 100 200 300 m

SCALE 1:10,000 (A3)

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SOURCE:

1. Base aerial imagery sourced from Land Information New Zealand (LINZ)

2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'

3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 17 - 200 Year ARI WDC Hazard Category, Pre Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Flood Depth (m)

< 0.05 (not shown)

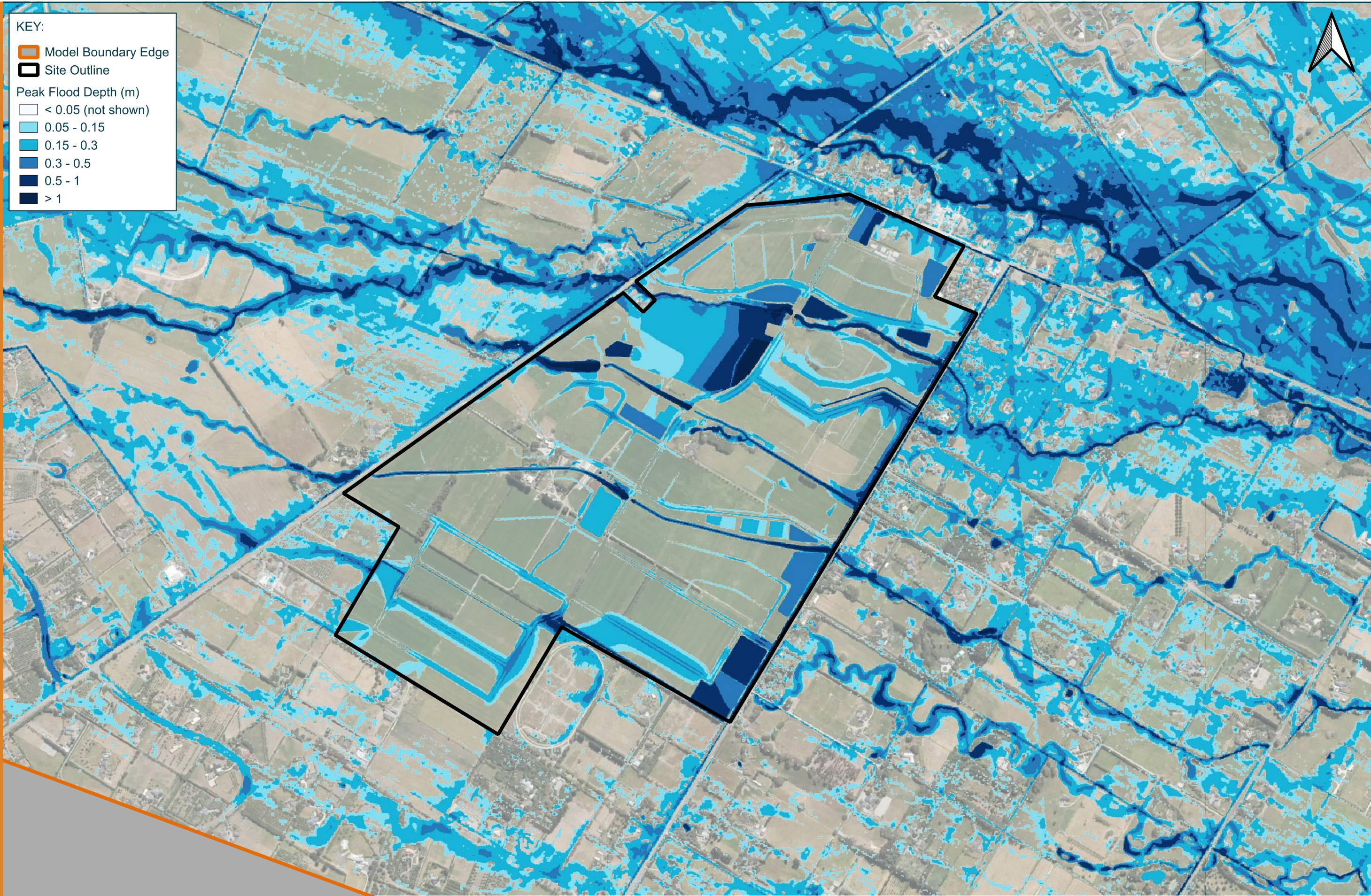
0.05 - 0.15

0.15 - 0.3

0.3 - 0.5

0.5 - 1

> 1



0100200300 m
SCALE 1:10,000 (A3)

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		BY

SOURCE:

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2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

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CARTER GROUP

FIGURE

Figure 18 - 200 Year ARI Peak Flood Depth, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

Peak Velocity (m/s)

<= 0.10

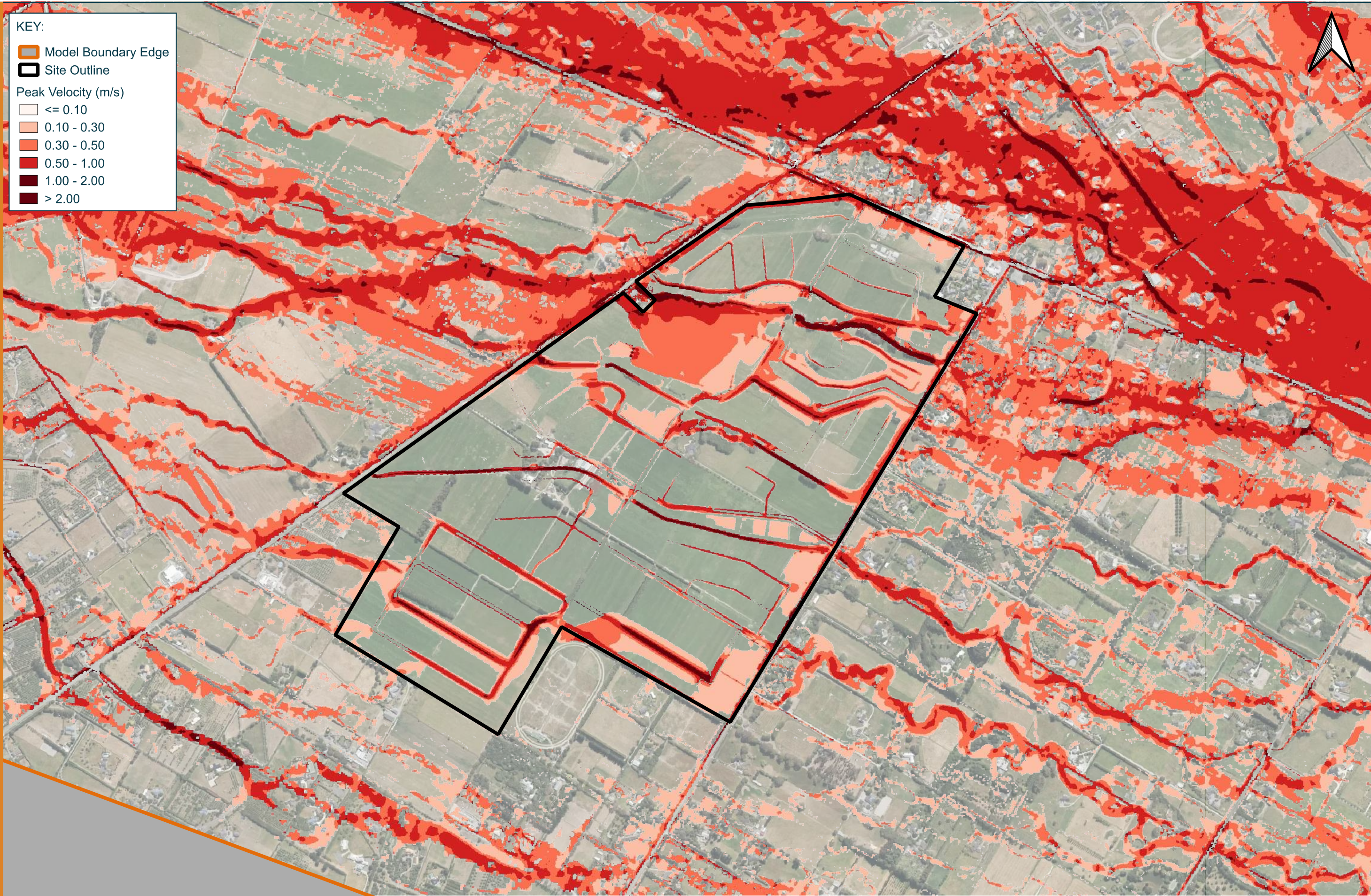
0.10 - 0.30

0.30 - 0.50

0.50 - 1.00

1.00 - 2.00

> 2.00



SCALE 1:10,000 (A3)

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SOURCE:
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2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'
3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130

CLIENT



FIGURE

Figure 19 - 200 Year ARI Peak Velocity, Post Development

PROJECT

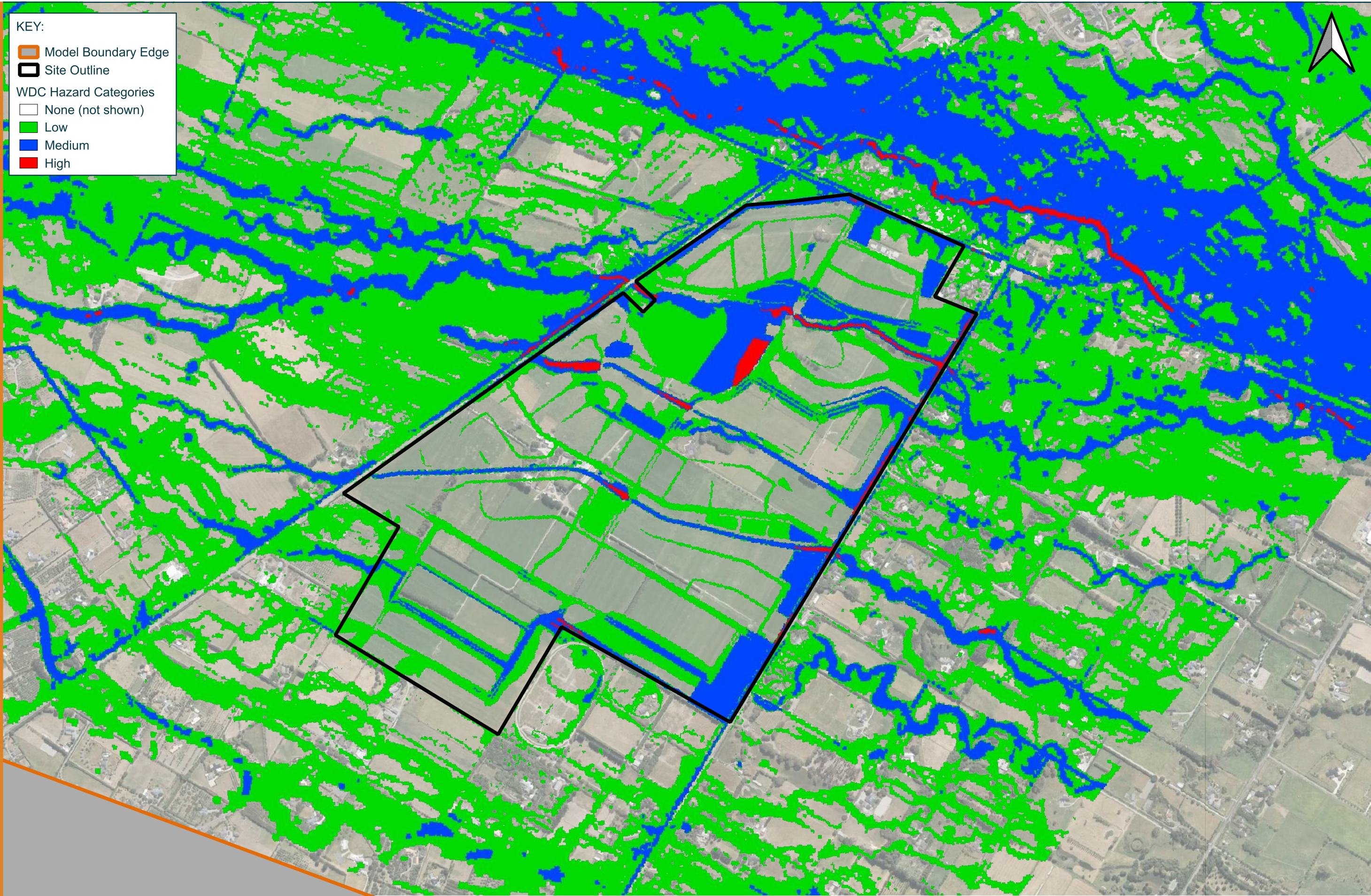
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

WDC Hazard Categories



0 100 200 300 m

SCALE 1:10,000 (A3)

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		AW
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SOURCE:

1. Base aerial imagery sourced from Land Information New Zealand (LINZ)

2. Flood model build described in the report 'Flood Effects – 531 and 535 Mill Road, Ohoka'

3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 20 - 200 Year ARI WDC Hazard Category, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Change in peak flood level (m)

> 0.5 m decrease

0.25 to 0.5 m decrease

0.05 to 0.25 m decrease

0.015 to 0.05 m decrease

Less than 0.015 m

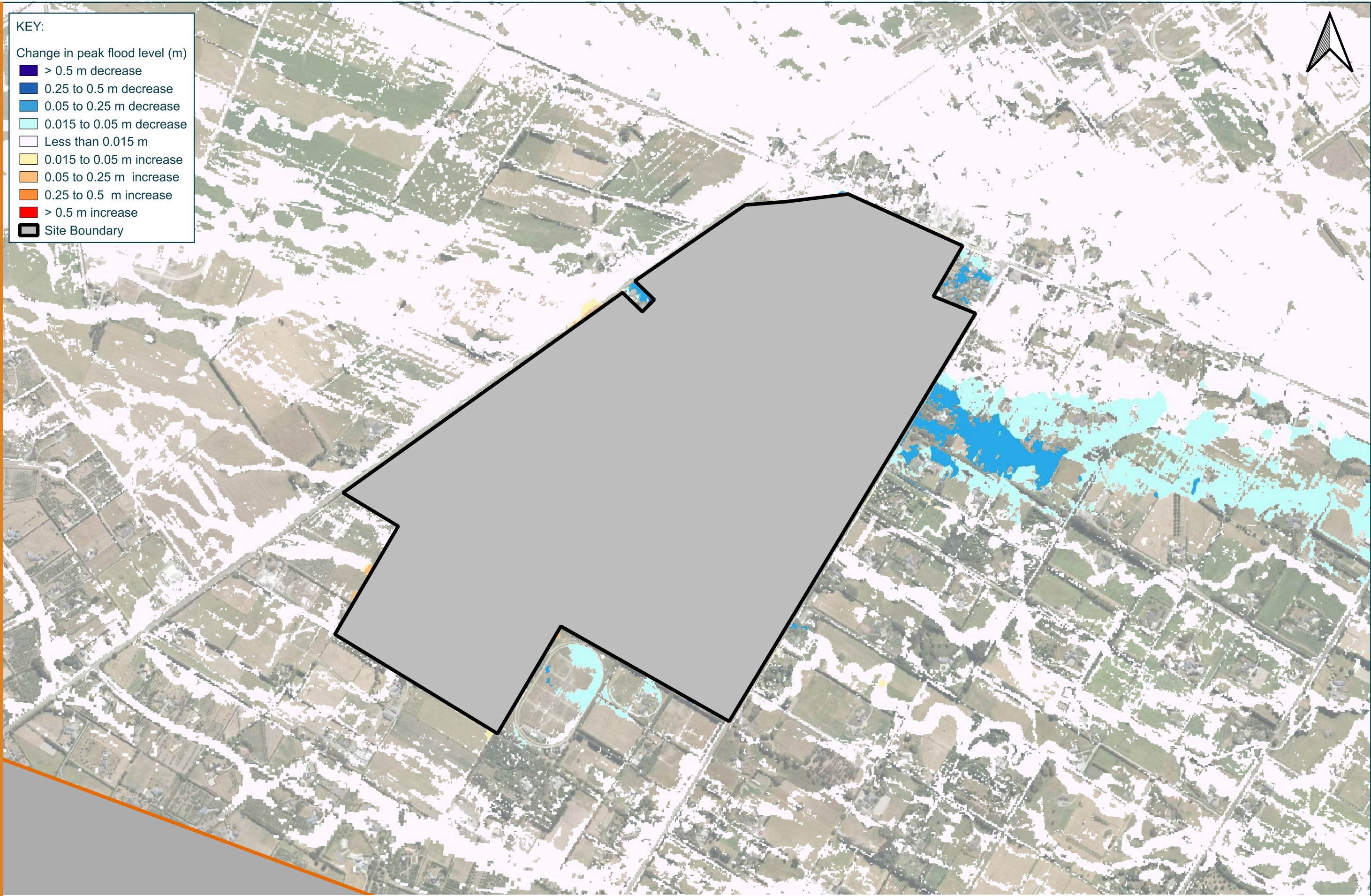
0.015 to 0.05 m increase

0.05 to 0.25 m increase

0.25 to 0.5 m increase

> 0.5 m increase

Site Boundary



0 100 200 300 m

SCALE 1:10,000 (A3)

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SOURCE:

1. Base aerial imagery sourced from Land Information New Zealand (LINZ)
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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 21 - 200 Year ARI Flood Level Difference, Post-Pre Development

PROJECT

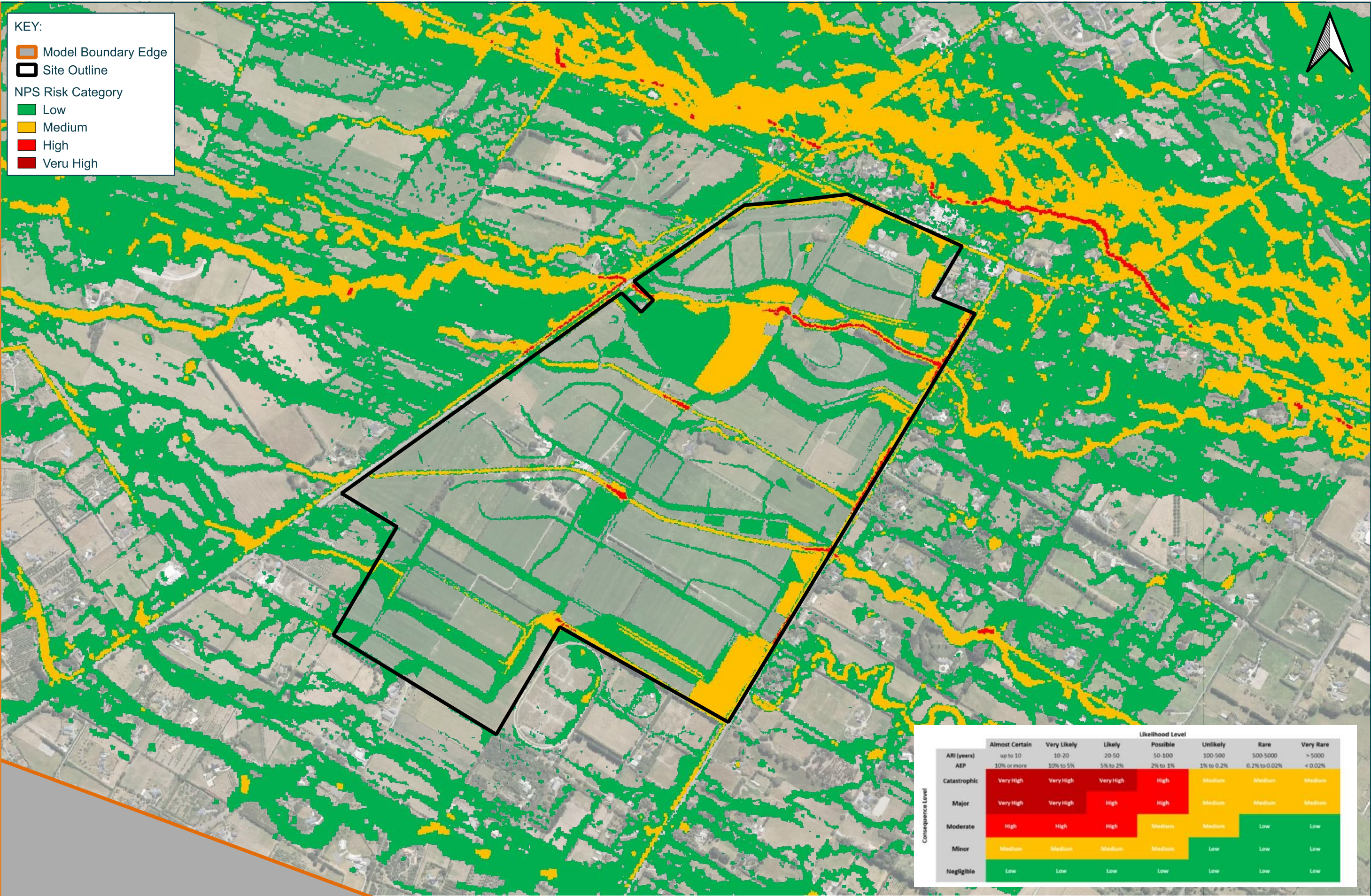
Flood Effects – 531 and 535 Mill Road, Ohoka

KEY:

Model Boundary Edge

Site Outline

NPS Risk Category

LowMediumHighVeru High

Consequence Level	Likelihood Level						
	Almost Certain	Very Likely	Likely	Possible	Unlikely	Rare	Very Rare
	ARI (years) up to 10	10-20	20-50	50-100	100-500	500-5000	> 5000
AEP	10% or more	10% to 5%	5% to 2%	2% to 1%	1% to 0.2%	0.2% to 0.02%	< 0.02%
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low



0 100 200 300 m

SCALE 1:10,000 (A3)

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SOURCE:

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3. Flood modelling includes an allowance for climate change as per RCP 8.5 projected to 2130



FIGURE

Figure 22 - Year ARI National Policy Statement - Natural Hazards Risk Category, Post Development

PROJECT

Flood Effects – 531 and 535 Mill Road, Ohoka



Downstream effects in a 50-year event

TO	Chris Bacon and Colin Roxburgh	FROM	Ben Throssell and Eoghan O'Neill
	Waimakariri District Council	DATE	05 August 2024
RE	Downstream effects of Ohoka Development in a 50-year event		

1.0 Purpose

During conferencing on flood matters (31 Aug 2024), concerns were raised regarding potential effects just upstream of Silverstream in a 50-year event. It was suggested that this area may be more sensitive to increased discharge volumes. Preliminary calculations undertaken during conferencing indicated that the additional discharge expected from a 24-hour, 50-year storm event could result in a 20 mm water level rise upstream of Silverstream, around the minor/less than minor threshold. This calculation was based on a discharge volume of 10,000 m³. After conferencing, WDC questioned what the effect might be if the additional discharge volume was 26,000 m³, the proposed volume of the stormwater basins. This memo aims to quantify this potential impact.

2.0 Methodology

During conferencing, these downstream effects due to the additional stormwater volume were estimated using a back of the envelope approach:

- Assume that all additional stormwater volume is released into the area upstream of Silverstream at the peak of the flood event. This assumption is conservative for two reasons:
 - o Not all additional stormwater will end up at Silverstream; and,
 - o Not all additional stormwater will be discharged at the peak of the event.
- Assume the area upstream of Silverstream acts as a bath-tub. This means flood levels are controlled entirely by volume rather than flow. Flood levels will be controlled by both flow and event volume but the assumption that flood levels are controlled entirely by event volume is conservative;
- Take the volume discharged and divide it by the ponded area to estimate the effect. In conferencing, as no modelled 50-year event was available, the ponded area was taken to be the area where flood depths exceeded 1.5 m in the 100-year event.

The methodology to assess the effects of the 26,000 m³ discharge followed in this memo largely aligns with the methodology applied in conferencing.

3.0 WDC Model

The WDC model considers the 100-year, 200-year and 500-year events and therefore cannot be used to directly estimate the extent of ponding in a 50-year event. However, model provides indicative flood levels of the ponding area in question (upstream of the Ohoka Stream/Kaiapoi River confluence). Figure 1 shows:

- The 500-year peak flood elevation is 4.80 mRL and maintained for eight hours;
- The 200-year peak flood elevation is 4.65 mRL and maintained for four hours; and,
- The 100-year peak flood elevation is 4.55 mRL and maintained for two hours.

Therefore, the flood elevation for the 50-year event will not exceed 4.55 mRL and is unlikely to be maintained for more than two hours.

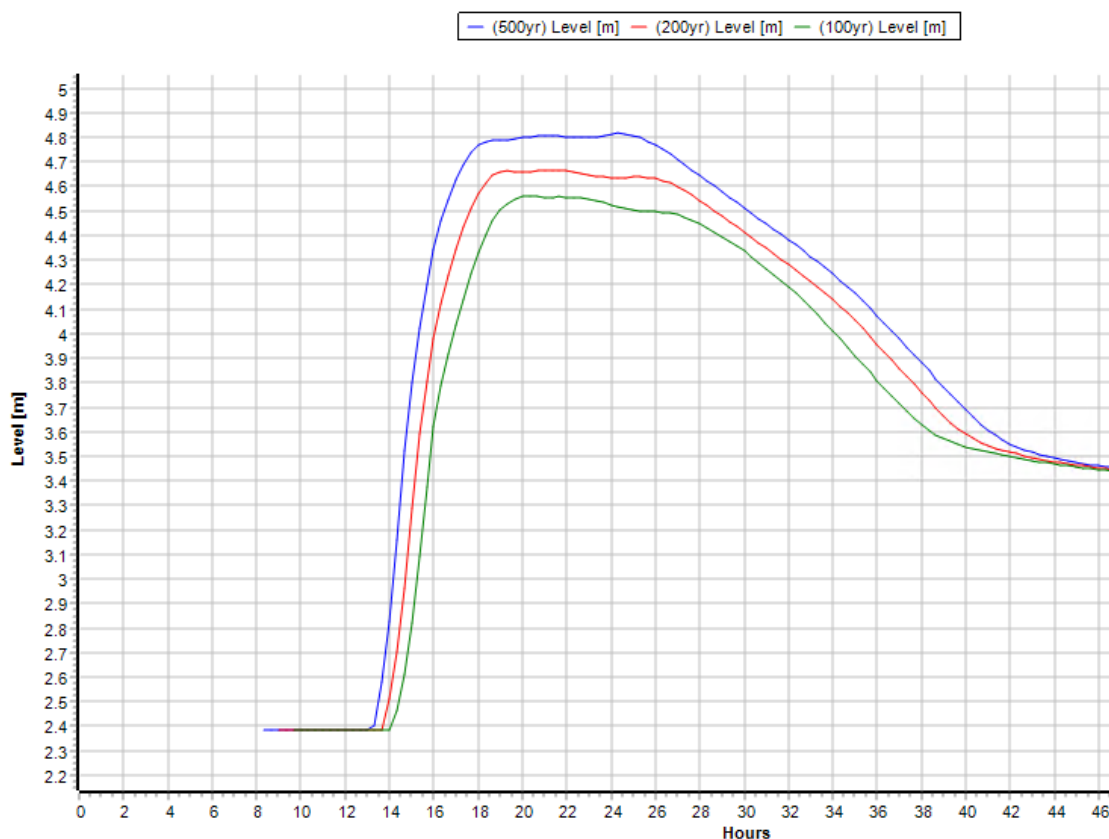


Figure 1: Modelled flood levels (LVD37) vs time for the Ohoka ponding area, abstracted from the WDC hydraulic model.

4.0 Hypsometric curves

To assess the potential impact of additional stormwater discharges on flood levels, we developed a hypsometric curve (Figure 2) using the 2014 LIDAR data (Figure 3). This curve relates ground elevation to areas and can be used to determine the elevation required to store a given volume.

Figure 2 shows:

- The primary y-axis shows the change in vertical elevation, two series are plotted on this axis, a volume released of 26,000 m³ (stormwater basins) and a volume released of 10,000 m³ (PDP hydraulic model difference);
- A 10,000 m³ discharge requires a 50 ha ponding area to limit flood level increases to 20 mm. This equates to an elevation of 2.87 mRL;
- A 26,000 m³ discharge requires a 130 ha ponding area to achieve the same level of protection. This equates to an elevation of 3.96 mRL; and,
- For the WDC modelled flood events (100-year, 200-year and 500-year), the flood elevations all exceed the minimum elevations required to limit flood level increases for the 26,000 m³ additional stormwater discharge.

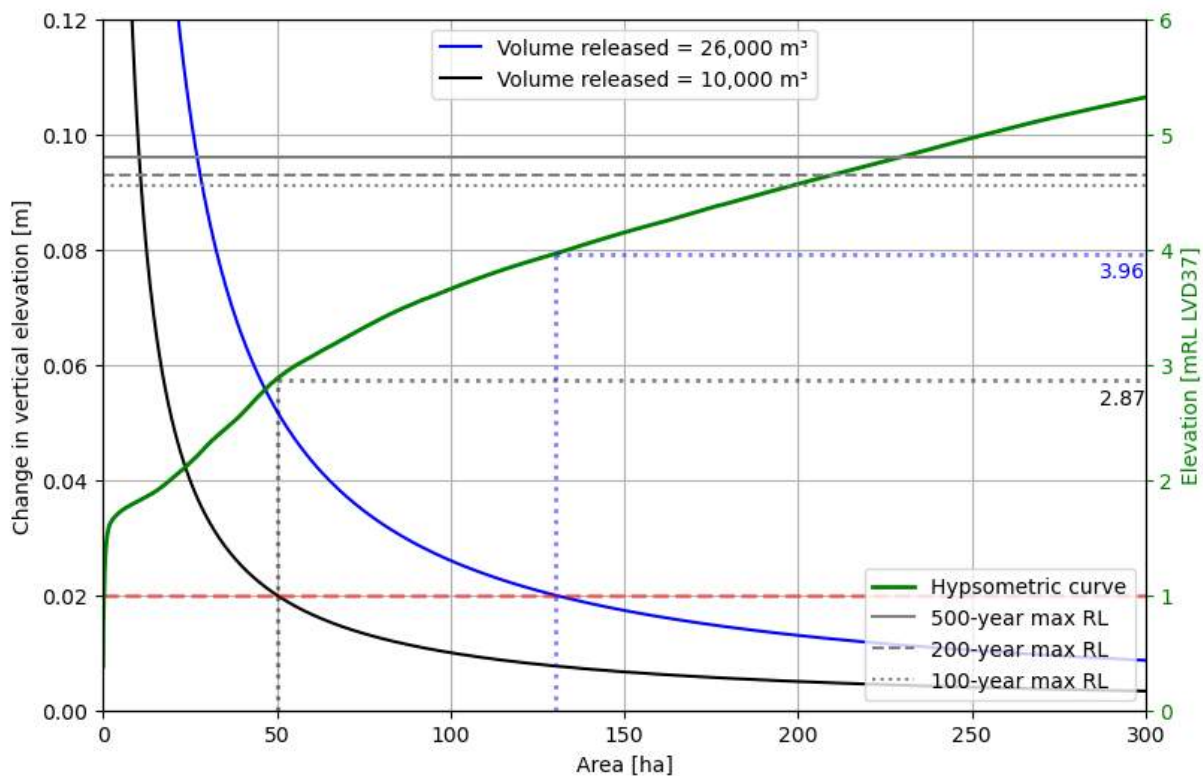


Figure 2: Hypsometric curve for LIDAR shown in Figure 3.

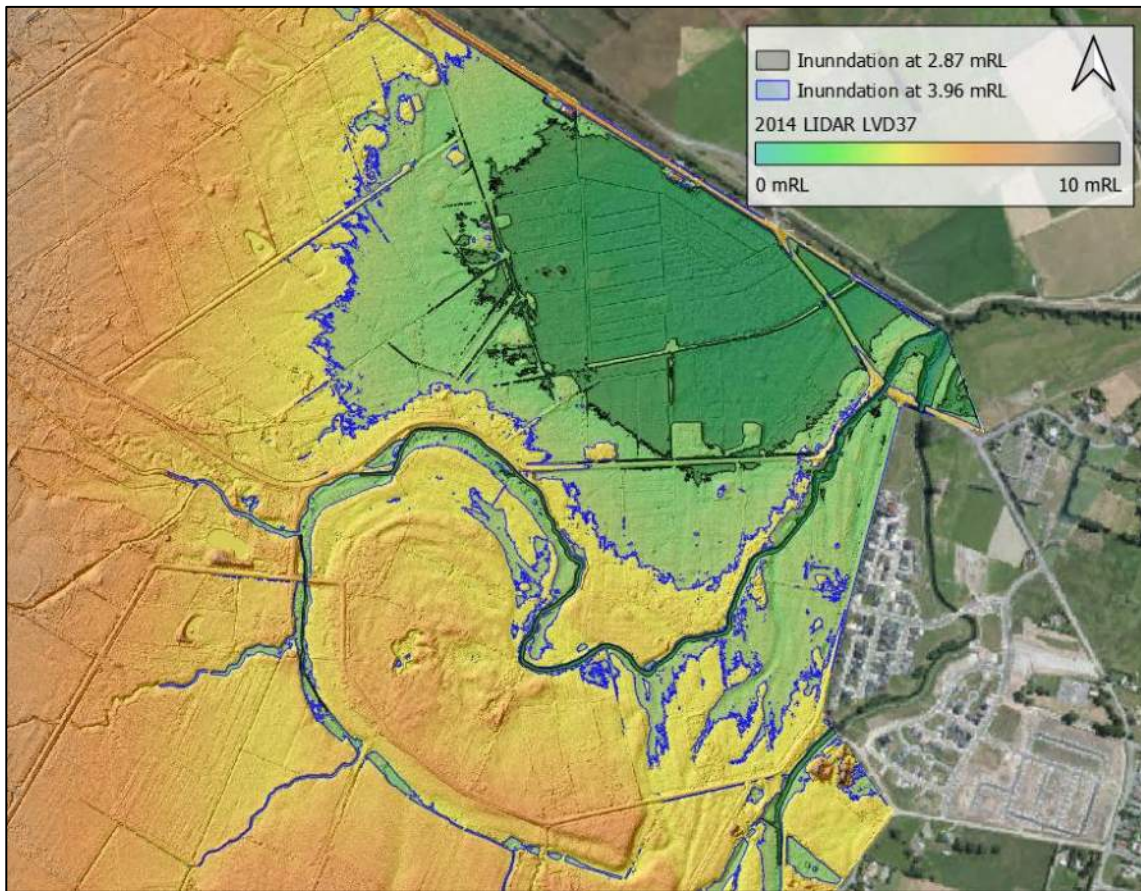


Figure 3: 2014 LIDAR (LVD37) used to generate hypsometric curve. The LIDAR has been clipped to expected flood extent for the Ohoka Stream. 2014 Environment Canterbury (ECan) aerial employed as the background.

4.1 Analysis

The WDC model predicts maximum flood elevations for the 500-year, 200-year and 100-year events of 4.80, 4.65 and 4.55 mRL respectively. The minimum flood elevation required to ensure that the additional discharge (26,000 m³) from a 50-year event does not exceed 20 mm is 3.96 mRL. Whilst the 50-year event has not been modelled by WDC, from the progression of flood levels of the larger events, it appears reasonable to infer that a 50-year flood elevation would likely exceed 3.96 mRL. This means that the increase in flood levels due to this additional discharge would be less than 20 mm.

2014 Flood Event

To provide additional context, we compared the minimum required ponding areas (for additional stormwater releases of 10,000 m³ and 26,000 m³) to the extent of flooding observed during the 2014 event. The additional stormwater discharges used in our analysis correspond to a projected 50-year flood event, including climate change factors. Therefore, it is useful to have an indication on the magnitude of the 2014 event as this will determine if the assessment is conservative or not.

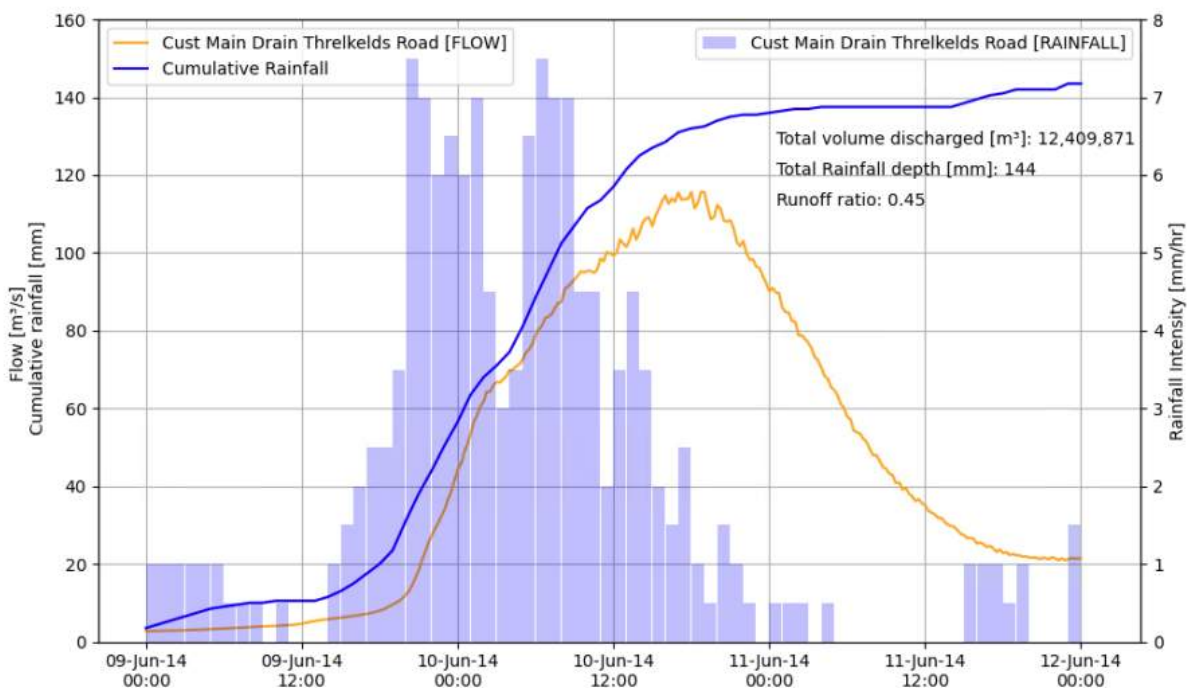
4.2 Assigning a return period to the 2014 event

The 2014 event was described in the PC31 evidence of Ben Throssell. Figure 4 shows the accompanying attachment from this evidence. In summary, paragraph 76 and 77 state:

- The Ōhoka rainfall recorder was not operative at this time and therefore, I have relied on the Cust recorder²⁶ (at Threlkelds Rd) to determine sub-hourly rainfall data:
 - 40.0 mm was recorded over a six-hour duration, between a 5-year (36.6 mm) and 10-year (44.6 mm) event according to HIRDS V4;
 - 76.2 a maximum depth of 72.0 mm was recorded over a 12-hour duration, about a 20-year event (73.4 mm) according to HIRDS V4; and,
 - 76.3 a maximum depth of 114.0 mm was recorded over a 24-hour duration, exactly a 40-year (114 mm) event according to HIRDS V4.
- The flow recorded in Cust River peaked at 115.634 m³/s. My flood frequency analysis shows that this flow has a return period of somewhere between 20 years (102 m³/s) and 50 years (125 m³/s).

Since the time of writing evidence, ECan have updated¹ their flood frequency statistics for Cust Main Drain. ECan estimate the 50-year event at 136 m³/s and the 20-year event at 109 m³/s. which puts the 2014 event as somewhere between the two. The only larger recorded flow event over the 37-year record was in 1995 (117 m³/s).

In summary, our best estimate for the 2014 event at Silverstream is around, a 50-year event or less. We acknowledge WDC consider it was closer to a 100-year event.



Attachment 3: Recorded flows and depths for Cust River at Threlkelds Road for 9 June to 12 June 2014

Figure 4: Reproduction of Attachment 3 from Ben Throssell's PC31 evidence.

¹ <https://api.ecan.govt.nz/TrimPublicAPI/documents/download/4873422>

4.3 Comparison with HIRDS rainfall data

Table 1 shows the HIRDS data for 100-year historic event and 50-year event with climate change. This table shows that depths for the 50-year event with climate change will exceed a 100-year historic event.

Table 1: HIRDSV4 rainfall depths for Ohoka		
HIRDS	6HR	24HR
100-year historic	75.9 mm	138 mm
50-year RCP8.5 2081-2100	85.2 mm	147 mm

In summary, we concluded that the 50-year RCP8.5 2081-2100 event is larger than the 2014 event. That is, the estimated additional stormwater generated by the site (between 10,000 and 26,000 m³ is likely an over-estimate for the volume that would have been released in the 2014 event and this makes the comparison conservative.

4.4 Historic imagery

To further assess the potential impact of additional stormwater discharge, we compared the required ponding areas with historical flood data from the June 2014 event. ECan's Flood Imagery Register² (FIR) provides oblique aerial photographs (Figure 5) captured at the peak flow of the Cust Main Drain on June 10th, 2014 (4 pm). These images have been georeferenced and traced to estimate the flood extent in 2014. Figure 6 shows:

- The inundation extent associated with 3.96 mRL (minimum elevation for a 26,000 m³ discharge with no more than 20 mm flood level increase) is shown, alongside the extent for a 10,000 m³ discharge (2.87 mRL).
- The traced flood extent derived from the two georeferenced images obtained from the FIR (Figure 5). The 2014 flood extent roughly matches the 3.96 mRL extent, with some discrepancies:
 - Downstream section (adjacent to Cust Main Drain): The 3.96 mRL extent overestimates the flood extent.
 - Upstream section (adjacent to Ohoka Stream): The 3.96 mRL extent underestimates the flood extent.
- These discrepancies are likely due to variations in the hydraulic grade along the Ohoka Stream which is not reflected in the bath-tub analysis.

² <https://apps.canterburymaps.govt.nz/FIR>

3000 - Looking north across Butchers Road toward Ohoka Stream



3001 - Ohoka Stream. Looking north toward Mill Road



Figure 5: Oblique aerials obtained from the FIR of the 2014 event. Ohoka Stream in the foreground and Cust Main Drain in the background.

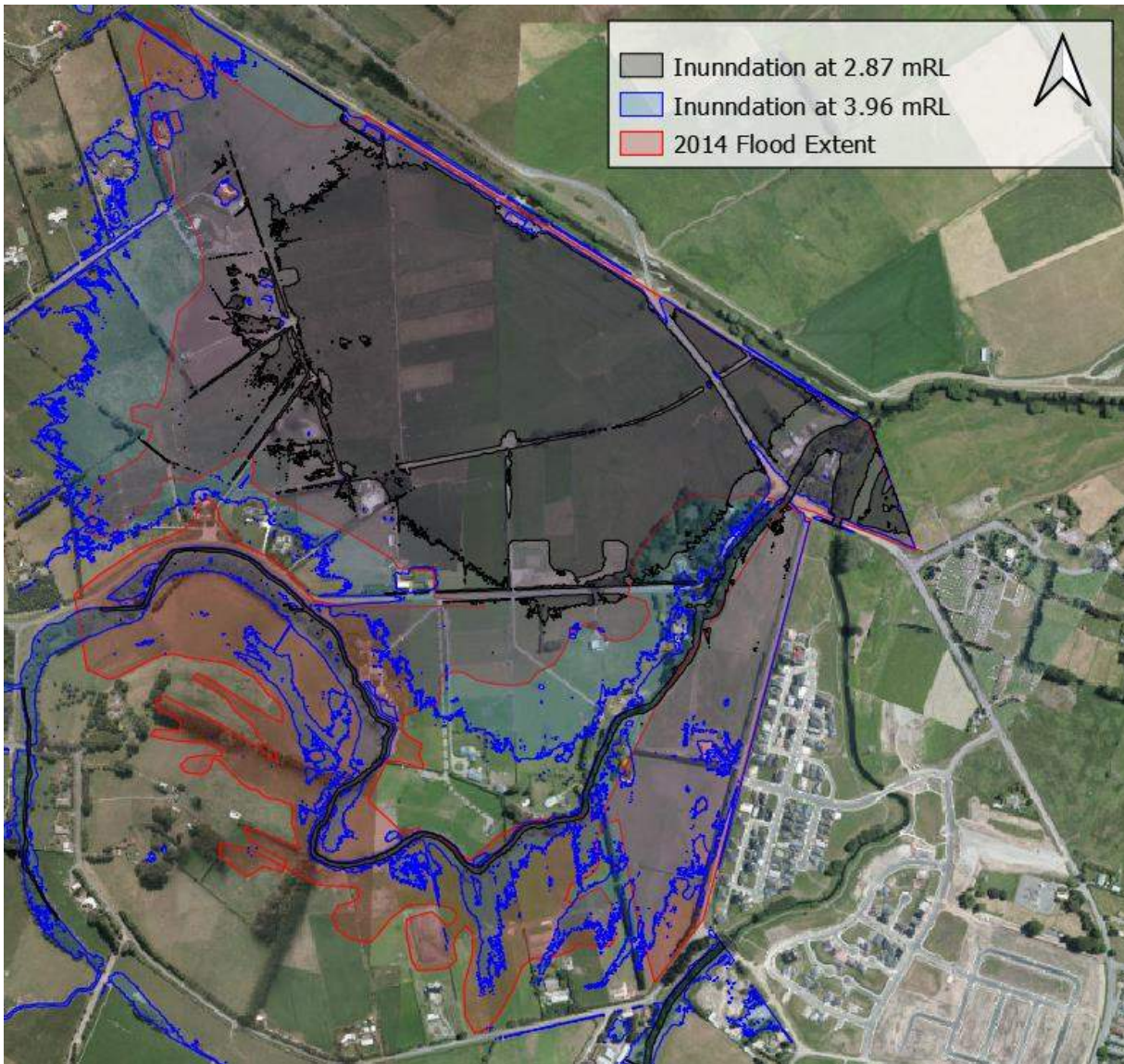


Figure 6: Comparison of 2014 flood extents taken from geo-referenced imagery (Figure 5) and the minimum ponded extents.

5.0 Conclusions

Our analysis undertaken to quantify the potential impact of additional stormwater discharge on flood levels upstream of Silverstream during a 50-year event adopts a conservative approach. The preliminary calculations presented during conferencing, which indicated a potential 20 mm rise in water levels due to a 10,000 m³ discharge, have been re-evaluated using the volume of the stormwater basins, 26,000 m³.

Key elements of this analysis include:

- **Peak Discharge Timing Assumption:** Assuming that all additional stormwater volume is released at the peak of the flood event is conservative as it is unlikely that all additional stormwater will discharge simultaneously over the period of peak flood levels. The WDC model the peak flood level for the 100-year event will be maintained for around two hours and a peak level for the 50-year event will likely be maintained for less than two hours.
- **Volume-Controlled Flood Levels:** Treating the area upstream of Silverstream as a bath-tub, where flood levels are controlled entirely by volume rather than flow and volume is also conservative.

- **Ponding Area Estimates:** Using the 2014 event which was less than a 50-year event with climate changed to compare ponded extents for a stormwater volume from a 50-year event with climate change is also conservative.

Comparative analysis with the historic 2014 flood event, which was likely smaller than the 50-year event used to estimate the additional stormwater discharge, shows the effects are likely to be around the minor/less than minor threshold of 20 mm.

The WDC model, which does not directly provide data for a 50-year event, predicts peak flood levels of 4.80m, 4.65m, and 4.55m for the 500-year, 200-year, and 100-year return periods, respectively. Our analysis indicates that to accommodate an additional 26,000 m³ of stormwater without exceeding a 20 mm rise in water level, a minimum elevation of 3.96 mRL is required. Given the trend in flood levels for larger events, it is likely that a 50-year flood would surpass this threshold meaning the effects of the additional stormwater discharge would be less than 20 mm.

In conclusion, whilst the methodology and assumptions adopted in this analysis are conservative, they still show that the estimated effects from the additional stormwater discharge will be a flood level increase of less than or close to 20 mm. This is the threshold of a minor or less than minor effect.

6.0 Limitations

This memorandum has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Waimakariri District Council and others (not directly contracted by PDP for the work), including Environment Canterbury, National Institute of Water and Atmosphere and Land Information New Zealand. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

Prepared by

Ben Throssell

Service Leader

Reviewed and approved by

Eoghan O'Neill – Technical Director

Technical Director