

# Flood Effects – 531 and 535 Mill Road, Ohoka

✦ Prepared for

Carter Group Limited (CGL)

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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.

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## Executive Summary

Pattle Delamore Partners (PDP) was engaged by Rolleston Industrial Developments Limited (RIDL) to undertake a flood effects assessment for the proposed residential development at 531 and 535 Mill Road, Ōhoka. This assessment, supported by detailed hydraulic modelling, evaluates potential flood-related effects arising from the development and is intended to inform a fast-track consenting application. The study considers existing flood characteristics and assesses the impacts of the development under 50-year, 200-year, and 500-year Average Recurrence Interval (ARI) design flood events, including allowances for future climate change.

### Methodology

A two-dimensional (2D) hydraulic model (TUFLOW HPC) was developed for the Ōhoka area and its contributing catchments. The model build incorporated recent LiDAR topographic data, surveyed information for hydraulic structures, and land cover-based roughness parameters.

The model was calibrated and validated against three significant historical flood events (June 2014, July 2022, and July 2023) by comparing modelled hydrographs with recorded flow data from the Cust Main Drain at Threlkelds Road. Further site-specific validation for the Ōhoka area involved comparing modelled flood extents and depths from the July 2023 event with available site photography. Sensitivity analyses were also undertaken on key model parameters, confirming the robustness of the model predictions.

The validated model was then used to simulate design flood events under both pre-development (existing) and post-development conditions, including the proposed subdivision layout, earthworks, and internal infrastructure.

### Existing Flood Environment

The Ōhoka area, including the proposed development site, is subject to overland flow and floodplain inundation during significant rainfall events, characteristic of the Canterbury Plains. The site receives considerable flow from catchments upstream of Bradleys Road. Modelling of the pre-development scenario for a 500-year ARI event indicates that flood hazard across the development site and areas south of Mill Road is predominantly 'Low' (H1 – generally safe for people and buildings) outside of defined channels. In contrast, areas north of Mill Road (not part of the development site) have higher existing flood hazard classifications.

### Internal subdivision flooding

The proposed development has been designed to manage flood risk effectively within its boundaries:

- ∴ Finished Floor Levels (FFLs): Minimum FFLs for all new habitable dwellings will be set at least 500 mm above the modelled 200-year ARI flood level (including climate change). This meets the requirements of the Partially Operative Waimakariri District Plan for minimum finished floor levels in medium to high hazard areas and is consistent with local planning principles and best practice in New Zealand.
- ∴ Building Platforms: Modelled building platforms are at suitable elevations to achieve the required FFLs through standard foundation design. Predicted flood depths on these platforms during a 200-year ARI event are generally less than 100 mm, and well below the proposed FFLs.
- ∴ Internal Roads & Drainage: While some sections of internal roads may experience depths restricting general vehicle access during major events (e.g., >300 mm in a 50-year ARI event in limited locations), the primary objective of protecting habitable dwellings is achieved. The internal stormwater network and overland flow paths will be refined at the detailed design stage to manage on-site ponding and optimize accessibility where practicable.

### External subdivision flooding

Adjacent Properties & Buildings: No existing habitable dwellings are predicted to experience an increase in average flood levels greater than 20 mm. The vast majority (over 1100) of surrounding building footprints experience no material change (< ±10 mm).

Critical Infrastructure: No major lifeline utilities or designated critical transportation routes are adversely affected. Minor increases in shallow flood depths on adjacent local roads (e.g., Whites Road) are not considered significant and do not unduly compromise passability for most vehicles in extreme events.

Cultural and Heritage Sites: Identified heritage sites in the vicinity are predicted to experience either a decrease or a negligible increase (<10 mm) in flood levels.

### Conclusion

This Flood Effects Assessment demonstrates that the proposed residential development at 531 and 535 Mill Road, Ōhoka, can be designed and constructed to effectively manage flood risk and ensure that its impacts on the surrounding flood environment are acceptable.

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## 1.0 Introduction

Pattle Delamore Partners (PDP) has been engaged by Carter Group Limited (CGL) (the Client) to complete a flood effects assessment for the proposed residential development at 531 and 535 Mill Road, Ohoka. This assessment and the hydraulic modelling herein are intended to support a fast-track consenting application for the development by evaluating potential flood-related effects.

The site is located to the southwest of Ōhoka township, within the Waimakariri District, and is bordered by Bradleys Road and Whites Road. The current 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 potential retirement village area.

The site location is indicated in Figure 1 below.



**Figure 1: Location of proposed development.**

The hydraulic model has been used to:

- ∴ assess effects on flooding as a result of the proposed development;
- ∴ assess internal flood depths on roads for the 50-year event; and,
- ∴ provide indicative finished floor levels.

A 2D hydraulic model was constructed using the TufLOW modeling software. TufLOW is a computational software which contains a 1D and 2D engine to numerically model free surface flows. The 2D depth averaged, momentum and continuity equations for free-surface flows are solved using a 2<sup>nd</sup> order semi-implicit solver.

This report documents the model build process, validation of the model using flow data for the Cust Main Drain and flood effects of the proposed development.

Unless otherwise specified, the datums employed for this model are:

- ∴ NZVD2016 for the vertical datum and
- ∴ NZTM2000 (ESPG 2193) for the horizontal datum.

## 1.1 Background

The proposed development is located between Bradleys Road and Whites Road directly south of Mill Road. Current land use for the site is rural pasture with the intention to develop to predominantly residential land use. An overview of the site is shown in Figure 2 below.

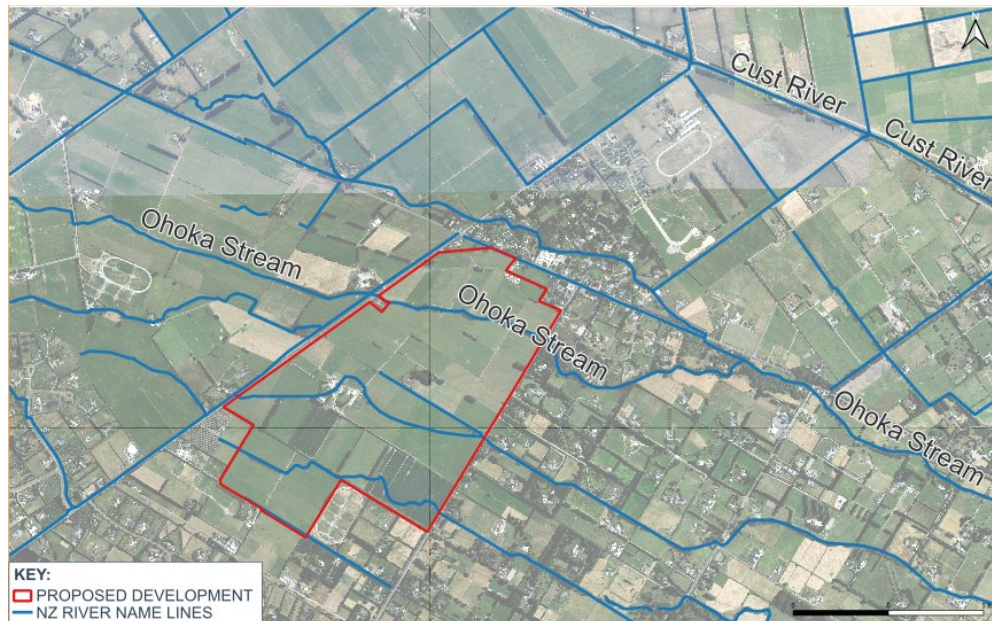
### 1.1.1 Historical Flood Events

To ensure the hydraulic model accurately represents local hydrological responses, it was validated against three significant historical flood events recorded in the Cust Main Drain: June 2014, July 2022, and July 2023. These events had estimated ARIs ranging from approximately 10 to 50 years.

- ∴ June 2014: A peak flow of almost 120 m<sup>3</sup>/s was recorded in the Cust Main Drain (20 to 50-year event) and 40 mm of rainfall was recorded over six hours at Threlkelds Rd (approximately 2.5 km East of Ohoka);
- ∴ July 2022: A peak flow of just over 100 m<sup>3</sup>/s was recorded in the Cust Main Drain (20-year event) and 35 mm of rainfall was recorded over six hours at Threlkelds Rd); and,
- ∴ July 2023: A peak flow of around 90 m<sup>3</sup>/s was recorded in the Cust Main Drain (10 to 20-year event) and 63 mm of rainfall was recorded over six hours at Threlkelds Rd);

These events are described in further detail in Section 4.1 of the report, which discusses the model calibration and validation process.

There are four established water courses (Figure 2) flowing west to east through the site, the Ōhoka Stream, Ōhoka South Branch and two unnamed water courses. The nearest major water course is the Cust Main Drain (also referred to as the Cust River) which flows west to east and is located to the north of the Ōhoka township (Figure 2).



**Figure 2. Site overview and existing watercourses**

## 1.2 Previous Modelling

### 1.2.1 PDP Modelling

PDP previously undertook hydraulic modelling (Report: C04518300R001 Effects on Flooding – 535 Mill Road, Ōhoka – Stormwater Management) to support an earlier plan change request for the site. That 2D TufLOW model primarily investigated potential flood effects (changes to flood hazard and water levels) resulting from floodplain displacement associated with a previous development layout.

The main conclusions of this model were:

- ∴ The proposed development is consistent with the Environment Canterbury Regional Policy Statement. Floor levels will be located above the 200YR event, no development will take place in areas designated 'high hazard' and there will be no increased risk to life as a result of the development;
- ∴ The effects on flood flow vary throughout the subdivision. The model predicts that flow over the south-eastern boundary of the subdivision (Whites Road) is increased by 300 L/s (36.1 m<sup>3</sup>/s to 36.4 m<sup>3</sup>/s). Flow over the north-eastern boundary of the subdivision (Mill Rd) decreases slightly by approximately 40 L/s. Peak flow over Mill Rd is around 8.7 m<sup>3</sup>/s;

- ∴ The predicted increase in flood level for habitable dwellings is no greater than 45 mm for average flood depth and no more than 39 mm for peak flood elevations. This demonstrates that there is a feasible solution for the development of this land which will ensure the effects of development are less than minor; and,

No change to the high hazard classification with the exception of some locations along the realigned streams. The layout of the proposed development has since been revised and the model has been reconfigured with the new development layout.

### 1.2.2 WDC Modelling

A district wide model has also been 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 910m<sup>3</sup>/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.

## 2.0 Data Register

Data Register				
Type	Name	Provider Obtained	Used For	Comments
Topography	Canterbury LiDAR 1m DEM (2020 – 2023)	data.linz.govt.nz	Building the model DTM	Downloaded as a raster in the NZVD 2016 Datum
	Subdivision surface	Via email, Sanna Soederlind (Inovo) to Ben Throssell (PDP) on 6 June 2025	Adjusting the post development DTM	0.5 m resolution in the NZVD datum
Land Use	LCDB V5	Iris.scinfo.org.nz 6-Nov-24	Building the roughness layer	Used as the base layer of the roughness file
	NZ Road Centrelines (Topo 1:50K)	data.linz.govt.nz 6-Nov-24	Roughness and precipitation layers for the model	A 6 m buffer was applied to this layer which was employed to represent the road
	NZ Building Outlines	data.linz.govt.nz 6-Nov-24	Building the roughness layer, assessing hazard	
Hydrometric	sub-Hourly rainfall	Tony Gray, Email dated 1/11/2024  Graham Harrington (email dated 31/10/2024)	Validating calibration flow and determining rainfall depths for calibration	

### 3.0 Model Validation

Model validation and/or calibration should be completed to refine parameters which have a high degree of uncertainty. For a rain on grid model, the infiltration parameter usually has a high degree of uncertainty. Validation of the model was completed in two stages:

**Stage 1:** The initial stage focused on calibrating key model parameters, primarily infiltration rates and roughness, by comparing modelled hydrographs against observed flow data for the Cust Main Drain. This catchment-scale calibration aimed to refine the model's (named V01) ability to accurately simulate runoff generation and routing from significant historical rainfall events.

**Stage 2:** Whilst the Cust Main Drain catchment shares similar infiltration and roughness characteristics to the Ohoka development, it is a separate and distinct catchment (from the Ohoka development site's local catchment). Therefore, a second validation stage was undertaken. This stage focused specifically on the Ohoka site area, using the refined V02 model extent. Modelled flood depths and extents for the July 2023 event were compared against available flood photography from the site to confirm satisfactory local-scale performance. Key model settings (such as calibrated infiltration parameters) from Stage 1 were incorporated into the V02 model.

The validation model for Stage 1 is referred to as "V01" whilst stage 2 is referred to as "V02".

#### 3.1 Model Purpose

**V01:** The primary purpose of the V01 model was to calibrate infiltration parameters and validate the general roughness parameters at a catchment scale by achieving a reasonable match with recorded hydrographs in the Cust Main Drain.

**V02:** The V02 model was developed to validate the calibrated model parameters specifically for the Ohoka development site and its surrounding area, ensuring the model's suitability for assessing flood effects on and around the proposed subdivision.

#### 3.2 Model Settings

For both models (V01 and V02) the following model settings were employed:

- ∴ The HPC solver employed was 2023-03-AC;
- ∴ Sub grid sampling was employed. This feature allows the 2D hydraulic calculations to account for finer-scale topographic variations within each grid cell, improving the representation of flow paths and storage without requiring an excessively fine grid resolution across the entire model.;

- ∴ A cell wet/dry depth of 0.0002 m (0.2 mm) was adopted, consistent with TUFLOW recommendations for rain-on-grid models to ensure appropriate initiation of runoff.
- ∴ The single precision solver was employed rather than the double precision solver. The HPC solver inherently conserves mass and volume effectively, making the use of a double precision solver, which can increase runtimes, unnecessary for this application.

### 3.3 Digital Elevation Model

For both models (V01 and V02), the digital elevation model was constructed from available LiDAR across the model extent. LiDAR used for the model was the Canterbury LiDAR 1m DEM (2020-2025) sourced from LINZ<sup>1</sup>. 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 into the DEM. These defined the crests of stopbanks along the Cust Main Drain and the crests of significant roads within the model domain.

### 3.4 Model Extents

The V01 and V02 models used different computational extents and grid resolutions, due to their specific validation objectives.

**V01:** The V01 model encompassed a larger area, including the upper catchment of the Cust Main Drain and the Ōhoka site environs (Figure 3). This model was run with a 7m grid resolution, appropriate for assessing the catchment-scale hydrological response and validating flows at the Cust Main Drain gauge.

**V02:** The V02 uses a more focused extent, centred on the Ōhoka development site and its immediate flow paths (Figure 4) This allowed for a finer grid resolution to be employed: a base resolution of 4m, with a further refinement to 2m specifically over the Ōhoka development area. This increased detail is crucial for accurately assessing site-specific flood depths and extents.

Modelled outputs from common areas in both V01 and V02 were compared for key validation events to ensure consistency in overall flood behaviour between the two model configurations, despite the differing resolutions.

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



Figure 3. V01 model extent, boundary conditions and rainfall gauges

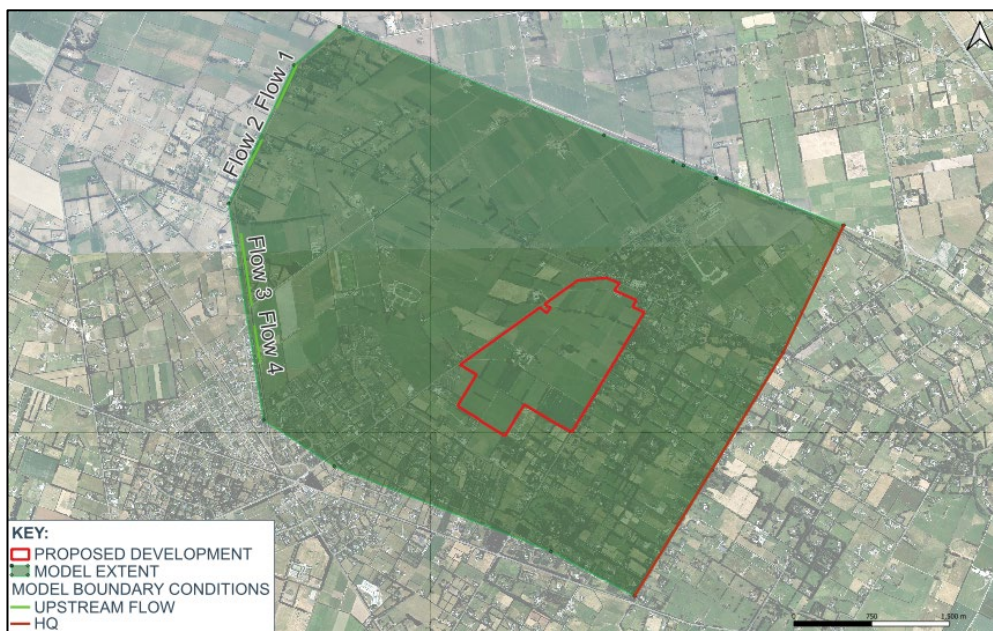


Figure 4. V02 Model extent and boundary conditions

### 3.5 Boundary Conditions

#### 3.5.1 V01

The boundary conditions applied to the wider model were:

- ∴ A rain on grid boundary applied over the model extent, representing rainfall for the three storm events: June 2014, July 2022 and July 2023; and,
- ∴ A downstream normal depth boundary. The slope for this boundary was derived from the average bed slope of the main watercourse in that vicinity.

The rainfall was applied spatially based on rainfall data from five separate rain gauges across the model extent (Figure 3). The model applied an inverse distance weighting approach to interpolate between the rain gauges. Figure 5 shows the hourly rainfall depths at each of the five gauges over the three events. Figure 5 shows:

- ∴ For the **2014 event**, the greatest intensities were recorded at Threlkelds Road (close to the proposed subdivision). The event was a prolonged, but generally low intensity with rainfall recorded at consistent intensities over the three days. Intensities were varied throughout the catchment with less rainfall recorded in the south (Poyntzs Road);
- ∴ For the **2022 event**, the rainfall at all recorders was characterised by a peak occurring around hour 32-35 of the event. Ashley recorded the highest peak intensity at approximately 9.5 mm/hr, followed closely by Peraki St which reached about 8.5 mm/hr. The event showed relatively consistent timing across all gauges, with most locations experiencing their peak rainfall within a narrow 3-4 hour window. Poyntzs Road recorded the lowest intensities during this event. The rainfall pattern was distinctly different from 2014, being much more concentrated and intense over a shorter duration.
- ∴ The **2023 event** displayed the most variable rainfall pattern of the three events. Threlkelds Road recorded the highest peak intensity at approximately 15 mm/hr around hour 28, making it the most intense of all recorded events. The spatial variability of rainfall was more consistent than 2014 but less so than 2022, with Threlkelds Road and Ashley showing the highest intensities, while Poyntzs Road again recorded lower values.

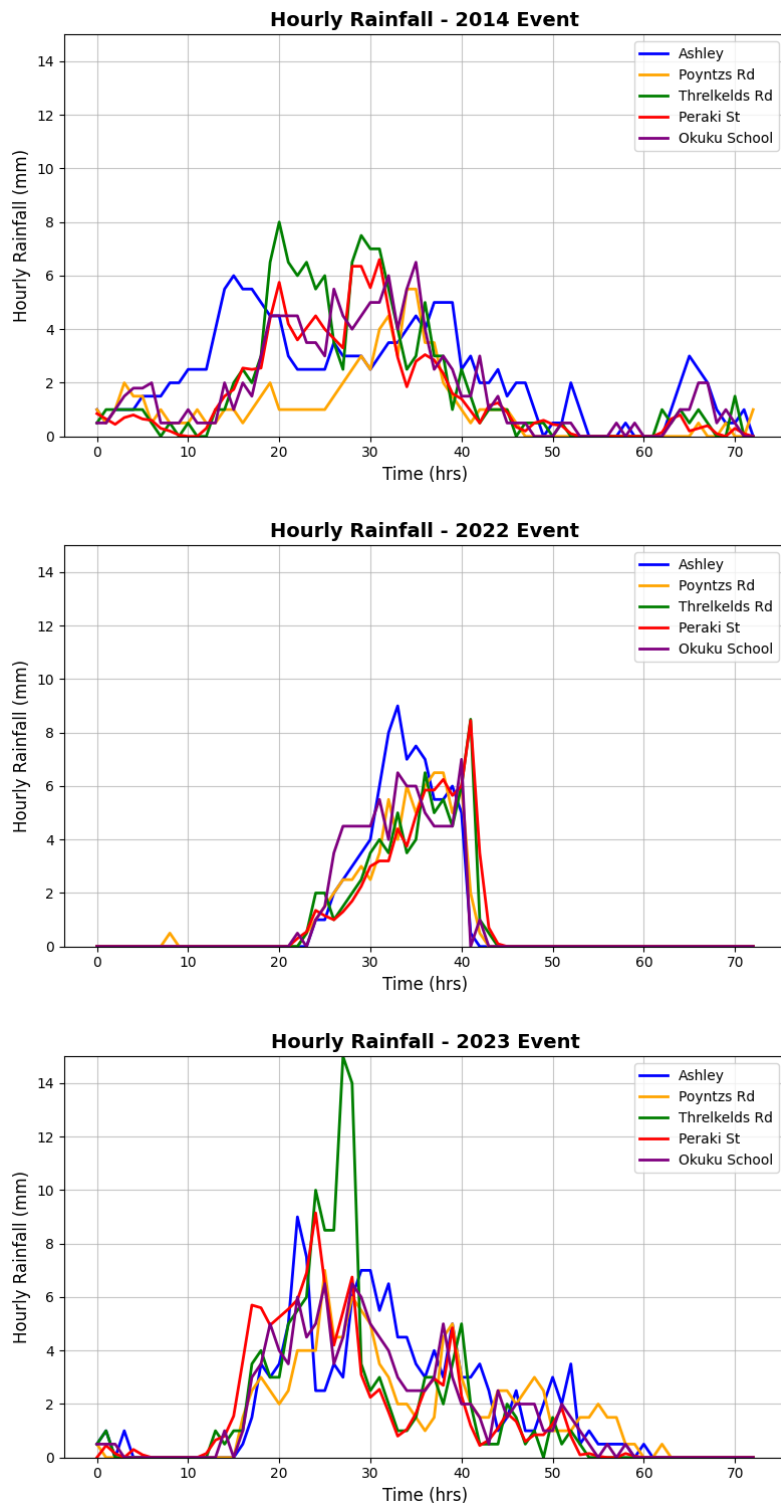


Figure 5. Hourly rainfall depths for the 2014, 2022 and 2023 event

### 3.5.2 V02

For the refined V02 model, inflow hydrographs were extracted from the V01 model results at appropriate locations upstream of the Ōhoka Site. These hydrographs, representing the flow contribution from the wider catchment, were then applied as upstream flow (QT) boundary conditions to the V02 model. The specific inflow hydrographs applied for the July 2023 validation event are shown in Figure 6.

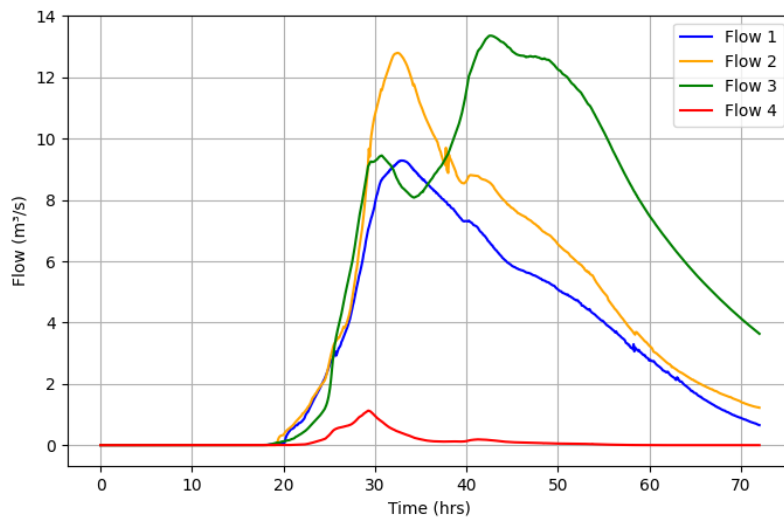
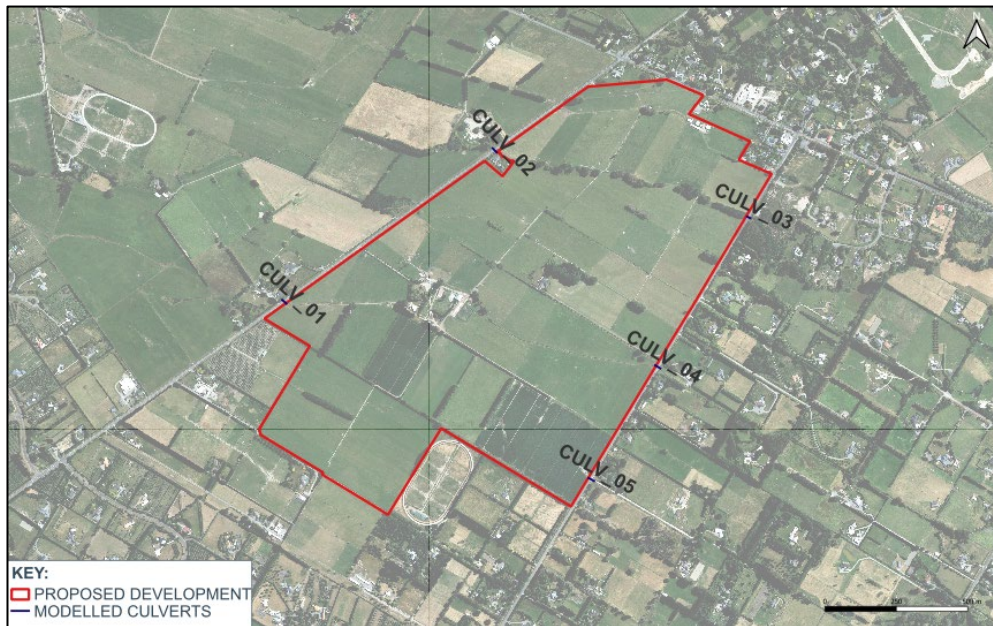


Figure 6. Ōhoka V02 Flow Boundary Conditions for the 2023 event

### 3.6 Structures

Key hydraulic structures, specifically culverts along Bradleys Road and Whites Road, were incorporated into the V02 model. These were defined based on survey information collected by PDP in 2022. The parameters for these existing culverts are detailed in Table 1. The locations of these modelled culverts (CULV\_1 to CULV\_5) are shown in Figure 7.

Table 1: Model Culvert Parameters					
ID	Type	Culvert Width (m)	Culvert Height (m)	Upstream Invert (m RL)	Downstream Invert (m RL)
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



**Figure 7: Existing culvert locations included in the hydraulic model. Refer Table 1 for dimensions**

### 3.7 Roughness

The roughness values across the model area were determined using a combination of the LCDB V5 database, the NZ building outlines, and the NZ road centrelines (Topo 1:50k). A 6 m buffer was applied to the road centrelines layer to represent the roads within the model. The roughness values applied for the model are provided in Table 2 below.

Table 2: Adopted Manning’s Roughness Values		
Material ID	Roughness	Description <sup>[2],[3] and [4]</sup>
1	1 <sup>[1]</sup>	Building Footprint
2	0.02	Roads
3	0.035	High Producing Exotic Grassland
4	0.02	Lake or Pond
5	0.15	Exotic Forest
6	0.16	Forest – Harvested
7	0.125	Deciduous Hardwoods
8	0.1	Manuka and/or Kanuka

Table 2: Adopted Manning's Roughness Values		
Material ID	Roughness	Description <sup>[2],[3] and [4]</sup>
9	0.037	Orchard, Vineyard or Other Perennial Crop
10	0.1	Short-rotation Cropland
11	0.125	Gorse and/or Broom
12	0.039	Gravel or Rock
13	0.04	River
14	0.1	Broadleaved Indigenous Hardwoods
15	0.033	Low Producing Grassland
16	0.02	Built-up Area
17	0.1	Herbaceous Freshwater Vegetation
18	0.033	Urban Parkland/Open Space
19	0.028	Surface Mine or Dump
20	0.15	Indigenous Forest
21	0.16	Ferland
22	0.016	Transport Infrastructure
23	0.015	Estuarine Open Water
24	0.08	Mixed Exotic Shrubland
25	0.07	Medium Dense Bush (connecting southern channels)
26	0.11	Dense Bush (connecting southern channels)
27	0.035	Grassland
28	0.07	Swale
29	0.045	North Channel
30	0.01	Mid North Channel
31	0.035	Mid South Channel

**Notes:**

1. This high manning's rough value allows for floodplain storage within the building footprint but prevents any significant conveyance.
2. Sources: Cardno. (2021). Flood Hazard Modelling Standard. Wellington: Greater Wellington Regional Council.
3. Defra (2004) Reducing Uncertainty in River Flood Conveyance: Conveyance Manual (DEFRA)
4. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), 2019

### 3.8 Infiltration

Horton's infiltration method was applied in both the V01 and V02 models. Initial infiltration parameters (initial loss, initial rate, final rate, decay constant) for the V01 model were assigned based on soil classifications derived from the Iris data dictionary V3<sup>2</sup> (Landcare Research). These initial values, guided by literature such as the Christchurch City Council Waterways, Wetlands and Drainage Guide, were subsequently calibrated during the Stage 1 validation process by adjusting them to achieve a satisfactory match with recorded flows in the Cust Main Drain.

The soil classification for wider catchment area is shown in Figure 8. The standard infiltration parameters that were adopted are provided in Table 3.

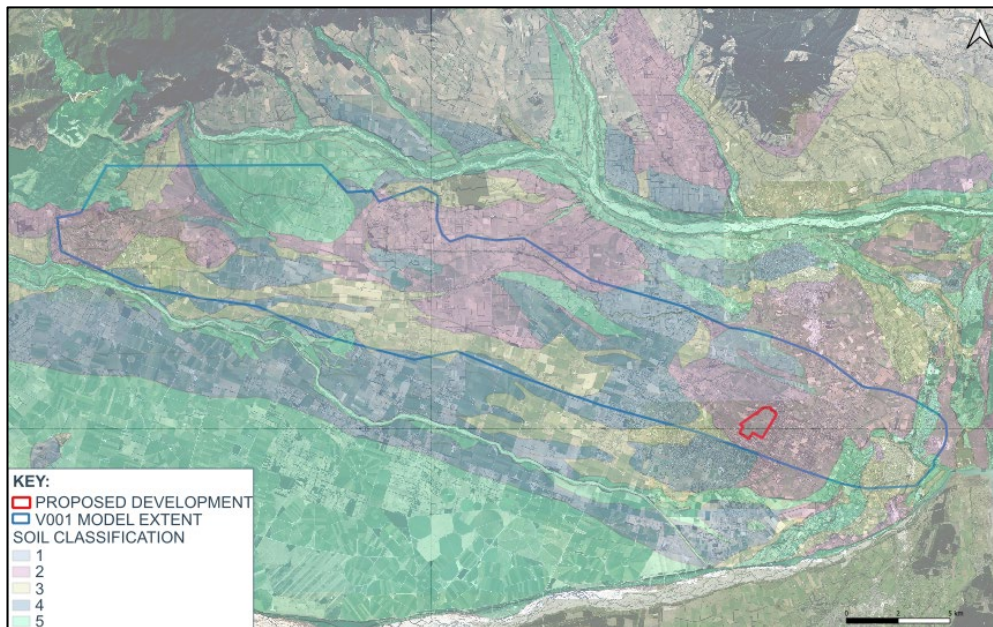


Figure 8. Soil classifications for the model area

Table 3: Adopted Horton's Roughness Values					
Soil ID	Soil Class	Initial Loss (mm)	Initial Loss Rate (mm/hr)	Final Loss Rate (mm/hr)	Exponential Decay Rate (h <sup>-1</sup> )
1	Class 1 – Very Poorly Drained	0	2.5	1	5.4
2	Class 2 – Poorly Drained	0	5	1.75	2.88

<sup>2</sup> <https://iris.scinfo.org.nz/document/9162-Iris-data-dictionary-v3/>

**Table 3: Adopted Horton’s Roughness Values**

Soil ID	Soil Class	Initial Loss (mm)	Initial Loss Rate (mm/hr)	Final Loss Rate (mm/hr)	Exponential Decay Rate (h <sup>-1</sup> )
3	Class 3 – Imperfectly Drained	0	7.5	2.5	0.360
4	Class 4 - Moderately Well Drained	0	10	3.75	0.234
5	Class 5 – Well Drained	0	12.5	5	0.108
99	Impervious	No infiltration	-	-	-

## 4.0 Validation Results

This section details the results of the model validation process. The V01 model, encompassing the wider Cust Main Drain catchment, was validated against three historical flood events (June 2014, July 2022, and July 2023) by comparing modelled hydrographs with recorded flow data. The V02 model, focusing on the Ōhoka site, was validated against the July 2023 event using available flood photography to assess modelled flood extents and depths.

### 4.1 Historic events

Three historic events were available for validation of the models (V01 and V02). The V01 model was validated against all three events whilst the V02 model was only validated against the 2023 event due to limitations of available data. 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)<sup>3</sup> 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 m<sup>3</sup>/s on 6 August 1995, very similar to the recorded peak for the 10 June 2014 event (115.634 m<sup>3</sup>/s) and the 12 July 2022 event (103.501 m<sup>3</sup>/s).

<sup>3</sup> Email from Tony Gray (ECan) to Ben Throssell (PDP) on 23 May 2023

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.

#### 4.1.1 2014 flood event

The NIWA weather catalogue<sup>4</sup> 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 9 shows the recorded rainfall and flow data. The Cust Main Drain recorded a peak flow of around 115 m<sup>3</sup>/s and a flood frequency analysis shows that this flow has a return period of somewhere between 20 years (102 m<sup>3</sup>/s) and 50 years (125 m<sup>3</sup>/s).

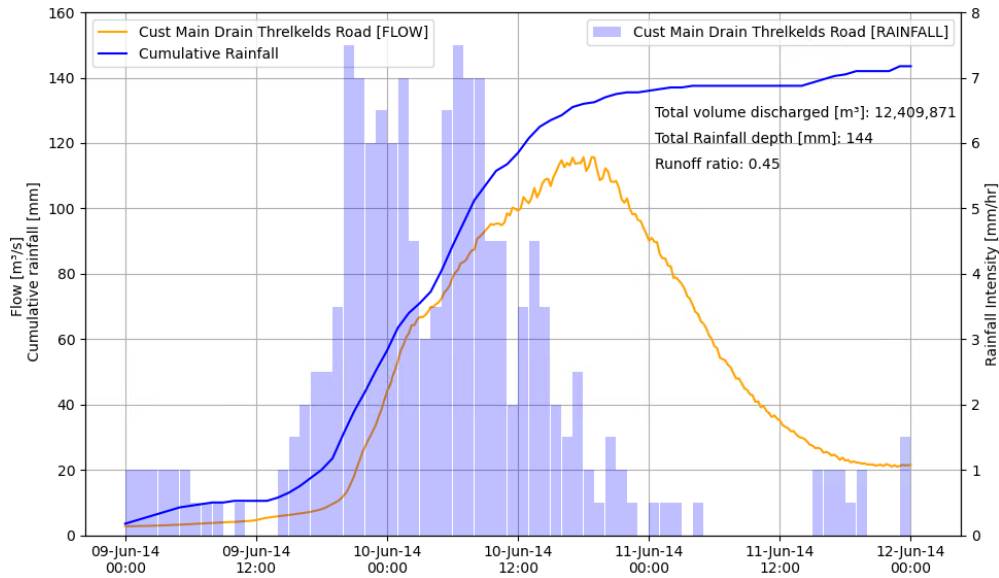
A total rainfall depth of 144 mm and maximum intensity of 7.5 mm/hr was recorded. The Cust recorder<sup>5</sup> (at Threlkelds Rd) provides sub-hourly rainfall data:

- ∴ 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.

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<sup>4</sup> [https://hwe.niwa.co.nz/event/June\\_2014\\_New\\_Zealand\\_Storm](https://hwe.niwa.co.nz/event/June_2014_New_Zealand_Storm)

<sup>5</sup> Supplied by Tony Gray (ECan) to Ben Throssell (PDP) on 15 June 2023



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

4.1.2 2022 flood event

NIWA, in their monthly climate summary, reported<sup>6</sup>:

“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 m<sup>3</sup>/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:

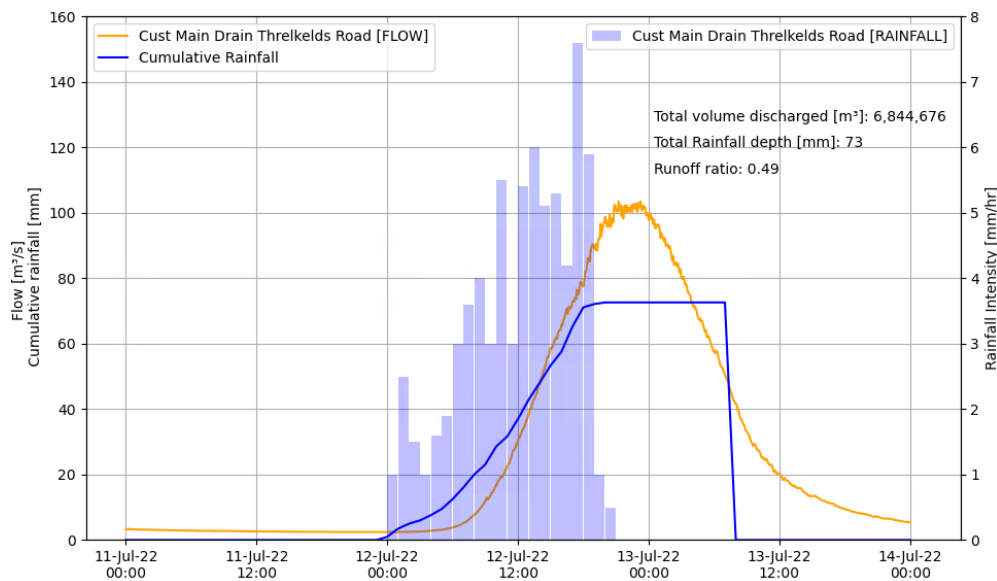
- ∴ 34.8 mm was recorded over a six-hour duration, about a 5-year event (36.6 mm) according to HIRDS V4;

<sup>6</sup> [https://niwa.co.nz/sites/niwa.co.nz/files/Climate\\_Summary\\_July\\_2022\\_Final-v3.pdf](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 m<sup>3</sup>/s and 20-year flow of 102 m<sup>3</sup>/s. ECan report<sup>7</sup> a 10-year flow of 90 m<sup>3</sup>/s for the same recorder. The flow recorded in Cust Main Drain for the July 2022 peaked at 103.501 m<sup>3</sup>/s. The flood frequency analysis shows that this flow has a return period of 20 years (102 m<sup>3</sup>/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 Poyntz Rd shows 30.5 mm. Therefore, the return period of this flood event, for Ohoka, was likely between 10 and 20 years.



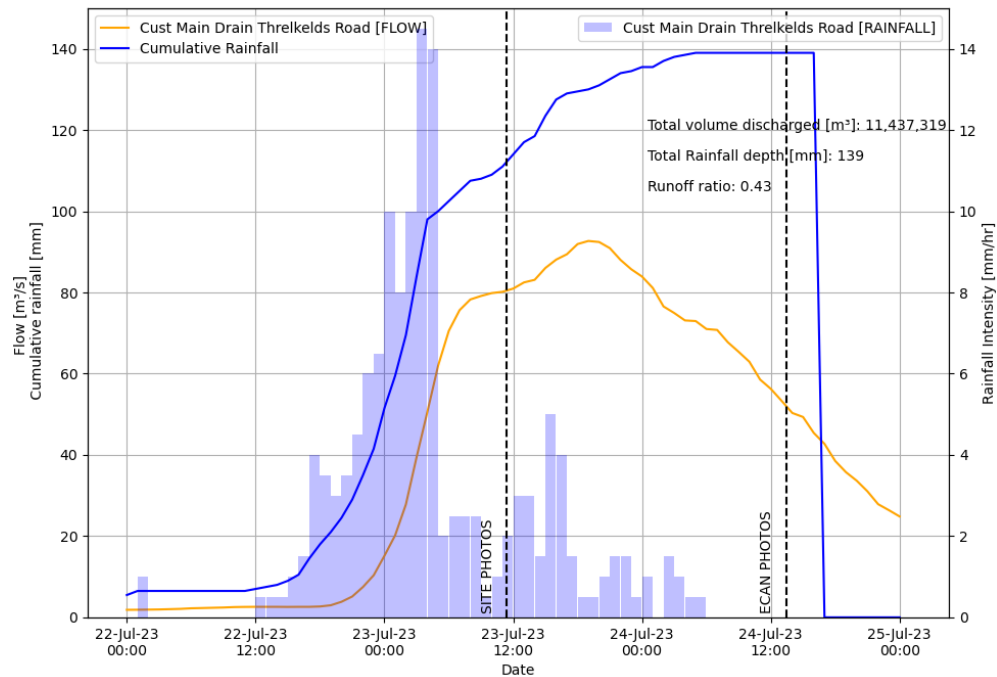
**Figure 10. Recorded flows and depths for Cust Main Drain at Threlkelds Road for 11 July to 14 July 2022**

<sup>7</sup> <https://www.ecan.govt.nz/data/riverflow/>

4.1.3 2023 flood event

Niwa report<sup>8</sup>:

“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 11. 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,
- ∴ 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.

<sup>8</sup> [https://niwa.co.nz/sites/default/files/Climate\\_Summary\\_July\\_2023\\_Final.pdf](https://niwa.co.nz/sites/default/files/Climate_Summary_July_2023_Final.pdf)

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 m<sup>3</sup>/s. Flood frequency analysis (prepared prior to this event) shows that this flow has a return period of somewhere between 10-years (84 m<sup>3</sup>/s) and 20-years (102 m<sup>3</sup>/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.

#### 4.2 V01 – Cust Main Drain Validation

The purpose of the more extensive V01 model is to validate the infiltration and roughness parameters.

**Infiltration:** Two infiltration scenarios were considered:

- ∴ a standard infiltration model with parameters as described in Table 3; and,
- ∴ a low infiltration model which adopted the same decay rate but decreased the initial and final loss rates. Iteration of this parameter showed that the best match to measured flow data was achieved when a reduction rate of 75% was applied. Final infiltration parameters for the low infiltration model are presented in Section 5.4.

**Roughness:** Two roughness scenarios were considered, a standard roughness model, with parameters as described in Table 2. A depth varied roughness model, for the High Producing Exotic Grassland and Short-rotation cropland classifications was also considered. For both classifications roughness values were:

- ∴ if depth is less than 0.1 m,  $n = 0.25$ ;
- ∴ if depth is greater than 0.3 m,  $n = 0.06$ ; and,
- ∴ between depths of 0.1 and 0.3 m,  $n$  is interpolated (between 0.25 and 0.06).

In total, 12 validation models were run:

- ∴ three (2014, 2022 and 2023) rainfall events;
- ∴ two infiltration scenarios (standard and low); and,
- ∴ two roughness scenarios (static and depth varied).

**Table 4: Model scenarios for validation model V01**

Short ID	Model	Event	Roughness	Infiltration
V01_2014_nStatic_IStd	V01	2014	Static	Standard
V01_2014_nStatic_ILow				Low
V01_2014_nDepthV_IStd			Depth varied	Standard
V01_2014_nDepthV_ILow				Low
V01_2022_nStatic_IStd		2022	Static	Standard
V01_2022_nStatic_ILow				Low
V01_2022_nDepthV_IStd			Depth varied	Standard
V01_2022_nDepthV_ILow				Low
V01_2023_nStatic_IStd		2023	Static	Standard
V01_2023_nStatic_ILow				Low
V01_2023_nDepthV_IStd			Depth varied	Standard
V01_2023_nDepthV_ILow				Low

#### 4.2.1 Results

The modelled hydrographs for all 12 scenarios were compared against the recorded flow data at the Cust Main Drain (Threlkelds Road). Figure 12 shows the predicted and modelled flows at the Cust Main Drain recorder for the 2014 event whilst Figure 13 and Figure 14 shows flows for the 2022 and 2023 validation events. Summarising these figures:

For the **2014 event**, the best validation for timing of the peak is achieved by the depth varied roughness models and the best validation for magnitude of the peak is achieved by the low infiltration models. Both standard infiltration models significantly underestimate the peak, and whilst the low infiltration, static roughness model gives the best approximation of the observed peak flow, the low infiltration, depth varied roughness model better approximates the timing whilst being within an acceptable range of the observed peak. In conclusion:

- ∴ Either low infiltration model (depth varied or static roughness) could be adopted for this event.

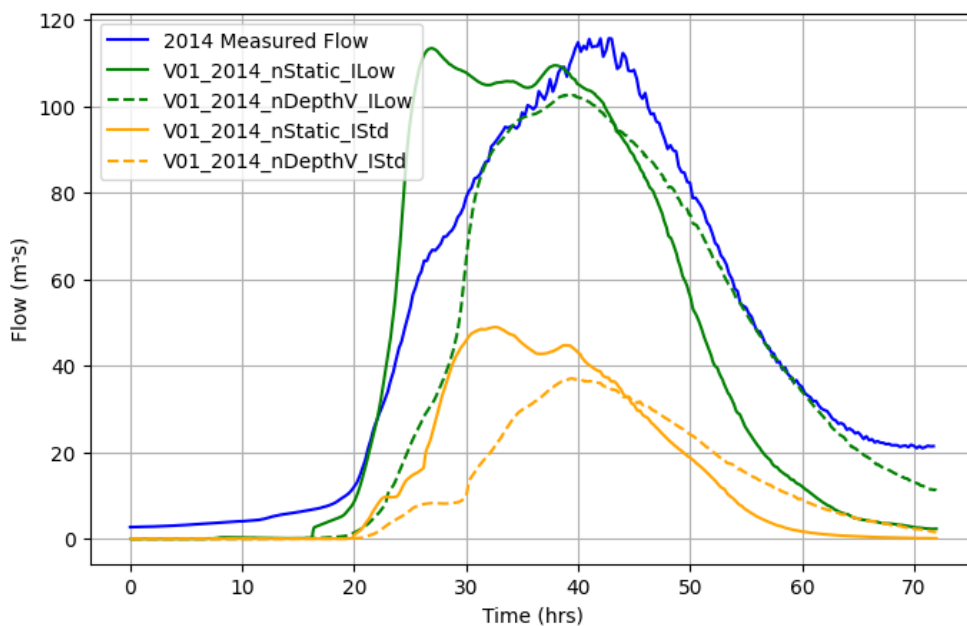


Figure 12. Cust Main Drain Validation Results for the 2014 Event

For the **2022 event**, the best validation for timing of the peak is achieved by the depth varied, low infiltration model and the static roughness, standard infiltration model, both of which also achieve the best match to the observed peak flow. The other two models either over or underestimate the flow magnitude. In conclusion:

- ∴ Either low infiltration and depth varied roughness model or static roughness and standard infiltration model could be adopted for this event.

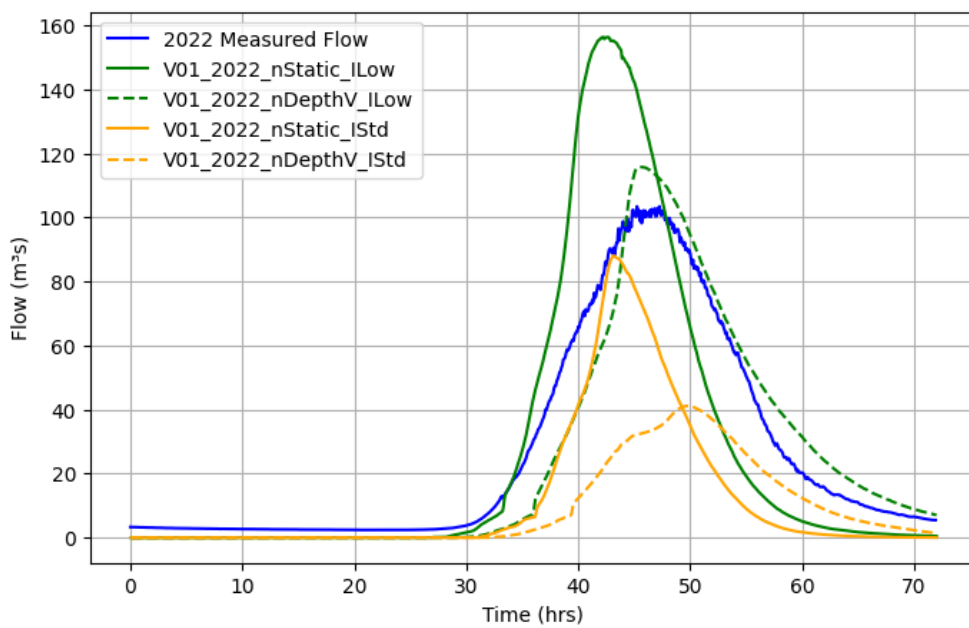
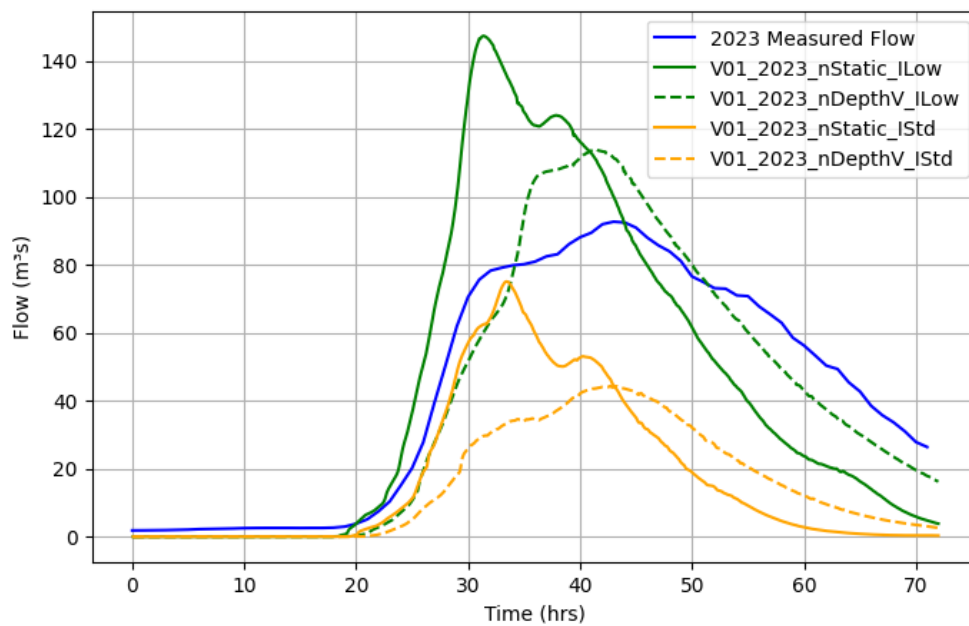


Figure 13. Cust Main Drain Validation Results for the 2022 Event

For the **2023 event**, the best validation for timing of the peak is achieved by the depth varied roughness models whilst the best match to the observed peak flow peak is achieved by the depth varied, low infiltration model and the static roughness, standard infiltration model. The other two models either over or underestimate the flow magnitude. In conclusion:

- ∴ The depth varied roughness model could be adopted for this event.



**Figure 14. Cust Main Drain Validation Results for the 2023 Event**

#### 4.2.2 Conclusion

Across all three historical events, the scenario combining 'low infiltration' parameters with 'depth-varied roughness' consistently provided the most acceptable predictions of both hydrograph shape (timing) and peak flow magnitude.

Specifically, this adopted parameter set:

- ∴ Accurately predicted the timing of the flood peak for all events.
- ∴ Overestimated the peak flow for the 2022 and 2023 events by approximately 20%.
- ∴ Underestimated the peak flow for the 2014 event by approximately 20%."

This level of variation ( $\pm 20\%$  on peak flow) is considered acceptable for a catchment-scale model validation, particularly given the inherent uncertainties in rainfall data, antecedent conditions, evolving catchment characteristics over the

years, and flow gauging accuracy. Therefore, these calibrated 'low infiltration' parameters and the 'depth-varied roughness' approach were selected and carried forward for the V02 site-specific model validation and subsequent design event modelling. The tendency of this parameter set to overestimate flow for two of the three events suggests a slightly conservative calibration, which is appropriate for a flood effects assessment.

### 4.3 V02 – Ōhoka Site Model

The V02 model provide a more detailed assessment of the model performance in the Ōhoka area. The V02 model was validated using photos taken during the July 2023 event which were compared to the predicted flood extent.

Previous flooding assessments (Section 1.2.1) found that effects were generally confined to locations near the proposed development. Therefore, this validation exercise has focussed on those critical locations which include dwellings and property downstream of Whites Road and the Ōhoka Township (adjacent to Mill Rd).

A detailed comparison between the model results and the flood photos is provided in Appendix B.

The main observations from the validation are:

- ∴ A good match was achieved for the critical ponding location across Whites Road (at 401 Whites Road).
- ∴ The model flood extent within the proposed site is greater than the flood photos at certain locations along Whites Road.
  - Specifically at the areas north of the Ōhoka Stream and south of the Ōhoka South Branch;
  - This is potentially influenced by the height of the grass which may mask ponding within the photos.
- ∴ A good match was achieved along the Bradleys and Mill Road boundaries of the proposed development.

#### 4.3.1 Conclusion

The model validation was considered successful, and no modifications were necessary before proceeding to the design stage. As noted in the validation of the V01 model, the model appears to be slightly conservative.

## 5.0 Design Model Build

This section describes the development of the hydraulic models used to assess the proposed development under design storm conditions. The design model setup builds directly upon the validated V01 and V02, incorporating the proposed subdivision layout and including design rainfall events.

### 5.1 Model Purpose

The purpose of the design model is to:

- ∴ Assess the effects of the proposed development on flooding;
- ∴ Determine the flood levels for the 200-year event which will be used to set finished floor levels; and,
- ∴ Determine the flood hazard for the 500-year event and ensure the proposed development is not subject to unsafe or hazardous conditions, recognising that this event is an overdesign scenario.

Two design model configurations were constructed, designated D001 and D002, mirroring the extents of the V01 and V02 validation models respectively:

**D001**, This model shared the same spatial extent and grid resolution as the V01 validation model. Its primary function in the design assessment was to simulate catchment-wide response to design rainfall events, providing inflow hydrographs for the more detailed D002 model.

**D002**, similar to V02, this was a smaller more detailed model that was constructed so the model resolution could be increased without adversely impacting run times. All post development models have been run using the D002 model, with the D001 model only used to obtain pre-development flows which can be applied as a boundary condition to the D002 model.

### 5.2 Model Extents

The model resolutions D001 and D002 were the same as those applied respectively in the V01 and V02 models (further details in Section 3.4). For both models, the sub-grid sampling module was employed and for the D002 model, the extent was run at a 4 m grid resolution with a refinement to 2 m resolution for the Ōhoka development area.

### 5.3 Design Surface

For the D002 model only, a design surface for the proposed development was provided by Inovo<sup>9</sup> which was incorporated into the model terrain for the post development model. Adjustments to the surface were made to ensure external road heights were not modified whilst also connecting internal roads to external roads at appropriate locations. The final surface used in the post development model is presented in Figure 15.

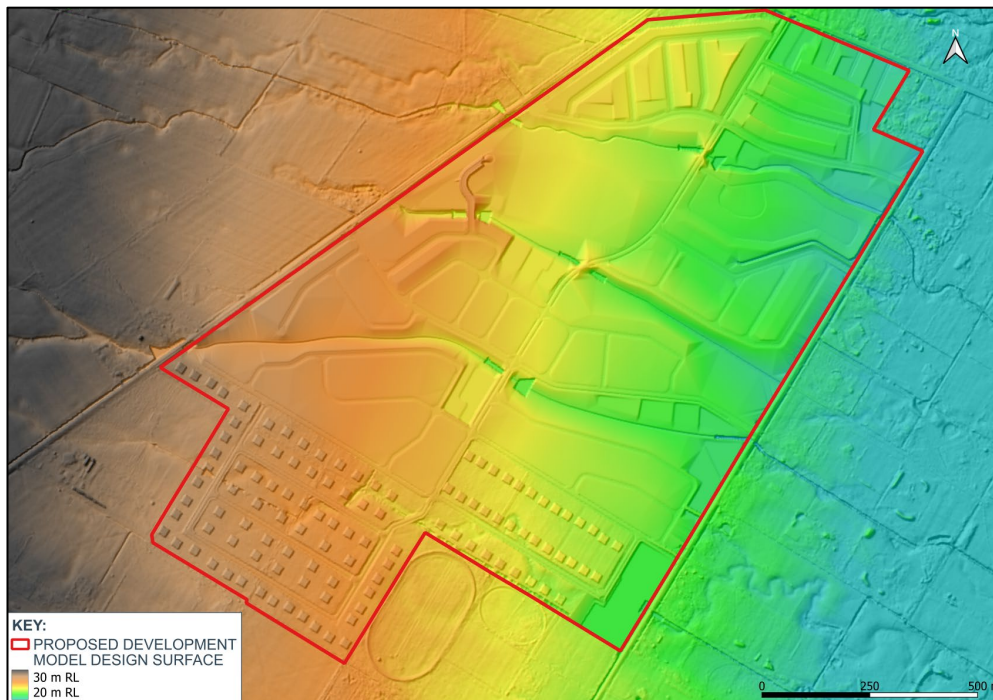


Figure 15. Post development design surface

### 5.4 Selecting Model Infiltration

For both models, the low infiltration soil parameters determined during the validation stage were used for the existing scenario within the design model. These values are provided in Table 5 below.

<sup>9</sup> Via email, Sanna Soederlind (Inovo) to Ben Throssell (PDP) on 6 June 2025

**Table 5: Calibrated Horton’s Infiltration Values**

Soil ID	Soil Class	Initial Loss (mm)	Initial Loss Rate (mm/hr)	Final Loss Rate (mm/hr)	Exponential Decay Rate (h <sup>-1</sup> )
1	Class 1 – Very Poorly Drained	0	0.75	0.3	5.4
2	Class 2 – Poorly Drained	0	1.5	0.525	2.88
3	Class 3 – Imperfectly Drained	0	2.25	0.75	0.36
4	Class 4 - Moderately Well Drained	0	3	1.125	0.234
5	Class 5 – Well Drained	0	3.75	1.5	0.108
99	Impervious	No Infiltration	-	-	-

For the post development model scenario, impervious areas were added to the model based on the subdivision layout. Roads and high-density residential blocks were modelled as fully impervious surfaces. For the larger lots to the southwest of the development 400 m<sup>2</sup> blocks were included as impervious areas to represent houses.

### 5.5 Roughness

For both models (D001 and D002), the depth varied roughness scenario was selected for all design runs. For the proposed subdivision, a roughness value of 1 was applied to the high-density residential blocks and houses for the post development scenario. The roads within the development were modelled with a roughness value of 0.02 and the developed ecological corridors adjacent to waterways were modelled with a roughness of 0.06 to 0.075.

### 5.6 Boundary Conditions

A nested storm profile was used for the rainfall boundary condition for both model extents. This was derived for the 50, 200 and 500 YR, RCP8.5 2081-2100 storm events using HIRDS. The rainfall boundary condition was applied to the internal model area for both models. The rainfall profiles applied are shown in Figure 16 below.

For the refined model extent (D002), the upstream flow boundary condition was extracted from the D001 model. The flows used are shown in Figure 17, Figure 18 and Figure 19 below.

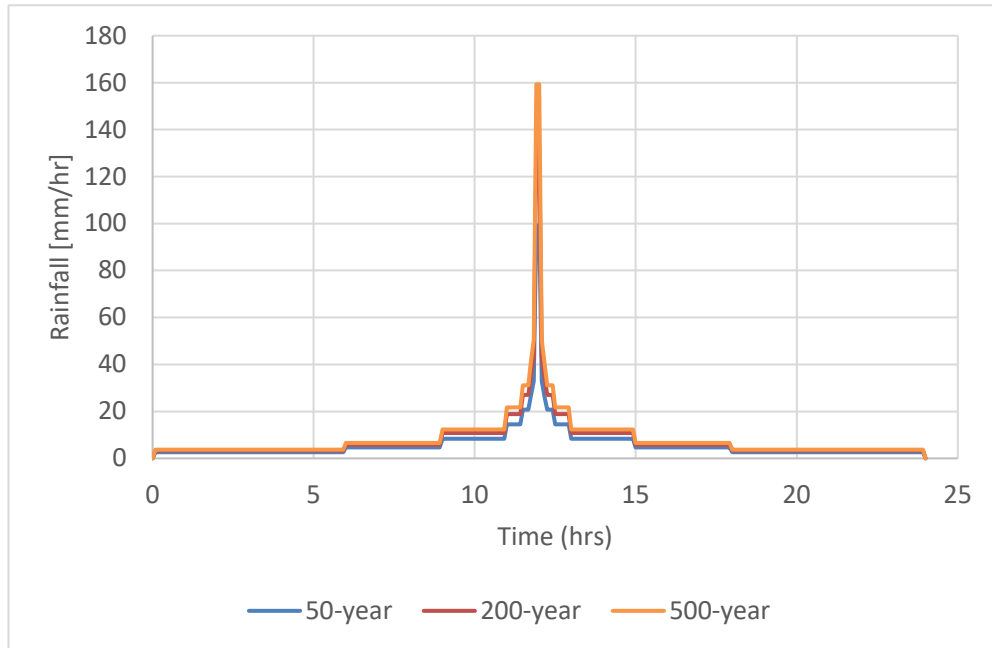


Figure 16. Ōhoka D001/D002 Rainfall Boundary Condition

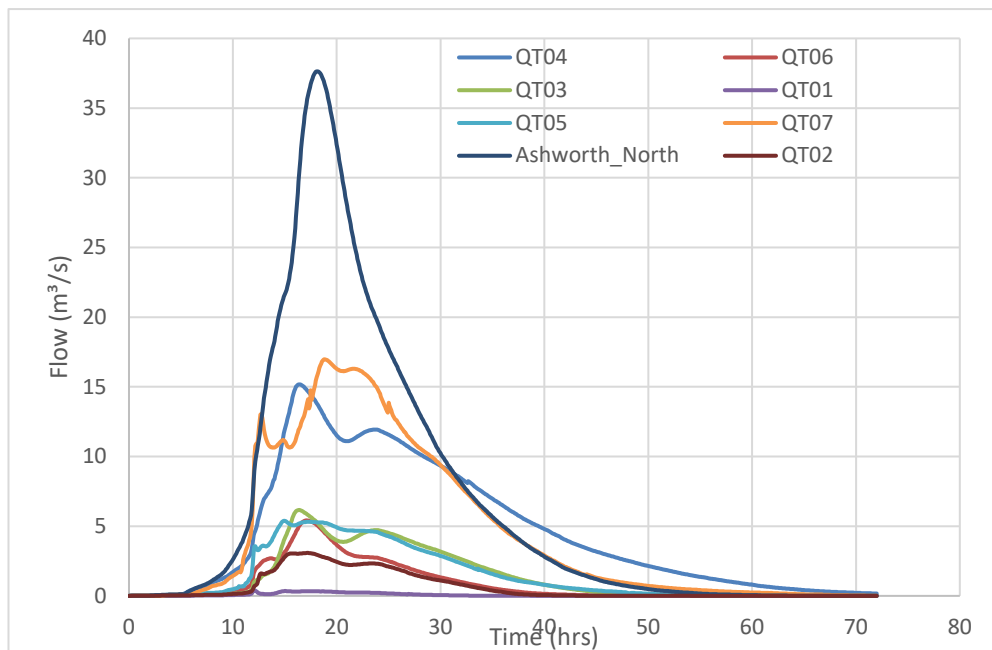


Figure 17. Ōhoka D002 Flow Boundary Condition - 50YR

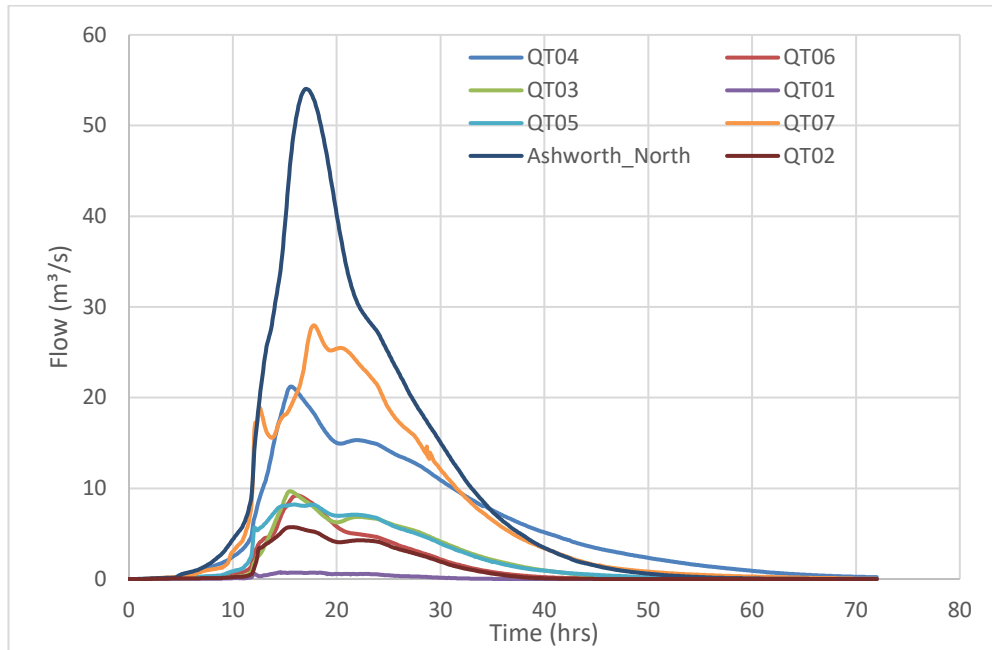


Figure 18. Ōhoka D002 Flow Boundary Condition - 200YR

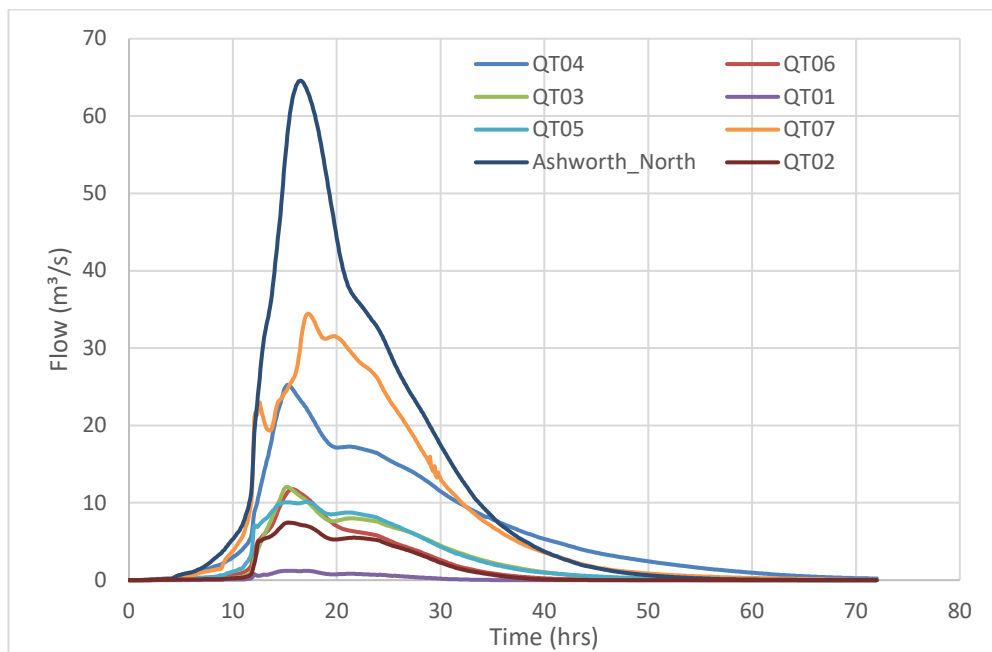


Figure 19. Ōhoka D002 Flow Boundary Condition - 500YR

The downstream boundary was modelled as a normal depth (HQ) with the grade set to the approximate grade of the terrain (1 in 200).

### 5.7 Structures

Additional culverts were added to the model for the post development scenario. These were included where the roads within the proposed development crossed the main waterways through the site. Table 6 shows the additional culverts that were added to the post development model.



**Figure 20. Additional culverts included in the post development model**

The parameters for the additional culverts proposed as part of this subdivision are provided in Table 6 below.

Table 6: Post Development Model Culvert Parameters						
ID	Type	Upstream Invert (m RL)	Downstream Invert (m RL)	Width or diameter (m)	Height	Number
BRADLEYS_01	Circular	26.14	26	0.9	0	1
BRADLEYS_02	Circular	24.492	24.487	0.9	0	1
CULV_06	Box	22.68	22.58	1.5	1	1
CULV_07	Box	23.832	23.684	1.5	1	1
CULV_08	Circular	22.424	22.257	0.9	0	1
CULV_09	Box	21.8	21.647	4	1.5	2

**Table 6: Post Development Model Culvert Parameters**

ID	Type	Upstream Invert (m RL)	Downstream Invert (m RL)	Width or diameter (m)	Height	Number
CULV_10	Box	26.969	26.852	1.5	1	1
MILLS_01	Circular	20.768	20.715	0.9	0	1
WHITES_01	Box	19.896	19.83	8	0.6	1
WHITES_02	Circular	19.675	19.625	0.9	0	2
WHITES_03	Circular	20.2	20.18	0.9	0	2
WHITES_04	Circular	21.972	21.829	0.9	0	1

*Notes:*  
Roughness of 0.014 used for all culverts

### 5.8 Model runs

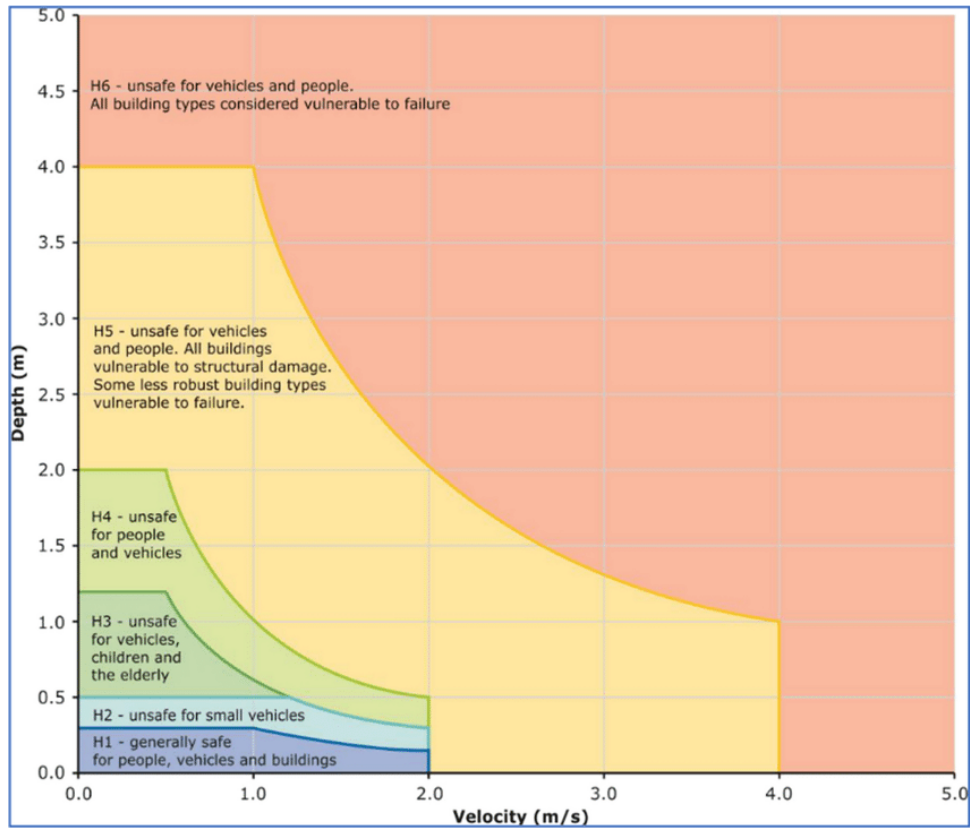
A table of design model runs is provided in Table 7. In total, six design runs were completed for two development states (pre and post) and three hydrological events (50-year, 200-year and 500-year). Models were run for 25 hours (1 hour longer than the 24-hour storm duration).

**Table 7: Design model runs**

Short ID	Model	Event	Development
D02_50YR_Pre	D02	50-year	Pre
D02_50YR_Post			Post
D02_200YR_Pre		200-year	Pre
D02_200YR_Post			Post
D02_500YR_Pre		500-year	Pre
D02_500YR_Post			Post

### 6.0 Flood Hazard

The flood hazard classifications specified by the Australian Rainfall and Runoff Guidelines have been adopted for this assessment (Figure 21) which was adopted from Smith et al., (2014). These flood hazard curves are often employed in New Zealand and are the hazard curves recommended by the Greater Wellington Regional Council Flood Hazard Modelling Standard (GWRC, 2021).



**Figure 21: Flood hazard curves (Smith et al., 2014)**

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

**Magnitude of Effect:** For this assessment, the effect is quantified by changes to the flood depth/level and changes to the flood hazard classification.

**Event Scale:** An effect for a smaller, more frequent, event is considered worse than the same effect for a larger, less frequent event.

**Property Sensitivity:** Properties with existing flood vulnerabilities have a lower tolerance for additional flooding compared to those with low or no flood hazards.

**Land use:** The land use of the affected property is also a consideration. Rural land used for grazing/cropping/horticulture is considered to have a greater tolerance to flood effects when compared to residential dwellings.

**Scale of the proposal:** While less critical than the factors above, the size of the proposal generating the effect should be considered. A significant proposal, such as building a large subdivision like Ohoka, generating an effect is more acceptable than a smaller proposal (for example a development of ten houses) generating the same effect.

## 7.0 Model Results and Discussion

This section presents and discusses the results from the design flood event modelling. It evaluates the existing flood characteristics at the site and in the surrounding area, and then assesses the potential changes to flood depths, extents, hazards, and flow patterns resulting from the proposed development. The assessment considers the 50-year, 200-year, and 500-year ARI design events, including an allowance for future climate change.

### 7.1 Existing Development

To establish a baseline for assessing the effects of the proposed development, the existing flood characteristics were modelled for the 50-year and 200-year ARI design events (including climate change). The predicted flood depths under these pre-development conditions are provided in Figure A1 (50-year) and Figure A2 (200-year) in Appendix A.

These figures demonstrate that the proposed development site, in its current state, is subject to significant overland flow originating from the contributing catchments upstream (west) of Bradleys Road. Flood depths within defined watercourses naturally exceed 300-500 mm, with widespread out-of-bank floodplain flow occurring across the predominantly rural land. This broad, relatively shallow floodplain inundation is characteristic of flood behaviour on the Canterbury Plains during major rainfall events.

The pre-development flood hazard classification for the 500-year ARI event (including climate change) is presented in Figure A3 (Appendix A). This classification, based on the framework from Smith et al. (2014) as recommended in Australian Rainfall and Runoff (ARR) and commonly adopted in New Zealand, shows:

- ∴ South of Mill Rd (where the Site is located), the hazard in the vast majority of the area for this event is classified as low (H1) outside of the channels meaning that it is generally safe for people and buildings.
- ∴ North of Mill Road, the hazard classification outside of the Ōhoka Stream ranges from H2 (unsafe for small vehicles) to H4 (unsafe for people and vehicles).

Therefore, Figure A3 shows that in the 500-year event with climate change, areas north of Mill Road are more vulnerable to flooding when compared to the area south of Mill Road and downstream of Whites Road.

## 7.2 Flood Levels and Depths (Internal Subdivision)

The internal flood performance of the proposed subdivision was assessed primarily using the 50-year ARI design event (including climate change) to evaluate road accessibility and general site inundation. The 200-year ARI event results were used to determine appropriate minimum finished floor levels (FFLs).

Flood depths for the 50-year and 200-year post development runs are shown in Figures A4 and A5, Appendix A.

Figure A4 shows:

- ∴ Flood depths on the majority of proposed internal roads are predicted to be less than 300 mm, generally maintaining vehicular access. However, depths may exceed 300 mm on the proposed road connecting the polo field area to Whites Road, and on a section of internal road south of Stage 10. These areas would likely be impassable to light vehicles. Further detailed design of road profiles and local drainage will aim to optimise passability, though complete passability in all areas during a 50-year event may not be necessary if safe alternative access/egress is available and critical infrastructure is protected;
- ∴ Some ponding exceeding 300 mm is predicted within the proposed retirement village area and potentially other designated open spaces or low-lying areas. It is anticipated that these depths will be managed through the detailed design of the internal stormwater network, overland flow paths, and site grading to ensure they do not adversely affect habitable buildings or critical access;
- ∴ Building platforms are generally free of flooding (less than 50 mm). There is some nominal flooding (up to 100 mm) on several lots although finished floor levels will be set above this event meaning habitable dwellings will not be inundated; and,
- ∴ Areas within the retirement village footprint and lower-density residential Stages 10 and 11 show potential for depths exceeding 300mm in localised depressions or flow paths prior to detailed earthworks design. These are expected to be refined during detailed design to ensure compliance with FFL requirements and site drainage objectives.

Figure A5 (200-year event) shows similar results, albeit with more flooding, to the 50-year event;

- ∴ While more extensive than the 50-year event, the majority of internal roads are predicted to maintain depths that would allow for vehicle access; and,

- ∴ The depth of flooding on most building platforms is generally predicted to be less than 100 mm. Some isolated, small areas may experience depths between 100 mm and 300 mm. These depths are manageable through standard foundation design (e.g., bearers and piles, or raised slab-on-grade) to achieve the required FFLs, as discussed below.

#### 7.2.1 Minimum Floor Levels Within Site

We recommend that minimum floor levels within the subdivision should be set to 500 mm above the 200-year flood level (with climate change). Whilst not directly applicable, this is consistent with the Natural Hazard Standards within the Partially Operative Waimakariri District Plan. These require finished floor levels to be as stated in a Flood Assessment Certificate issued in accordance with NH-S1. A NH-S1 Flood Assessment Certificate is issued by Waimakariri District Council on application and contains the following information:

#### **“NH-S1 Flood Assessment Certificate**

1. The [District Council](#) will issue a Flood Assessment Certificate (which will be valid for three years from the date of issue) that specifies:
  - a. whether the activity is located on a [site](#) that is within a [high hazard area](#); and
  - b. whether the activity is located within an [overland flow path](#); and
  - c. where the activity is located on [land](#) that is within the Urban Flood Assessment Overlay, the minimum finished [floor level](#) in accordance with (e); or
  - d. where the activity is located on [land](#) that is within the Non-Urban Flood Assessment Overlay and is located on [land](#) that is outside of a [high hazard area](#), the minimum finished [floor level](#) in accordance with (e); and
  - e. the minimum finished [floor level](#) shall be calculated as the highest of the following:
    - i. flooding predicted to occur in a 0.5% [AEP](#) (1 in 200-year) Localised Rainfall Event plus up to 500mm freeboard (including allowances for climate change); or
    - ii. flooding predicted to occur in a 0.5% [AEP](#) (1 in 200-year) Ashley [River](#)/Rakahuri Breakout Event concurrent with a 5% [AEP](#) (1 in 20-year) Localised Rainfall Event plus up to 500mm freeboard (including allowances for climate change); or
    - iii. flooding predicted to occur in a 0.5% [AEP](#) (1 in 200-year) Storm Surge Event concurrent with a 5% [AEP](#) (1 in 20-

year) [River](#) Flow Event with an allowance for sea level rise, plus up to 500mm freeboard.

2. Freeboard will be applies as follows:
  - a. Low hazard - 400mm freeboard
  - b. Medium to High Hazard - 500mm freeboard"

### 7.3 Effects on Flooding (External)

The potential external effects of the development on flood levels and overland flow paths in the surrounding area were assessed by comparing the post-development model results with the pre-development (existing conditions) results. This assessment focused primarily on the 200-year ARI design event (including climate change).

Stormwater generated from impervious surfaces within the developed site itself (from shorter duration, higher intensity rainfall) would typically pass through the site's stormwater system before the arrival of the peak flood flows from the larger upstream catchment. Therefore, the primary focus of this external effects assessment is on how the development modifies the conveyance of these larger, upstream catchment flows.

Predicted flows in the 50-year and 200-year ARI design events across Mill Road are less than pre-development.

Figure A6 in Appendix A presents the predicted change in peak flood levels for the 200-year ARI event resulting from the proposed development. Differences of less than 10 mm are not shown.

Figure A6 shows:

- ∴ **Upstream of Bradleys Road:** No discernible change in flood levels, indicating the development does not cause any backwater effects upstream of its western boundary.
- ∴ **North of Mill Road:** Changes in flood levels are generally less than 10 mm. One isolated minor pocket shows a change slightly exceeding 10mm, but review of aerial imagery confirms this does not impact any existing buildings (habitable or otherwise); and,
- ∴ **South of Mill Road and East/Downstream of Whites Road:** The most noticeable changes occur immediately adjacent to the subdivision's eastern and southern boundaries, as expected due to the modification of flow paths through the site. These changes, comprising both small increases and decreases in flood level, generally dissipate rapidly as floodwaters move further east. Pockets of change exceeding 10 mm are located close to the subdivision boundary.

A more detailed assessment of the effects of flooding on buildings is provided below.

### 7.3.1 Effects on buildings

To assess the difference in flood elevations, all building footprints, not just habitable dwellings, were obtained from LINZ and the average water level over the footprint was extracted for both the post-developed and pre-developed 200-year flood level. The difference between these two water levels is taken to be the effects on the building footprint.

The analysis shows that the maximum predicted increase in average flood level at any existing building footprint is 60 mm, while the maximum predicted decrease is 107 mm. A detailed breakdown of the changes is as follows:

- ∴ No material change ( $< \pm 10$  mm): 1123 building footprints.

Increases in flood level:

- ∴ 10 to 20 mm: 11 building footprints.
- ∴ 20 to 50 mm: 4 building footprints.
- ∴ 50 to 60 mm: 1 building footprint.

Decreases in flood level:

- ∴ 10 to 50 mm: 18 building footprints.
- ∴ Greater than 50 mm: 2 building footprints.

Inspection of aerial imagery and google street view shows that the building footprint with an increase of greater than 50 mm is a shed. Additionally, the four buildings which record an increase of 20- 50 mm are also non-habitable dwellings. The locations of these non-habitable dwellings are shown in Figure 22 through to Figure 24.



Figure 22: 290 Whites Rd, sheds/garages with flood increase > 20 mm.

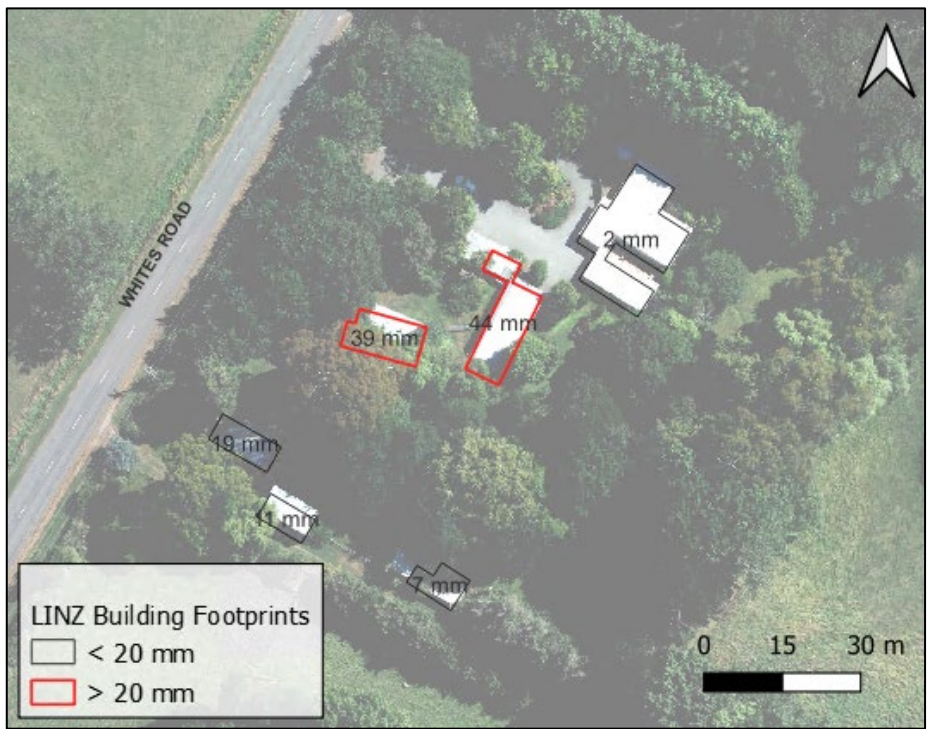
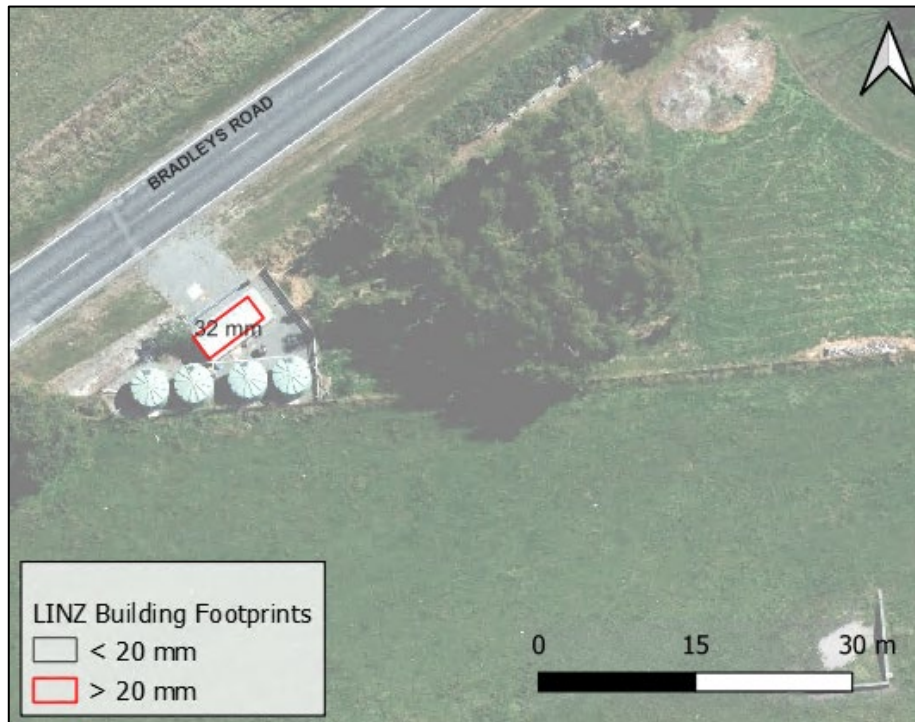


Figure 23: 372 Whites Rd, sheds with flood increase > 20 mm.



**Figure 24: 344 Bradleys Rd, water pumping shed with flood increase > 20 mm.**

The analysis demonstrates that the proposed development results in no material change in flood levels ( $< \pm 10$  mm) for the vast majority of existing building footprints in the vicinity. For a small number of buildings where increases are predicted to exceed 20 mm, the buildings are non-habitable where the actual adverse effect of such a change is negligible. Garages and the other non-habitable dwellings that have been identified are considered to have greater tolerance flood effects when compared to habitable dwellings. Therefore, the effects of the development on flood levels at existing buildings are considered to be less than minor.

### 7.3.2 Effects on critical infrastructure

An assessment of effects on critical infrastructure was undertaken. For the purposes of this assessment, critical infrastructure includes lifeline utilities (e.g., major power, water, wastewater, telecommunications assets) and key transportation routes essential for emergency response or community function.

No major lifeline utilities or designated critical transportation routes are located within the areas predicted to experience material changes in flood levels due to the development. Local roads such as Whites Road and Mill Road, while important for local access, are not considered as critical lifeline routes. However, the effect on Whites Road, adjacent to the proposed subdivision, was specifically considered:

- ∴ In the pre-development 200-year ARI scenario, the maximum flood depth on this section of Whites Road is approximately 155 mm;
- ∴ In the post-development scenario, this increases slightly to approximately 185 mm (+30mm); and,
- ∴ At both 155mm and 185mm, Whites Road would likely remain passable by most vehicles, particularly 4WDs and emergency service vehicles, during a 200-year ARI event. This minor increase in a shallow flood depth on a local road is not considered a significant adverse effect. Therefore, effects on critical infrastructure are considered less than minor.

### 7.3.3 Effects on cultural and/or heritage sites

The ECan Canterbury Maps viewer identifies three heritage listed sites located within the vicinity of the Ōhoka site. The heritage sites are located at 465 (6 mm increase), 528 (decrease in flood levels) and 536 Mill Road (decrease in flood levels). Therefore, the effects on cultural and heritage sites are considered less than minor.

### 7.3.4 Conclusion

In summary, the design flood modelling demonstrates that the proposed development can be designed to perform appropriately during major flood events up to and including the 200-year ARI (plus climate change) with respect to internal road access and finished floor levels. Furthermore, the assessment of external effects indicates that changes to off-site flood levels are generally minor and localised, with predicted effects on existing buildings, critical infrastructure, and heritage sites being less than minor.

## 8.0 Sensitivity model

### 8.1 Model runs

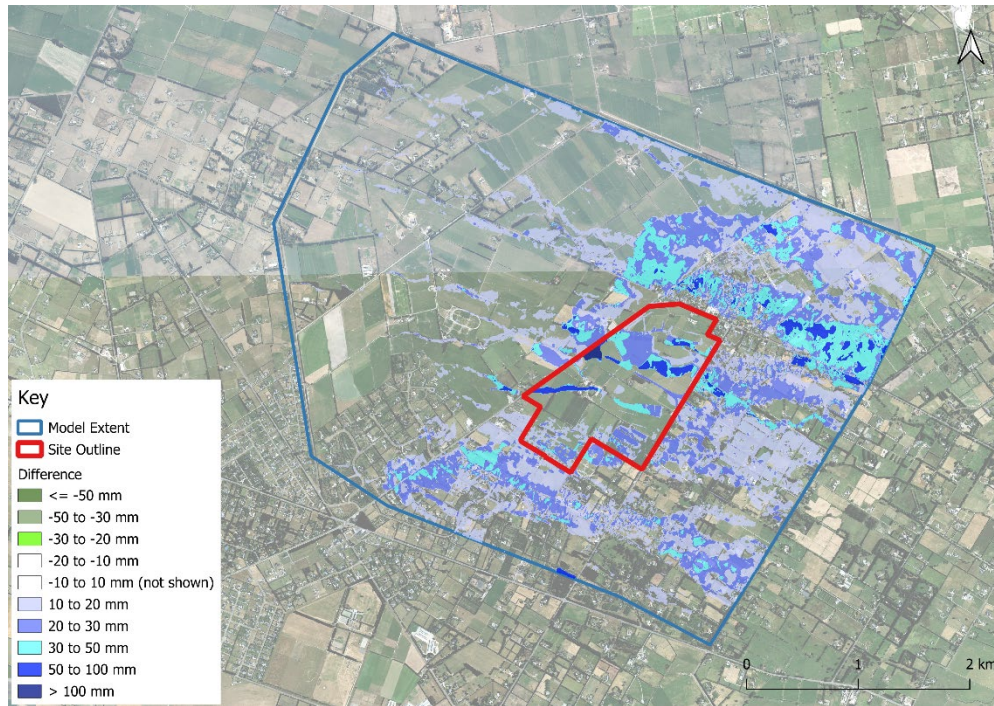
The sensitivity model runs are provided in Table 8. In total, seven sensitivity runs were completed. All sensitivity runs used the 200-year event, and six apply the post development scenario. The sensitivity model runs were for the purpose of testing:

- ∴ the sensitivity of the absolute flood level predictions, which impact the proposed finished floor levels for dwellings within the subdivision; and,
- ∴ the sensitivity of the flood effects predictions.

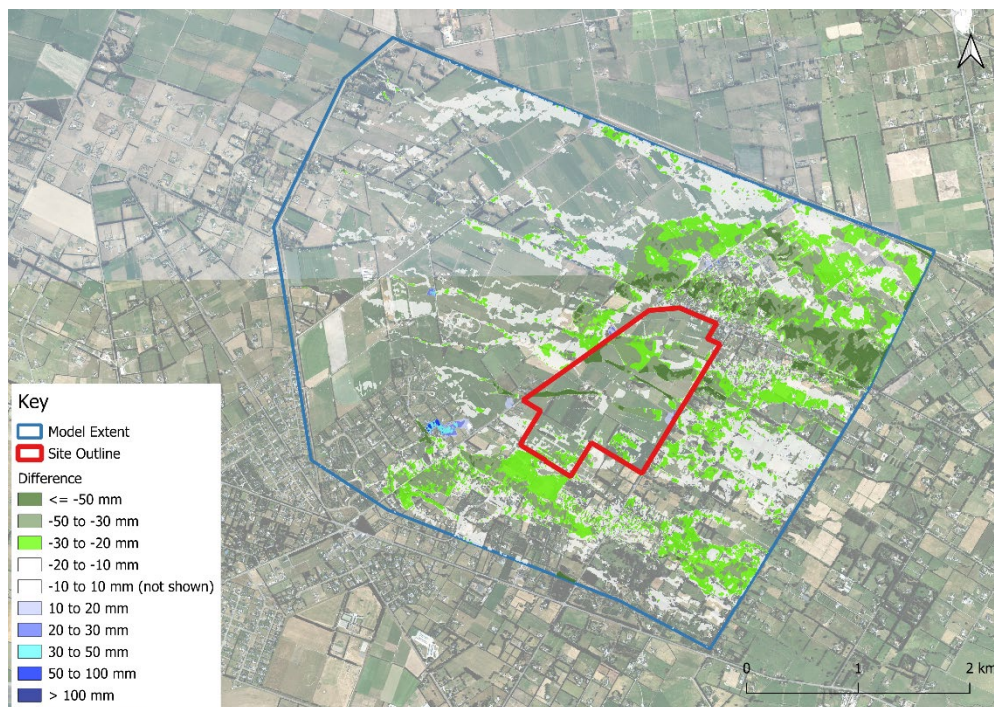
Table 8: Sensitivity model runs				
Short ID	Model	Event	Scenario	Development
S01_200YR_n+25pct	S01	200-year	+25% roughness	Post
S01_200YR_n-25pct			-25% roughness	Post
S01_200YR_l+50pct			+50% infiltration	Post
S01_200YR_l-50pct			-50% infiltration	Post
S01_200YR_incrME_pre			Increased model extent	Pre
S01_200YR_incrME_post			Increased model extent	Post
S01_200YR_dwnstrmB			Downstream boundary	Post

### 8.2 Sensitivity of flood levels to model roughness

The model sensitivity shows that the results are highly sensitive to the model roughness parameters. Figure 25 and Figure 26 show the difference between the D02 model results and with plus and minus 25% of the roughness values respectively.



**Figure 25. Difference between the base model roughness and plus 25% model roughness**



**Figure 26. Difference between the base model roughness and minus 25% model roughness**

Increasing the roughness values by 25% has resulted in depth increases of up to 110 mm across the model extent. Conversely, reducing the roughness values by 25% has resulted in depth decreases of up to 165 mm across the model extent.

### 8.3 Sensitivity of flood levels to infiltration

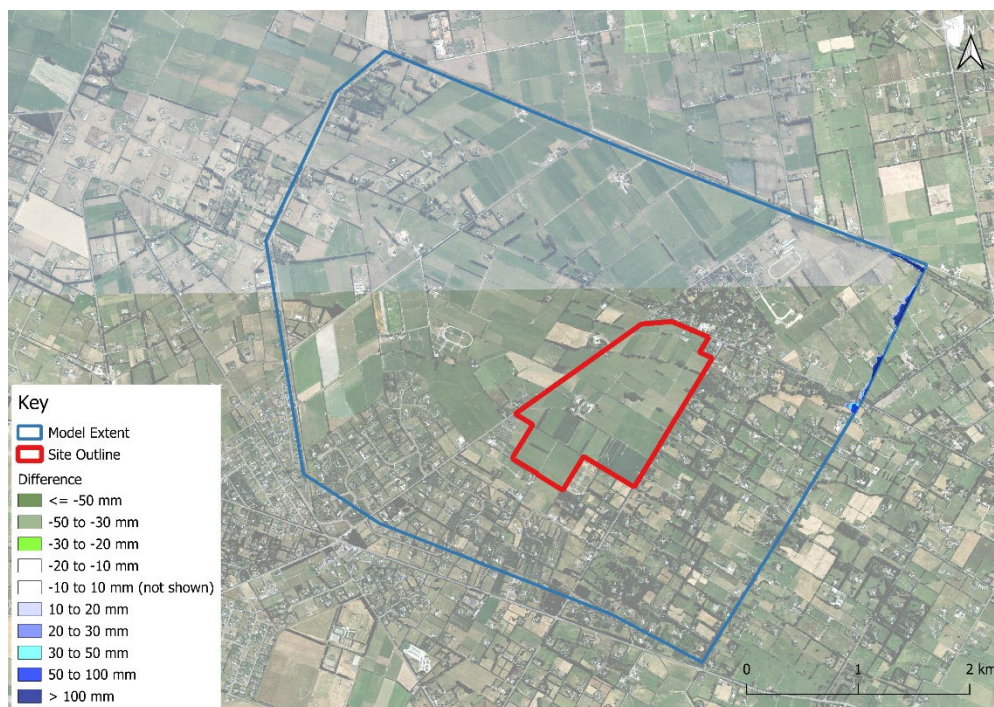
The sensitivity results have shown that the model is not sensitive to the infiltration parameters. Both increasing and decreasing the infiltration parameters by 50% resulted in no change to flood depths across the area of investigation.

### 8.4 Sensitivity of flood effects to increased model extent

Sensitivity to the model extent was tested by extending the model further downstream. This resulted in no change when compared to the base model extent. Therefore, the flood effects are not sensitive to the model extent.

### 8.5 Sensitivity of flood levels to downstream boundary

The effect of the downstream boundary on the flood levels was tested by reducing the normal depth slope from 0.005 to 0.001 within the model. This resulted in localised differences along the downstream boundary but had no effect on the flood levels within the site or area of investigation. The sensitivity results for the downstream boundary test are shown in Figure 27.



**Figure 27. Difference between the downstream boundary normal depth slope of 0.005 and normal depth slope of 0.001.**

## 9.0 Conclusions

This flood effects assessment, based on hydraulic modelling validated against historical events, concludes that the proposed residential development at 531 and 535 Mill Road, Ōhoka, can be designed and constructed such that its effects on flood risk, both within the site and on the surrounding environment, can be considered less than minor.

The Ōhoka area is known to be susceptible to flooding during significant rainfall, with historical events in June 2014, July 2022, and July 2023 having magnitudes in the order of 10-year to 50-year ARI. The proposed development incorporates an internal stormwater management system designed to mitigate any additional stormwater runoff generated by the site itself for events up to this scale.

For more extreme events, such as the 200-year ARI design flood (including an allowance for climate change):

**Off-site Effects:** The modelling demonstrates that the proposed development will have a less than minor effect on off-site flood levels and flood hazard.

Specifically:

- ∴ Changes in flood levels on properties north of Mill Road, an area identified with higher existing flood vulnerability, are predicted to be predominantly less than 10 mm;
- ∴ No existing habitable dwellings are predicted to experience an increase in flood levels greater than 20 mm. The average increase in flood levels at existing habitable dwellings is negligible; and,
- ∴ Effects on identified critical infrastructure and cultural/heritage sites are also assessed as less than minor.

### **On-site Performance:**

- ∴ New dwellings within the proposed development will achieve flood resilience by having minimum finished floor levels (FFLs) set at least 500 mm above the modelled 200-year ARI flood level (plus climate change);
- ∴ Proposed building platforms are shown to be at suitable elevations to allow standard foundation construction (e.g., bearers and piles, or raised slab-on-grade) to meet these FFL requirements; and,
- ∴ While some internal roads may experience depths that restrict general vehicle access during a 200-year ARI event, the primary objective of protecting dwellings is achieved. Further refinement of internal road elevations at the detailed design stage can optimise internal accessibility where practicable.

Overall, the assessment demonstrates that the flood risks associated with the proposed development are understood and can be appropriately managed through established engineering design and mitigation measures. The residual flood effects are considered to be acceptable and fall within the 'less than minor' threshold.

## 10.0 References

ARR. (2019). Australian Rainfall & Runoff: A Guide to Flood Estimation. Australian Rainfall & Runoff.

Cardno. (2021): Flood Hazard Modelling Standard. Wellington: Greater Wellington Regional Council.

Chow, V. T. (1959). Open-channel hydraulics. Tokyo: McGraw-Hill Civil Engineering Series.

Christchurch City Council: Waterways wetlands and Drainage Guide

GWRC (2021): Flood Hazard Modelling Standard

TUFLOW, (2018), TUFLOW 1D/2D Fixed Grid Hydraulic Modelling: TUFLOW Classic/HPC User Manual, Build 2018-03-AD



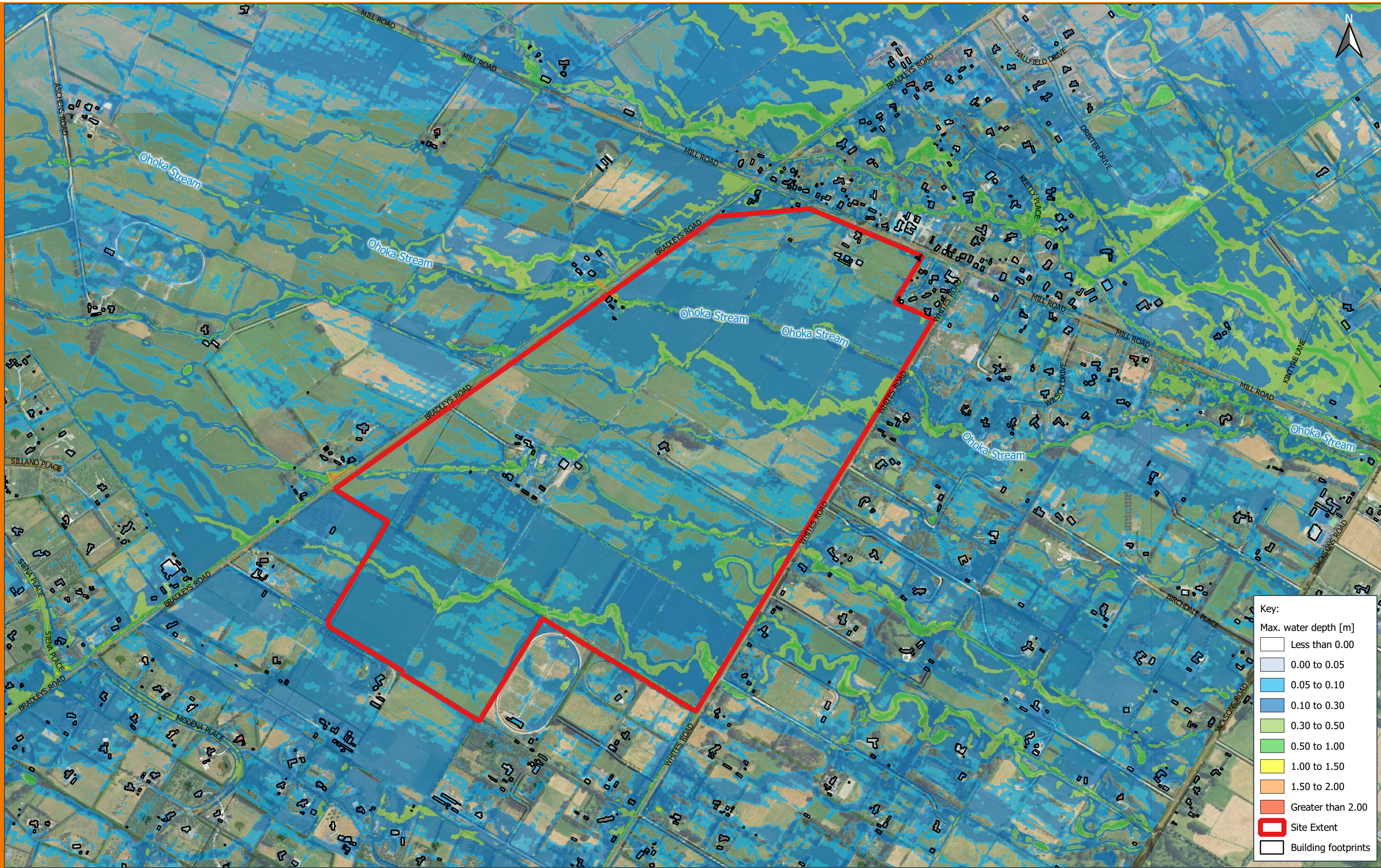


Figure A1, Pre-development flood depths for the 50-year event with climate change (D02\_50YR\_Pre). Depths less than 50 mm not shown

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

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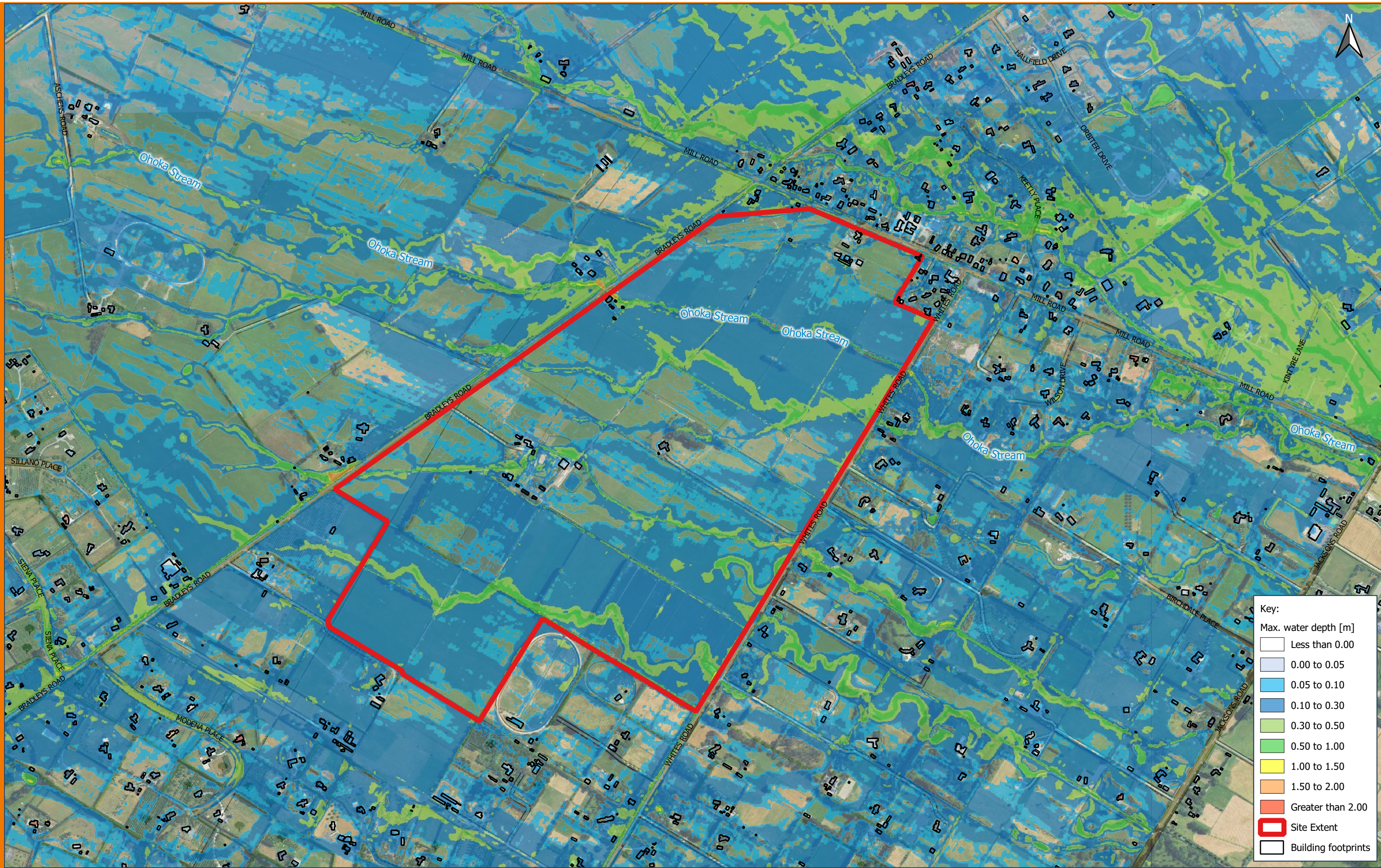


Figure A2, Pre-development flood depths for the 200-year event with climate change (D02\_200YR\_Pre). Depths less than 50 mm not shown

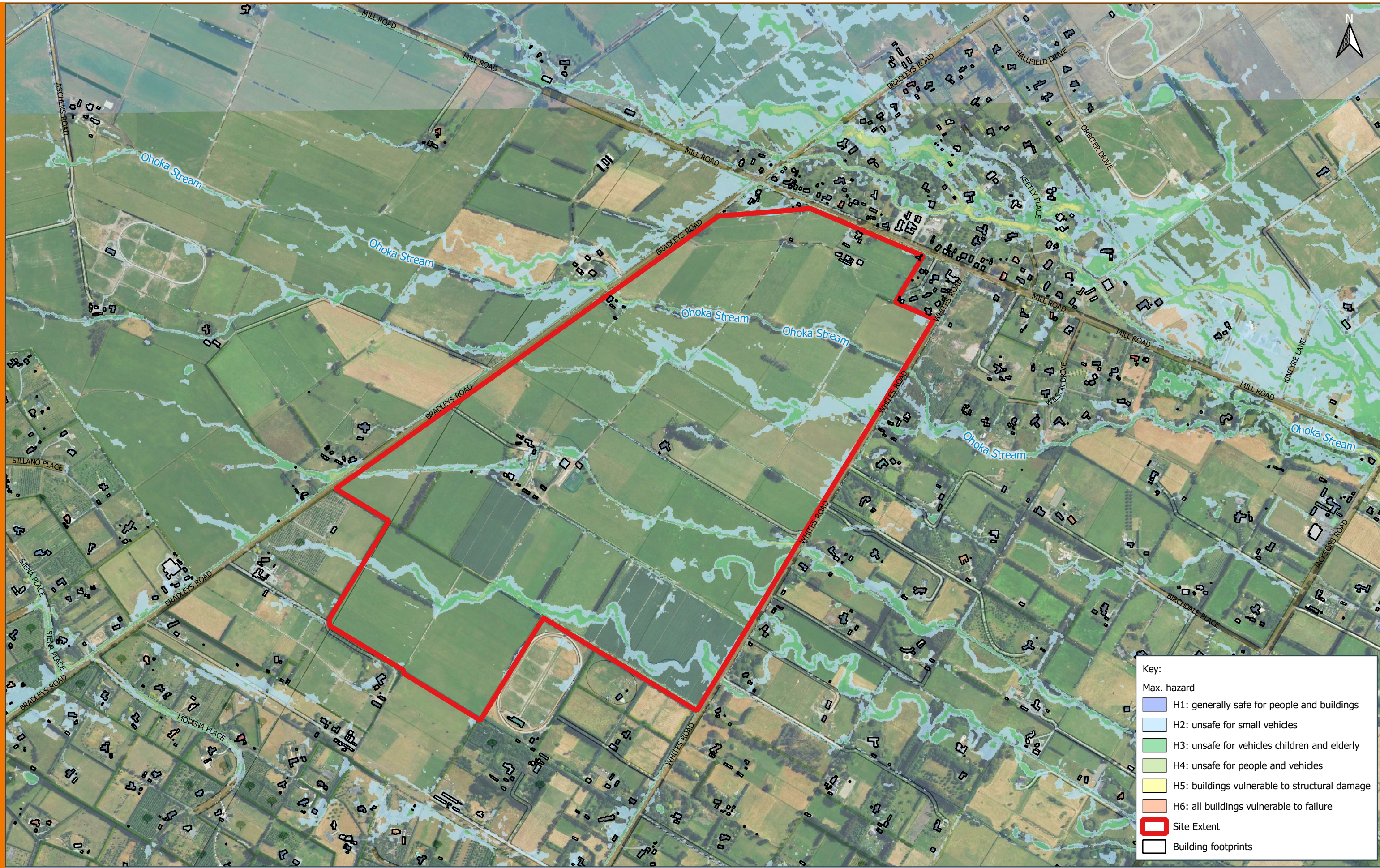
NOTES:  
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Key:

Max. hazard

- H1: generally safe for people and buildings
- H2: unsafe for small vehicles
- H3: unsafe for vehicles children and elderly
- H4: unsafe for people and vehicles
- H5: buildings vulnerable to structural damage
- H6: all buildings vulnerable to failure
- Site Extent
- Building footprints

**pdp** Figure A3, Pre-development flood hazard for the 500-year event with climate change (D02\_500YR\_Pre). H1 areas not shown

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

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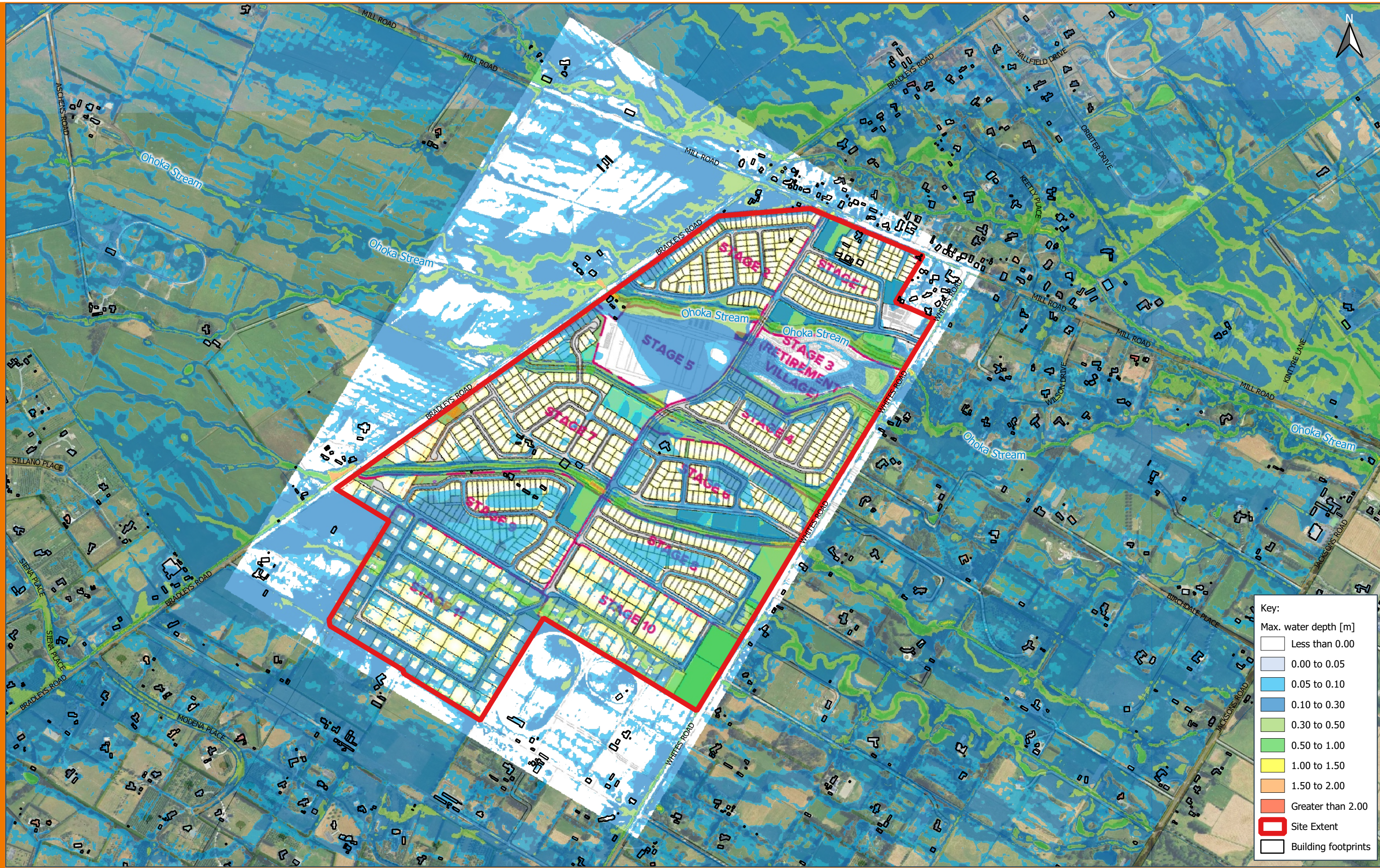


Figure A4, Post-development flood depth\_posts for the 50-year event with climate change (D02\_50YR\_Post). Depths less than 50 mm not shown

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

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Key:

Max. water depth [m]
Less than 0.00
0.00 to 0.05
0.05 to 0.10
0.10 to 0.30
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
Greater than 2.00
Site Extent
Building footprints

**pdp** Figure A5, Post-development flood depths for the 200-year event with climate change (D02\_200YR\_Post). Depths less than 50 mm not shown

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

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**pdp** Figure A6, Flood difference (post-pre development) for the 200YR event with climate change. Differences less than 10 mm are not shown

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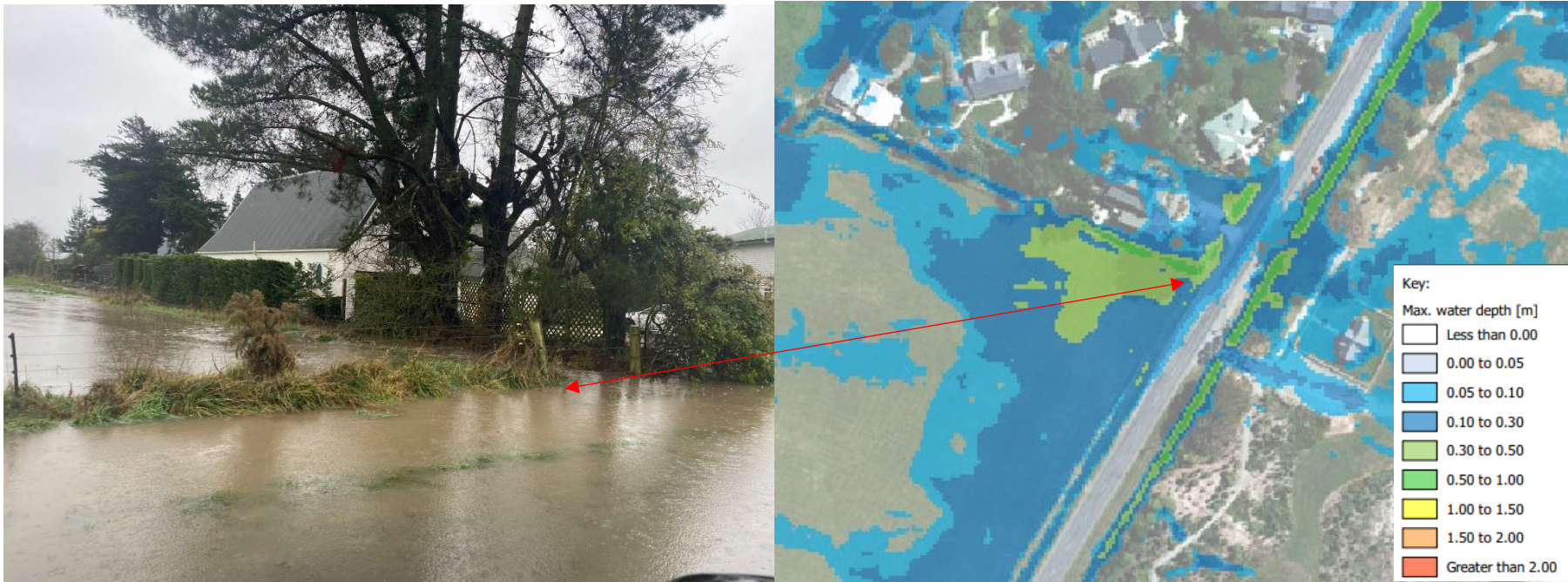
SCALE : 1:10,000 (A3)

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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



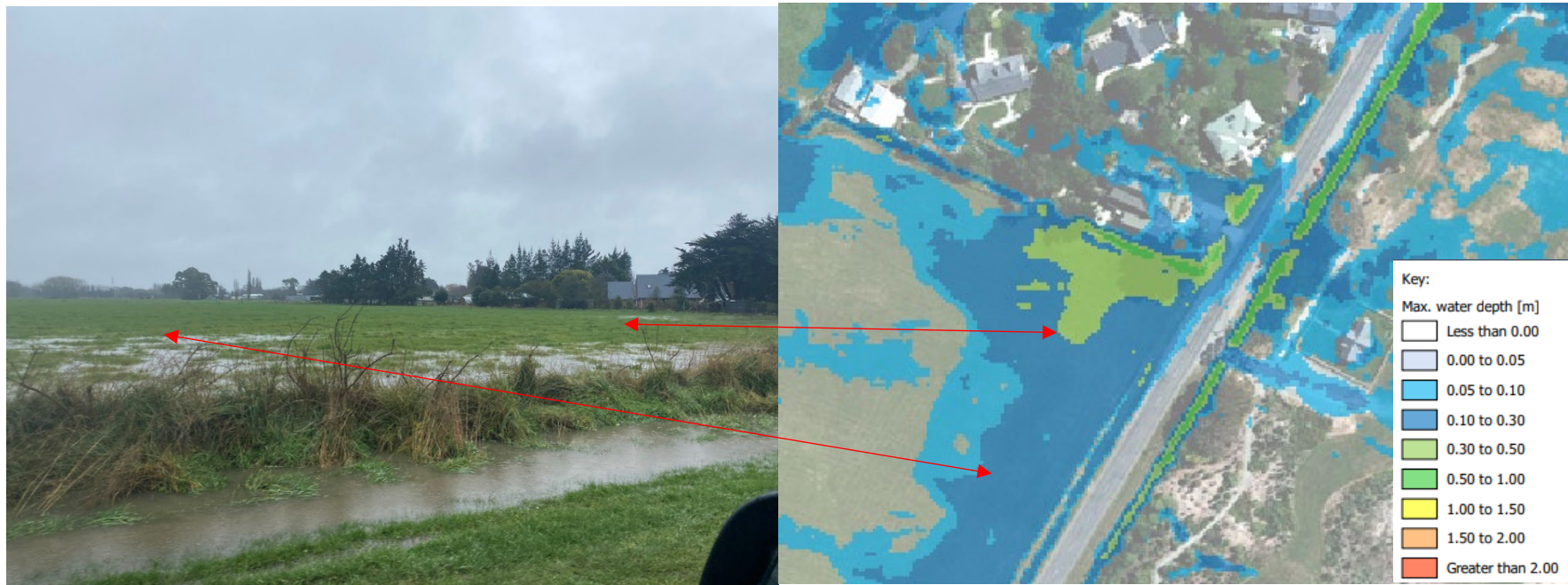
This was considered to be the critical validation location for the model. A good match has been achieved for the ponding across the road. (Depths less than 0.05 m not shown)

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



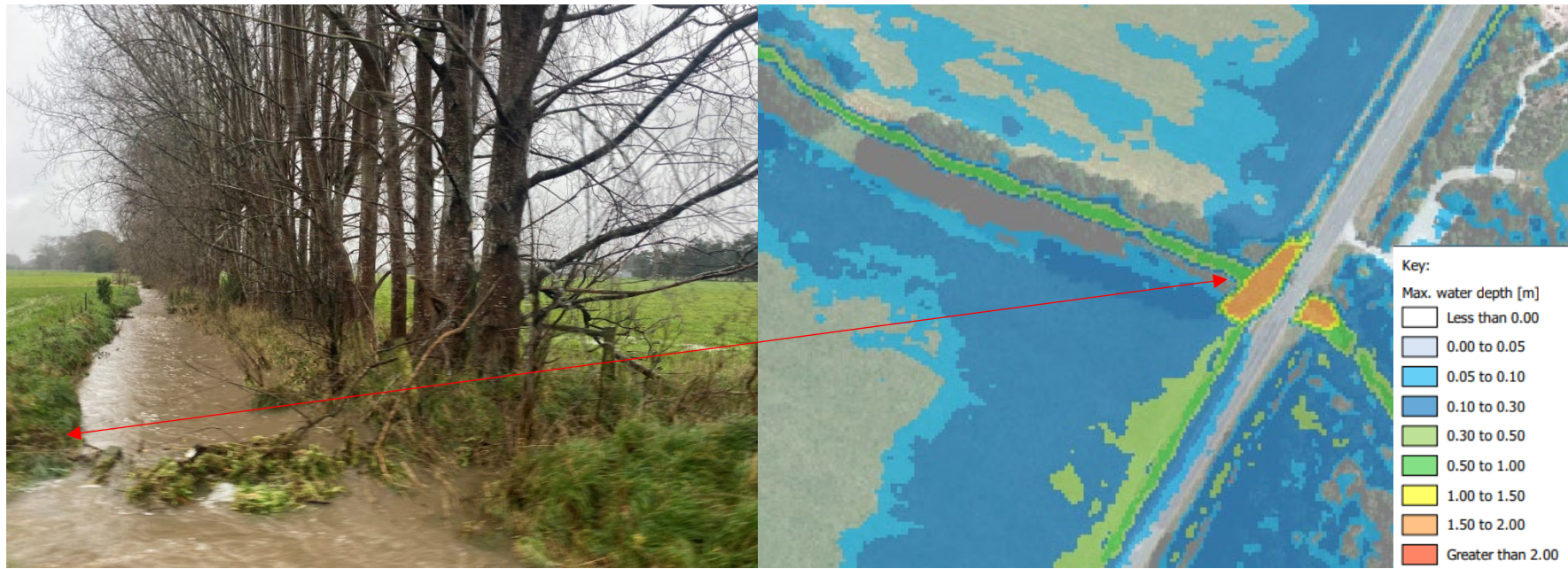
The model shows depths that are higher than the photo within the paddock. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

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



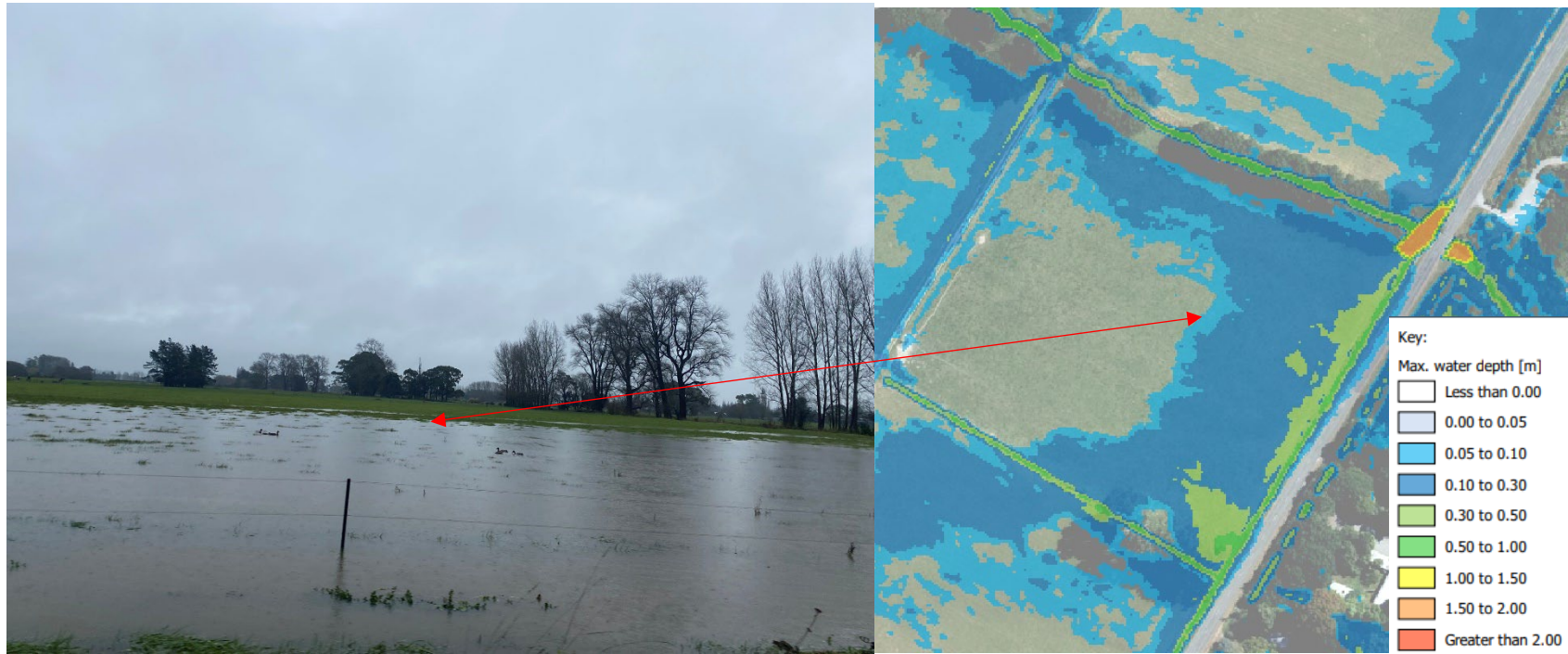
The model shows depths that are higher than the photo within the paddock. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

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



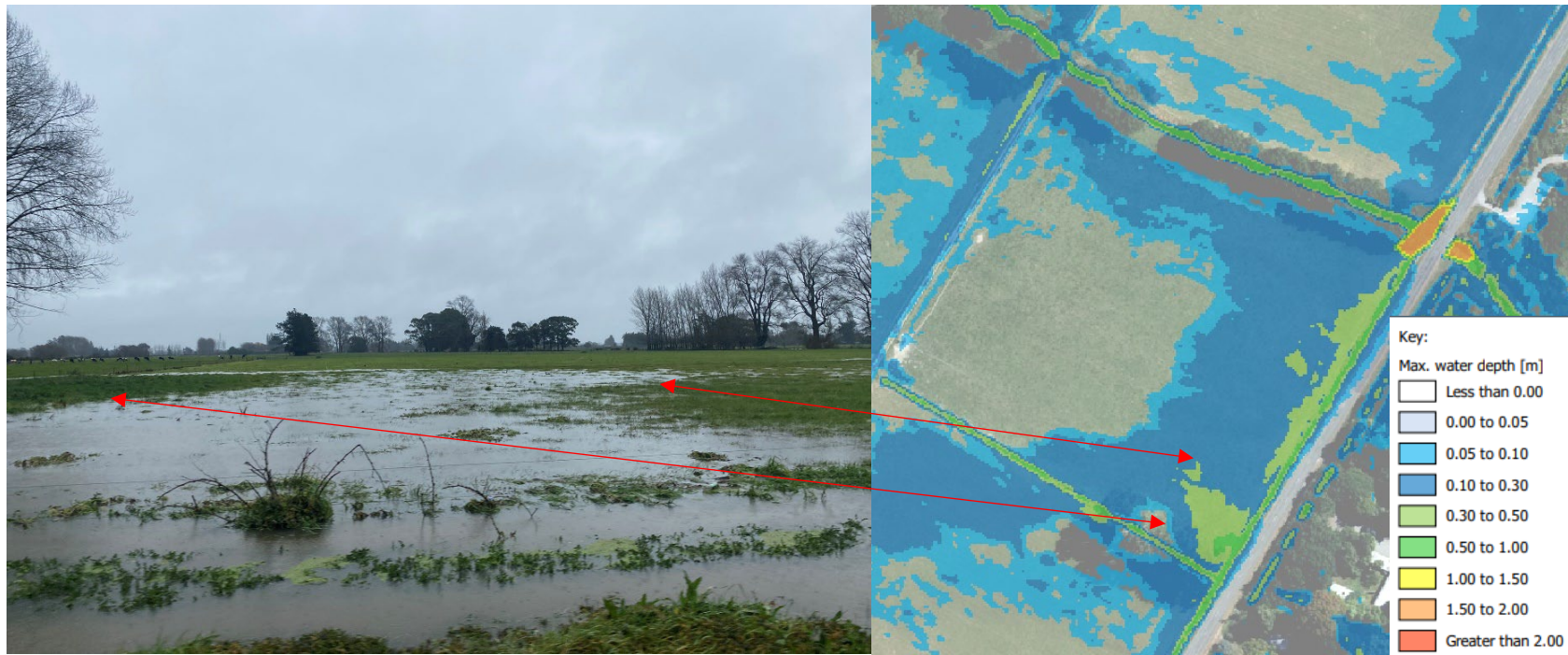
Ohoka Stream is flowing below bank full height for both the photo and model depths. (Depths less than 0.05 m not shown)

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



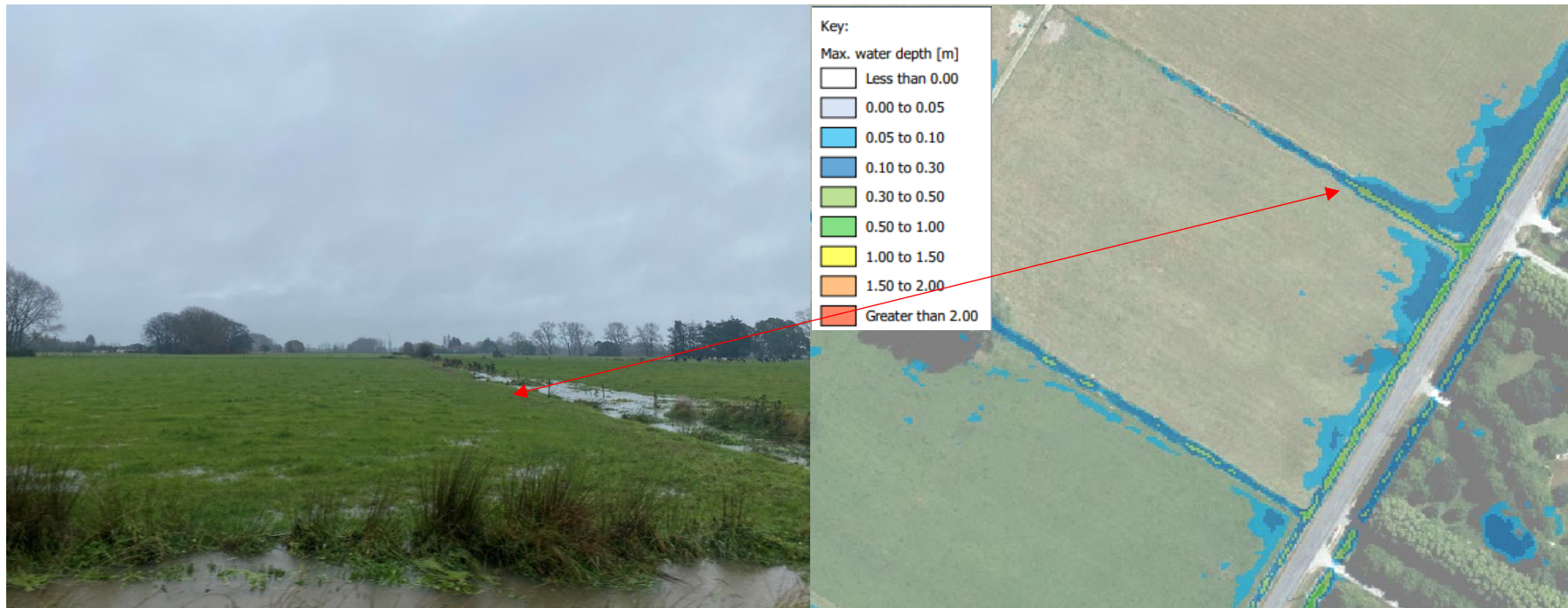
The model shows a good match to the photo at this location. (Depths less than 0.05 m not shown)

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



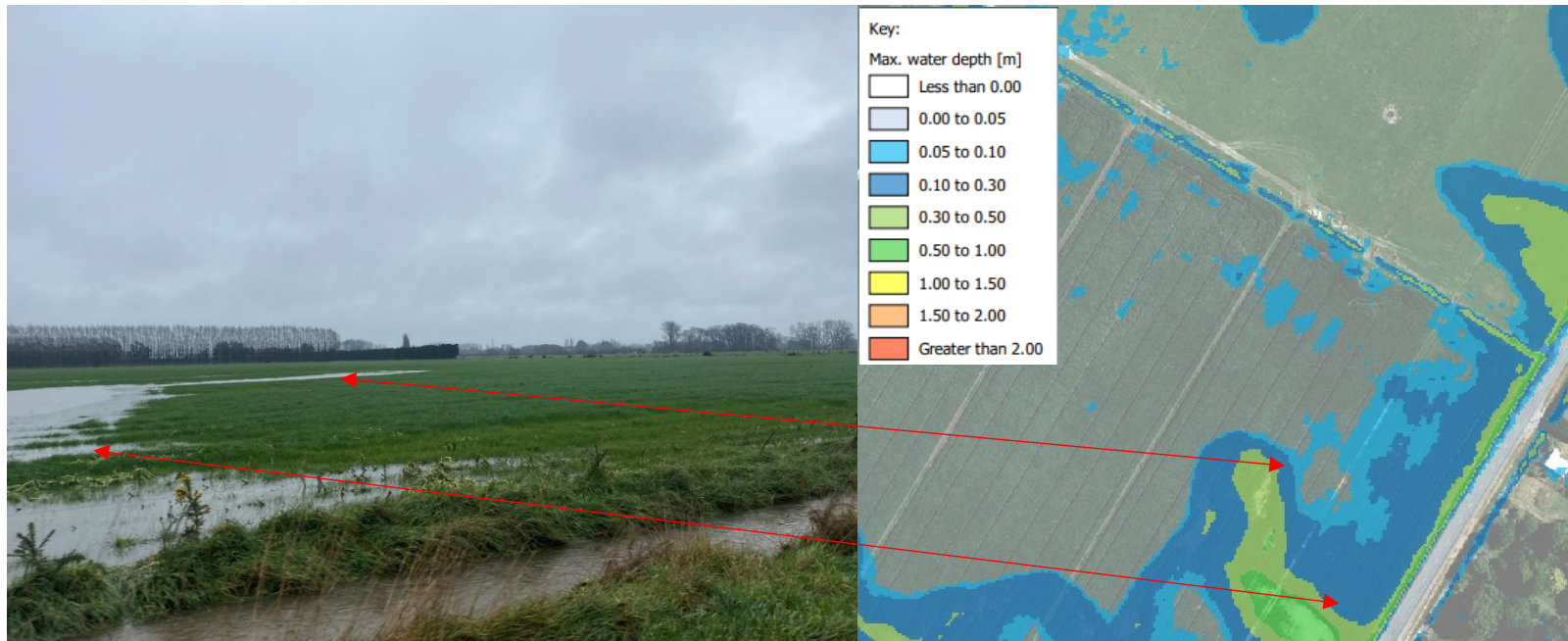
The model shows depths that are higher than the photo. The ponding depth in the photo may be masked by the height of the grass. (Depths less than 0.05 m not shown)

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)