

Belfast to Pegasus Motorway & Woodend Bypass Pre-implementation and MSQA Professional Services

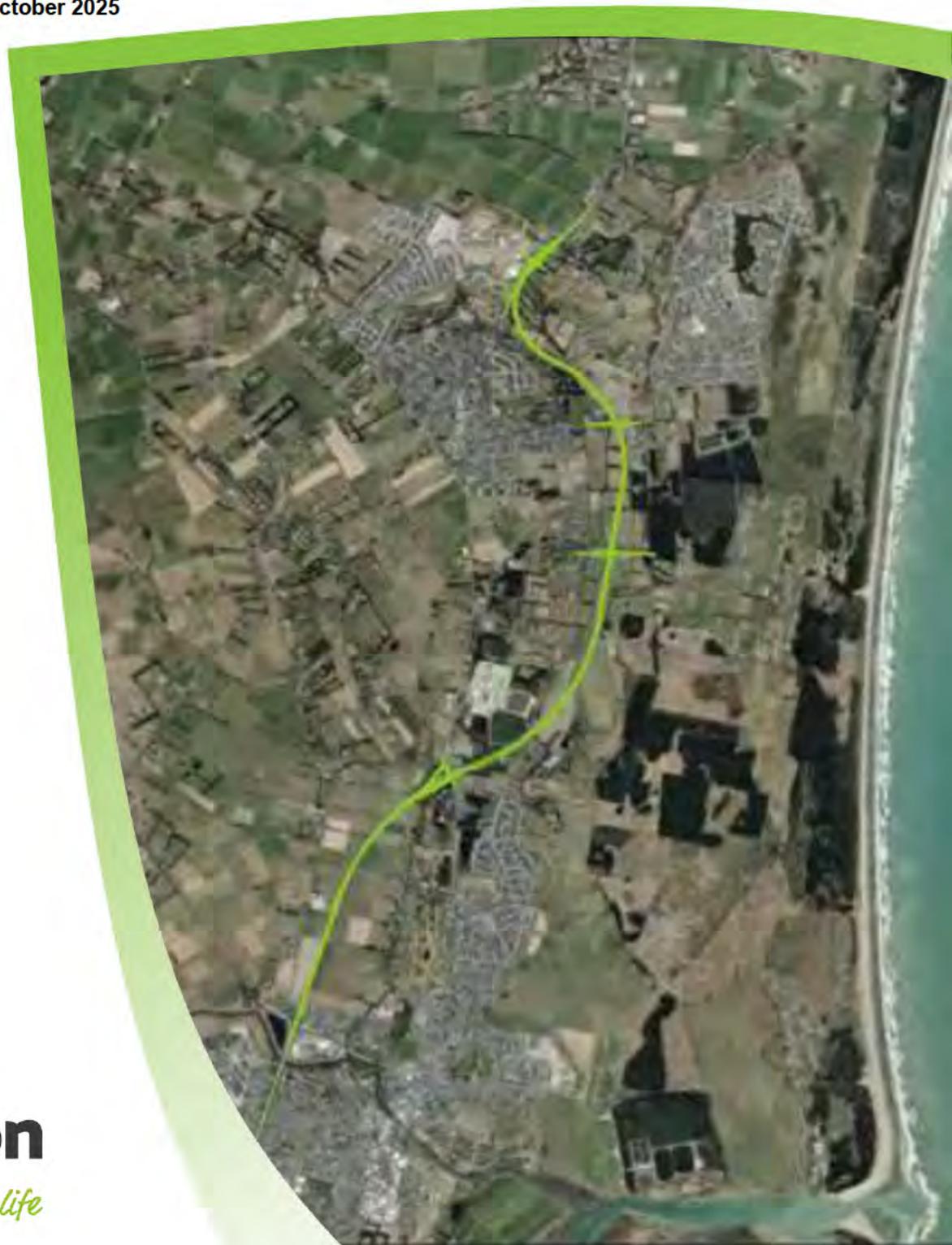
Stormwater and Flooding Assessment

NZ Transport Agency (NZTA)

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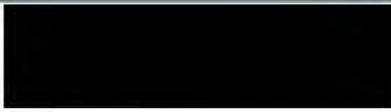
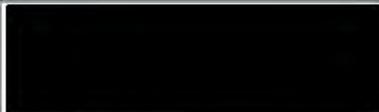
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Abbreviations And Definitions

Abbreviation	Term
AEP	Annual Exceedance Probability
CC	Climate Change
Ch.	Chainage
CIA	Cultural Impact Assessment
CMA	Coastal Marine Area
Culvert	Stormwater conduit that conveys either (or combination of) external, pervious and/or treated stormwater runoff from the upstream side of a road/motorway to the downstream outfall
DBC	Detailed Business Case
DOC	Department of Conservation
EclA.	Ecological Effects Assessment
HEC14	Hydraulic Engineering Circular 14
HEC18	Hydraulic Engineering Circular 18
HIRDS	High Intensity Rainfall Design System
HRT	Hydraulic Residence Time
Km	Kilometres
m	Metres
MCA	Multi-criteria assessment
NCHRP	National Cooperative Highway Research Program
NOR	Notice of Requirement
NUO	Network Utility Operator
NZCPS	New Zealand Coastal Policy Statement
NZTA	NZ Transport Agency Waka Kotahi
NZVD-16	New Zealand Vertical Datum 2016
Outfall	Downstream discharge location of a stormwater pipe, culvert or open channel
Project	State Highway 1 North Canterbury – Woodend Bypass Project (Belfast to Pegasus) (the construction, operation, and maintenance thereof)
RL	Relative Elevation
RoNS	Roads of National Significance
RMA	Resource Management Act 1991
SH1	State Highway 1 (note this refers to both portions of the existing roadway and the proposed motorway)
SLR	Sea level rise
SLS	Serviceability Limit State
ToC	Time of concentration
ULS	Ultimate Limit State

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1 Executive Summary

The New Zealand Transport Agency Waka Kotahi (NZTA) proposes to construct, operate, and maintain the State Highway 1 North Canterbury – Woodend Bypass Project (Belfast to Pegasus). The Project extends the Christchurch Northern Motorway by approximately 11 kilometres, providing a four-lane, grade-separated motorway that bypasses Woodend township and delivers improved safety, access, and reliability along this strategic transport corridor.

This technical report assesses the stormwater management and hydrological effects associated with the Project to support the resource consent application. It describes the existing stormwater and hydrological environment, evaluates the potential impacts arising from the operation of permanent stormwater infrastructure, and outlines mitigation and management measures to ensure that effects are appropriately managed.

The Project traverses a number of catchments, including the Kaiapoi River, Cam River, McIntosh Drain, Waihora Stream, and Taranaki Stream. Existing stormwater systems in these catchments are generally limited, with many discharges from the existing SH1 alignment currently untreated. Flooding is concentrated along defined channels and low-lying areas, with tidal influences present in the lower river reaches. The Project introduces earthwork, new impervious areas, realigned channels, culverts, and bridge structures that have the potential to alter flow paths, increase contaminant loads, and exacerbate flooding if not managed appropriately.

To address these potential effects, the Project incorporates a number of stormwater management measures. These include grass-lined swales, bioinfiltration and bioretention swales and basins, and proprietary treatment devices where necessary. These devices have been selected and designed in accordance with NZTA standards to provide effective contaminant removal, including suspended solids, hydrocarbons, and heavy metals. Flood modelling has informed the design of culverts, bridges, and channel diversions, demonstrating that, with mitigation, adverse flooding effects can be reduced to less than minor and confined to within the designation or existing drainage features.

Erosion and scour risks have been considered at all culvert outlets, realigned channels, and bridge crossings. Design measures such as riprap protection, energy dissipation structures, and revegetation planting will maintain channel stability and ensure long-term resilience. The assessment concludes that with the proposed mitigation, residual effects on hydrology, flooding, and stormwater quality will be less than minor.

Overall, the Project delivers enhanced stormwater management outcomes relative to the existing SH1 corridor. By adopting best practicable options for stormwater treatment, flood management, and channel stability, the Project achieves compliance with relevant standards, protects downstream environments, and ensures the resilience and functionality of the transport corridor into the future.

2 Introduction

2.1 Purpose and overview of the Project

The New Zealand Transport Agency Waka Kotahi (NZTA) proposes to construct, operate, and maintain the State Highway 1 North Canterbury – Woodend Bypass Project (Belfast to Pegasus) (the Project).

The Project is an extension of the Christchurch Northern Motorway and will provide four lanes of grade-separated motorway over an approximately 11 kilometre (km) length. The physical work commences approximately 200 metres (m) south of the Ohoka Road Overpass and extends to approximately 700 m north of the Pegasus/Ravenwood intersection, including a bypass of Woodend township.

The purpose of the Project is to provide an efficient and reliable state highway connection between Belfast and Pegasus, while delivering improved access, community safety and public health outcomes, and reduced severance through Woodend.

2.2 Purpose and content of this technical report

This report provides technical support to the Substantive Application Report (**SAR**) made by New Zealand Transport Agency Waka Kotahi (**NZTA**) under the Fast-track Approvals Act 2024 (**FTAA**).

This report assesses the stormwater management and hydrological effects resulting from the operation of permanent stormwater infrastructure and structures located within the Project Site and recommends mitigation and management measures to address any actual or potential adverse effects.

The report will:

- Describe the existing stormwater management and hydrological environment within the Project Site;
- Assess the effects of the proposed operational Project stormwater infrastructure; and
- Recommend mitigation and management measures to address potential adverse effects.
- Describe the effect of and proposed mitigations for flooding and water quantity impacts to the wider surrounding catchments

A more comprehensive background and description of the Project is contained in the SAR; please refer to the SAR for those details.

2.3 Expert witness statement

While this is not a matter before the Environment Court, the authors of this report have each read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023 ('Code'). The authors have each complied with the Code in the preparation of this report.

The data, information, facts and assumptions the authors have each considered as part of this report are set out in this report. The reasons for the conclusions of the report are also set out in this report. Unless stated otherwise, this report is within each of the authors' expertise and the authors have not omitted to consider material facts known to them that might alter or detract from the opinions expressed.

2.4 Applicability statement

We understand and agree that NZTA will submit this report as part of an application under the Fast-Track Approvals Act 2024 and the appointed panel will use this report for the purpose of assessing that application.

3 Existing Environment

The following is an overview of the existing environment, in context of stormwater and hydrology, within the Project Site and surrounding area. The motorway design chainages have been used to reference the locality of existing stormwater management devices. Refer to the design drawings for referenced motorway design chainages.

3.1 External Catchments

3.1.1 Overview of External Catchments

For the purposes of assessing stormwater effects, the following major catchments are traversed by the Project, from South to North (refer to Figure 3-1). Each of the catchments is discussed in detail below.

- Kaiapoi River Catchment (CH 0 to 600)
- Cam River Catchment (CH 600 to 3600)
- Quarry Lakes Catchment (CH 3600 to 4600)
- McIntosh Drain (CH 4600 to 5800)
- Waihora Stream (CH 6100 to 9300)
- Taranaki Stream (CH 9300 to 9900)

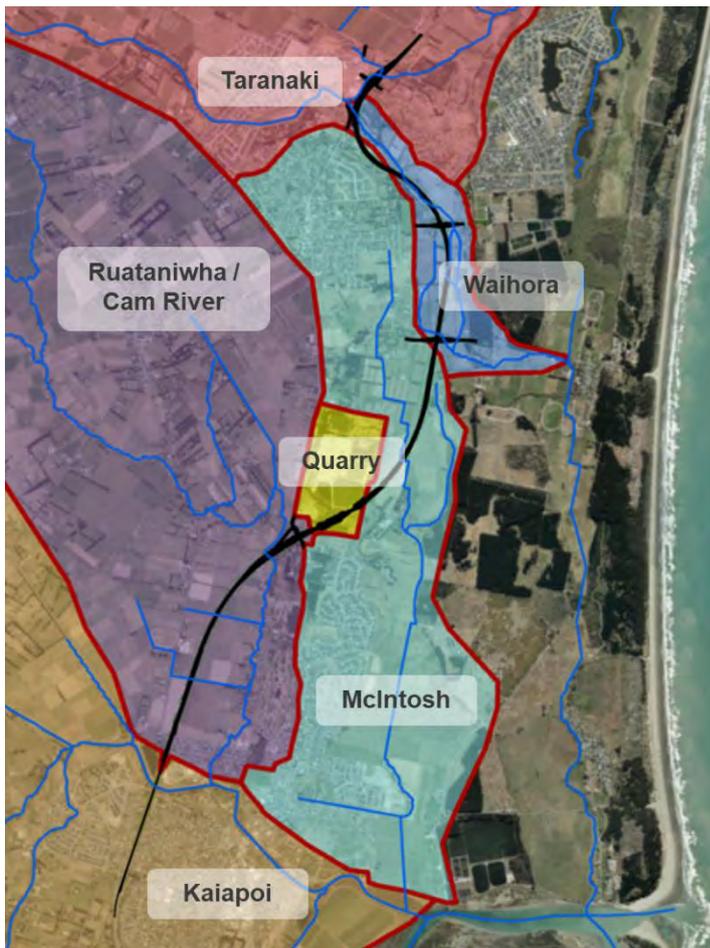


Figure 3-1 Wider catchments interfacing with Project

Kaiapoi River

The Kaiapoi River is a major tributary to the Waimakariri River, which it discharges into approximately 2km downstream of the motorway alignment. The Kaiapoi river has a catchment area of approximately 340 km² which extends across the Canterbury Plains into the foothills of the Southern Alps.

Land use within the Kaiapoi River catchment is dominated by the Kaiapoi urban environment in the lower reaches, and a mix of agricultural and large lot residential upstream of Kaiapoi.

Within the Project area, the Kaiapoi River experiences significant tidal effects, with high water levels largely driven by tidal tailwater.

Cam / Ruataniwha River

The Cam / Ruataniwha River is a perennial tributary to the Kaiapoi River (see above). Its 60km² catchment extends across the Canterbury Plains, encompassing the southern portion of Rangiora. The alignment crosses two drains Rossiters Drain and Wilsons Drain that discharge to the Cam River just south of the Cam River crossing.

The land use within this catchment is predominantly agricultural and large lot residential, however, it also incorporates suburban residential and commercial areas of Rangiora, including the Rangiora town centre.

Within the Project area, the Cam River experiences significant tidal effects, with high water levels largely driven by tidal tailwater.

Quarry Lakes

The quarry lakes are large excavations that are filled with groundwater and do not have a primary outlet. Water that is discharged into these ponds flows directly to groundwater through the gravel bottom and sides of the excavations. The land use within the quarry ponds catchment entirely consists of the quarried areas and the associated gravel processing operation.

McIntosh Drain



Figure 3-2 McIntosh Drain Near the Motorway Crossing

McIntosh Drain is a primarily manmade drain that runs north-south, parallel to the proposed motorway alignment, ultimately discharging into the Waimakariri River near its confluence with the Kaiapoi River. This drain has a catchment area of approximately 2.7km², which encompasses the southeastern portion of the Woodend township.

McIntosh Drain through the Project alignment can generally be described as a well-defined, steep sided, drain that perennially holds water.

The land use within the McIntosh Drain catchment is a mix of agricultural, large lot residential, and suburban residential land.

Waihora Stream



Figure 3-3 Waihora Stream is well defined in the upper reaches (left) but undefined in the lower reaches (right)

Waihora Stream is a distributary, or overflow channel, of the Taranaki Stream (see below). Waihora Stream flows south, parallel to the proposed roadway alignment before turning east south of Woodend Beach Road, discharging to the broad interdunal area west of Woodend Beach. This area ultimately discharges south through Kairaki Creek into the Waimakariri River near its mouth.

Surface flow into the upstream end of Waihora Stream is regulated by a weir along Taranaki Creek within the Ravenswood Subdivision and only flows in high flow events. Just downstream of the Taranaki Creek weir, Waihora Stream intercepts groundwater and the channel in this area perennially flows to the southeast, under SH1. Downstream of SH1, Waihora Stream passes through several ponds where all dry weather flow infiltrates. By the time the channel crosses Gladstone Road, 1700 metres to the southeast of SH1, Waihora Stream has become a broad, poorly defined, channel that only flows during flood flows.

Land use within the Waihora Stream catchment is almost entirely agricultural, however high flows diverted from Taranaki Creek include runoff from significant residential subdivision areas.

Taranaki Stream

Taranaki Stream is a well-defined, perennial waterway that has a catchment area of approximately 8 km². The catchment captures the easternmost portions of Rangiora, agricultural land, and the Ravenswood subdivision before crossing the existing SH1 alignment, draining to the east into the interdunal area, which ultimately discharges to the north to the Ashley River near its mouth.

3.1.2 Existing Flooding – Rainfall Runoff

A TUFLOW flood model has been developed to assess existing flood behaviour under a 100-year ARI event. The flood depth and level maps (Figure 3-4 and Figure 3-5) illustrate the primary flow paths within the Project area. Runoff is generally distributed in three directions: northward via the Taranaki Stream catchment toward Waikuku Beach, southward through the Waihora Creek catchment which then turns east toward Kairaki Creek, and through McIntosh Drain flowing south before merging with the Kaiapoi River.

The flood depth map highlights that overland flow is primarily confined to defined flow paths and low-lying areas, such as the quarry, basins within development zones, and upstream of Gladstone and Woodend Beach Roads, where culvert capacity and road embankments constrain flows. A broader floodplain extent is evident near McIntosh Drain at Fuller Road, where the channel is overtopped and floodwaters continue downstream.

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Figure 3-5 and Figure 3-6 present the flood depth and level maps for the 200-year ARI event. The flood patterns are generally consistent with those observed in the 100-year ARI event, except with an increased flood depths and a broader extent of inundation across the floodplain.

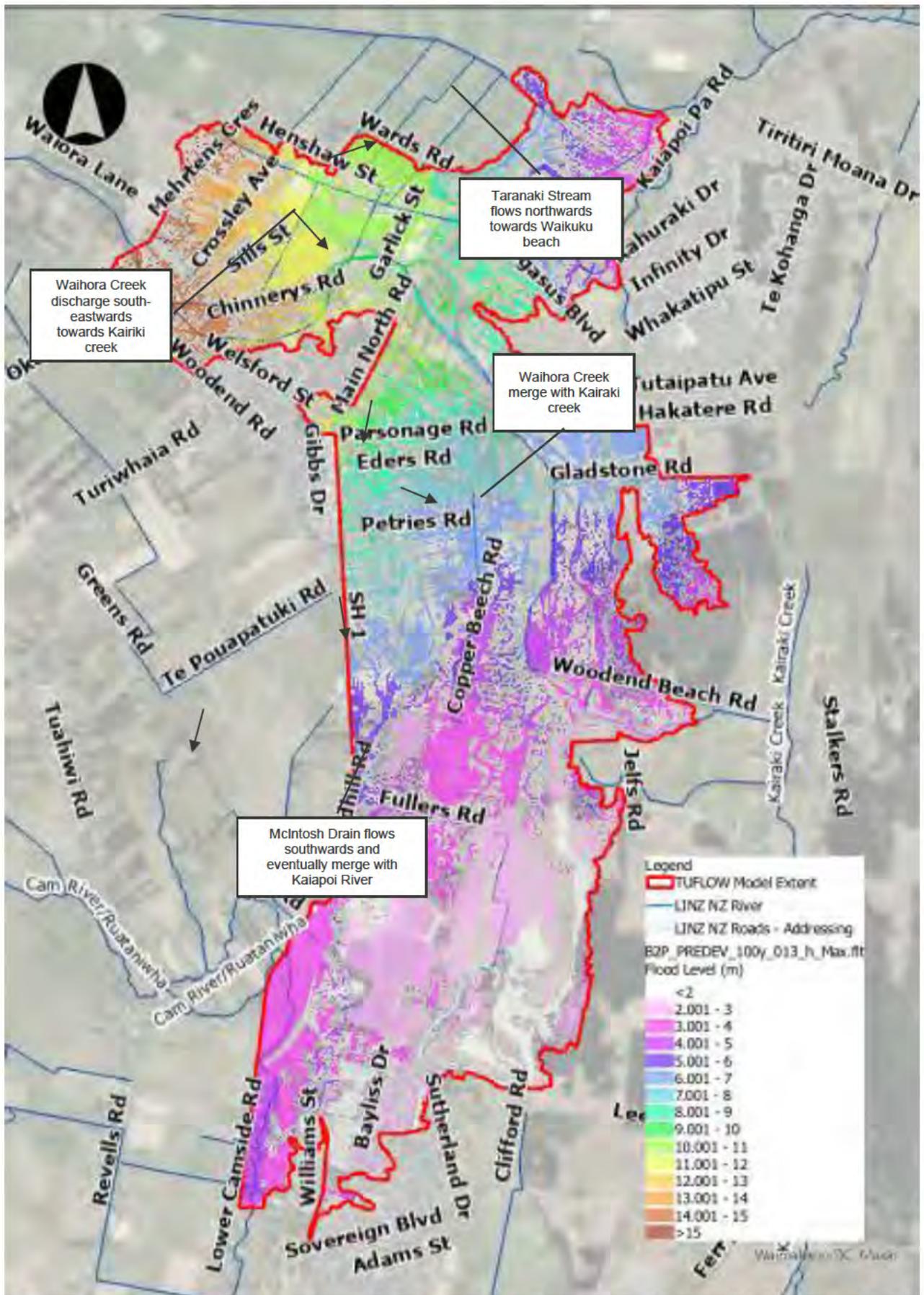


Figure 3-5 B2P-Woodend flood model pre-development flood level (mRL) under 100-year ARI event

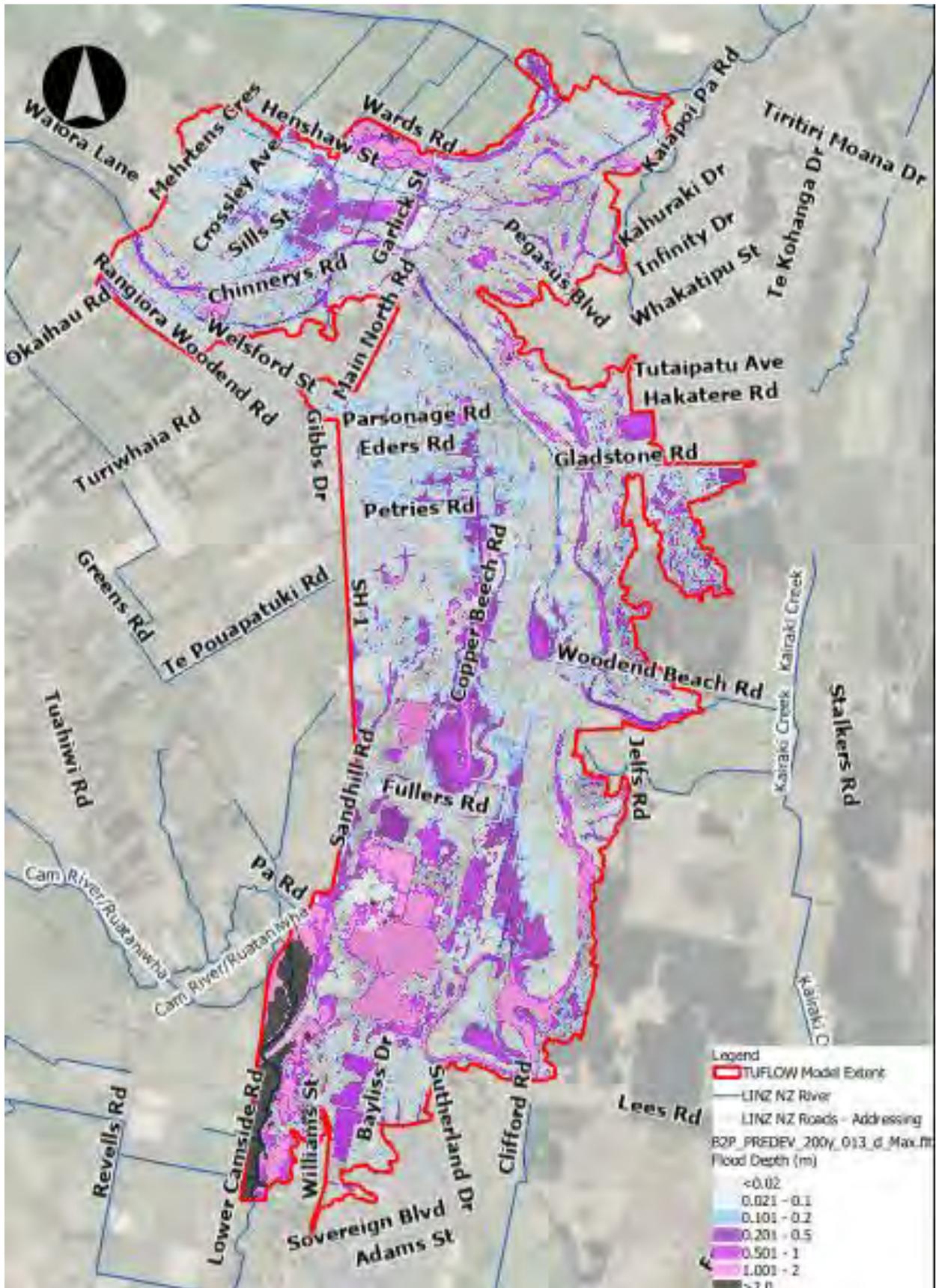


Figure 3-6 B2P-Woodend flood model pre-development flood depth (m) under 200-year ARI event

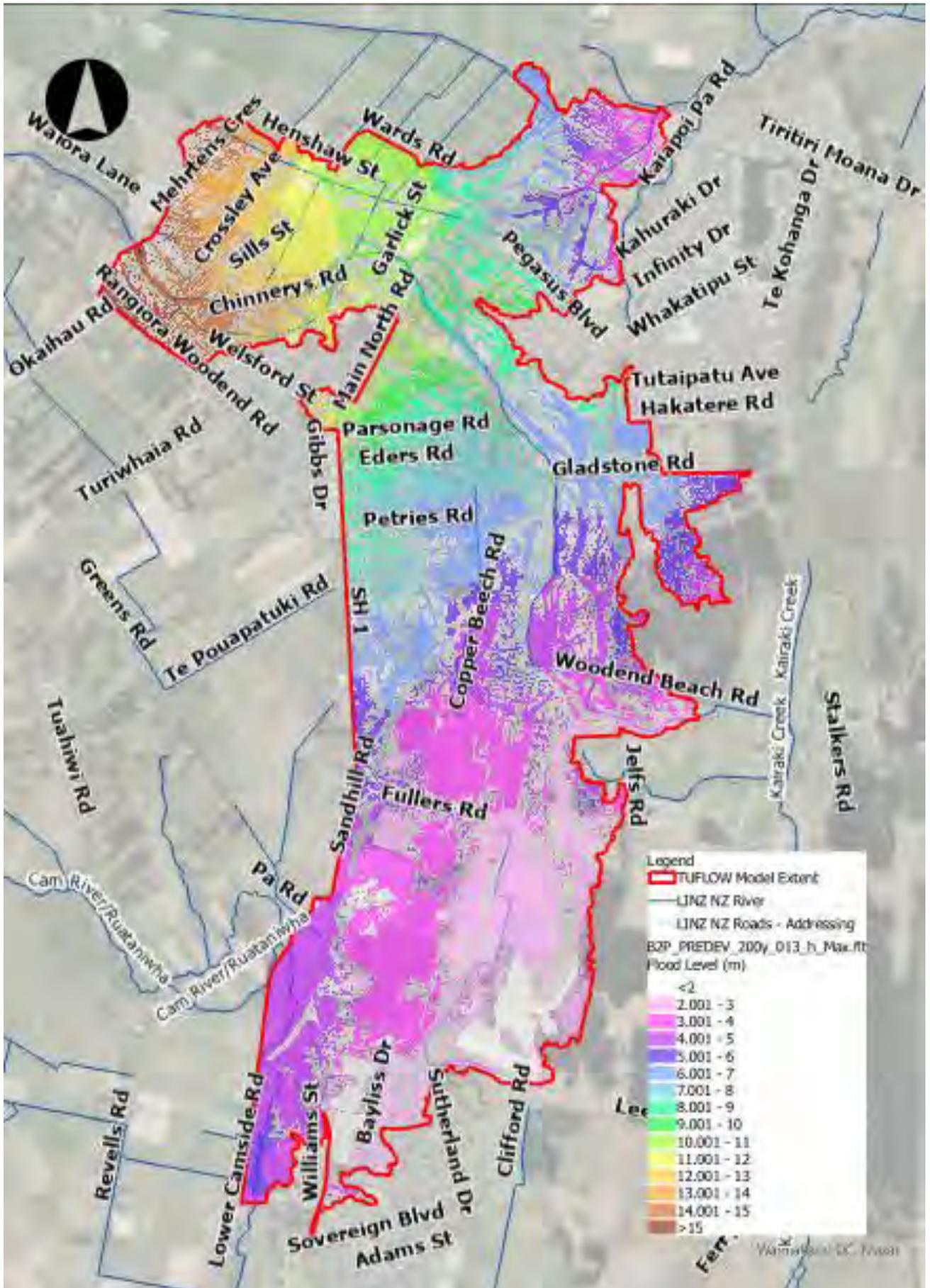


Figure 3-7 B2P-Woodend flood model pre-development flood level (mRL) under 200-year ARI event

3.2 Existing Roadway Stormwater Management

The existing roadway interfaces with the proposed motorway alignment on the north and south ends of the Project, with the central section widely deviating from the existing roadway. The stormwater management is discussed here for the portions of the existing roadway which are coincident with the proposed motorway works and where existing roads cross the proposed alignment.

3.2.1 Kaiapoi River Catchment (Kaiapoi Urban Area)

The limits of the Project begin within the Kaiapoi Urban Area near Ohoka Road. In this vicinity, only the southbound lane is affected by proposed works (a lane expansion) so the discussion below only discusses this side of the existing motorway.

South of the Kaiapoi River Bridge

Within the Kaiapoi urban area (between Ohoka Road and the Kaiapoi River), the Project interfaces with the southbound lanes of the existing motorway. In this area, the existing motorway drains to the east, over the embankment. For the southernmost 650 metres, roadway runoff flows directly to Parnhams Drain, an open drain that discharges via a stormwater pump station to the Kaiapoi River through a 1525mm diameter pipe.

For the northern 350 metres to the Kaiapoi River bridge, runoff travels over the embankment, likely entering the 1525mm pipe through catchpits and stormwater infrastructure. This area located behind private property and is inaccessible to confirm drainage patterns, however there have been no flooding complaints recorded, so this area likely has effective drainage infrastructure.

There do not appear to be any existing water quality or stormwater attenuation facilities in this reach.

Kaiapoi River Bridge Area

At the Kaiapoi River Bridge, flow from the bridge structure flows through deck drains directly to the underlying Kaiapoi River, rail corridor or Adderly Terrace.

For the first 100 metres north of the Kaiapoi River, runoff from the motorway runs down the embankment and joins a broad swale against the Kaiapoi River stopbank from where it is piped to the Kaiapoi River.

Although much of the flow from the Kaiapoi River Bridge discharges directly to the river, the swale that intercepts flow from the motorway north of the bridge is broad and flat, likely providing water quality improvement and flow attenuation prior to discharge to the Kaiapoi River.

3.2.2 Cam River Catchment

North of the Kaiapoi River Bridge, the roadway transitions into the Cam River catchment. From the Lineside Road area north, the existing roadway transitions to one lane in each direction and the proposed works impact both sides of the existing roadway.

Lineside Road Interchange

South of the Lineside Road overpass, flow from both mainline sides of the motorway drains to channels within the nose areas separating the mainline from the Lineside Road on and off ramps. These channels flow to the north where pipes on both sides of the motorway carry the flow beneath the Lineside Road overpass. These pipes, discharge into channels that parallel the motorway in the north side nose areas. Both channels flow through culverts that carry the flow under the northern on and off ramps, discharging into roadside channels that continue north.

There do not appear to be any formalised water quality or flow attenuation features to the existing stormwater system in this area. Most of the channels are relatively steep banked and narrow, limiting opportunities for both. However, the roadside channel in the northwestern quadrant, which collects runoff from the northbound lanes, is shallow, wide, and well grassed; potentially providing some attenuation and treatment.

Lineside Road to Cam River

Between Lineside Road and the Cam River, the existing roadway traverses agricultural land. The Cam River parallels the roadway to the east through this section. There are two major drains crossing the alignment, that discharge to the Cam River via 1500mm diameter culverts at CH1610 (Rossiters Drain) and 2350 (Wilsons Drain). Runoff from this portion of the roadway discharges into roadside drains, which discharge to the crossing drains.

The existing roadside drains are generally relatively steep sided, but longitudinally flat, likely providing limited water quality or stormwater attenuation benefit.

Cam River Bridge

As the roadway approaches the Cam River, it begins climbing. As a result, runoff from the entire roadway south of the Cam River is directed away from the main Cam River and into the drains described above. At the Cam River Bridge, runoff flows directly off the existing bridge into the river. North of the bridge, the roadway is superelevated to the northwest and runoff is directed into the Cam River, which parallels the west side of the roadway.

There do not appear to be any formalised stormwater treatment or attenuation facilities in this area.

Williams Street Intersection

Just north of the Cam River Bridge, the proposed motorway alignment deviates from the existing roadway alignment, veering to the northeast. The existing roadway between the Cam River and Williams Street is proposed to be utilised as an offramp for the motorway to Williams Street.

In this area, the existing roadway is superelevated with a single crossfall to the north, resulting in flow from the roadway discharging directly into the Cam River untreated and unattenuated.

3.2.3 Quarry Lakes Catchment

The existing SH1 roadway does not traverse the Quarry Lakes Area, passing to the east of it. As such, there are no existing roadway stormwater management systems in this catchment.

3.2.4 McIntosh Drain Catchment

The existing SH1 roadway does not cross McIntosh Drain, remaining well to the west of the drain. The motorway is proposed to cross McIntosh Drain approximately 1km to the east of the existing highway alignment in a location with no existing roadway infrastructure. In this area, the existing McIntosh Drain is steep sided and narrow, with minimal natural features.

3.2.5 Waihora Stream Catchment

As the proposed motorway traverses the Waihora Stream Catchment, it does not follow an existing roadway for the majority of the alignment. The only interactions with existing stormwater infrastructure are at the crossings of Woodend Beach Road, Gladstone Road, and at the northern end of the alignment, where it rejoins the existing SH1 alignment, near the Pegasus intersection.

Woodend Beach Road Area

The mainline alignment of the proposed motorway crosses Woodend Beach Road approximately 200 metres to the east of the location where Waihora Stream crosses beneath Woodend Beach Road. In this area, a channel on the north side of Woodend Beach Road collects flow from the poorly defined flowpaths that make up Waihora Stream, directing it to a 300mm culvert under Woodend Beach Road. There are no apparent water quality or stormwater attenuation features in this area.

Gladstone Road Area

The mainline alignment of the proposed motorway crosses Gladstone Road approximately 120 metres to the east of the location where Waihora Stream crosses under Gladstone Road via a 1250x500 mm box culvert. In this area, the channel upstream and downstream of the crossing is very poorly defined, consisting of a series of normally dry shallow overland flowpaths. There are no apparent water quality or stormwater attenuation features in this area.

Ravenswood Area

The proposed motorway rejoins the existing SH1 alignment at the location where Waihora Stream crosses the alignment. This location is 150 metres downstream of the location where Waihora Stream splits from Taranaki Stream, immediately intercepting spring flow.

The existing Waihora Stream culvert is a 4m x 2m box culvert under the SH1 roadway. Flow from the immediate vicinity of the Waihora culvert (approximately 200metres to the south and 100 metres to the north) discharges into roadside channels that discharge directly into Waihora Stream.

Approximately 185 metres north of the Waihora Road main crossing, a remnant Waihora branch intersects the roadway alignment. In this location, there is no culvert, so there is no split from the Taranaki Stream and all flow from the west side of the roadway is directed to the Taranaki Stream. A small portion of roadside channels on the east side of the roadway (approx. 75 metres) discharge into this branch.

There are no apparent existing water quality or stormwater attenuation features in this area.

3.2.6 Taranaki Stream Catchment

North of the Waihora Stream Crossing, the roadway enters the Taranaki stream catchment.

Pegasus Interchange

Taranaki Stream parallels the roadway to the west from the Waihora Stream Culvert to its crossing, approximately 120 metres north of the existing Pegasus roundabout. Runoff from the western side of the roadway is collected in kerb and channel, which discharges into a broad, shallow swale that parallels the roadway, discharging into Taranaki Stream just upstream of it.

On the eastern side of the roadway, runoff is collected in kerb and channel, and which is discharged directly into the golf course pond on the southeast quadrant of the intersection. This pond is the uppermost of a series of ponds throughout the Pegasus Golf Club that subsequently discharge into the Taranaki Stream.

The broad swale that collects and conveys the western side of the roadway appears to have been designed to provide swale based water quality treatment. There are no other apparent existing water quality or stormwater attenuation features treating road runoff in this area.

North of Pegasus

The final reach of the Project extends 700 metres north of the Pegasus intersection along the existing alignment of SH1. This reach is bisected by a branch of the Taranaki that passes under the roadway in a 650x850mm brick barrel culvert, 130 metres north of the main Taranaki culvert. The northbound portion of

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the roadway drains to the west, where a roadside channel intercepts it, discharging into the Taranaki branch. The southbound portion of the roadway runs off across the grass verge directly onto the Pegasus Golf Club, ultimately discharging to the course's pond system..

4 Description of Works

This section is to be read in conjunction with the Stormwater Drainage Design Drawings

4.1 External Stormwater Management

4.1.1 Cut-off Drains

Where external catchments cross proposed motorway alignments, cut-off drains are proposed to intercept offsite inflow, keeping it separated from roadway runoff and conveying it to a discharge location. All cut-off drains have been designed to accommodate 1 % AEP (incl. Climate Change (CC)) flows resulting from their respective upstream catchments, based on flows from catchment flood modelling. Cutoff drains have been designed to ensure that trans-catchment diversions do not occur. Where offsite flow is redirected, it is redirected back into its historic outfall.

Throughout the Project area, cutoff drains are generally proposed at, or above the existing ground level. As a result, the majority of the cutoff drains are not expected to intercept groundwater. There are, however, several locations where proposed cutoff drains may intercept groundwater. These are located in the Lineside to Cam River section (CH 0580 to 3190) on both sides of the proposed motorway. In this section, the proposed work represents replacement in kind of existing channels and conveyance structures at similar levels and grades. As such, while the proposed drains may potentially intercept groundwater during times of high groundwater levels, the nature of the interception will not result in an increase in groundwater intercepted in comparison to the existing channels.

4.1.2 Channel Realignment

Several portions of existing channel are proposed to be realigned to accommodate the new roadway. The realignments are summarised in the table below.

Table 4-1 Proposed Channel Realignments

Project Chainage	Channel	Realignment Distance	Channel Type
9700 to 9775	Taranaki North Branch	75m	Ephemeral
9640 to 9700	Taranaki Stream	60m	Perennial
9100 to 9220	Waihora Stream	120m	Perennial (spring fed)
7820 to 8270	Waihora Stream	450m	Perennial at top, transitioning to Ephemeral
7000 to 7600	Waihora Stream	600m	Ephemeral (poorly defined)

Taranaki Realignment

At CH 9700, the existing SH1 Taranaki Stream culvert is being extended and realigned to accommodate the proposed motorway. This will require a realignment of approximately 60 metres Taranaki Stream, and 75 metres of the northern branch channel that intercepts Taranaki at the upstream end of the existing SH1 culvert.

Taranaki Stream in this reach flows perennially. To ensure that ecological benefits of the channel are not impacted by the works, the realigned channel will match the geometry of the existing channel in consideration of fish passage requirements for the Taranaki Culvert as discussed in the following section.

Waihora Stream Realignments

The Waihora Stream channel is being relocated in a number of sections to accommodate the work. At the upstream end (CH 9100 to 9220), where the channel flows perennially with spring fed water, the realigned channel will match the geometry and grade of the existing channel in consideration of fish passage requirements for the Waihora Stream Culvert

In the other reaches where Waihora Stream proposed to be realigned, the channel is poorly defined, shallow and does not carry a baseflow, only flowing during high flow events. Through this portion, the channel is designed so that in both the 100- and 200-year events, no significant adverse offsite impacts result from the proposed new roadway and channel realignment, as identified by flood modelling and outlined in the flood modelling report.

4.1.3 Cross Culverts

Abandonment/Removal of existing Cross Culverts

Within the Project Site, where culverts affected by works require decommissioning, they will be removed and/or backfilled.

Proposed Cross Culverts

Cross culverts have been sized based on NZTA criteria (P46, NZTA stormwater specification), which requires 100-year ARI capacity, considering RCP 6.0 to 2110. Additionally, the culverts have been designed in consideration of floodplain modelling in both the 100-year and 200-year ARIs to ensure that no adverse impacts occur, see flood modelling report in Appendix A. The following culverts on the alignment are proposed

Table 4-2 Proposed Cross Culverts

Culvert ID	Chainage (m)	Nominal Size (mm)	Length (m)	Notes	Fish Passage
001	1610	1500	45	Wilson Drain, Replacement of existing culvert	Y
002	2350	1500	45	Rossiter Drain, Replacement of existing culvert	Y
003	640 (ramp)	600	60	Bioretention basin outlet to Cam, new culvert, dry channel	N
004	350 (Williams St.)	600	25	New culvert, dry channel	N
005	5000	6000 X 2000	50	McIntosh Drain, new culvert, wet	Y
006	6310	600	30	New culvert, dry channel	N
007	6380	1500 x 500	40	New culvert, dry channel	N
008	540 (Woodend Beach Rd)	Twin 2000 x 1000	30	Waihora Stream, new culvert, dry channel	N
009	7400	600	30	New culvert, dry channel	N
010	320 (Gladstone Rd)	Twin 1050	55	Waihora Stream, new culvert, dry channel	N

Culvert ID	Chainage (m)	Nominal Size (mm)	Length (m)	Notes	Fish Passage
011	240 (Gladstone Rd)	600	55	New culvert, dry channel	N
012	7970	600	30	New culvert, dry channel	N
013	9110	600	65	Dry channel,	N
014	9210	4000 x 1500	70	Waihora Stream, wet	Y
015	100 (Bob Robertson Dr)	2 - . 1800 x 1000	5	Extension of ex Bob Robertson culverts, wet	Y (match existing)
016	9700	2700 x 1500	90	Taranaki Stream, wet	Y
017	9830	2000 x 1000	55	Taranaki Branch, existing 650x850mm brick barrel, dry	N

Fish Passage and Geomorphic Connectivity

Culverts identified as requiring accommodations for fish passage are identified above. Fish passage design for these culverts is based on New Zealand Fish Passage Guidelines v2.0 (Niwa, 2024) and Fish Passage Guidelines for State Highways (NZTA, 2013).

Each culvert is being individually assessed for fish passage accommodation, which generally includes the following accommodations:

- Īnanga are present in all streams in the region, so will be used as the benchmark species for evaluating culvert water velocities.
- Brown Trout have been identified in Taranaki Stream and have had eDNA detected in the upper Waihora Stream, so will be used in addition to Īnanga as a benchmark species for culvert water depth in these streams.

Following the fish passage guidelines will also ensure that the culverts maintain the geomorphic connectivity of the waterway, allowing the passage of sediment and debris.

Culvert Outfall Erosion Protection

All culverts have been assessed for erosion risk based on the guidelines in HEC 14 - Hydraulic Design of Energy Dissipators for Culverts and Channels. Where necessary, riprap erosion protection is proposed to ensure that inlet and outlet velocities do not result in channel scouring. Due to the low energy environment of the site, riprap will be sufficient to manage energy dissipation - extensive energy dissipation structures (e.g. plunge pools, baffle blocks, etc) will not be required.

4.2 Proposed Bridge Improvements

There are two bridges impacted by the Project, the Kaiapoi River Bridge and the Cam River Bridge. These are discussed in detail below. Both bridges were assessed for the SLS (100-year) events as well as the ULS (1500-year) event for hydraulic capacity, structural loading and bridge scour.

4.2.1 Kaiapoi River Bridge

The Kaiapoi River Bridge is located within the portion of the Project with a single southbound lane widening to the inside. This structure is being maintained with its current geometry, however the structure is proposed to undergo structural strengthening to bring it into compliance with current engineering standards and to allow it to support the additional lane as part of the early works.

Hydraulic Analysis

To support the structural design of the bridge a hydraulic analysis was undertaken. This analysis is based on a HEC-RAS river model, incorporating detailed bridge design elements.

The hydraulic analysis indicates that the river is confined within the existing stopbanks for the SLS event, however the stopbanks overtop in the ULS event. Regardless, the ULS flows will not affect the bridge deck.

Scour Analysis

As part of this strengthening, a scour analysis was undertaken to determine the extent of scour that would be expected to occur in the Serviceability Limit State (SLS) event (100-year ARI) and the Ultimate Limit State (1500 year ARI) events. The preliminary scour outcomes are shown below.

Table 4-3 Scour depth (m) by bridge component in the worst case SLS and ULS event scenarios

	Contraction	Pier 1 (Northmost)	Pier 2	Pier 3	Pier 4	Pier 5 (Southmost)	South Abutment	North Abutment
SLS	0.1	0	3.20	3.20	0	0	0	0
ULS	0.17	1.5	3.99	3.99	0.88	1.25	1.79	2.68

Although there is moderate expected pier scour in both the SLS and ULS events, the magnitude of this scour is within acceptable structural limits for both the events, based on the NZTA Bridge Manual criteria. Due to the stopbanks confining the flow in the SLS event, the bridge abutments are not predicted to scour in the SLS event, and scouring in the ULS event is not predicted to affect the bridge's stability.

Proposed Scour Protection

Based on the predicted this analysis, no additional scour protection is recommended for the Kaiapoi River Bridge.

4.2.2 Proposed Cam River Bridge

While the existing Cam River Bridge is being retained to support a northbound offramp, a new bridge is proposed to carry the proposed mainline and southbound onramp. This bridge will be located to the east of the existing bridge structures, which will share a common abutment fill slope.

Hydraulic Analysis

To support the structural design of the bridge a hydraulic analysis was undertaken. This analysis is based on a HEC-RAS river model, incorporating detailed bridge design elements.

The hydraulic analysis indicates that regardless of tailwater conditions, high water levels in the Cam River are dominated by backwater effects from the Kaiapoi River impoundment area as discussed above. The effect of this is that high flows from the Cam River do not result in the highest water levels at the Cam River Bridge, instead these levels occur when the Kaiapoi River system inundates the bridge. During these events, the flow and velocities through the Cam River Bridge become insignificant due to the 'bathtub' effect.

To understand the potential effects on the bridge, the model considered a Cam River only flood scenario, with low tailwater on the receiving Kaiapoi system. For both the SLS and ULS scenarios, these events resulted in lower water levels, but higher velocities.

Scour Analysis

The scour analysis for the Cam River Bridge was based on the Cam River only flood events, as the regional flood events created a 'bathtub' effect, reducing water velocities to near zero. The preliminary results of the scour modelling are summarised below.

Table 4-4 Scour depth (m) by bridge component in the worst case SLS and ULS event scenarios

	Contraction	South Abutment	North Abutment
SLS	1.15	1.89	3.53
ULS	2.24	1.89	4.88

The results indicate that significant abutment scour is expected to occur at the north (true left) abutment and that bend scour is expected at the south (true right) side of the channel in both the SLS and ULS events. While the proposed bridge will be structurally designed to accommodate this scour depth, both abutment slopes are at risk of failure in SLS events, requiring scour protection.

Proposed Scour Protection

Protection against scour induced abutment failure has been designed in accordance with HEC23, the US Federal Highway Administration's Bridge Scour and Instability Countermeasures Design Guide. Specifically, Design Guideline 14 was used in the preparation of preliminary abutment riprap revetments for the northern abutment, while Design Guideline 4 was used to remediate the bend scour at the southern abutment. Both proposed scour revetments will encompass both the existing and proposed bridges, allowing for increased resilience of the existing bridge structure.

Note, the data included in Table 4-5 are preliminary in nature and subject to reassessment upon finalisation of the bridge design, during future design stages. The final design will be undertaken in general accordance with the design guidance documentation referenced above and not envisaged to extend further in plan than identified in this application.

Table 4-5 Scour Protection Summary

Parameter Description	Design Sizing
Minimum D_{50}^1 (m)	0.3m
Minimum Revetment Slope Layer Thickness (m)	0.6m
Minimum Toe Layer Thickness (m)*	2.0*
Minimum Material Specific Gravity	2.65

4.3 Overview of Proposed Stormwater Quality Management Methodologies

A number of methodologies are proposed for stormwater treatment across the Project. These methodologies are outlined below.

¹ D50 is the median particle diameter or median particle size

Table 4-6 Treatment Methodology Overview

Type	Vegetation	Primary Discharge	Secondary Discharge	Subsoil drains
Grass Lined Swale	Grass	Surface	Surface	No
Bioinfiltration Swale	Planted	Passive Infiltration	Surface	No
Bioretention Swale	Planted	Surface	Surface	As needed by grade and location
Bioinfiltration Basin	Planted	Passive Infiltration	Surface	No
Bioretention Basin	Planted	Surface	Surface	As needed – Drain to stream
Proprietary Device (not part of current design)	N/A	Surface	Surface	May be included within device (e.g. proprietary raingardens)

4.3.1 Grass Lined Swale

Grass Lined Swales are intended to improve stormwater quality through sediment filtering within wide, grass bottom channels. Grass lined swales are generally utilised where there is sufficient roadside space to achieve the necessary width to accommodate the mowable grass batters and wide bases necessary to achieve the low velocities and extended residence times necessary to ensure the treatment process, and where infiltration based processes are either unnecessary or prohibitive. Where utilised on the Project, treatment swales will be designed as per the requirements in P46.

Grass Lined Swales are particularly effective at removing total suspended solids (TSS), with removal efficiencies often exceeding 80%. Swales can also remove heavy metals, especially where they are attached to sediment, however, have limited ability to remove dissolved heavy metals and nutrients.

4.3.2 Bioinfiltration Swale

Bioinfiltration Swales are channels that are intended to improve stormwater quality via bio- and phytoremediation processes within the soil layers of the base of the swale, before infiltrating the ground via high infiltration subsoils, maintaining the hydraulic neutrality by facilitating infiltration as close as possible to the point of origin. Bioinfiltration swales utilise check dams to impound water within the swales, allowing for infiltration through an engineered base material.

Bioinfiltration swales are proposed in locations where the stormwater management requires infiltration-based processes to achieve hydraulic neutrality within the catchment, as allowed by soil infiltration characteristics and groundwater levels

Bioinfiltration swales will be designed to infiltrate a minimum of 5mm/hour runoff from the roadway in accordance with Waimakariri District Council guidelines for infiltration treatment devices. During high inflows, when the hydraulic loading exceeds the ponding and infiltration capacity of the swales, runoff cascades downstream through the swale system, ultimately being discharged into surface waters.

Bioinfiltration swales exhibit very high TSS removal efficiencies and enhanced removal efficiencies of dissolved heavy metals and nutrients due to the biological treatment processes within the soil layers.

4.3.3 Bioretention Swale

Bioretention Swales are similar to bioinfiltration swales, however they do not rely on infiltration to achieve treatment. Bioretention swales are planted swales, with permeable check dams that retain water within vegetated segments. Treatment is achieved through settlement of suspended solids and, partially, soil

treatment within the vegetated topsoil layers. Bioretention swales are designed to provide impoundment volume for a first flush of up to 5mm/hr of runoff to ensure treatment outcomes. As bioretention swales are not intended to fully infiltrate treatment flows, they do not require an engineered base material to ensure infiltration rates, allowing water to slowly seep through their permeable check dams over time.

Bioretention swales exhibit high removal rates of TSS and attached heavy metals, however, have potentially limited dissolved heavy metal and nutrient treatment capability.

4.3.4 Bioinfiltration Basin

Bioinfiltration basins are basins that are intended to improve stormwater quality via bio- and phytoremediation processes within the soil layers of the bottom of the basins, before infiltrating the ground via high infiltration subsoils. Bioinfiltration basins are designed to impound the first flush of up to 25mm of runoff, allowing for slow infiltration and treatment through their vegetated, engineered base material.

Runoff in excess of the water quality volume is discharged via overflow weir to nearby surface waters.

4.3.5 Bioretention Basin

Similar to bioinfiltration basins, bioretention basins are intended to capture a first flush of up to 25mm of runoff, providing treatment through a combination of settlement and soil-based bio- and phytoremediation processes, slowly releasing water over 48-72 hours. Bioretention basins will be planted throughout in native vegetation to allow for uptake and treatment of contaminants.

4.3.6 Proprietary Device

Proprietary devices are currently not proposed on the Project but may be used if necessary to treat isolated areas. Depending on the proprietary device selected, the treatment efficacy can match or exceed the devices shown above.

4.4 Proposed Motorway Stormwater Drainage Overview

4.4.1 Kaiapoi River Catchment

South of the Kaiapoi River Bridge (CH -500 to 320)

South of the Kaiapoi River Bridge, within the Kaiapoi urban area, the proposed southbound widening to the central median will have a crossfall into the median. In this area, a grass treatment swale is proposed to collect and treat runoff from the added lane. This treatment swale will flow to an existing 600mm stormwater pipe that crosses the motorway alignment at chainage -380. This pipe discharges into Parhams Drain on the east side of the motorway, from where it is discharged through the pump station to the Kaiapoi River.

Kaiapoi River Bridge Area (CH 320 to 580)

At the Kaiapoi River Bridge, the proposed new lane will fall toward the existing roadway, where flow is discharged via deck drains directly to the underlying river, rail corridor of Adderly Terrace. Based on the existing bridge arrangement no water quality treatment is practical at this location, as the bridge cannot be easily retrofitted to capture and convey runoff to a location to treat it.

In the approximately 100 metres north of the bridge, the additional lane will continue to fall toward the existing SH1 southbound lanes, flowing over the embankment and where it will be collected by the existing stormwater network that parallels the Kaiapoi River stopbank. This system includes a broad swale that likely provides treatment prior to discharge to the Kaiapoi River.

4.4.2 Cam River Catchment

Lineside Road to Cam River (CH 0580 to 3190)

Through this section, the scope of the proposed improvements expands to include an additional lane in each direction from Ch 1400. Stormwater management in this reach consists of bioretention swales on both sides of the roadway that discharge into the Cam River branch Drains at CH1610 and 2350.

In addition to the treatment swales, cutoff drains will manage off site flows, to prevent intermingling offsite water with the roadway runoff.

Cam River Bridge and Williams Street Interchange (CH 3190 to 3620)

Between the Cam River Bridge and the William Street overpass, runoff from the mainline lanes and the southbound onramp will be collected in a stormwater network. This stormwater network will discharge into a proposed bioretention basin located in the triangle between the motorway mainline, the northbound offramp and Williams Street. Stormwater in this area will be treated by the bioretention facility prior to being released to the Cam River via a proposed pipe beneath the northbound offramp.

The northbound offramp itself will be treated by a treatment swale prior to being discharged to the Cam River.

Williams Street is proposed to be realigned to accommodate the new ramps. South of the intersection with the northbound offramp, runoff for Williams Street will be managed by a series of swales and catchpits that discharge into the bioretention basin.

North of the offramp, the flow will be collected in a treatment swale on the east side of the (superelevated) roadway before flowing beneath the roadway and being discharged into the Cam River via a cutoff drain.

4.4.3 Quarry Lakes Catchment

Quarry Lakes (CH 3620 to 4730)

North of the Williams Street overpass, the proposed roadway alignment enters the Quarry Lakes Catchment. For this catchment, stormwater treatment will be managed through 2 proposed bioinfiltration basins, located on the north side of the roadway, atop the quarry lakes hydraulic fill. This fill material provides a highly permeable connection to the lakes, allowing for installation of the passive groundwater infiltration-based treatment facility. For the initial 200 metres beyond the Williams Street Interchange, runoff will be collected within a stormwater reticulation which will discharge to the south side of the bioinfiltration basin. Within the remainder of this catchment, runoff is either discharged directly into the basin from the superelevated roadway, or via short swales.

4.4.4 Mcintosh Drain Catchment

CH 4730 to 5800

After traversing the Quarry Lakes, the alignment enters the McIntosh Drain Catchment, crossing McIntosh Drain itself at CH 5000. The existing land use in this catchment entirely consists of undeveloped greenfield land, with agricultural use and very little existing stormwater infrastructure.

Throughout this entire reach, the proposed roadway is superelevated to the west, requiring stormwater management only on the west side of the roadway.

Runoff from the roadway is collected in proposed vegetated bioretention swales, providing treatment before discharge to McIntosh Drain on the west side of the roadway.

Proposed cutoff drains on both sides of the of the proposed roadway collect offsite flows, separating them from the roadway runoff and conveying them to McIntosh Drain.

4.4.5 Waihora Stream Catchment

From CH 5800, the roadway enters the Waihora Stream Catchment. This catchment is characterized by undeveloped greenfield land, with agricultural use and two major roadway crossings. As discussed above, the lower reaches of Waihora Stream consists of poorly defined broad channels, with soils with very high characteristic infiltration rates, while the upper portion consists of a spring fed perennial stream, which infiltrates via high porosity soil wetlands downstream of the existing roadway crossing.

CH 5800 to Woodend Beach Road (CH 6400)

From CH 5800, stormwater runoff from the roadway is directed to the north, to Waihora Stream. In this location, there is no superelevation, therefore bioinfiltration swales on each side of the roadway will collect runoff allowing for passive infiltration, treatment and attenuation. These swales discharge excess flow into the cutoff drain and its associated 600mm culvert at CH6300, on the south side of the proposed Woodend Beach Road overpass. This drain flows to the east, discharging into a Waihora Stream tributary channel approximately 100 metres upstream of Waihora Stream.

The Project includes a significant realignment of Woodend Beach Road to facilitate its overpass of the proposed motorway. Through this realignment, Woodend Beach Road is elevated above the ground levels on both sides as it ramps up and over the motorway. Stormwater on these embankments is collected in a stormwater reticulation on both sides of the overpass. On both sides, the reticulation ties into a bioinfiltration swale that runs along the embankments back to the motorway, ultimately discharging into Waihora Stream, which crosses Woodend Beach Road via the proposed 1500 x 750 mm culvert, approximately 200 metres east of the overpass.

Roadway runoff from the mainline north of Woodend Beach Road (up to CH 7100) flows in bioinfiltration swales on either side of the proposed motorway, which join Waihora Stream via channels and culverts on the north side of Woodend Beach Road.

Woodend Beach Road to Gladstone Road (CH 6400 to 7700)

From Woodend Beach Road north, runoff from the proposed motorway is directed into bioinfiltration swales on both sides of the roadway, discharging to the south as discussed in the previous section. At CH 7000, the roadway transitions into a superelevated section, falling to the west, so the eastern bioinfiltration swale is discontinued at this point. At CH 7100, the roadway passes a high point, thus the western bioinfiltration swale transitions to flowing north. Runoff from the western bioinfiltration swale between CH 7100 and 7770 (approx. 170 metres north of Gladstone Road) discharges to a proposed 600mm culvert beneath the mainline at CH7400. This culvert joins the proposed Waihora Stream diversion on the eastern side of the roadway, which ultimately rejoins the existing Waihora Stream alignment at CH 7000.

Gladstone Road is proposed to pass over the Motorway at Ch 7600. As Gladstone Road ramps over the motorway, runoff from the embankments on both sides is collected in proposed stormwater reticulations that ultimately discharge into bioinfiltration swales on the northern side of Gladstone Road, on both sides of the Motorway. On the western side of the motorway, this bioinfiltration swale joins the motorway's western bioinfiltration swale described above. On the eastern side of the motorway, the swale joins the proposed realignment of Waihora Stream, passing through a proposed culvert under Gladstone road approximately 50 metres east of the overpass.

Gladstone Road to Pegasus Interchange (CH 7700 to 9570)

Between Gladstone Road and CH 8400, the motorway remains superelevated, falling to the west. In this section, a proposed bioinfiltration swale on the west side of the road collects roadway runoff from the proposed culvert at CH 7980, which discharges into the realigned Waihora Stream on the east side of the

roadway. Immediately upstream (north) of Gladstone Road, this realigned channel traverses a historic landfill, that has been identified as a HAIL site for a distance of approximately 100 metres.

At CH 8400, the roadway transitions to superelevation, falling to the east. As a result, between Ch8400 and 8850, the roadway runoff is collected in a bioinfiltration swale on east side of the motorway that discharges into the beginning of the realigned section of Waihora Stream at CH 8270.

From CH 8850 to the culvert at CH 9100, the roadway remains superelevated to the east and there is a bioinfiltration swale flowing north, discharging into Waihora Stream.

Between CH 9100 and the Pegasus interchange (CH 9570), flow from the mainline and southbound Pegasus onramp discharge into a series of swales and stormwater reticulations, that are ultimately flow to a proposed bioretention basin located just northeast of the Waihora Stream Culvert at CH 9250.

4.4.6 Taranaki Stream Catchment

Pegasus Interchange Area (CH 9150 to 9830)

South of the Pegasus Interchange, the mainline of the proposed motorway and the southbound onramp both drain to Waihora Stream as described above. However, the northbound offramp flows to Taranaki Stream. Runoff from this offramp flows to a swale and stormwater pipe located between the offramp and mainline. This system discharges to the proposed bioretention basin, spanning both sides of Bob Robertson Drive (Pegasus Blvd) between CH 9500 and 9700.

This proposed bioretention basin also collects flow between from Pegasus Blvd beneath the overpass and the northbound onramp through channels and stormwater reticulation systems. This proposed bioretention basin discharges directly into the proposed Taranaki Stream Culvert at Ch 9700.

The proposed southbound offramp follows the alignment of the existing SH1 roadway, falling to the east , where runoff is collected in a series of short bioinfiltration swales that discharge into Taranaki Stream at CH 9700 and its tributary channel at CH 9830.

North of Pegasus Interchange (CH 9830 to 10300)

North of the Pegasus interchange the motorway transitions back into dual carriageway, tapering to match the existing SH1 geometry. This section has no superelevation, and stormwater is discharged to either side of the road. On the western side of the road, a proposed bioretention swale between CH 9830 and CH 10100 collects and treats runoff, discharging south, discharging to the Taranaki Branch culvert inlet at CH 9830.

On the eastern side of the road from the Taranaki Branch culvert north to the Project limits, the existing roadway runoff discharges to the golf course in a dispersed manner, with the golf course essentially forming a wide vegetated buffer, slowing and treating runoff before discharging into the golf course ponds. In order to maintain this dispersed drainage arrangement and to avoid concentrating flow, there are no swales proposed within this location. This is supported by the minimal additional impervious surfaces added at this location.

On the west side of the road from CH 10100 north, a proposed bioretention swale collects and treat roadway runoff, discharging to the existing SH1 roadside swales at the Project limits at CH 10300.

Garlick Street

The Project works include an extension of Garlick Street, adjacent to the Ravenswood subdivision, to tie into the existing SH1 alignment. This section of roadway will be collected by proposed kerb and channel, which will be discharged into the existing Ravenswood stormwater management system for treatment and attenuation.

5 Assessment of Effects

The following sections discuss the positive effects and the potential adverse impact of the Project works resulting from stormwater management.

5.1 Stormwater Quality

5.1.1 Potential Effects

Increased Surface Water Runoff Contaminant Loading

Stormwater runoff from roadways contains a wide range of contaminants introduced through both direct vehicular activity and atmospheric deposition. Among these, suspended solids, hydrocarbons, and heavy metals are of particular concern due to their prevalence, persistence, and environmental impact. Suspended solids often consist of fine particles such as silt, organic matter, tire wear debris, and dust from pavement abrasion. These solids can reduce water quality by increasing turbidity, transporting attached pollutants, and affecting aquatic habitat by smothering benthic organisms or altering stream geomorphology.

Hydrocarbons can degrade water quality through both direct and indirect contamination. When they enter aquatic environments, such as through oil spills or road runoff, they often form surface films that limit oxygen exchange, which can harm aquatic life. In addition, the breakdown of hydrocarbons by microbes can consume large amounts of dissolved oxygen, sometimes leading to low-oxygen or even oxygen-free conditions that threaten aquatic ecosystems.

Heavy metals, including zinc, copper, lead, and cadmium, are introduced through wear and corrosion of vehicle components (e.g., brake pads, tires, and engine parts), as well as from road surface degradation and atmospheric fallout. These metals can be toxic to aquatic life even at relatively low concentrations and have a tendency to accumulate in sediments, where they can pose long-term ecological risks.

When comparing stormwater runoff quality from the proposed motorway to the existing, primarily agricultural, land uses, the most pronounced increase in contaminant loading typically occurs in the concentrations of heavy metals and suspended solids. Agricultural runoff may already contain elevated levels of nutrients (e.g., nitrogen and phosphorus from fertilizers) and microbial contaminants (e.g. from livestock waste), but generally exhibits lower levels of heavy metals.

Increased Groundwater Contaminant Loading

Although there are no proposed formalised point soakage facilities (e.g. soakpits), throughout much of the Project area, stormwater discharges to ground during frequent low flow runoff events are expected, and part of the overall project's hydraulic neutrality philosophy.

Infiltration processes tend to favour the transport of dissolved pollutants over particulate-bound contaminants, as suspended solids and particulate-associated heavy metals are more likely to be retained in the upper soil profile or intercepted by vegetation and surface roughness. In contrast, dissolved species, including ionic forms of metals such as zinc, copper, and cadmium, are more mobile and can percolate through the vadose zone to reach the groundwater table. These dissolved heavy metals are of particular concern due to their potential toxicity, persistence, and ability to bioaccumulate in aquatic ecosystems if groundwater contributes to baseflow in nearby streams or wetlands.

There is a risk that the portion of the realigned Waihora Creek channel that traverses the historic landfill / HAIL site mobilises contaminants from the historic landfill. There are a series of options under consideration for the management of this site, which are discussed in detail in the Construction Methodology Statement. These options include partial or full removal of landfill materials depending on geotechnical suitability.

The risk of increased contaminant loading to groundwater is therefore an important consideration in the overall assessment and design of stormwater effects.

5.1.2 Proposed Mitigations

The primary mitigation for stormwater quality is the inclusion of stormwater treatment facilities. The Project proposes treatment for all runoff from motorway pavements within the Project extents, with limited exceptions, in accordance with the NZTA P46 stormwater specification and the NZTA stormwater treatment standard.

The proposed treatment devices are capable of removing a broad spectrum of contaminants including total suspended solids, heavy metals, hydrocarbons and nutrients. While it is noted that the efficacy of stormwater treatment devices varies widely depending on vegetation cover, contaminant loading, hydrological cycles, and seasons, the proposed devices have been selected to achieve the required NZTA treatment standards.

The general efficacy in terms of expected contaminant removal percentages of the various proposed stormwater treatment devices is shown below, these devices are discussed in detail in Section 4.3 of this AEE:

Table 5-1 Expected Treatment Efficacy Overview

Device	Total Suspended Solids (TSS)	Heavy Metals	Nutrients
Grass Lined Swale	70%	60%- 75%	20% - 30%
Bioinfiltration Swale	80%	70% - 80%	30% - 60%
Bioretention Swale	70%	60% - 75%	20% - 30%
Bioinfiltration Basin	80%	70%-80%	30% - 60%
Bioretention Basin	75%	40% - 50%	30% - 55%

Values taken from NZTA Stormwater Treatment Standard

Within the historic landfill / HAIL site north of Gladstone Road, the realigned Waihora Stream channel will be managed to preclude mobilising contaminants. Depending on the option selected for management of this site, this may include providing an impermeable liner within this portion of the channel to minimise infiltration to groundwater. Refer to the Groundwater Effects Assessment report and Contaminated Land Investigation for further information.

This analysis is generalised, covering the primary classes of contaminants present in roadway runoff and broad treatment efficiencies for various components within each class.

5.1.3 Summary and Residual Effects

Stormwater water quality treatment devices are to be installed in general accordance with NZTA P46 and NZTA stormwater treatment standard guidelines. Any future design refinements to the proposed water quality treatment devices to be in general accordance with the relevant guidelines and engineering practice. These devices provide means for promoting infiltration, settlement and the biological treatment of pollutants, all of which contribute to downstream water quality. The performance of the treatment devices will be supported through regular inspection and maintenance to ensure continued effectiveness in the long term.

Where the Project is coincident with the existing SH1 alignment (within the Cam River, Waihora Stream and Taranaki Stream catchments), there is expected to be a substantial Improvement of water quality discharging to the receiving environment. SH1 currently has no formal treatment devices within the project area and the Project proposes the installation of treatment devices to treat stormwater runoff from the vast

majority of proposed motorway impervious surfaces. Furthermore, the reduction in traffic volumes to the existing SH1 alignment north of Cam River will reduce contaminant inflows from the existing SH1 roadway.

Although the proposed treatment devices will remove a significant fraction of the contaminants generated by the proposed motorway, no treatment device is capable of full removal of all contaminants. The selected devices align with engineering practice and are intended to minimise the residual effects of contaminants on the receiving environment, reducing the effects to less than minor.

5.2 Flooding and Stormwater Quantity

5.2.1 Potential Effects

Localised Increase in Flood Depths in a Private Property

The Project proposes to place fill within flooding zones, install new bridges and culverts, realign channels and modify overland flow paths. Without appropriate design and mitigation, these activities can result in adverse impacts to private property adjacent to, and downstream of the work.

Increase in Stormwater Volumes Conveyed to Downstream Catchments

The Project also proposes to place a significant amount of new impervious area. This could result in an overall increase runoff resulting from additional impervious areas project wide resulting in an increase in the frequency, duration, and volume of runoff resulting from rainfall events.

5.2.2 Proposed Mitigations

Flood modelling has been undertaken to identify the potential impact of the proposed motorway on flooding in the vicinity of the Project. This flood modelling is intended to holistically quantify the effects of proposed earthworks, hydraulic structures, and added impervious areas. The effect of the Project on flooding outcomes adjacent to the site is documented in the flood modelling report, which is included in Appendix A.

The flood modelling analysis indicated flood levels increased in various locations due to the proposed road development, with most flooded zones confined to the vicinity of the proposed road corridor. Additionally, elevated flood levels were observed in the residential areas along Main North Road, Woodend Beach Road, and Wards Road during both the 100-year and 200-year ARI events.

Two primary measures, being the introduction of additional culverts and the diversion of flow path channels, are proposed and modelled to manage and mitigate the flood impacts. The mitigation model demonstrates that these measures effectively reduce flood impacts during both the 100-year and 200-year ARI events, with significant improvements at previously affected properties, excluding those identified for acquisition, which will be demolished.

Additional mitigation measures as discussed in Appendix A Section 2.5.1 are proposed to further reduce flood impacts, including adjustments to bypass channel levels at the north of Pegasus roundabout, upsizing culverts on Gladstone Road and Woodend Beach Road, and introducing check dams or detention basins to manage downstream effects. Overall, the current mitigation strategy demonstrates the Project's ability to meet flood management objectives.

Table 5-2 200-year ARI flood level and differences at buildings (Mitigation vs Pre-development scenario)

Point ID	Location	100-year ARI			200-year ARI		
		Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)	Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)
1	5 Wards Rd*	8.26	8.26	0	8.37	8.28	-90
2	196 Woodend Beach Rd	4.13	4.14	4	4.23	4.22	-13
3	1271 Main North Rd*	8.11	8.11	0	8.16	8.07	-83
4	1263 Main North Rd	8.29	8.29	0	8.29	8.29	0
5	1279 Main North Rd*	8	8	0	8.03	8.02	-10
6	1273 Main North Rd*	8.09	8.09	0	8.15	8.10	-50
7	1277 Main North Rd*	8.02	8.02	0	8.07	8.05	-20
8	1319 Main North Road	6.41	6.41	0	6.46	6.46	1

* Properties will be acquired as part of project work delineation. Flood impacts within designation have been considered acceptable.

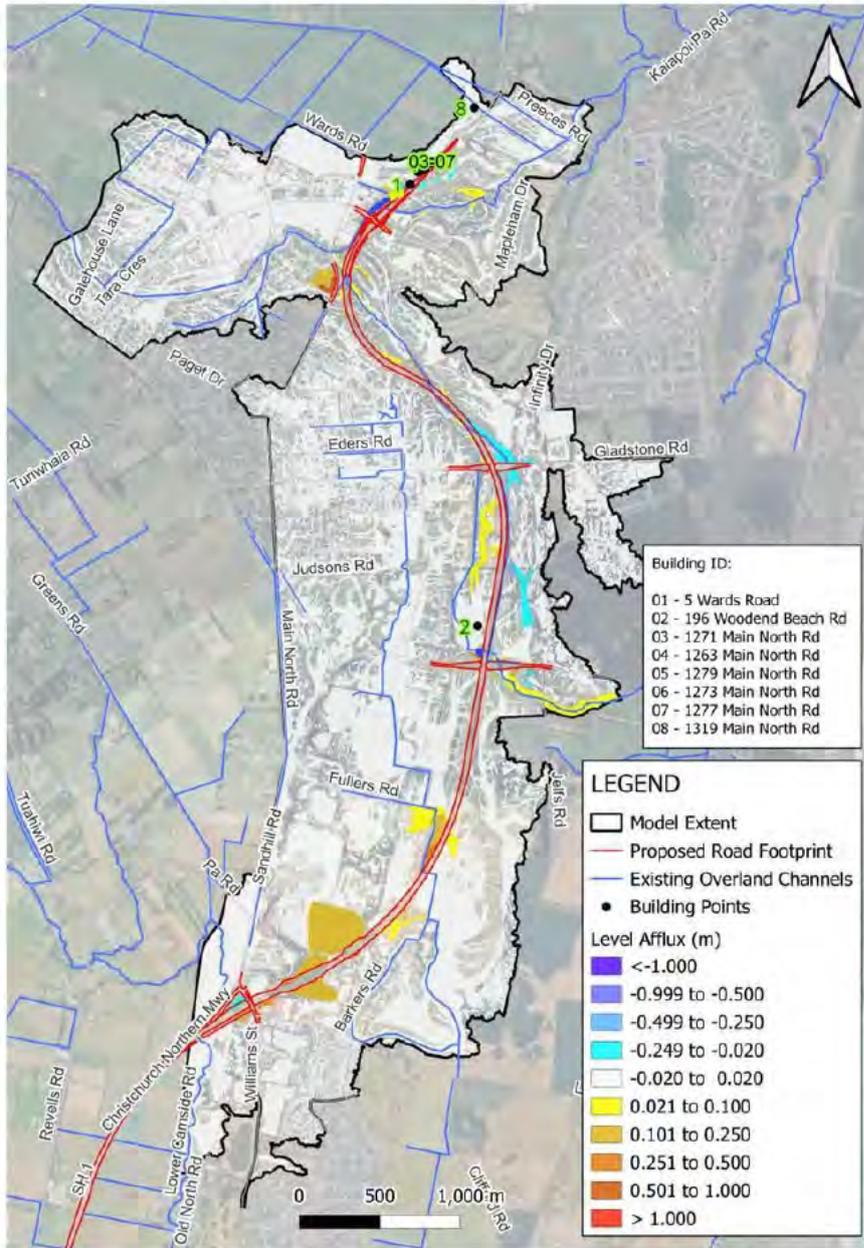


Figure 5-1 Private buildings affected under 200 year ARI (mitigated scenario)

Water level increases have been observed in the locations listed in Table 5-3 and as shown in Figure 5-2, which are outside the designation boundary. However, these increases do not affect any property buildings.

Table 5-3 Locations that observed a water level increase outside of designation boundaries

Locations	Max Afflux (mm)		Comments
	100-yr	200-yr	
1. Mapleham Dr	2	20	The increase in water depth is due to the upsizing of the Taranaki Stream culvert. However, the impacts remain within the channel and do not affect any buildings.

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Locations	Max Afflux (mm)		Comments
	100-yr	200-yr	
2. Basin within Ravenswood residential area	200	670	Water depth increase is caused by raising the overflow weir from RL 10.20 m to RL 10.40 m to accommodate the proposed road (Garlick Street). The increased depth is confined within the basin and poses no risk to nearby properties.
3. Downstream of Waihora Creek	210	440	Higher water levels indicated in the model due to reduced roadway overtopping of Taranaki Stream north of Bob Robertson Drive, redirecting slightly more runoff into Waihora Creek. The impact is contained within the channel and does not affect any buildings.
4. West of Copper Beech Road	40	50	Water ponding is due to the motorway cutting off an existing overland flow path. The ponding is localised and does not impact any buildings.
5. Downstream of Woodend Beach Road	20	50	Flood levels within Waihora Creek rise slightly due to more efficient conveyance from the proposed bypass and both culverts at Gladstone Road and Woodend Beach Road have been upsized. No buildings are affected, and the impacts are confined within the channel.
6. Upstream of McIntosh Drain	130	280	For the upstream reach of McIntosh Drain, fully resolving the flood impacts remains challenging since maintaining the original flow area, spanning approximately 300 meters, will require significant structural measures (e.g. more culverts, bridges, etc.). This increase is largely confined to land owned by NZTA which does not include any residential properties.
7. Within the Quarry Lake.	0	120	Water level increases are shown within the model resulting from storage loss from the proposed bypass road infilling the lake. It is noted that the water level in the ponds generally reflects existing groundwater levels and the model assumes no infiltration. However, as the quarry bottom is directly connected to groundwater, flood afflux is expected to be minimal due to this continuous interchange with groundwater.

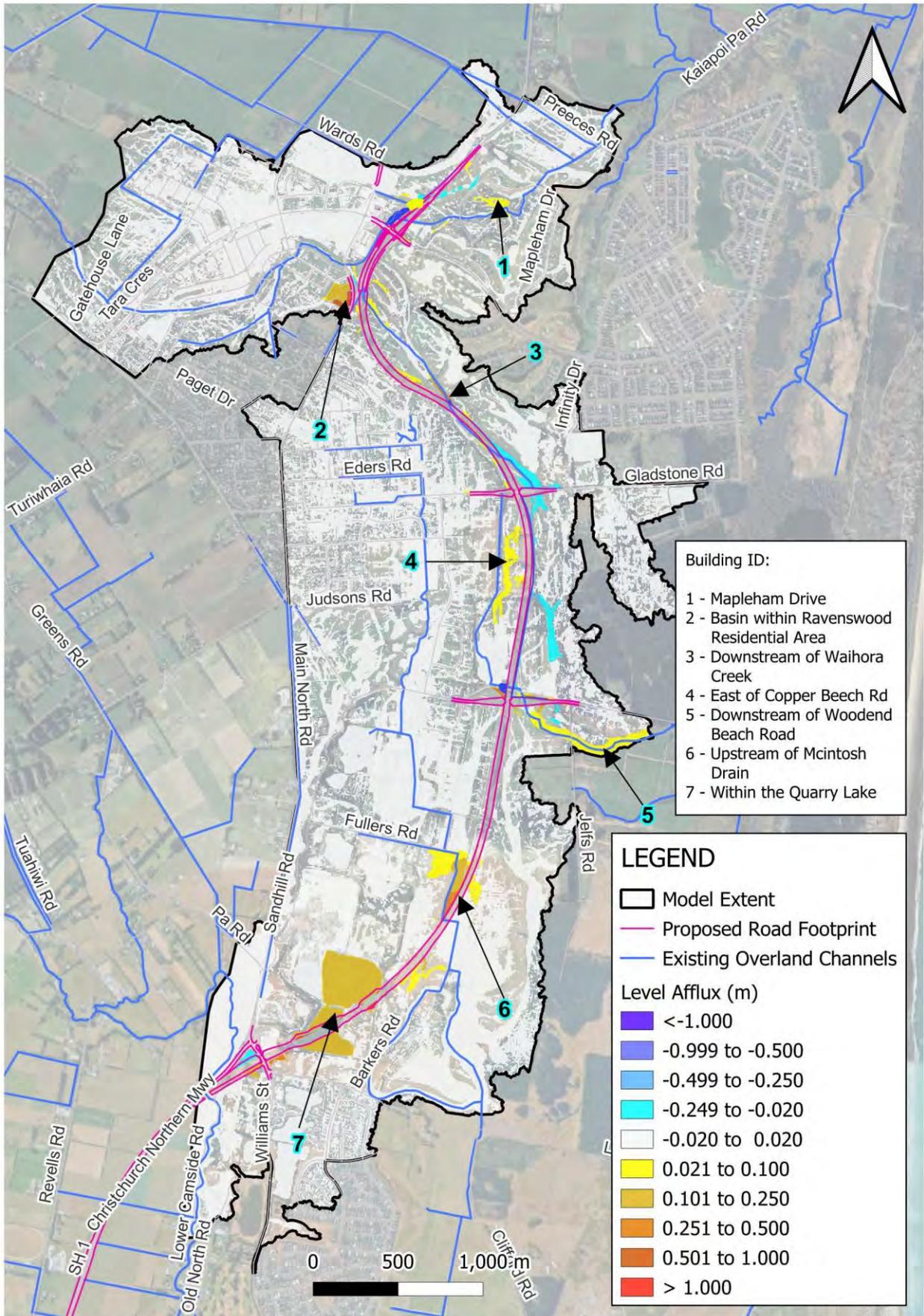


Figure 5-2 Residual impacts outside the designation but does not impact any property buildings (200 year ARI afflux level)

Within the Cam River catchment, between Lineside Road and the Cam River, the Project traverses a wide, shallow basin, that impounds water. The roadway in this section is sited below the modelled flood level. In this reach, the roadway improvements are limited to adding lanes, without increasing the existing roadway crest level. This ensures that floodwaters will move over the road in the same flow patterns as existing. As a result, the potential flood impacts of the work are related to displacement of flood storage within the impounded floodwaters. An assessment has been completed, considering the impact of the proposed roadway fill on the modelled flood levels. Based on this assessment, the calculated potential increase in flood levels within this impounded flood area is limited to 1.5mm to 3mm, considered a negligible effect.

The Project proposes the installation of swales that include features to slow and impound water, allowing for infiltration and peak flow attenuation prior to discharge to the receiving environment. In catchments where the existing hydrologic regime is dominated by infiltration (i.e. Quarry Ponds and Waihora Stream), distributed infiltration methods (i.e. bioinfiltration swales and basins) are utilised, allowing for infiltration to occur as close to the point of origin. These features will allow the proposed stormwater network to closely mimic the natural system's infiltration regime, minimising the impact of the Project. It is noted that this enhanced infiltration is not included in the flood modelling discussed above, and thus the results presented above are conservative.

5.2.3 Summary and Residual Effects

To mitigate potential adverse flooding impacts, the Project has proposed a best practicable option to mitigate the extents and depth of increased flooding on adjacent properties by undertaking an iterative flood modelling driven design approach to limit and mitigate adverse flood impacts. All impacts to buildings have been mitigated by the proposed flood management scheme. Where increases in flood levels are unavoidable, the increases are confined to existing stormwater conveyance channels and basins or are within NZTA property areas.

By incorporating swales and natural drainage features that promote primary infiltration as close as possible to the point of origin, the proposed system will mimic, to the greatest extent possible, the current hydrogeological response of the existing catchment.

Additionally, the Project proposes to increase the resilience of the overall network through replacement of existing cross culverts within the Cam River catchment and at the existing Waihora, Taranaki and Taranaki Branch culverts. This will reduce the risk of culvert failure, potentially causing adverse flooding impacts to the respective catchments.

While the increase in impervious area will locally result in increased volume of excess runoff, this has been considered in the Tuflow flood modelling, ensuring the flood carrying capacity of the waterways is not adversely affected.

Within the Cam River catchment, the proposed work consists of expanding the existing 2 lane roadway to 4 lanes and the addition of new access ramps to facilitate the Williams Street interchange. This work is expected to add approximately 3.8 ha of new impervious area to the catchment. This represents a very small percentage of the overall Cam River catchment of approximately 5,000 ha. Due to the location near the mouth of the Cam and Kaiapoi Rivers peak runoff from the site is not expected to coincide with the timing of peak flows given the extended time of concentration for these catchments.

Additionally, within the Williams Street interchange, a proposed water quality pond will have extended capture volume of approximately 2,000 m³, delaying discharge and attenuating flows from the Williams Street interchange area. Whilst this pond is not being designed to a specific attenuation outcome, it will reduce peak discharges from the most significantly developed portion of added impervious areas within the Cam River catchment.

While the design is optimised to balance the hydraulic and hydrologic effects of the work, there are unavoidable impacts resulting in impacts beyond the Project. These impacts, as documented above, are considered less than minor, resulting in a less than minor impact to the surrounding areas.

5.3 Erosion, Scour and Channel Stability

5.3.1 Potential Effects

Erosion Potential at Culvert Outfalls

There is a risk of erosion and scour at culvert and pipeline outlets during high flow events resulting from localised increased velocities, especially during the initial establishment phase. Concentrated discharges can mobilise fine sediments, undercut outlet structures, and create local depressions that may expand over time if left unmanaged.

Within the Project area, this risk is significantly reduced by the flat, low energy nature of the surroundings, where floodwater dispersal and high tailwaters typically result in floodwaters often not exceeding erosion thresholds.

Scour Potential at Bridges

Bridge scour can significantly contribute to channel erosion and instability by removing sediment from the vicinity of bridges and their approach embankments during high-flow events. This localized erosion alters flow patterns, concentrating energy at the base of manmade structures in the waterway and deepening the channel bed. As scour holes develop, they can undermine structural elements and change how water moves through the channel, often increasing flow velocity and turbulence. These changes can initiate further erosion both upstream and downstream, disrupting the channel's natural equilibrium.

Beyond the immediate vicinity of the bridge, scour can trigger broader geomorphic changes that compromise long-term channel stability. As sediment is removed and not replaced, the channel may begin to incise or shift laterally, leading to bank erosion, habitat degradation, and increased risk to nearby infrastructure. The constriction caused by bridge structures can intensify these effects by accelerating flow and altering sediment transport dynamics. Over time, these changes can set off a cycle of instability that is difficult to reverse without significant intervention.

Realignment or Modification of a Natural Watercourse

As discussed in the previous section, several reaches of the Waihora Stream and Taranaki Creek require realignment to facilitate the proposed motorway. The realignment of a natural watercourse can result in a range of potential adverse effects. It is noted that this report only considers effects related to the hydrologic and hydraulic regime of the watercourses – ecological outcomes are considered within the EclA report.

Changes to channel length, slope, and cross-sectional geometry can disrupt the natural flow regime, leading to either increased velocities and erosion potential or sediment deposition and reduced conveyance capacity. An over-steepened realigned section may cause downstream scour, while flatter sections may accumulate fine sediments, leading to channel instability.

Realigned channels may initially lack the bank stability of natural systems, especially if soils are disturbed and vegetation is not well-established. This can result in bank erosion, slumping, and increased sediment load downstream.

5.3.2 Proposed Mitigations

To mitigate against erosion at culvert and pipeline outlets, erosion protection at discharge locations is to be installed in general accordance with the HEC 14 design guidelines. These guidelines dictate the design and installation of energy dissipation structures, typically consisting of rock riprap at culvert outlets. Ongoing monitoring during the early operational period will help identify any emerging erosion features so they can be addressed promptly, ensuring the long-term stability of outlet areas and minimising sediment inputs to downstream environments.

Scour protection at the proposed Cam and Kaiapoi River bridges will be installed in general accordance with scour assessment and the abutment scour protection measures in accordance with NZTA Bridge Manual guidelines, including HEC 18 and abutment scour protection countermeasures design to be revised in accordance with relevant HEC23 design guidelines.

Where channels are realigned, the channel form will maintain the existing form in geometry and function, maintaining the overall channel geomorphic balance of the existing channels, ensuring long term channel stability. As vegetation is an important element in the long term stability of waterways, proposed planting will ensure that realigned channels are revegetated in a manner that ensures long term stability. Although the low energy of the surrounding environment will maintain low velocities throughout, in locations where hydraulic forces may be concentrated, such as at channel bends and confluences, geotechnical reinforcement linings will be provided to prevent scour and erosion before the establishment of vegetation. Riprap and rock linings are not proposed within any of the realigned channels except at bridge structures and culvert outlets.

5.3.3 Summary and Residual Effects

Overall, the risk of erosion, scour and channel instability throughout the Project area is low. This is primarily due to the low gradient nature of the catchments both upstream and downstream of the Project, and resulting low waterway velocities, and supported by the mitigations discussed above.

These measures will substantially reduce the potential for localised erosion, protect structural integrity, and improve resilience to flooding through strengthened bridge foundations and embankments. Some minor, localised erosion or sediment movement may still occur during extreme events, especially in the early establishment period; however, with ongoing monitoring and maintenance, residual effects on the erosion characteristics of the catchment are expected to be negligible.

6 Conclusion

The stormwater management and hydrological assessment for the State Highway 1 North Canterbury – Woodend Bypass Project demonstrates that the proposed infrastructure has been designed to appropriately manage the effects of proposed earthworks, increased impervious surfaces, altered flow paths, and hydraulic structures. A suite of stormwater treatment and conveyance measures, including swales, bioinfiltration and bioretention basins, and channel realignments, will ensure that the quality of runoff is managed in accordance with NZTA standards and that discharges are treated prior to entering receiving environments.

Flood modelling has confirmed that while the Project introduces changes to flow regimes, the proposed mitigation package, consisting of culverts, channel diversions, and localised storage, effectively addresses potential adverse flooding outcomes. Any residual increases in water levels are confined to existing drainage features or NZTA property and do not result in material effects on third-party assets.

Scour and erosion risks at culverts, bridges, and realigned watercourses have been addressed through targeted design measures, including riprap protection and engineered stabilisation. With these mitigations in place, the residual risk of erosion and scour is expected to be low, and long-term channel stability will be maintained.

Overall, the proposed stormwater and hydrological management framework for the Project represents the best practicable option, balancing the requirements of flood conveyance, water quality treatment, ecological considerations, and infrastructure resilience. With the recommended measures implemented and supported by appropriate monitoring and maintenance, the Project is expected to give rise to effects that are less than minor, while providing improved environmental outcomes relative to the existing SH1 corridor.

Appendices



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Appendix A

Flood Modelling Report

Belfast to Pegasus Motorway & Woodend Bypass Pre-implementation and MSQA Professional Services

Flood Assessment Report

NZ Transport Agency (NZTA)

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1 Introduction and Background

1.1 Background

Waka Kotahi has engaged Aurecon to support the resource consent applications in the proposed Belfast to Pegasus Motorway and Woodend Bypass. In line with this project, a flood assessment has been conducted to evaluate the impact of a 100-year and 200-year Average Recurrence Interval (ARI) storm event on the proposed road development.

For the purposes of the current assessment and to optimise the computation time, a cut-down catchment model tailored to the Project Site and adjacent surroundings as shown in Figure 1-1 has been built using TUFLOW modelling software. The model will be referred to as the “B2P Flood Model” throughout the rest of this report.

The purpose of this report is to outline the following:

- The methodology for building the B2P Flood Model
- A comparison of flood impacts before and after the road development



Figure 1-1 B2P Flood Model Extent with the Proposed Belfast to Pegasus Motorway and Woodend Bypass Road Alignment

1.2 Objectives and Scope of Assessment

The objectives of the current assessment include developing the B2P Flood Model to analyse flood impacts before and after development.

Based on local authority advice, the following objectives have been established for this project:

- No significant increase in flood levels at neighbouring dwellings for the 100-year ARI event.
- Any increase in flood levels at neighbouring dwellings for the 200-year ARI event should be limited to 20 mm.

- Reduce the risk of ponding/runoff buildup that will be brought about by the barrier effect of the proposed road development on adjacent surroundings. Mitigation measures will consist of provision of additional culverts across the road alignment, improvement/rehabilitation of existing culvert structures, and provision of additional channels to improve flow of runoff.

1.3 Flood Model History

Figure 1-2 shows the model extent of the Waimakariri District Council (WDC) South Ashley Flood Model. This flood model was developed in 2019 by DHI using MIKE by DHI modelling software. Detailed information with regard to model build is documented in the May 2020 “Flood Hazard Models Update” report¹.

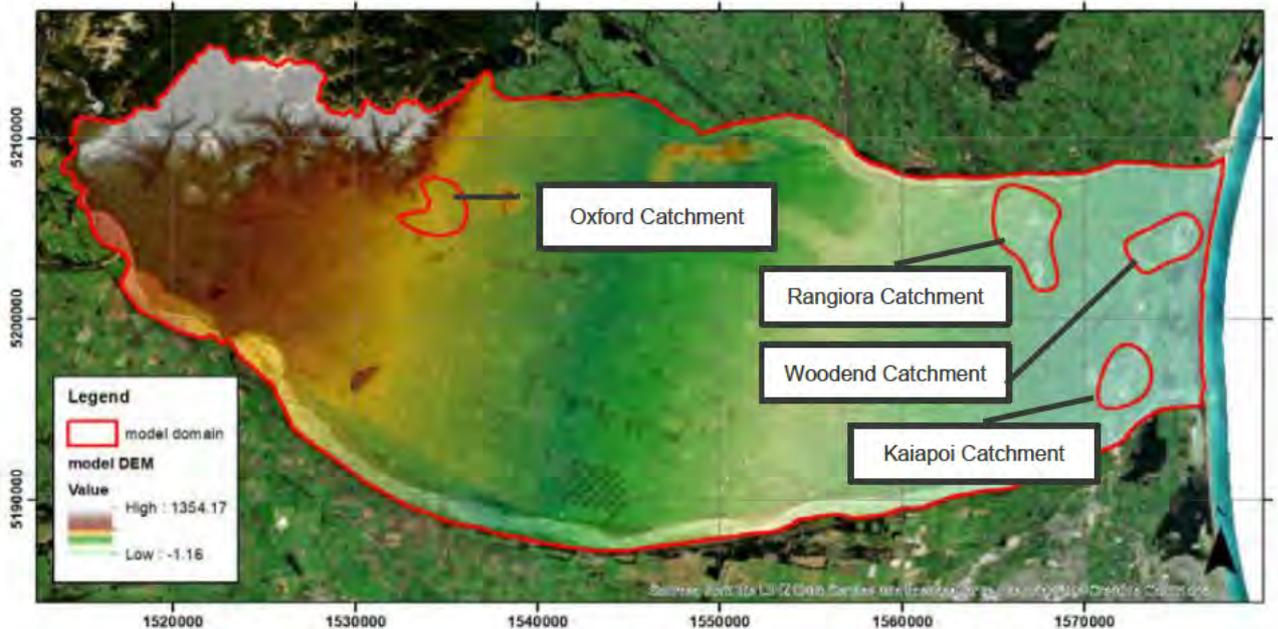


Figure 1-2 South Ashley Model catchment extent²

In this study, the B2P Flood Model has been created for the Project Site by utilising TUFLOW modelling software (Figure 1-3), using the WDC South Ashley Model as a reference.

¹ DHI (May 2020). *Flood Hazard Models Update*.

² Extracted from Flood Hazard Models Update Report.

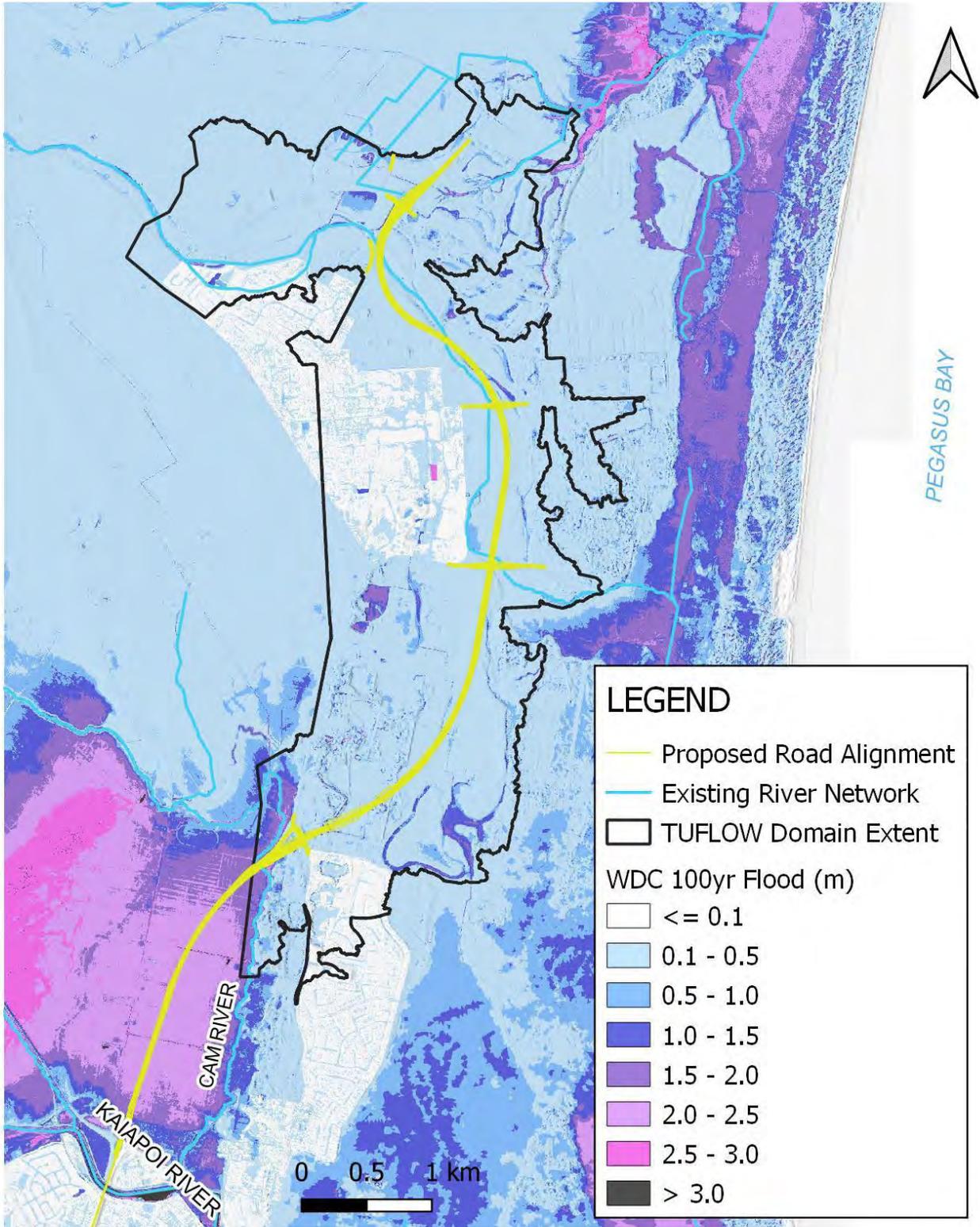


Figure 1-3 Model Extent of B2P - Woodend Flood Model

2 B2P Flood Model Development

The B2P Flood Model extent is a cut-down catchment model tailored to the Project Site and has been built using TUFLOW modelling software. Three modelling scenarios, the Pre-development, Post-development, and Mitigation scenarios were developed and assessed.

The purpose of each scenario is listed in Table 2-1. Further details of these scenarios are discussed in Appendix A. Each scenario has been run for the 100-year and 200-year ARI storm events.

Table 2-1 Model scenarios and purpose

Model Scenario	Scenario Case	Purpose
PREDEV	Existing/pre-development scenario	To understand the existing flooding conditions. This will be the baseline model for the flood impact assessment.
POSTDEV	Design/post-development scenario with Bypass Motorway included	To understand the flood impacts due to Bypass Motorway.
MITIG	Design/post-development scenario with mitigation solution included	To resolve flood impacts identified under the design scenario.

The B2P Flood Model terrain has been updated to incorporate the 2020 LiDAR Digital Elevation Model (DEM) and available surveyed data. The hydrological and hydraulic input data such as rainfall, ground infiltration, and surface roughness are extracted from the WDC South Ashley Model. The detailed model build methodology is described in Appendix A.

Note that for vertical datum, as described in Appendix A, the original flood model was carried out in Lyttleton Vertical Datum (LVD), whereas the B2P Flood Model is in New Zealand Vertical Datum 2016 (NZVD16). Levels within this memorandum are quoted in NZVD16 unless otherwise stated.

The B2P Flood Model is mainly built as a two-dimensional (2D) model, integrating open channels into the DEM, with culverts represented using a one-dimensional (1D) model. Pipe reticulation has been excluded from the B2P Flood Model, in compliance with the WDC requirements regarding the modelling of full pipe blockages.

In the B2P Flood Model, three principal river channels have been identified, as shown in Figure 2-1: the Taranaki Stream, located to the north of Bob Robertson Drive; the Waihora Creek, situated near Garlick Street; and the McIntosh Drain, which lies between Quarry Lake and Woodend Beach Road. The Taranaki Stream flows northward towards Waikuku Beach, while the Waihora Creek initially flows south, then turns east towards Kairaki Creek, close to Woodend Beach Road. The McIntosh Drain also flows south and ultimately merges with the Kaiapoi River.

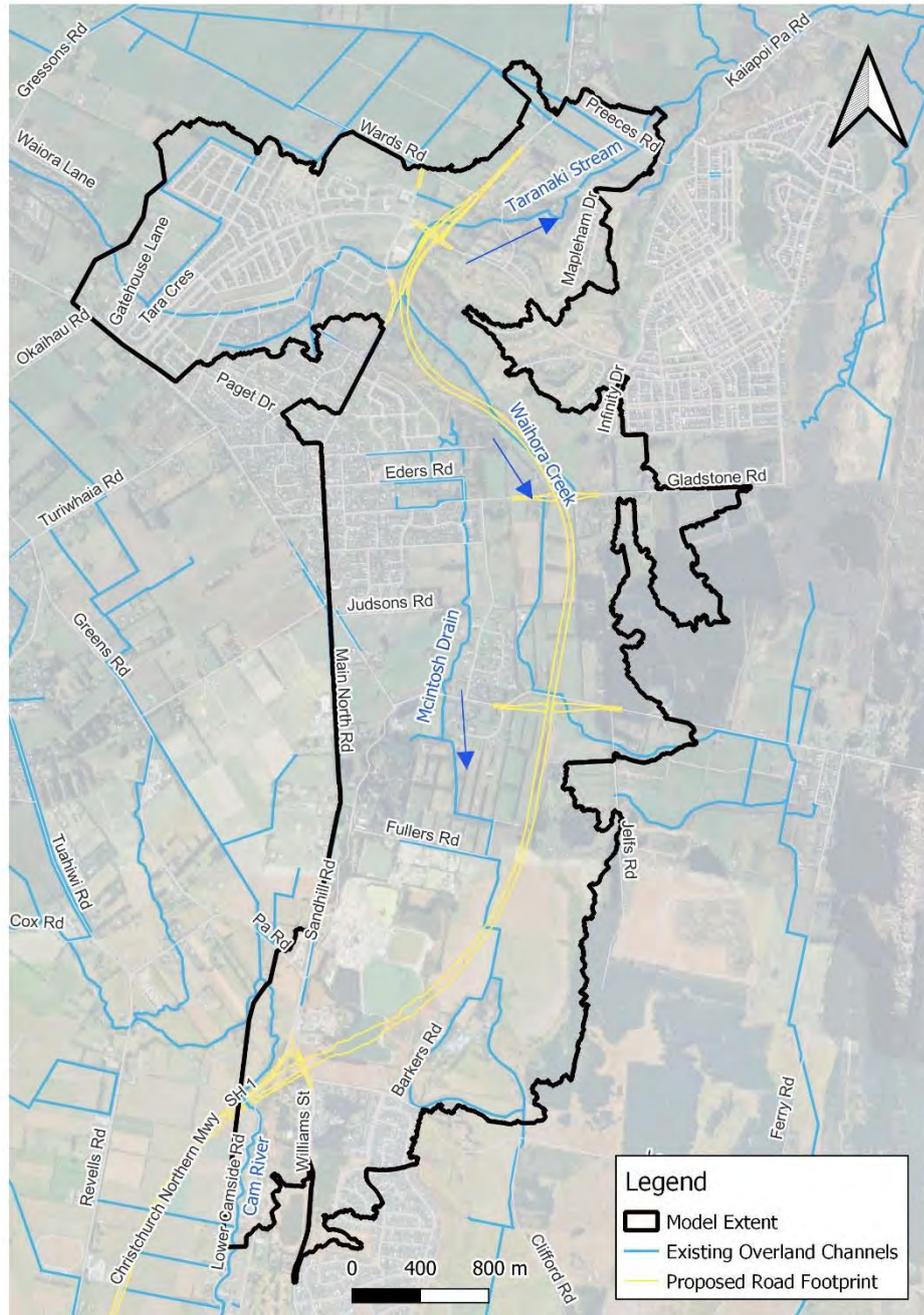


Figure 2-1 Principal River channels within the model catchment extent

A detailed account of the model development methodology is provided in Appendix A, while the updates representing various post-development and mitigation scenarios can be found in Appendix B.

2.1 B2P Pre-Development Model

The detailed model build methodology for B2P Flood Model pre-development scenario (PREDEV) is described in Appendix A Table 1.

Figure C-1 and Figure C-2 (refer to Appendix C) show the maximum flood depth and flood level of the pre-development scenario under the 100-year ARI storm event, Figures C-3 and C-4 present the maximum flood depth and flood level under the 200-year ARI storm event.

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The pre-development model comprises of six existing culverts, that are crossing the project site as shown in Figure 2-2. This includes an irregular twin DN1800 culvert³ on Bob Robertson Drive, a 2.2m x 1.2m box culvert³, and a DN750⁴ circular culvert that cross State Highway 1 (SH1) discharging into the Taranaki Stream, a 4m x 1.5m box culvert³ crossing SH1 that discharges into Waihora Creek, and a 1.25m x 0.5m box culvert located on Gladstone Road and a DN600 circular pipe situated on Woodend Beach Road.

Survey shows that the existing irregular twin DN1800 was embedded by 300mm as part of the fish passage consideration, which will be maintained in the Post-Development and Mitigation scenarios. Ecological assessments have also found that fish are present along the major streams that are affected by the proposed roadway, namely McIntosh Drain, Taranaki, and Waihora Streams. Accessibility for fish movement will be preserved along these streams and will be considered in the proposed mitigation measures.

The Stormwater Network and Culverts inventory, as discussed in Appendix A, details all the culverts that have integrated the passage of fish, in all three case scenarios. Only the effective flow opening area of these culverts have been modelled, with higher surface roughness to incorporate the substrate infill within the culvert.

³ To simplify the modelling process, culverts with fish passage considerations are modelled using only their effective flow opening area.

⁴ Existing 0.85 (W) x 0.65 (H) arch culvert. For modelling simplicity, culvert modelled as DN750 circular culvert.

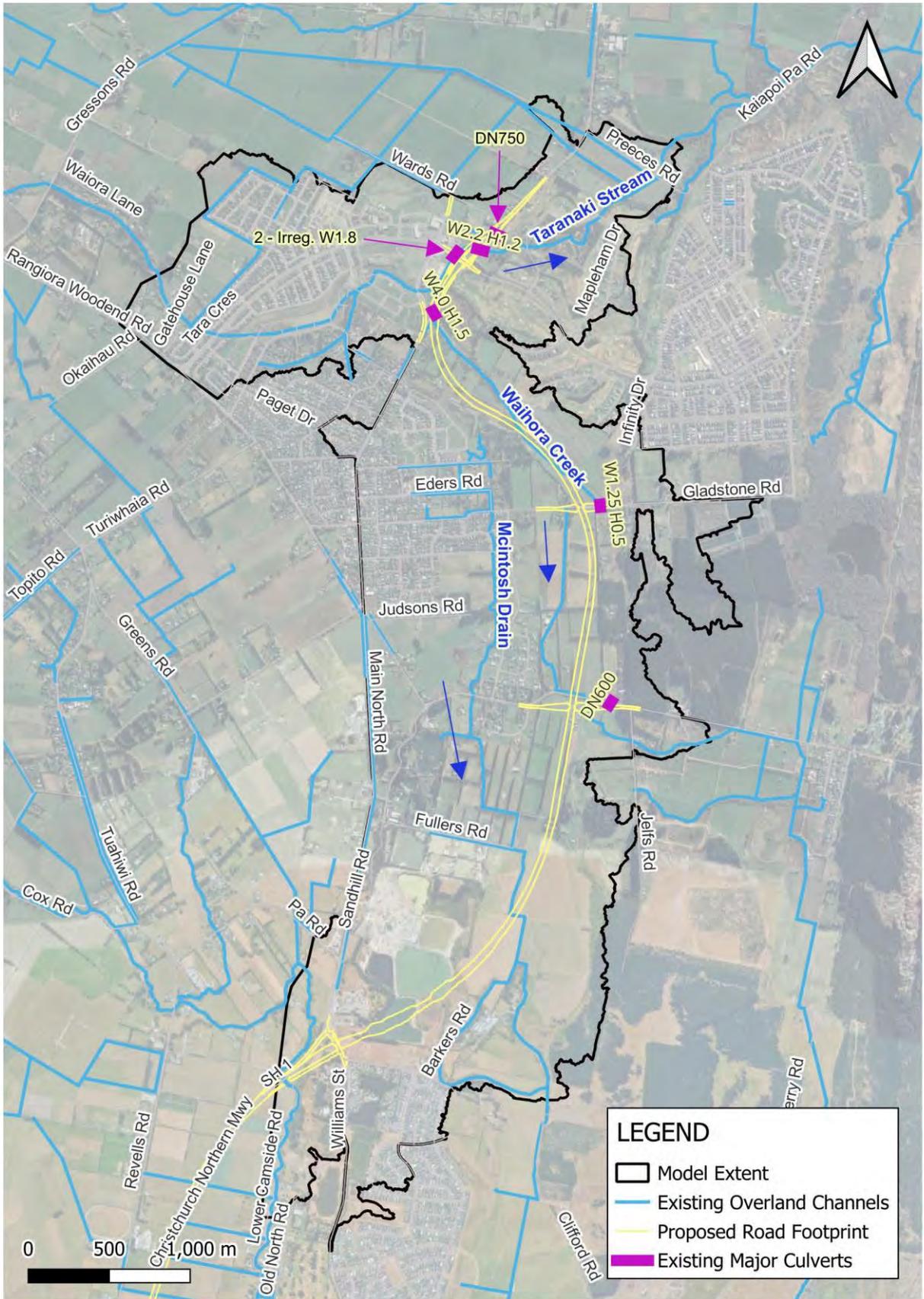


Figure 2-2 Existing culverts crossing proposed road alignment

As shown in Figure 2-3, the runoff splits into three directions:

- The Taranaki Stream catchment flow northward towards Waikuku Beach
- The Waihora Creek catchment flow towards the south and turns east towards the Kairaki Creek
- The McIntosh Drain flow south and ultimately merges with the Kaiapoi River.

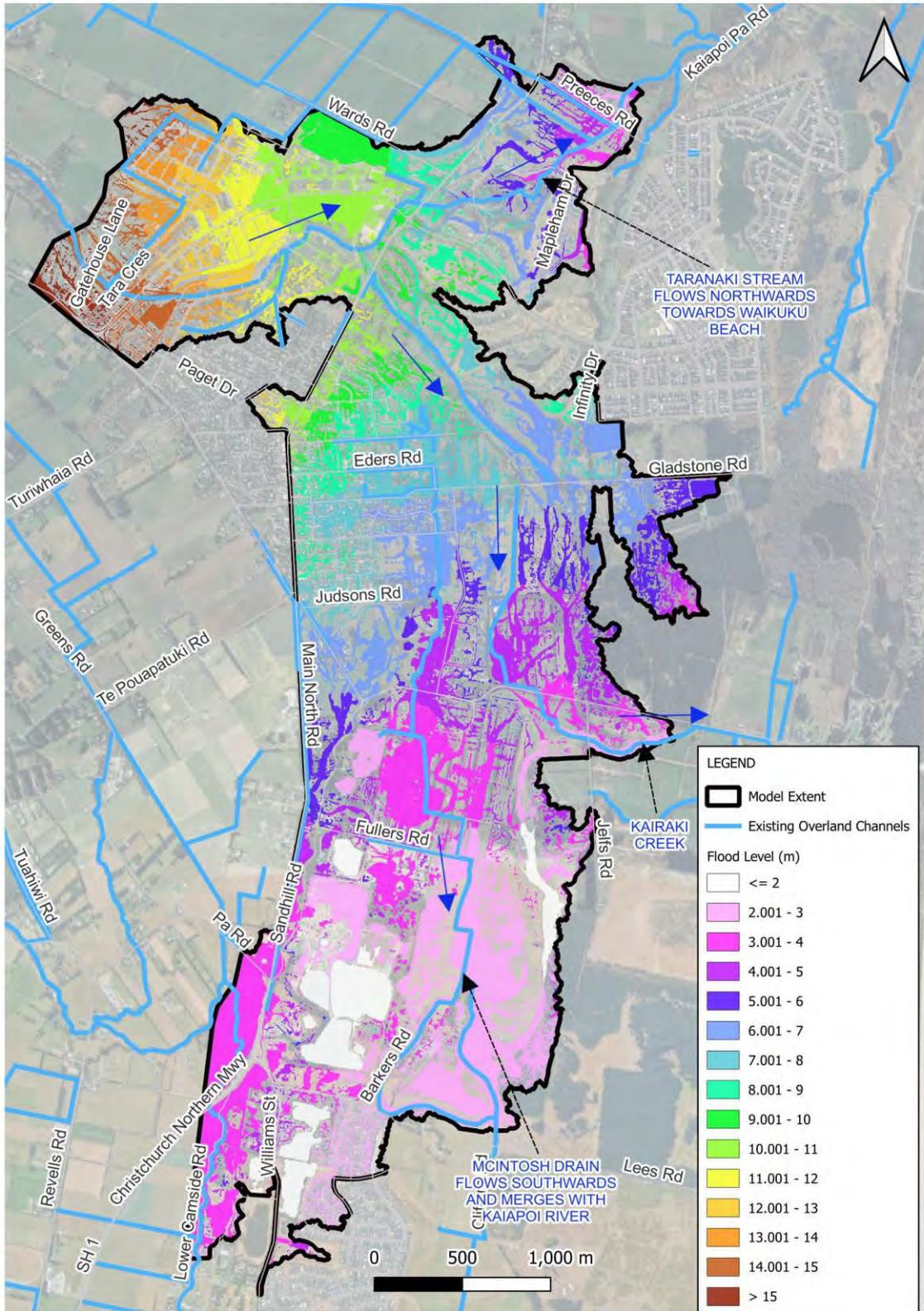


Figure 2-3 B2P Flood Model pre-development flood level under 100-year ARI

2.1.1 Flood Model Validation

Figure 2-4 shows the maximum predicted flood depths for the Existing Scenario in the WDC South Ashley Model for the 100-year ARI event. In comparison with the maximum predicted flood depths of the B2P Flood Model (refer to Figure 2-5), it can be observed that the flood extents are relatively similar, except for a few localised areas which are discussed in Table 2-2.

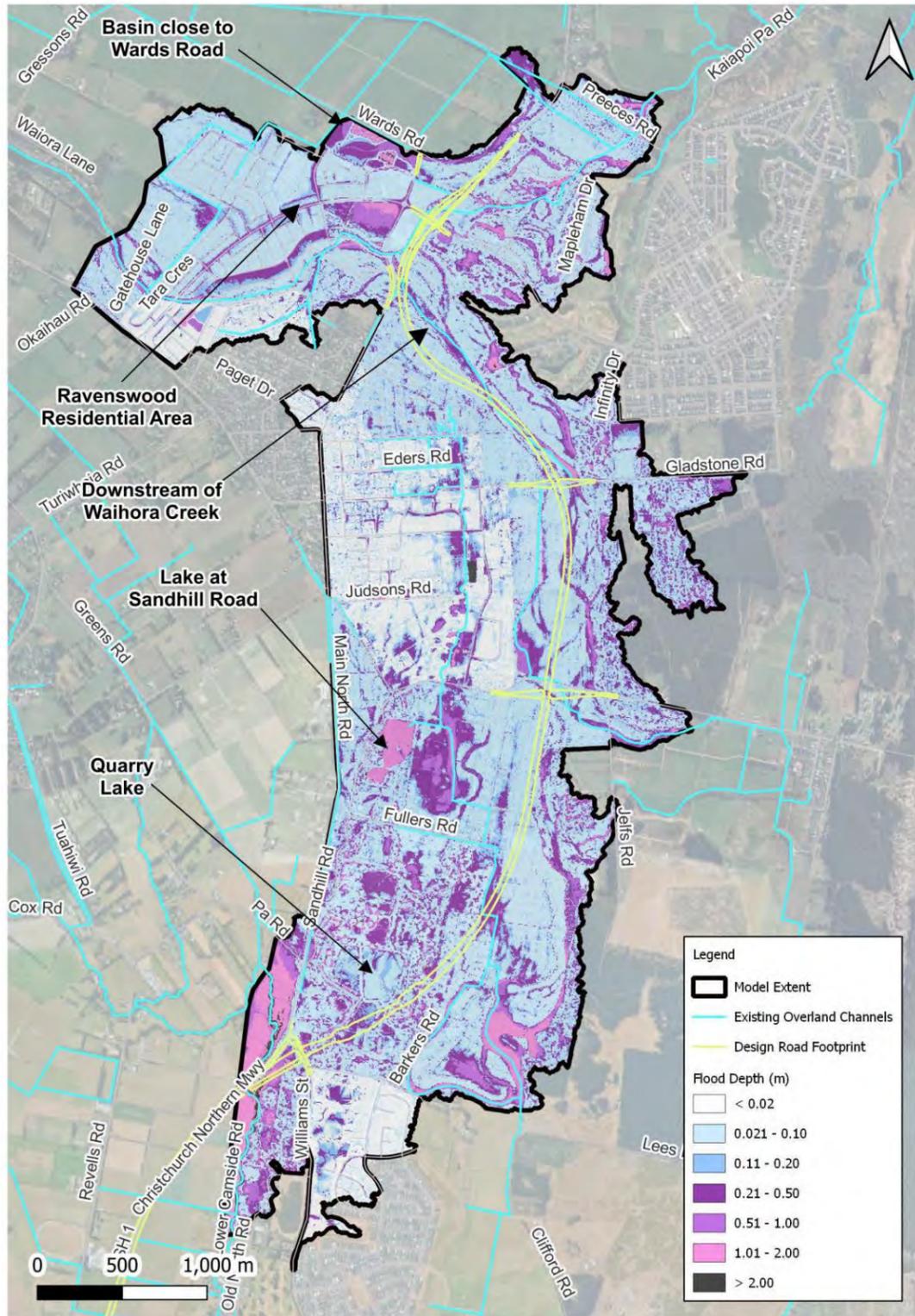


Figure 2-4 WDC South Ashley Model pre-development flood depth for 100-year ARI event

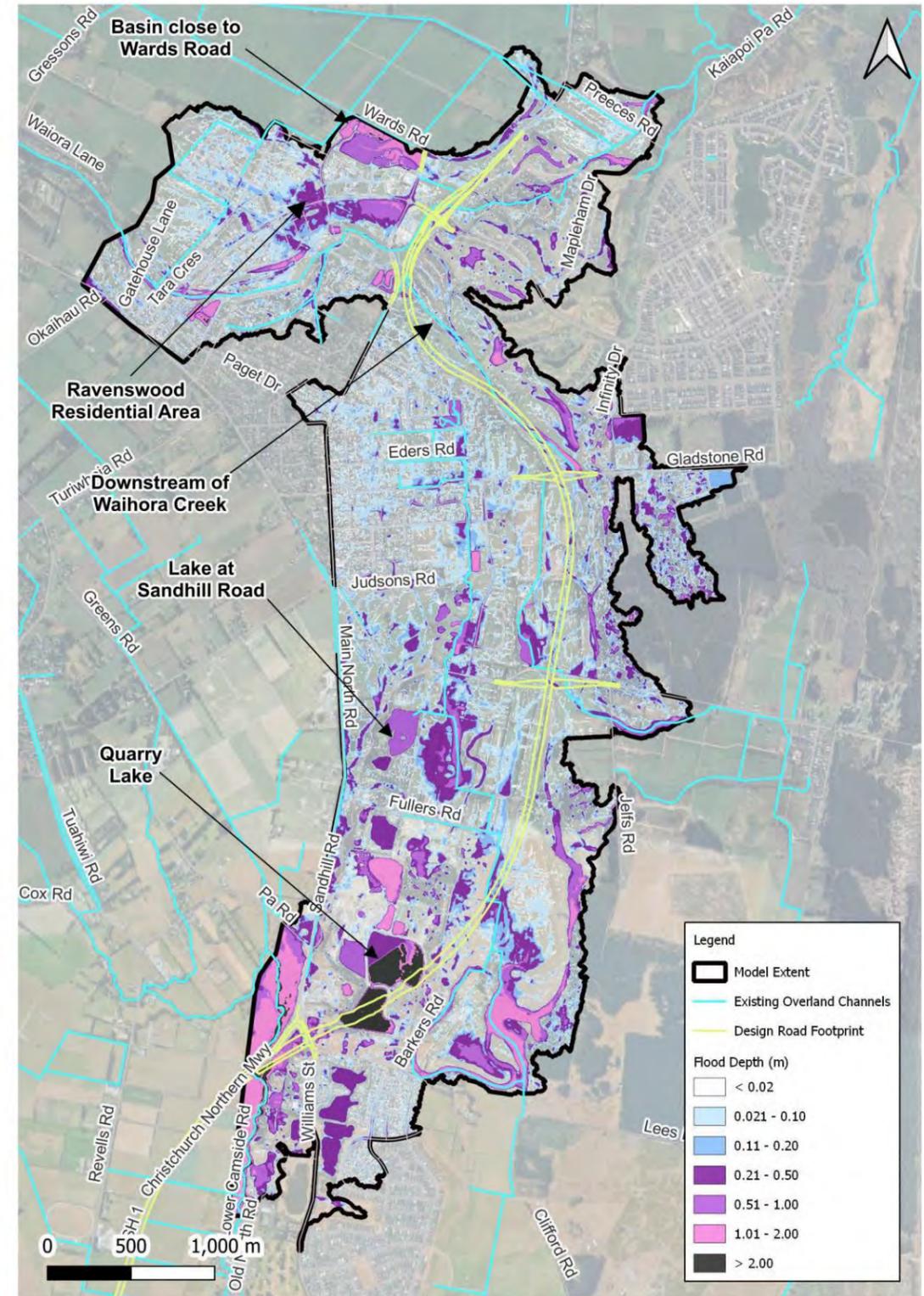


Figure 2-5 B2P-Woodend flood model pre-development flood depth for the 100-year ARI event

NOT FOR CONSTRUCTION

Figure 2-6 illustrates the differences in flood depth between the B2P Pre-development flood model and the localised flood depth map from the WDC South Ashley Model, specifically for the 100-year ARI event. Areas shaded in blue indicate regions where the flood depth is greater in the WDC South Ashley Model compared to the B2P Pre-development flood model, and vice versa.

Figure 2-7 shows the differences in ground level between the B2P Pre-development flood model and the localised flood depth map from the WDC South Ashley Model. Areas marked in blue indicate regions where the ground level is higher in the WDC South Ashley Model than in the B2P Pre-development flood model, and vice versa.

Overall, the discrepancies in results can be attributed to several factors. These include the coarser cell sizes utilised in the WDC South Ashley Model, large cross-sectional areas of open channels burnt in the road to represent cross culverts in that model, and recent ground level updates in newly developed areas. The locations where significant differences have been identified are summarised in Table 2-2.

Table 2-2 Locations where large discrepancies are identified

Locations	Reasons
Ravenswood residential area (B2P Flood Model > WDC South Ashley Model)	As shown in Figure 2-7, the Ravenswood residential area was not included in the WDC South Ashley model but has been incorporated into the B2P Flood Model. This inclusion has resulted in the increased flood depth in the affected areas.
Basin close to Wards Road (B2P Flood Model > WDC South Ashley Model)	As shown in Figure 2-7, the basin was not included in the WDC South Ashley Model but has been incorporated into the B2P Flood Model. This inclusion has resulted in increased flood depths in the affected areas.
Downstream of Waihora Creek (WDC South Ashley Model > B2P Flood Model)	Figure 2-8 shows a 40m wide trapezoidal cross-section was used in the WDC South Ashley Model to represent the existing 4m x 2m box culvert. This design facilitates a higher runoff flow downstream, leading to greater flood depths in those areas when compared to the B2P Flood Model. This has been replaced by a 1D network in the B2P Flood Model.
Lake at Sandhill Road (WDC South Ashley Model > B2P Flood Model)	As shown in Figure 2-7, variations in water levels may have resulted from the DEM which shows a higher water level in the WDC South Ashley Model compared to the B2P Flood Model.
Quarry Lake (B2P Flood Model > WDC South Ashley Model)	As shown in Figure 2-7, variations in flood depth is resulted from the ground levels, which have captured a higher water level in the B2P Flood Model compared to the WDC South Ashley Model.

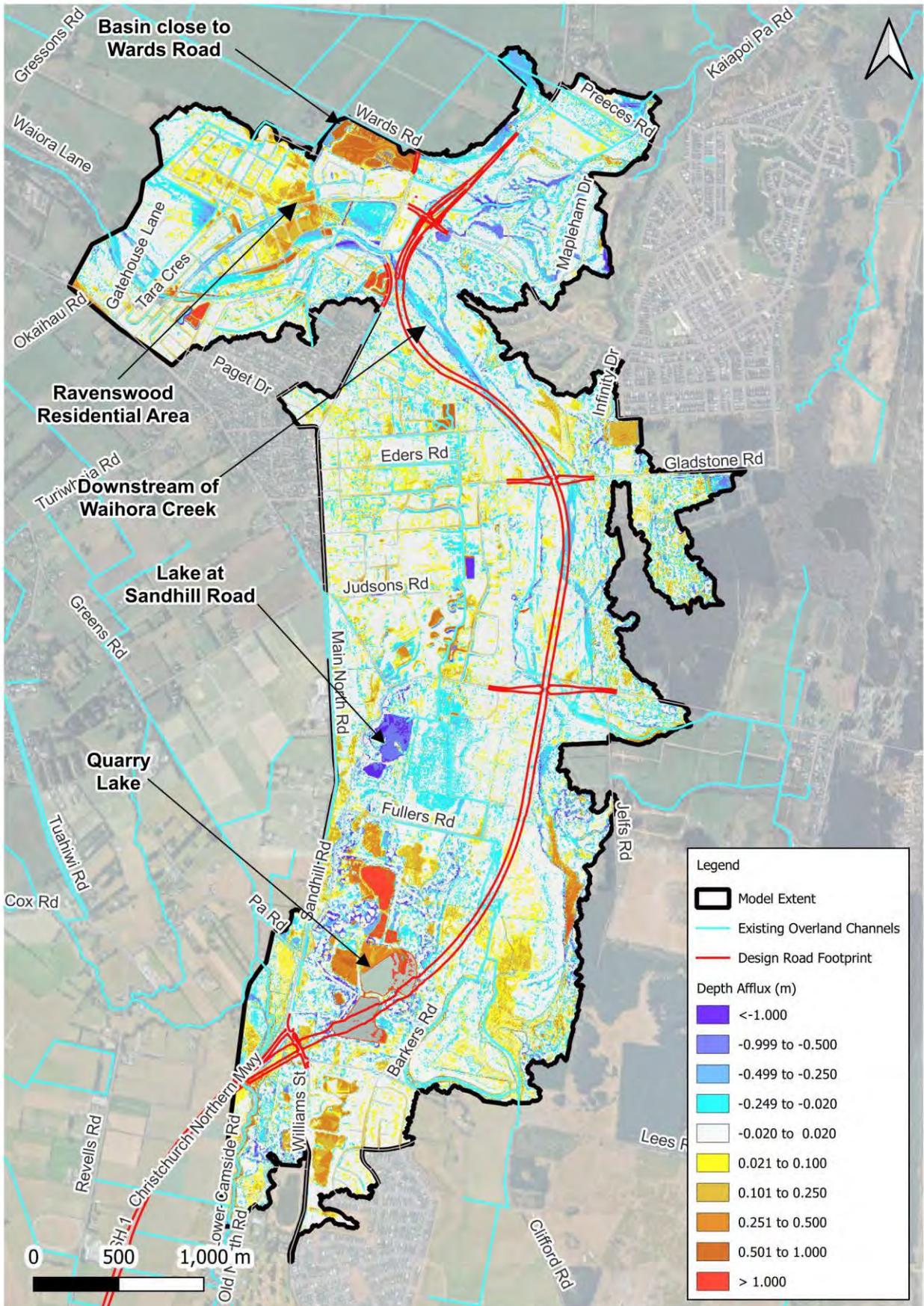


Figure 2-6 B2P Flood Pre-development model 100year ARI flood depth minus WDC South Ashley Model localised flood depth map under 100-year ARI event

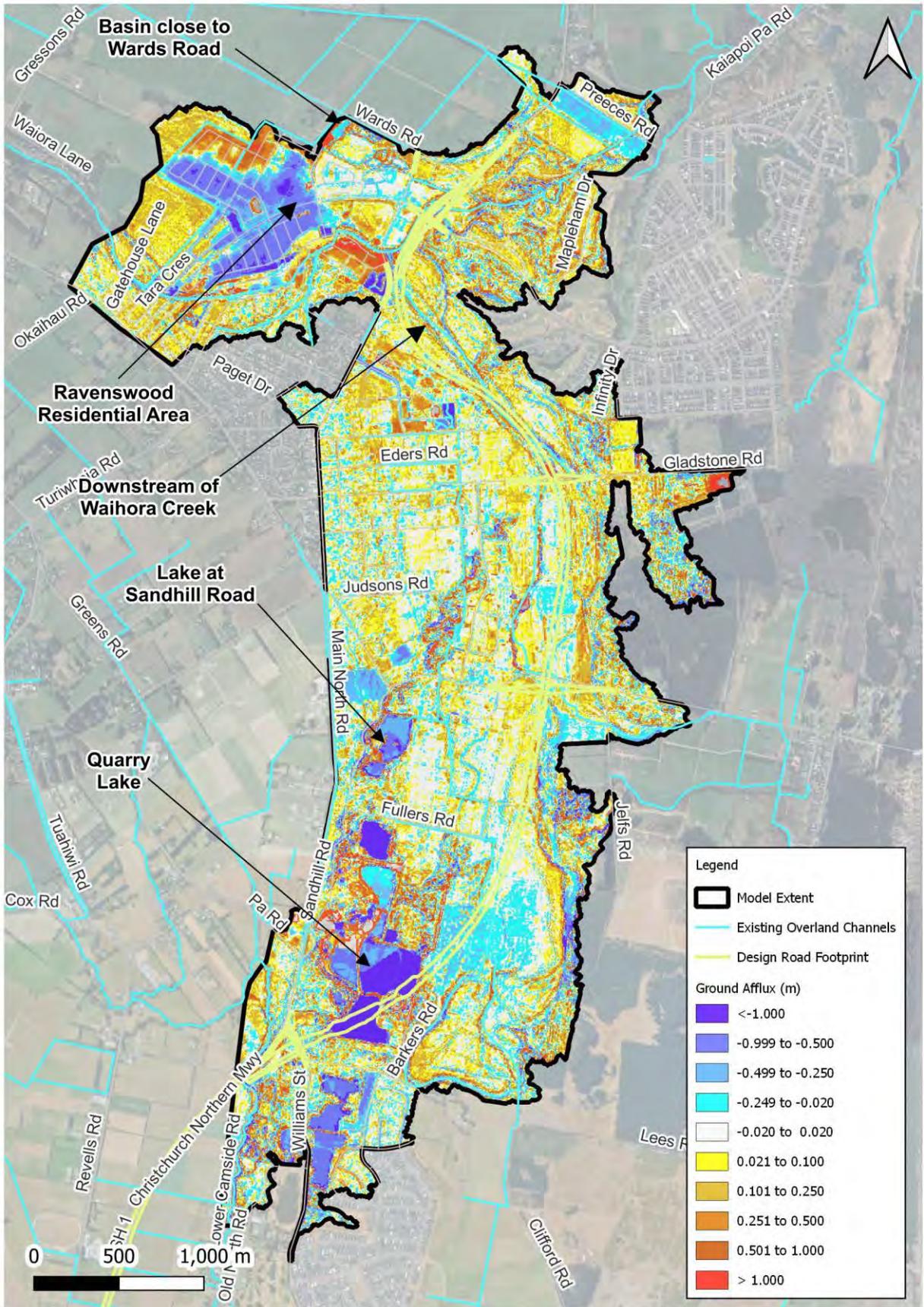


Figure 2-7 B2P Flood Model ground level minus WDC South Ashley Model ground level

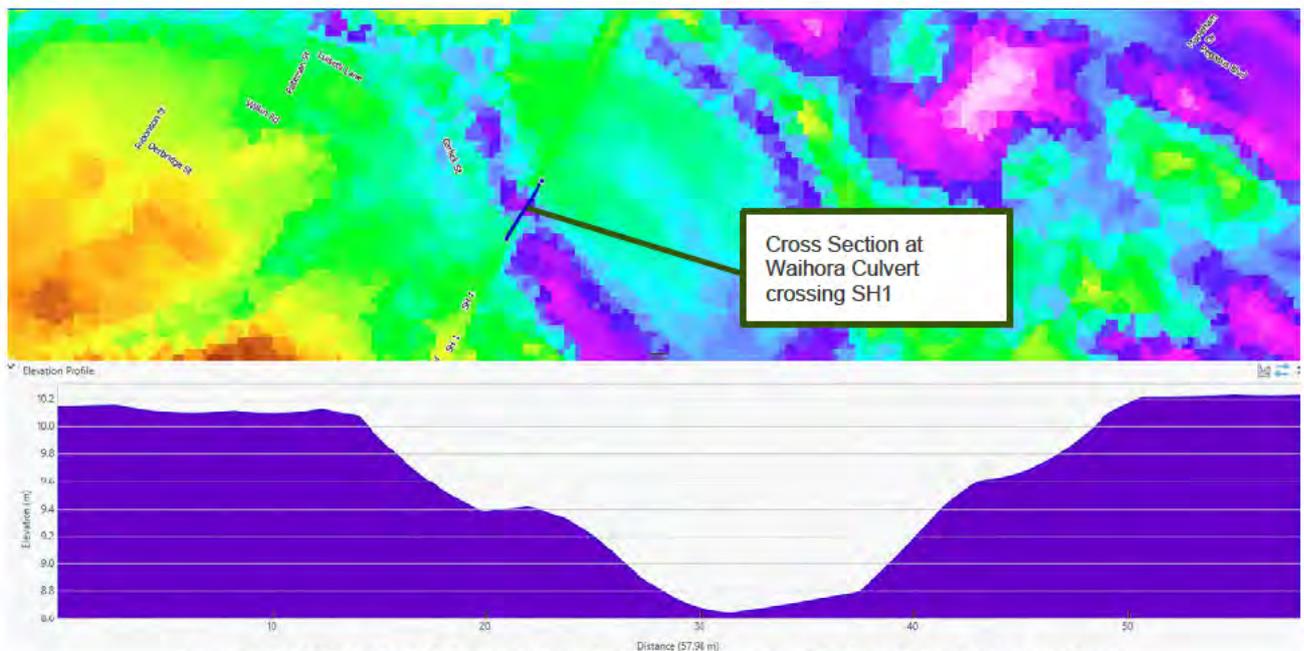


Figure 2-8 WDC Model Ground Level representing an existing 4m x 2m box culvert

2.2 B2P Post-Development Flood Model

The detailed model build methodology for B2P Flood Model post-development scenario (POSTDEV) is described in Appendix A Table 6.

Figure 2-9 illustrates the proposed design surface level for the entire road alignment. The proposed alignment generally follows the existing ground levels, with raised embankments incorporated along its length. However, the construction of these embankments alters the natural flow path, leading to the potential for water pooling behind the embankments due to the disruption of drainage. No mitigation measures have been developed in this model since the goal is to determine the effects of the bypass road and its comparison with the Pre-Development Model.

Existing culverts that fell within the designation boundary were removed, while culverts that are outside were maintained. The only culvert that was modelled with a fish passage consideration was the DN1800 culvert that crosses Bob Robertson drive, similar to the Pre-Development Model.

Comparable to the baseline flood model, the post-development flood model was developed under the assumption that the stormwater pipes are completely blocked.

Figure C-5 and Figure C-6 (refer to Appendix C) show the maximum flood depth and flood level of the post-development scenario under the 100-year ARI storm event, while Figure C-7 and Figure C-8 present the maximum flood depth and flood level under the 200-year ARI storm event.

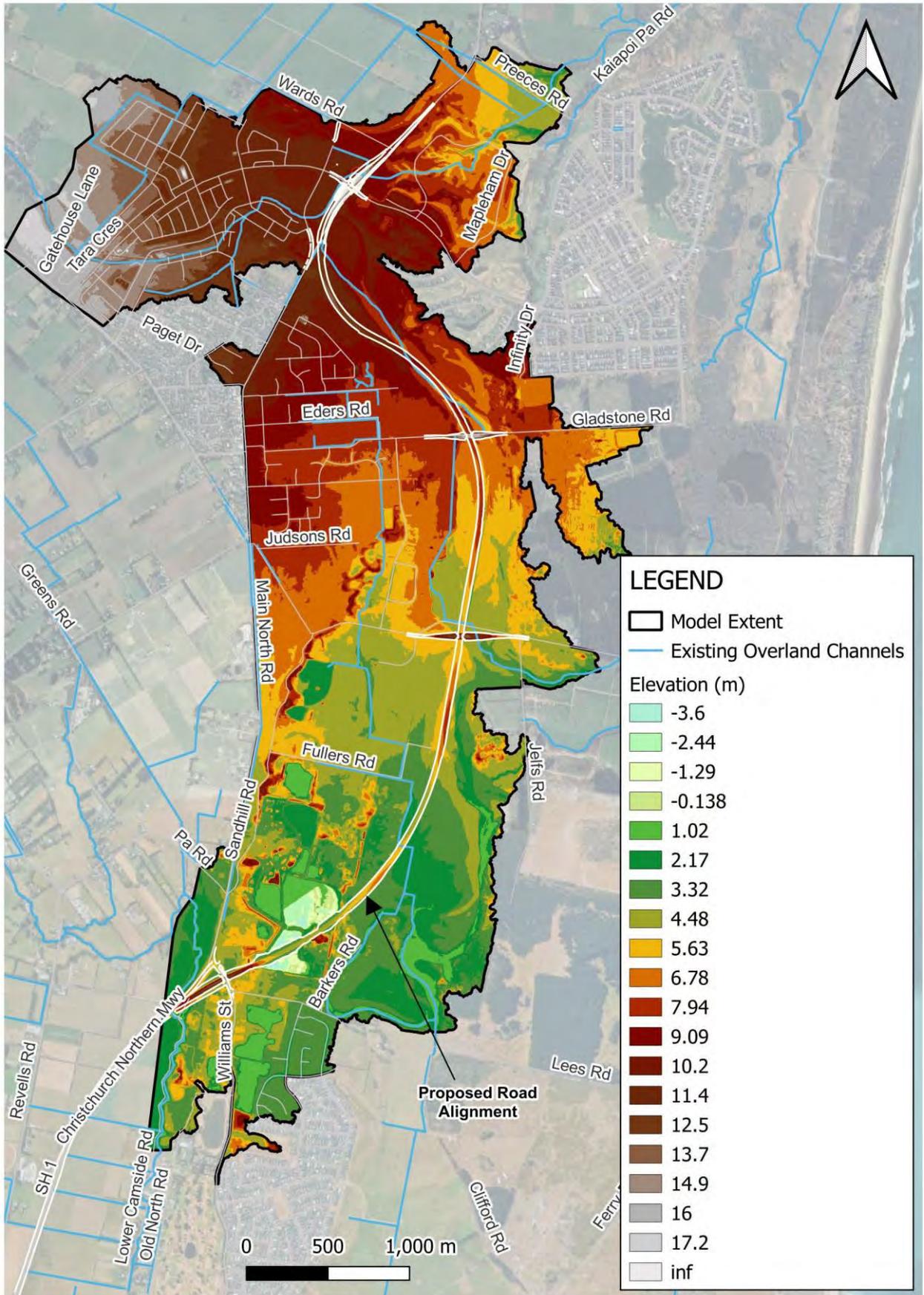


Figure 2-9 Proposed B2P-Woodend design surface level

2.2.1 Post-Development Scenario Result Discussion

Maximum flood level difference maps were developed to compare the post-development scenario with the pre-development scenario. These are presented in Figures C-9 and C-10 (see Appendix C) for the 100-year and 200-year ARI events.

Based on the Figures C-9, C-10, the proposed state highway remains dry under both the 100-year and 200-year ARI scenarios, with the exception of the road section north of Bob Robertson Drive, where floodwaters overtop the road as shown in Figure 2-10. The road overtopping is primarily due to a low existing road level and undersized existing culverts. To address this issue, the 2.2m x 1.2m culverts at Taranaki stream and DN750 at north of Taranaki stream are proposed to be upsized. This will allow more runoff to be conveyed downstream through culverts instead of overtopping the road.

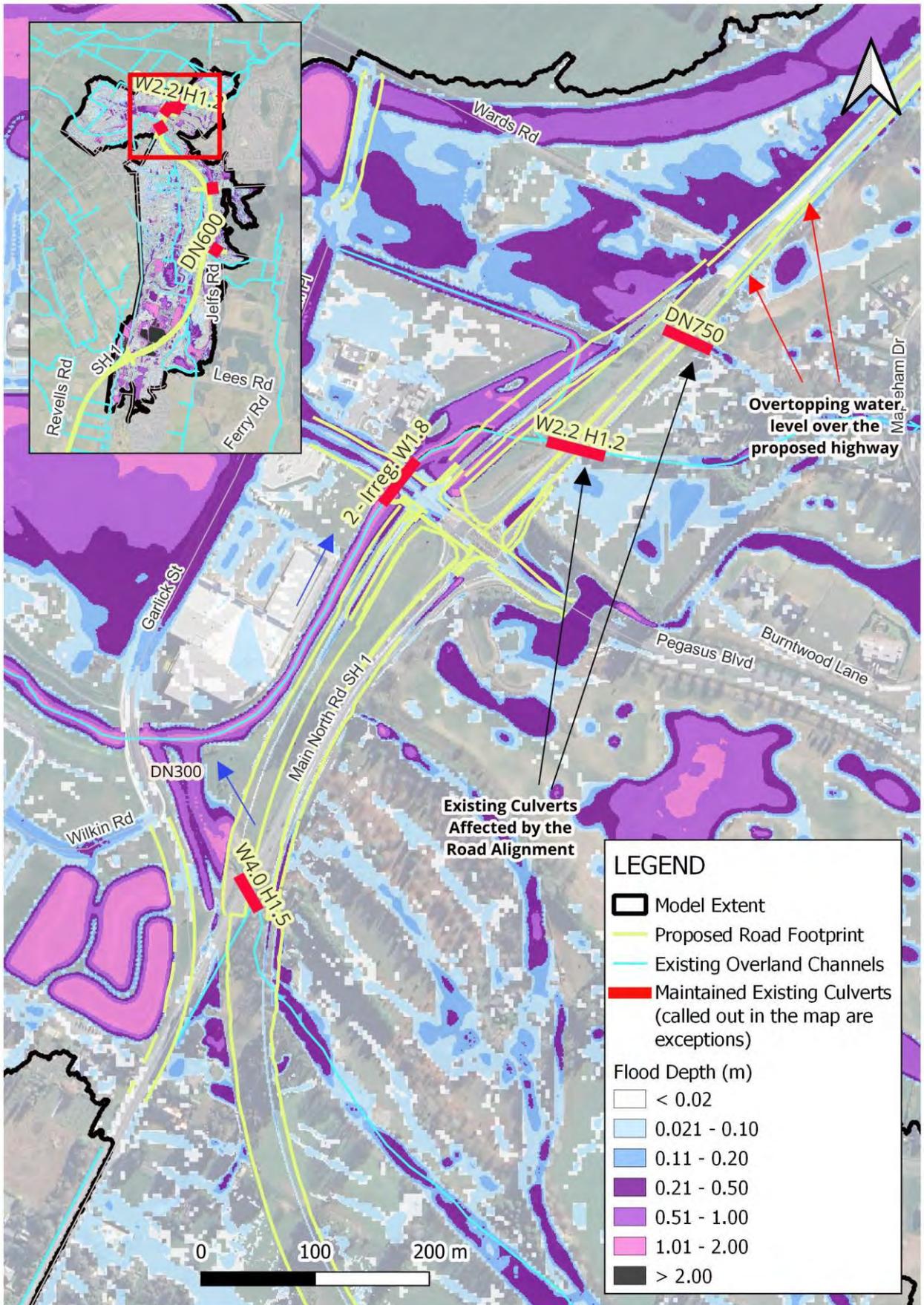


Figure 2-10 Floodwaters overtop the road at north of Bob Robertson Drive (200 year ARI Post-Development Scenario)

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Figures C-9 and Figures C-10 indicate that most flooded zones are confined adjacent to the proposed road corridor. However, elevated flood levels are observed in the residential area along Main North Road, Woodend Beach Road and Wards Road during both the 100-year and 200-year ARI events.

The increase in flood level is attributed to the impact of road embankment towards the natural flow of runoff, such that existing channels are blocked by the road embankment that eventually contributed to the runoff buildup. Flood depth, flood levels, and their differences at the eight impacted properties (as shown in Figure 2-11 are presented in Table 2-3).

The following tables present the findings in terms of flood level and their difference between the post-development and pre-development cases at varying ARIs (100 and 200-year):

Table 2-3 100-year and 200-year ARI Flood Levels and Differences (Post-Development vs. Pre-Development Scenario)

Point ID	Location	100-year ARI			200-year ARI		
		Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)	Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)
1	5 Wards Rd*	8.28	8.42	140	8.37	8.5	137
2	196 Woodend Beach Rd	4.13	4.33	193	4.23	4.57	335
3	1271 Main North Rd*	8.11	8.29	183	8.16	8.33	171
4	1263 Main North Rd	8.28	8.31	30	8.29	8.35	58
5	1279 Main North Rd*	8.01	8.13	120	8.03	8.15	114
6	1273 Main North Rd*	8.10	8.24	140	8.15	8.28	130
7	1277 Main North Rd*	8.02	8.18	160	8.07	8.21	142
8	1319 Main North Road	6.41	6.44	27	6.46	6.55	91

*Property will be acquired as part of project work delineation. Flood impacts within designation have been considered acceptable

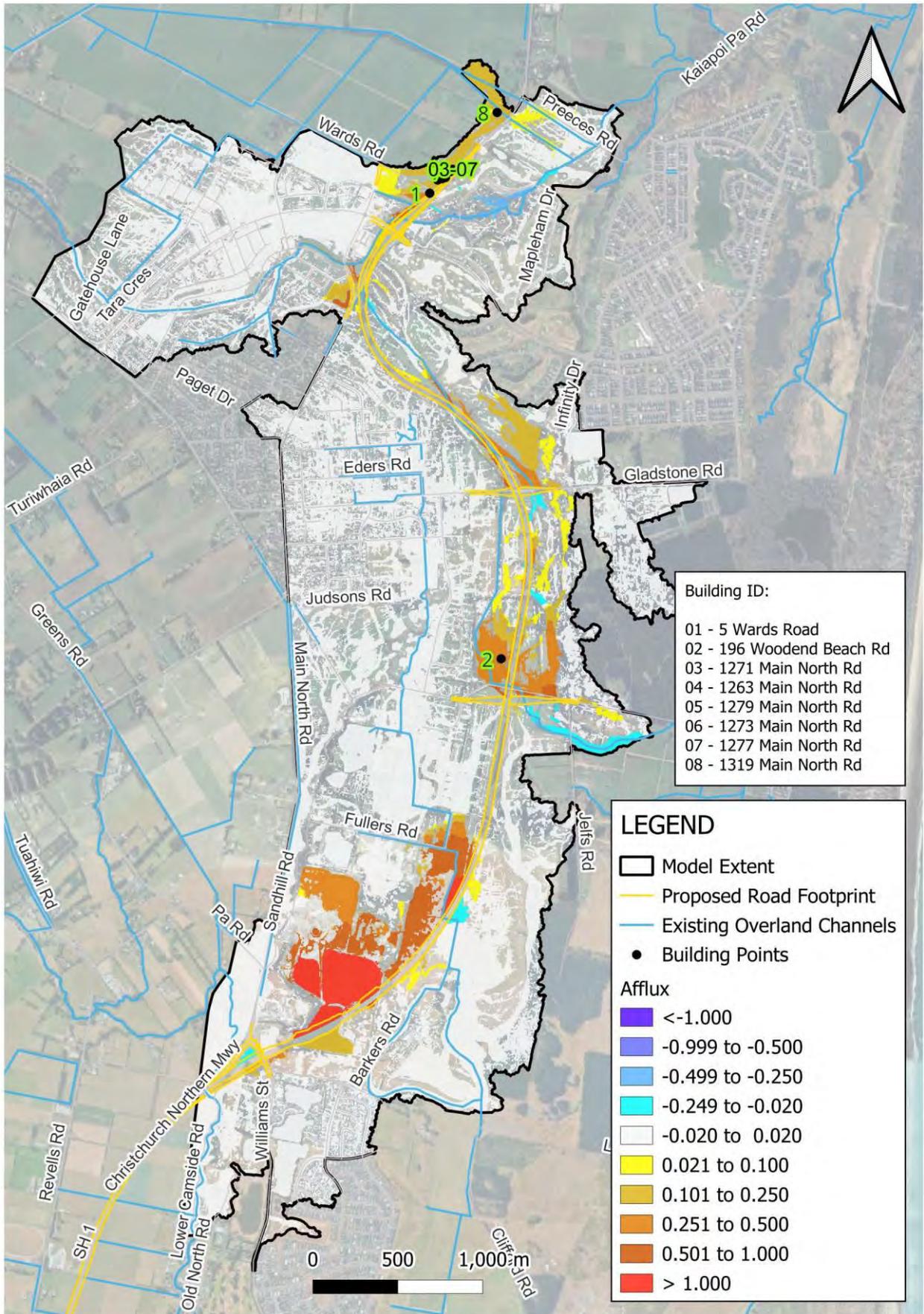


Figure 2-11 Impacted properties with 200yr afflux level map (post-development scenario) as background

These findings indicate that the increases exceeded the project objectives, which require that no flood level increase affecting neighbouring properties under the 100-year ARI event, and that any increase for the 200-year ARI event should not exceed 20 mm.

Of the eight impacted properties, five will be acquired as part of the project work delineation. Flood impacts within the designated area have been considered acceptable, if the flooding does not overtop the road.

Given the increase in flooding at the above three locations, flood mitigation measures are necessary to reduce impacts on these zones. The following solutions will be considered during detailed design:

- Provision of adequate culverts across the design road alignment.
- Divert impounded runoff through additional channel alignments.

2.3 B2P Mitigation Flood Model

The methodology for the B2P Flood Model post-development scenario with mitigation solution is outlined in Appendix A Table 6. The key components of the mitigation solution include:

- Provision of culvert crossings:
 - Culvert structures shall be added along critical areas beside the road alignment to avoid runoff build-up. These structures are incorporated in the flood model to properly represent the mitigation solution once the road embankment is constructed.
 - Culverts sizing at Taranaki Stream, Waihora Creek and McIntosh Drain include the 300mm embedment depth for fish passage consideration.
 - The design invert levels for the culvert structures are based on the provided survey data, such that the defined upstream and downstream invert levels are enough to have a minimum adequate slope to convey runoff without overflowing at the road level.
 - Where road widening is proposed at Bob Robertson Drive, existing culverts are to be extended or replaced with like-to-like sizes to avoid introducing flood impacts downstream.
- Provision of flow path channel diversions:
 - Additional channels are accounted for the model to ensure smooth flow behaviour of impounded runoff from upstream to downstream.
 - The design slopes of channels are established to match the natural topography to permit the flow of runoff without causing impounding upstream.

Figure 2-12, Figure 2-13, Figure 2-14, Figure 2-15, and Figure 2-16 show the locations where culverts and flow paths diversions are proposed as part of mitigation solutions. Some major flow changes due to proposed mitigating structures are shown in the following figures. Blue arrowheads represent the flow direction of runoff.

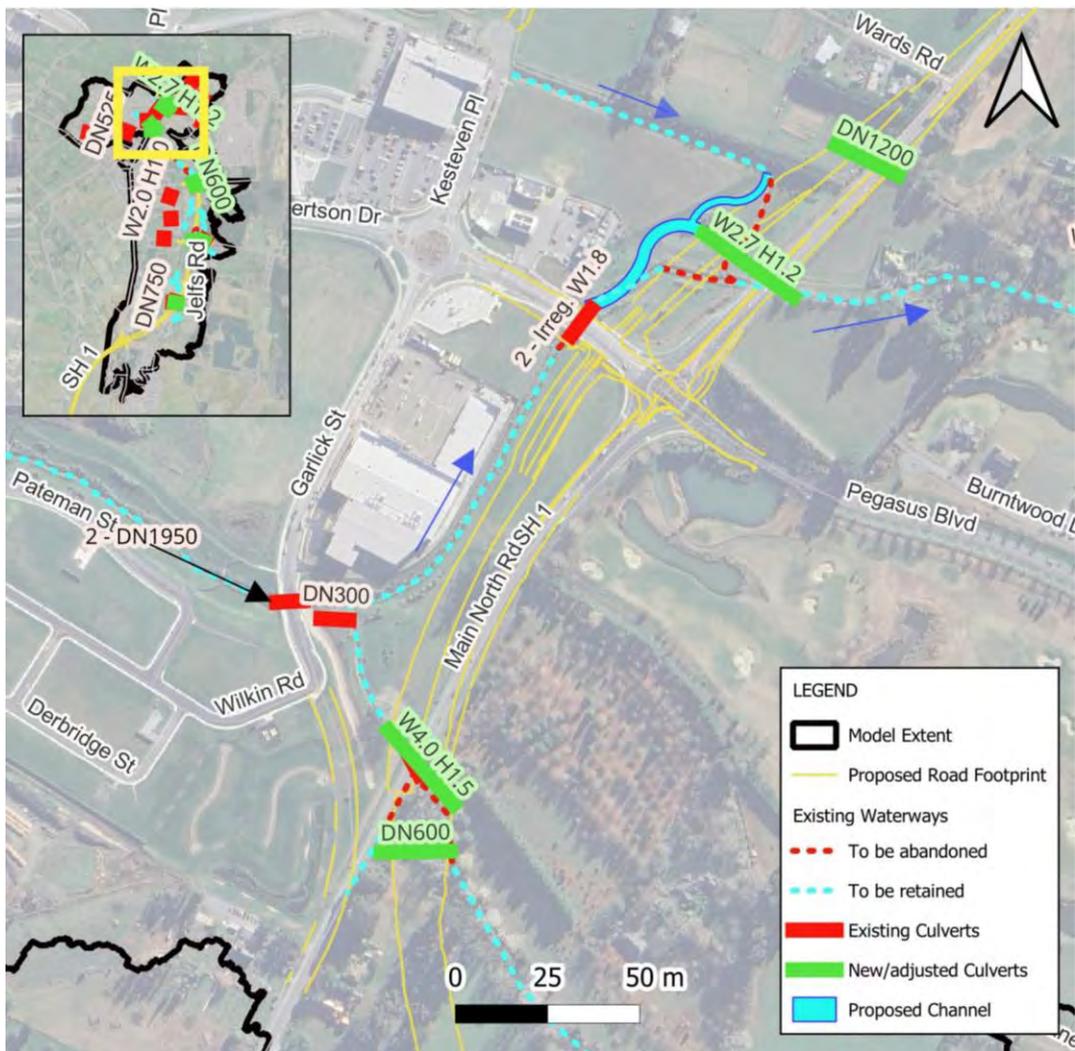


Figure 2-13 Proposed culvert alignments (upper zone)

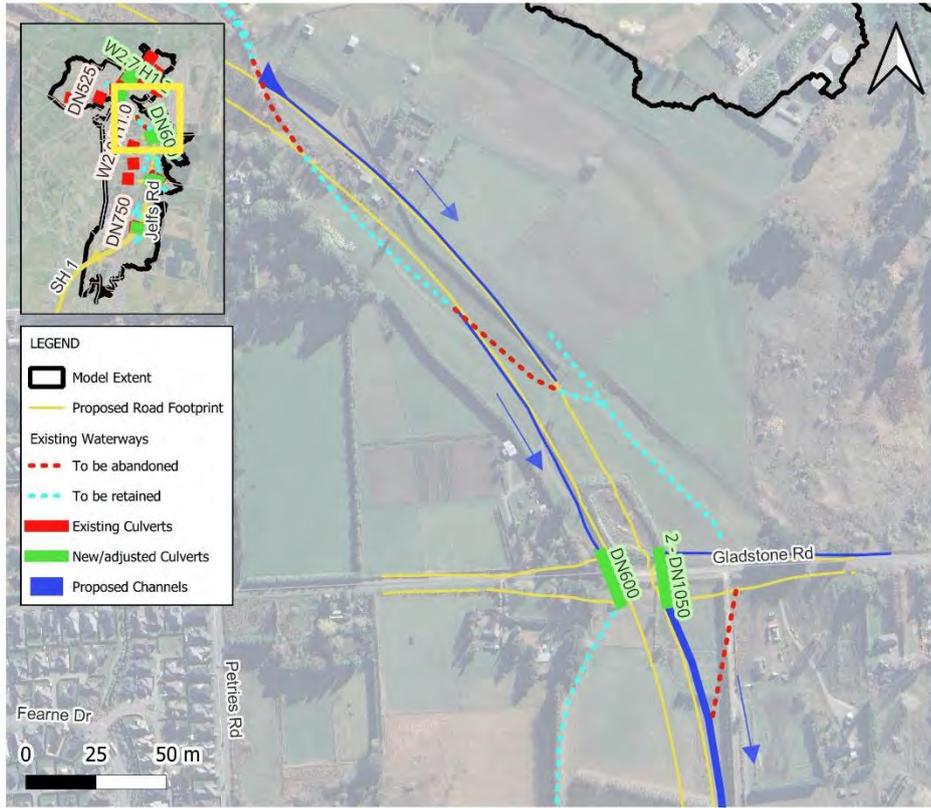


Figure 2-14 Proposed culvert alignments (upper central zone)

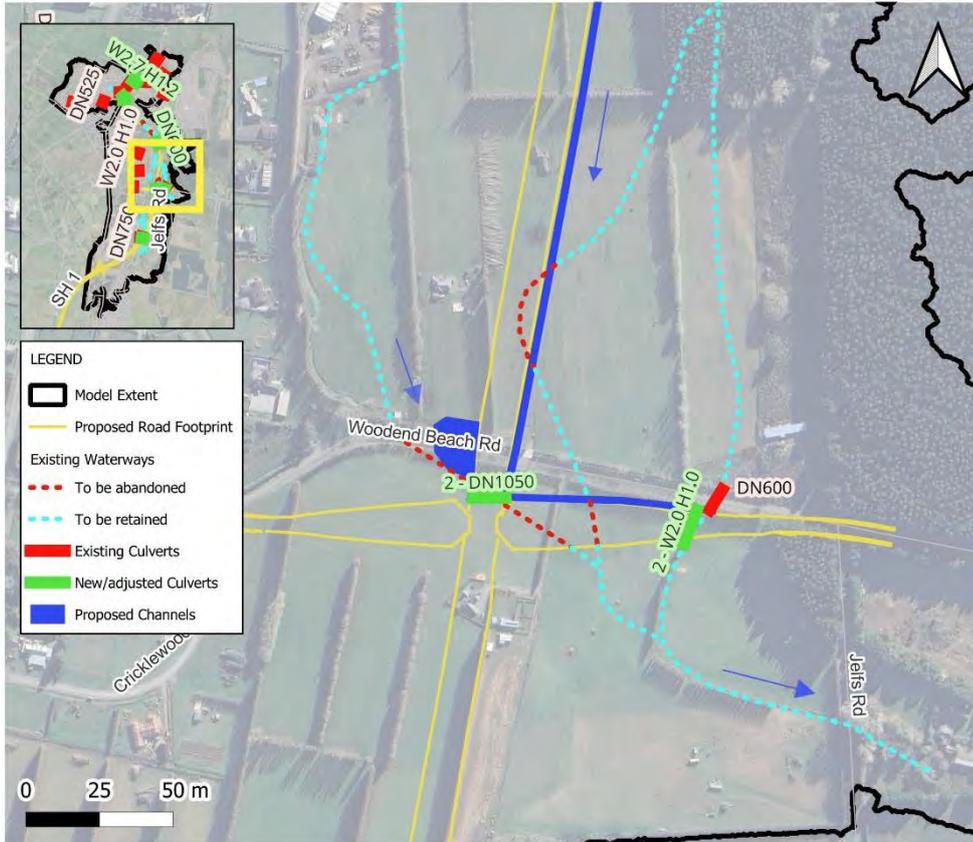


Figure 2-15 Proposed culvert alignments (central lower zone)

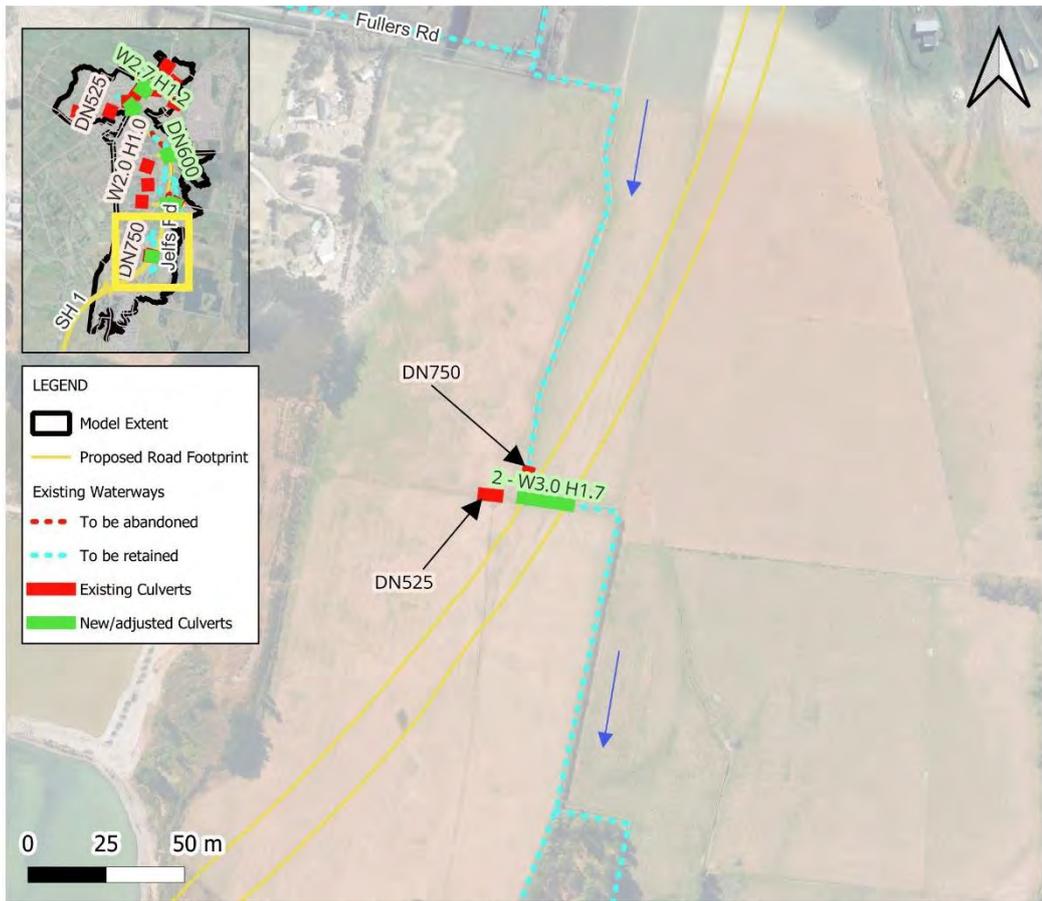


Figure 2-16 Proposed culvert alignments (lower zone)

2.3.1 Mitigation Scenario Result Discussion

Figures C-11 and C-12 (refer to Appendix C) illustrate the maximum flood depth and flood level for the mitigation scenario under a 100-year ARI storm event, while Figures C-13 and C-14 represent these parameters for the 200-year ARI storm event.

Maximum flood level difference maps, comparing the mitigation and pre-development scenarios, are shown in Figures C-15 and C-16 for the 100-year, and 200-year ARI events, respectively. Based on these figures, with the mitigation measures implemented, the proposed state highway remains dry under both the 100-year and 200-year ARI scenarios.

Table 2-4 100-year and 200-year ARI flood level and differences (Mitigation vs Pre-development scenario)

Point ID	Location	100-year ARI			200-year ARI		
		Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)	Pre-development flood level (m)	Post-development flood level (m)	Difference (mm)
1	5 Wards Rd*	8.26	8.26	0	8.37	8.28	-90
2	196 Woodend Beach Rd	4.13	4.14	4	4.23	4.22	-13
3	1271 Main North Rd*	8.11	8.11	0	8.16	8.07	-83
4	1263 Main North Rd	8.29	8.29	0	8.29	8.29	0
5	1279 Main North Rd*	8	8	0	8.03	8.02	-10
6	1273 Main North Rd*	8.09	8.09	0	8.15	8.10	-50
7	1277 Main North Rd*	8.02	8.02	0	8.07	8.05	-20
8	1319 Main North Road	6.41	6.41	0	6.46	6.46	1

* Properties will be acquired as part of project work delineation. Flood impacts within designation have been considered acceptable.

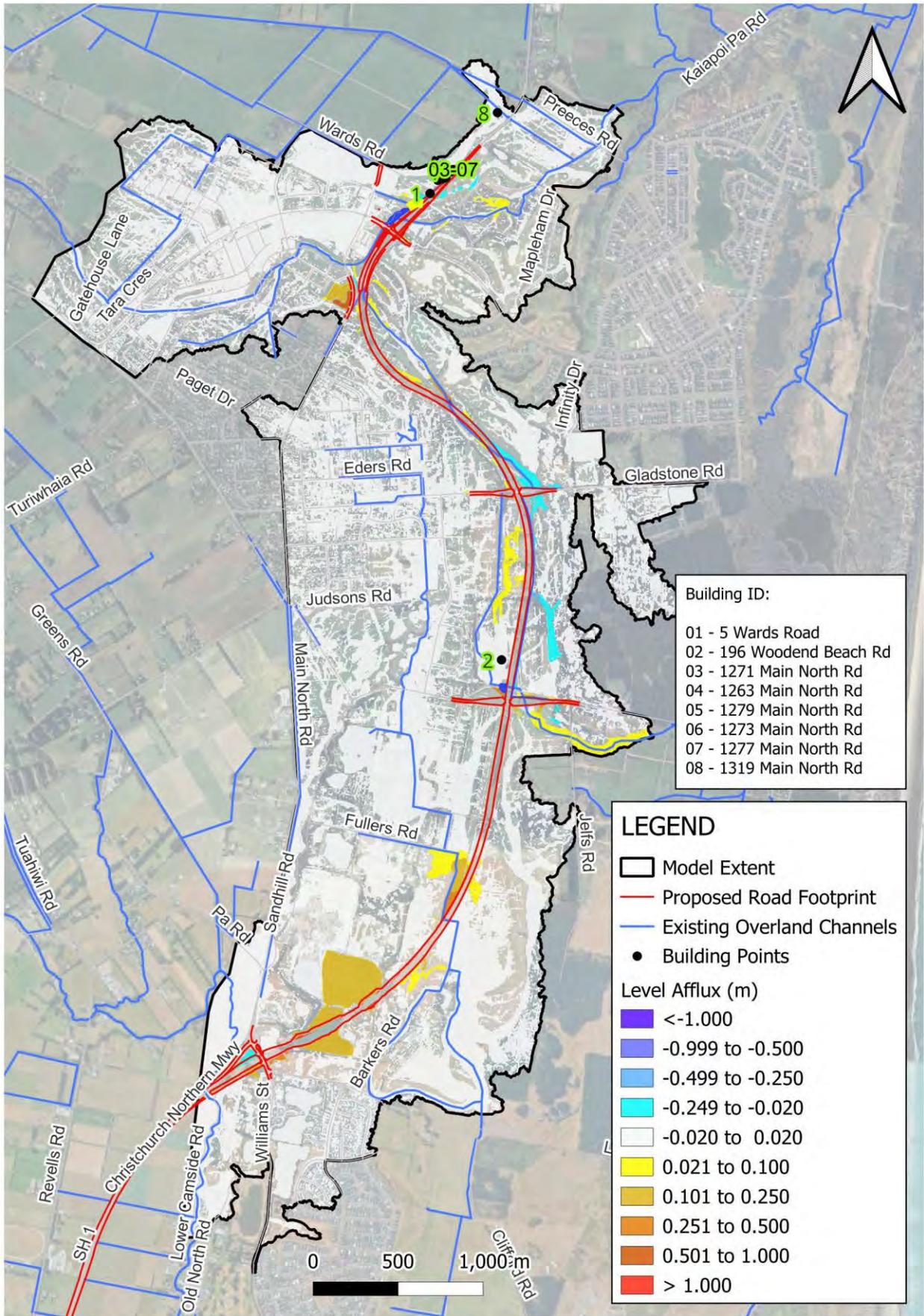


Figure 2-17 Impacted buildings with 200yr afflux level map (Mitigation scenario) as background

NOT FOR CONSTRUCTION

Based on the results presented in Table 2-4 and illustrated in Appendix C, the mitigation model has successfully reduced flood impacts across most areas, including at previously affected buildings (excluding the five buildings identified for acquisition as part of project delineation) during the 100-year and 200-year ARI event.

Water level increases have been observed in the locations listed in Table 2-5 and as shown in Figure 2-18, which are outside the designation boundary. However, these increases do not affect any property buildings.

Table 2-5 Locations that observed a water level increase outside of designation boundaries

Locations	Max Afflux (mm)		Comments
	100-yr	200-yr	
1. Mapleham Dr	2	20	The increase in water depth is due to the upsizing of the Taranaki Stream culvert. However, the impacts remain within the channel and do not affect any buildings.
2. Basin within Ravenswood residential area	200	670	Water depth increase is caused by raising the overflow weir from RL 10.20 m to RL 10.40 m to accommodate the proposed road (Garlick Street). The increased depth is confined within the basin and poses no risk to nearby properties.
3. Downstream of Waihora Creek	210	440	Higher water levels indicated in the model due to reduced roadway overtopping of Taranaki Stream north of Bob Robertson Drive, redirecting slightly more runoff into Waihora Creek. The impact is contained within the channel and does not affect any buildings.
4. West of Copper Beech Road	40	50	Water ponding is due to the motorway cutting off an existing overland flow path. The ponding is localised and does not impact any buildings.
5. Downstream of Woodend Beach Road	20	50	Flood levels within Waihora Creek rise slightly due to more efficient conveyance from the proposed bypass and both culverts at Gladstone Road and Woodend Beach Road have been upsized. No buildings are affected, and the impacts are confined within the channel.
6. Upstream of McIntosh Drain	130	280	For the upstream reach of McIntosh Drain, fully resolving the flood impacts remains challenging since maintaining the original flow area, spanning approximately 300 meters, will require significant structural measures (e.g. more culverts, bridges, etc.). This increase is largely confined to land owned by NZTA which does not include any residential properties.
7. Within the Quarry Lake.	0	120	Water level increases are shown within the model resulting from to storage loss from the proposed bypass road infilling the lake. It is noted that the water level in the ponds generally reflects existing groundwater levels and the model assumes no infiltration. However, as the quarry bottom is directly connected to groundwater, flood afflux is expected to be minimal due to this continuous interchange with groundwater.

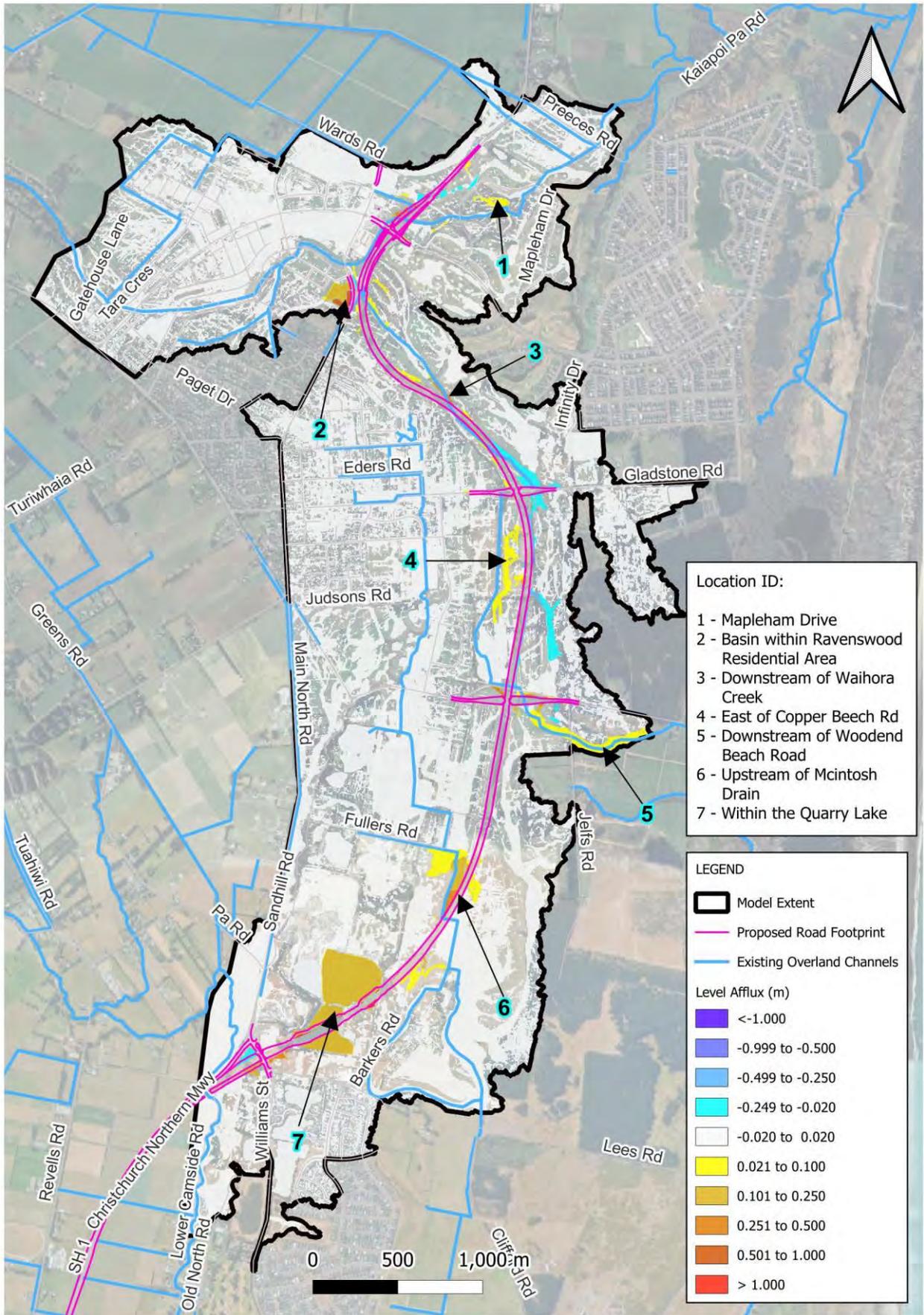


Figure 2-18 Residual impacts outside the designation but does not impact any property buildings (200 year ARI afflux level)

2.3.2 Flood Duration Impact Discussion

Flood hydrographs from the Pre-Development and Mitigation Scenarios were compared to determine if a prolonged flood event was observed, specifically along major waterways that intersect the proposed bypass road. Four locations were identified, which have also been the site of most mitigation measures with the goal of maintaining existing overland flow paths:

- Taranaki Stream (Figure 2-19 and Figure 2-20)
- Waihora Creek to Gladstone Road (Figure 2-21 and Figure 2-22)
- Woodend Beach Road (Figure 2-23 and Figure 2-24)
- McIntosh Drain (Figure 2-25 and Figure 2-26)

Taranaki Stream

Under the 100-year ARI event, hydrographs at both the upstream and downstream ends of Taranaki Stream (Figure 2-19) show minimal difference between the pre-development and mitigation scenarios.

Under the 200-year ARI event, the upstream hydrograph (Figure 2-20) shows a slight reduction in peak flow due to the proposed road reducing storage. The new Taranaki Stream culvert acts as a flow constriction, causing water to back up and divert via Waihora Creek. This is confirmed by the afflux maps (Figure C-16), which show increased flood levels upstream of Taranaki Stream and downstream of Waihora Creek.

Despite these local affluxes, flood extents remain unchanged and no increased flood risk to is expected to nearby properties.

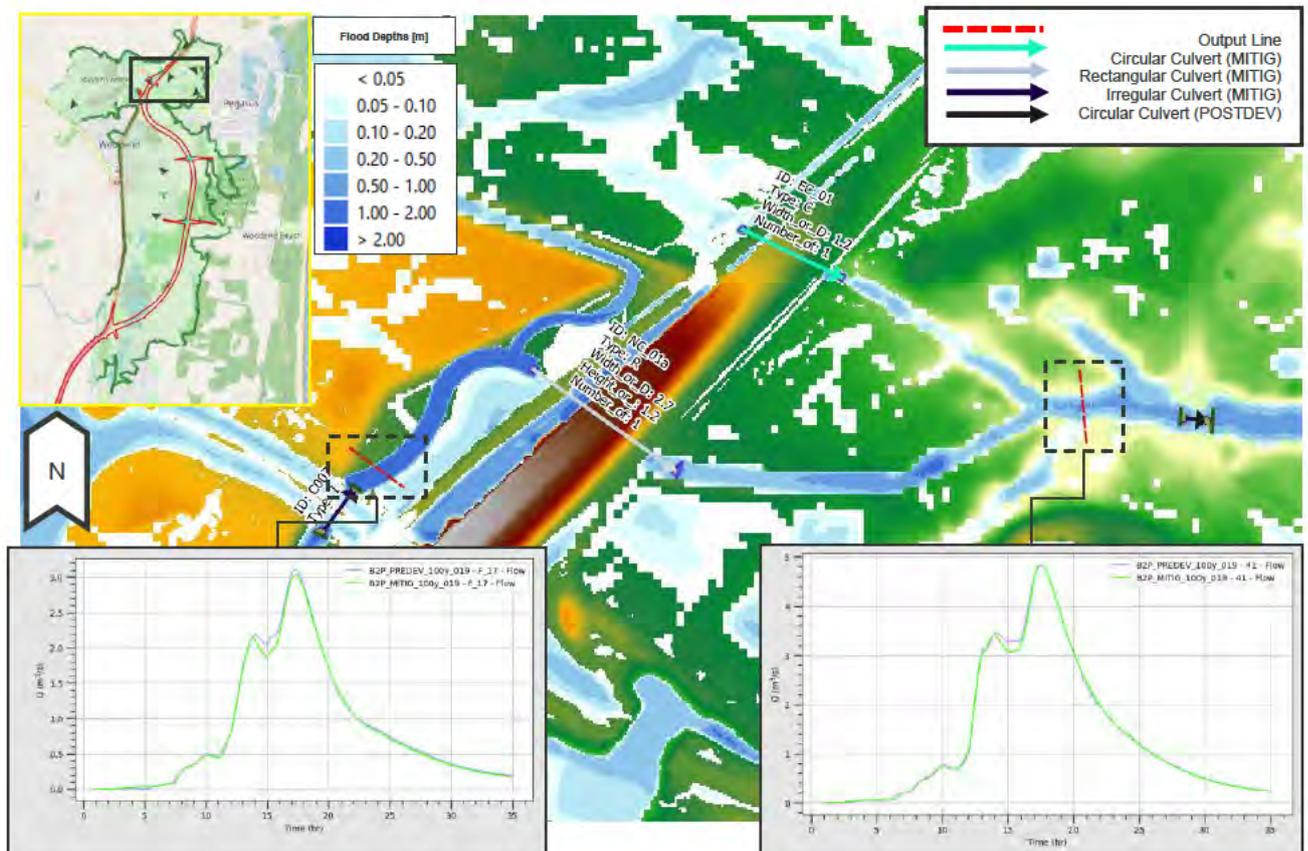


Figure 2-19 Taranaki Stream 100-year Flood Duration Assessment

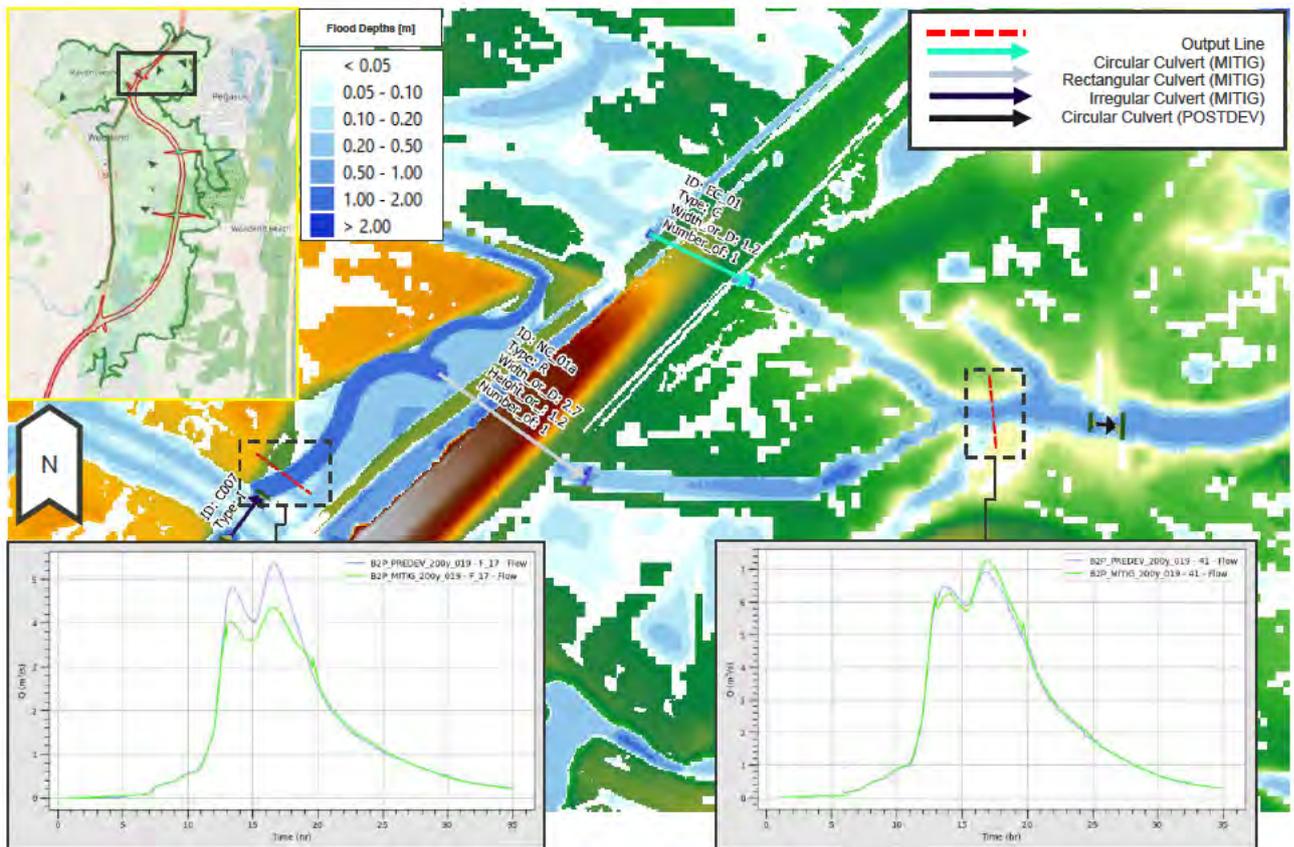


Figure 2-20 Taranaki Stream 200-year Flood Duration Assessment

Waihora Creek to Gladstone Road

The overland flow path connecting Waihora Creek to Gladstone Road functions as a key drainage route, conveying runoff through to Woodend Beach Road and ultimately eastward. During the 100-year ARI event (Figure 2-21) upstream hydrographs near Waihora Creek show similar dual-peak patterns for both pre-development and mitigation scenarios. At the downstream location near Gladstone Road, the pre-development peak is lower due to the undersized existing culvert, which causes runoff to back up and pond upstream before overtopping. In contrast, the mitigation scenario includes a larger culvert, allowing runoff to convey more efficiently downstream without ponding.

In the 200-year ARI event (Figure 2-22) the upstream hydrograph also shows a dual-peak pattern. The mitigated scenario has a lower first peak as more flow is initially conveyed to Taranaki Stream through the larger proposed culvert. Once the Taranaki Stream culvert reaches capacity, excess flow backs up and diverts into Waihora Creek, resulting in a higher second peak in the mitigation scenario.

Despite these local affluxes, flood extents remain unchanged and no increased flood risk to is expected to nearby properties.

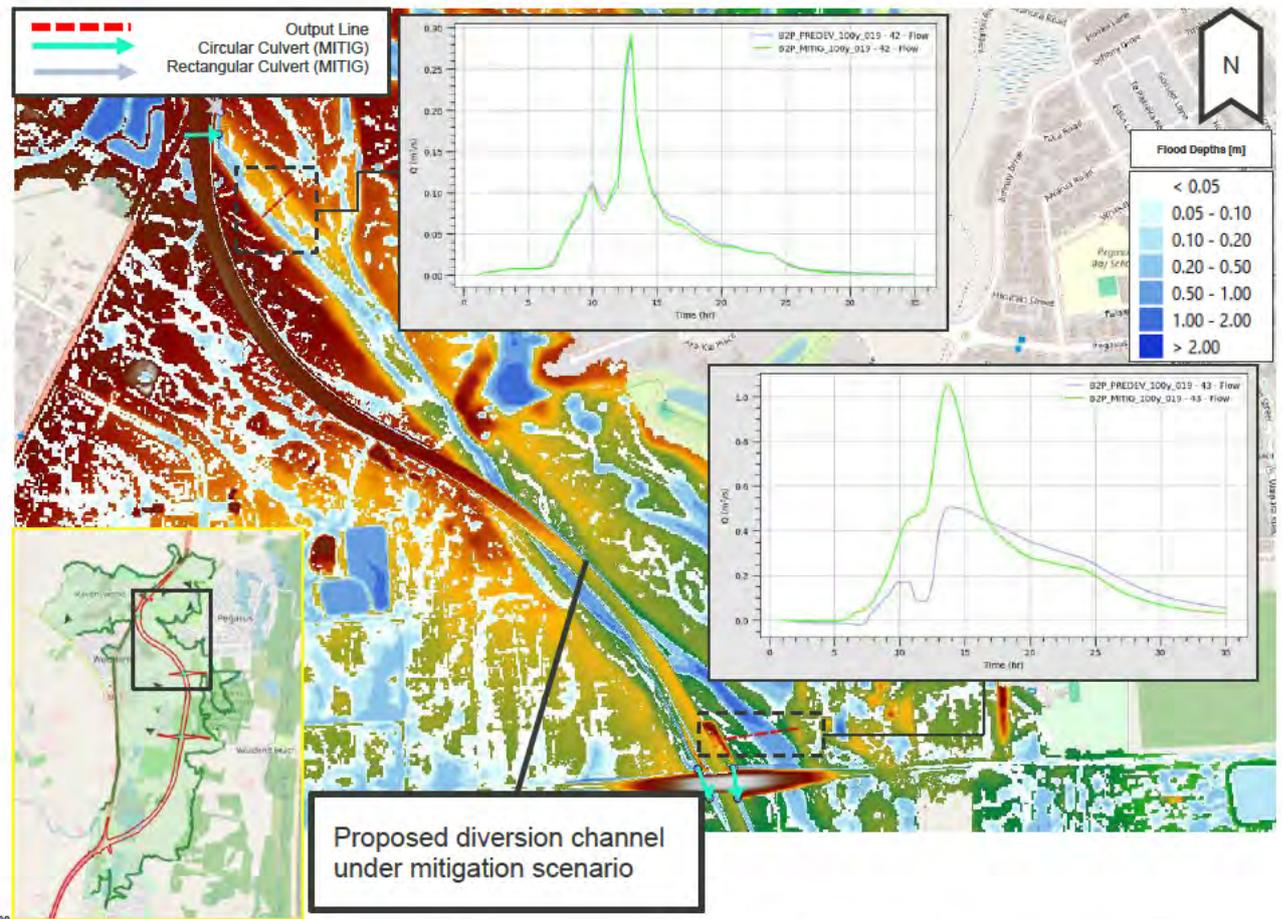


Figure 2-21 Waihora Creek to Gladstone Road 100-year Flood Duration Assessment

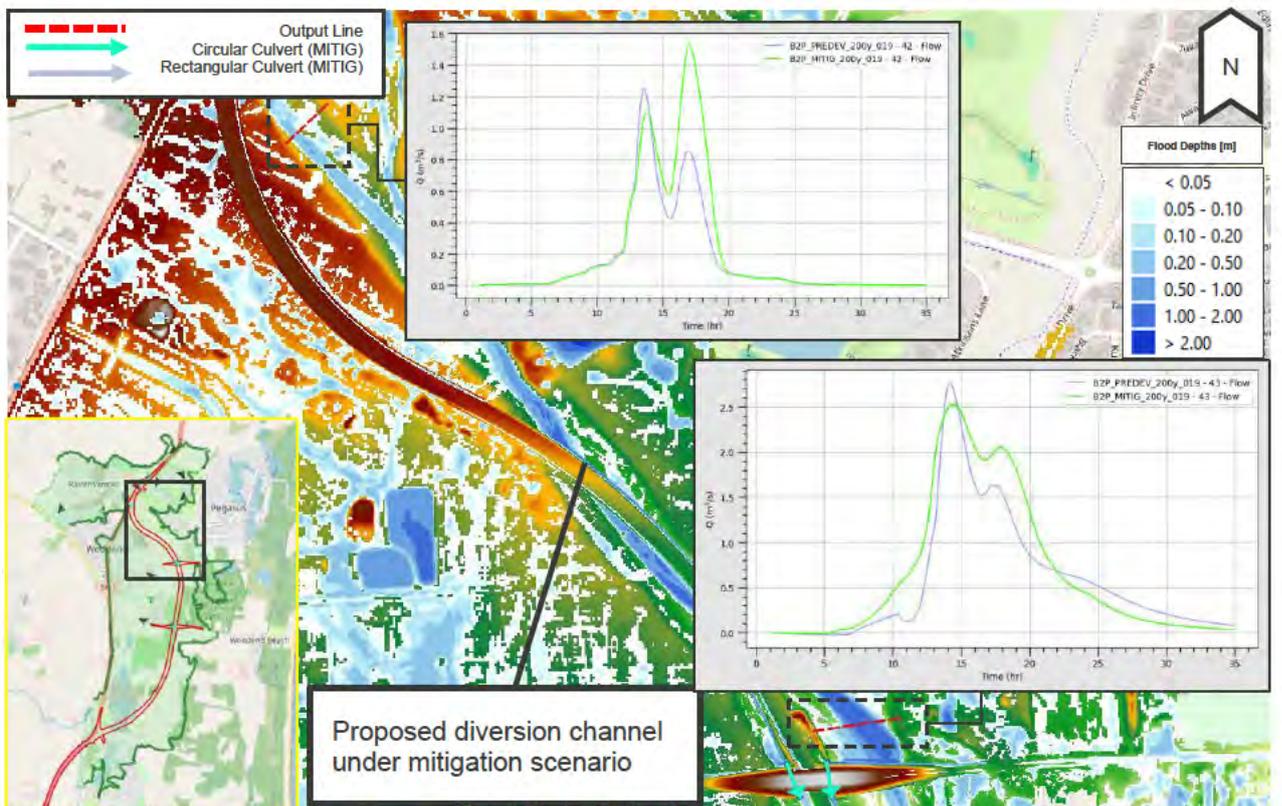


Figure 2-22 Waihora Creek to Gladstone Road 200-year Flood Duration Assessment

Woodend Beach Road

Similar to the situation at Gladstone Road, the proposed interchange at Woodend Beach Road functions as an impounding structure, temporarily storing runoff from the proposed eastern waterways of the bypass.

For the 100-year ARI event (Figure 2-23), the hydrographs at both the upstream and downstream of Woodend Beach Road show higher peaks in the mitigation scenario. This is due to the proposed larger culvert, which enables greater flow conveyance downstream. In the existing scenario, runoff ponds behind the road before overtopping downstream.

For the 200-year ARI event (Figure 2-24), the hydrograph patterns are similar, with the mitigation scenario again allowing slightly more runoff to travel downstream as a result of the culvert upsizing.

A positive afflux is observed downstream (Figure C-16). However, flood extents remain unchanged, and there is no increased flood risk to nearby properties.

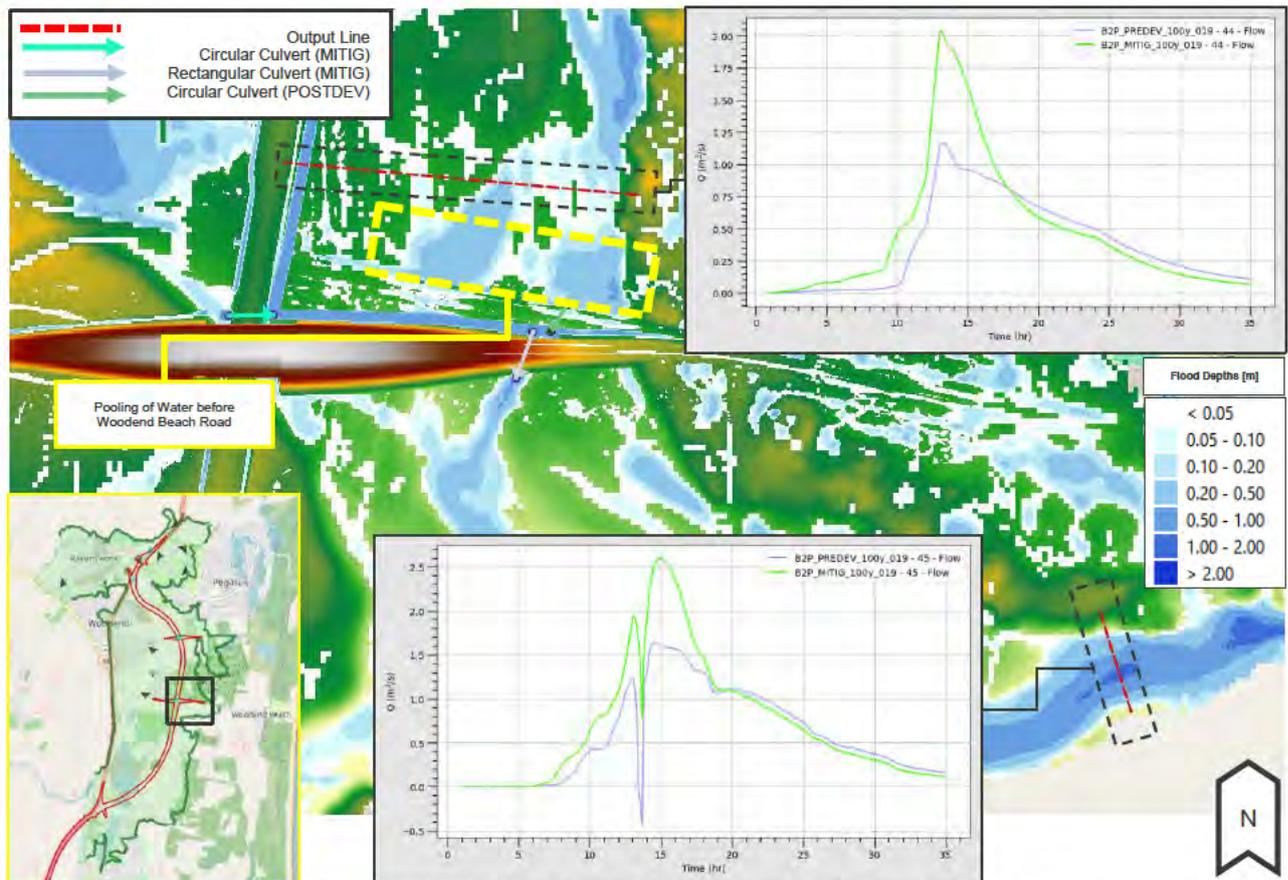


Figure 2-23 Woodend Beach Road 100-year Flood Duration Assessment

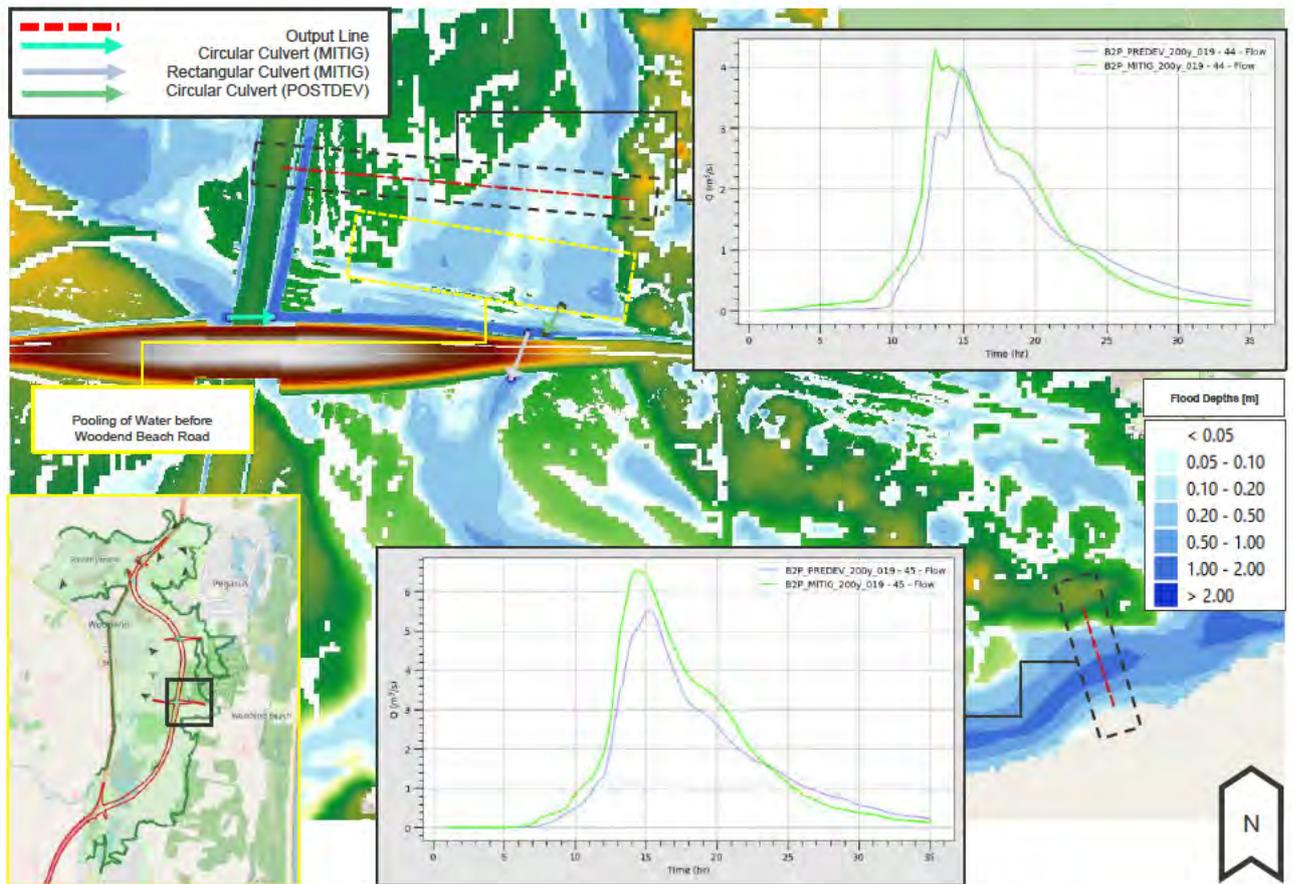


Figure 2-24 Woodend Beach Road 200-year Flood Duration Assessment

McIntosh Drain

The hydrographs for both the 100-year and 200-year ARI events (Figure 2-25 and Figure 2-26) show similar flow patterns between the pre-development and mitigation scenarios, with the pre-development scenario exhibiting a slightly higher peak. This is due to the wider overland flow path available under existing conditions, which becomes more constrained in the mitigation scenario as flows are directed through the proposed bypass and rely on the new proposed culvert for conveyance.

Overall, the drainage function is maintained. A positive afflux is observed upstream of McIntosh Drain (Figure C-15 and C-16), attributed to the raised elevation of the proposed road and a reduced cross-sectional flow area, which limits downstream conveyance. A wider flow path may be required to match pre-development levels. However, as there are no vulnerable assets within the affected floodplain, no increase in flood risk is anticipated.

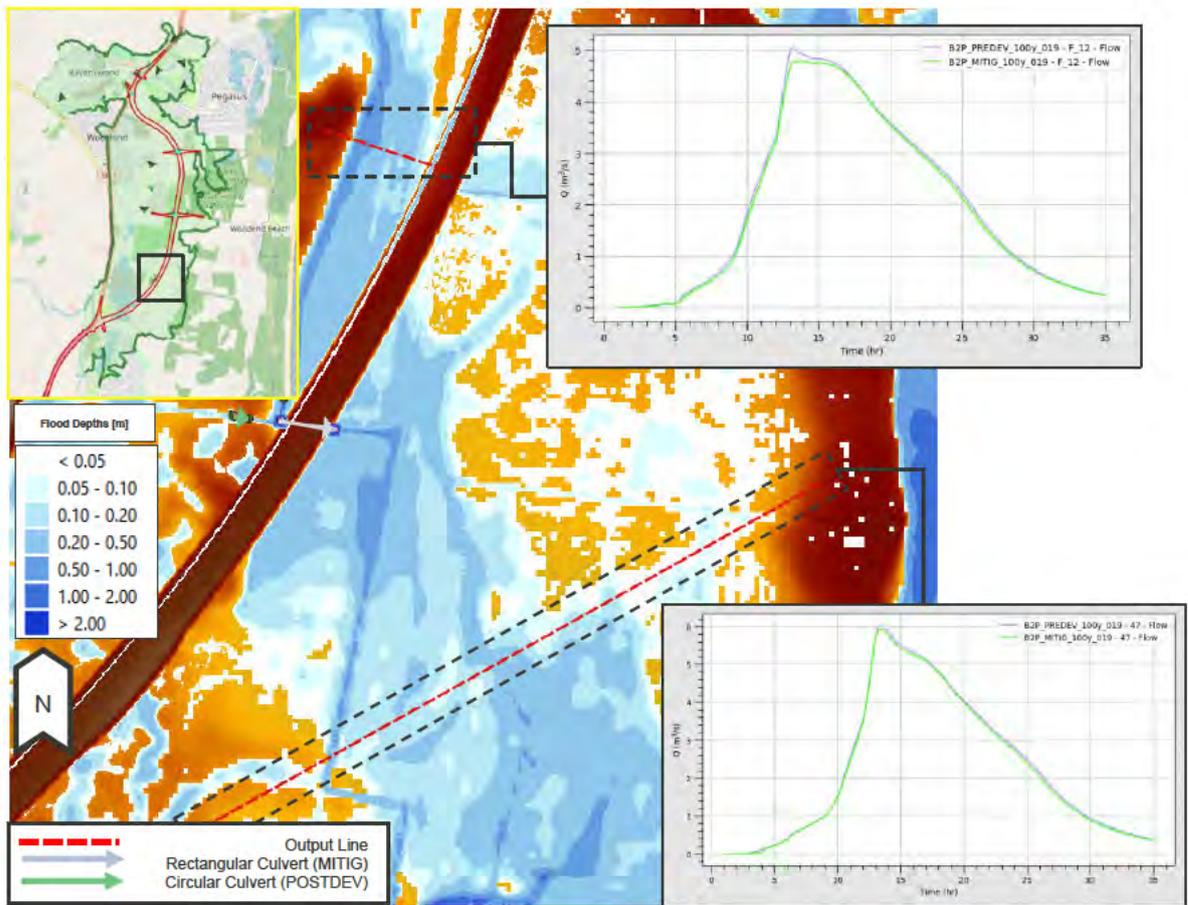


Figure 2-25 McIntosh Drain 100-year Flood Duration Assessment

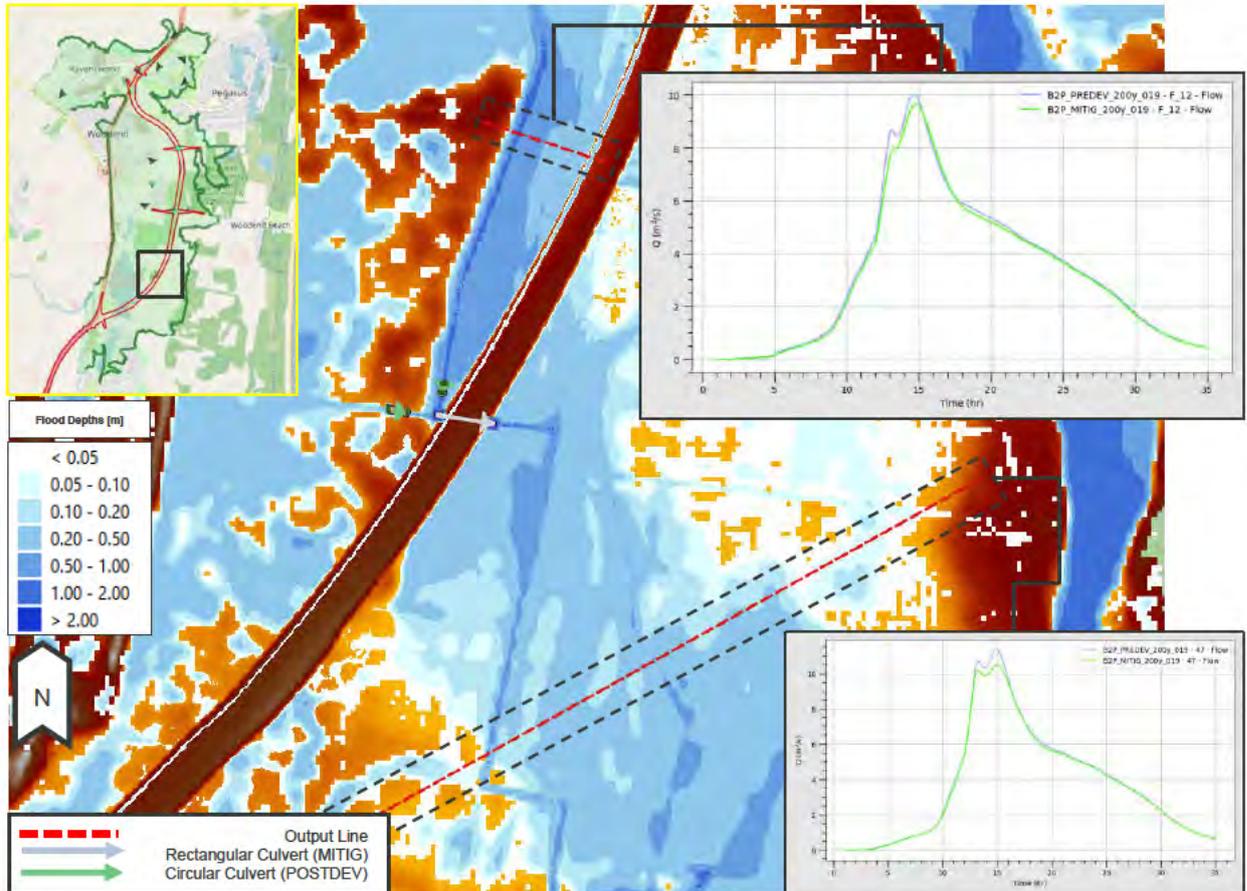


Figure 2-26 McIntosh Drain 200-year Flood Duration Assessment

3 Limitation and Applicability

The limitations and applicability of the study include the following:

- As with any model, this model still includes assumptions and simplifications of the complex real-world processes. On a broad scale, the model build provides a reasonable representation of flood depths and extents. The model, therefore, is deemed fit for purpose for broad-scale planning measures and for testing of flood impacts from proposed stormwater design and flood mitigation options.
- The B2P Flood Model has been developed using the hydraulic and hydrological data from WDC South Ashley Model. With this, all assumptions and limitations from the WDC model also apply. The 'Flood Hazard Models Update' report⁵ can be referred to for further information.
- Terrain data:
 - a. The B2P Flood Model is a snapshot of the catchment when the LiDAR was flown in 2020 and does not include new developments and future development. It may, therefore, not be applicable where flows from newly developed areas impact on results.
 - b. The existing basin surrounding the Ravenswood development area has not been accurately represented due to a lack of survey data and was not captured in the 2020 LiDAR data.
- It should be noted that localised ponding depths may vary significantly where overland flow is obstructed or blocked (e.g. by obstacles, debris, solid fences, retaining walls, sheds, etc.). Results could also be impacted in places which are not necessarily fully resolved by the 2-m grid used in this study.

⁵ DHI (May 2020). *Flood Hazard Models Update*.

4 Conclusion

This assessment has been carried out to investigate the flood impacts associated with the proposed Belfast to Pegasus Road development. A B2P Flood Model was developed using TUFLOW modelling software for this assessment. The following are the objectives of the flood assessment:

- No significant increase in flood levels at neighbouring dwellings for the 100-year ARI event.
- Any increase in flood levels at neighbouring dwellings for the 200-year ARI event should be limited to 20 mm.
- Ensure that the risks associated with the barrier effect induced by the proposed road development on the adjacent areas are reduced through various mitigation measures such as additional culverts, improvement/rehabilitation of existing culverts, and provision of additional channels to maintain or improve flow of runoff.

Three models have been developed, namely Pre-Development, Post-Development, and Mitigation models. The Pre-Development model assessed the current conditions of the model domain, including existing culverts and overland flow paths. It was considered as the base line model where flows, flood levels, and extents will be maintained through the proposed mitigation measures. The model was calibrated and validated with the WDC Flood Model in terms of flood levels and extents. The observed variations were attributed to mainly topographical differences and areas that were not incorporated in the WDC model but were updated and included in the TUFLOW model. The Post-Development model accounts for the proposed roadway, without the mitigation measures and shows the exacerbation of impacts and flood levels. These impacts were reduced in the Mitigation model through the installation of new culverts and channels to maintain the original drainage line and storage capacities of the surrounding areas.

The assessment findings indicate a flood level increase in various locations due to the proposed road development, with most impacted zones confined to the vicinity of the proposed road corridor. Additionally, elevated flood levels were observed in the residential areas along Main North Road and Woodend Beach Road, during both the 100-year and 200-year ARI events.

To ensure compliance with the regional policy statement and council requirements, two primary measures were proposed and modelled to reduce the flood impacts: the introduction of additional culverts and the diversion of flow path channels. The mitigation measures have demonstrated that effective reduction in flood impacts can be achieved across most areas during both the 100- and 200-year ARI events. The three impacted properties in the post-development model have been fully resolved in the mitigation model, with impacts less than 20mm.

Positive affluxes are still observed in seven areas outside of the designation boundary; however, these increases do not affect any property buildings, with mitigation measures only considered if deemed necessary.

Appendices



Appendix A

B2P Flood Model Build Methodology

B2P Flood Model Development

Appendix A Table 1 provides an overview of the model build methodology of the B2P Flood Model for pre-development scenario (PREDEV) and summarises the hydrological and hydraulic parameters used. This also compares the parameters used in the B2P Flood model with the WDC South Ashley Model.

Appendix A Table 1 Comparison of WDC South Ashley Model and B2P Flood Model build

Parameter	WDC South Ashley Model	B2P Flood Model (PREDEV)
Software version	<ul style="list-style-type: none"> MIKE FLOOD 	<ul style="list-style-type: none"> TUFLOW-2023-03-AC-ISP-w64
Projection	<ul style="list-style-type: none"> NZGD 2000 New Zealand Transverse Mercator 	<ul style="list-style-type: none"> NZGD 2000 New Zealand Transverse Mercator
Vertical datum	<ul style="list-style-type: none"> Lyttelton Vertical Datum (LVD) 	<ul style="list-style-type: none"> New Zealand Vertical Datum 2016 (NZVD16)
Computational and simulation parameters	<ul style="list-style-type: none"> Minimum timestep: 1e-05s Maximum timestep: 1s Simulation time: 56hr Results save timestep: 5min 	<ul style="list-style-type: none"> 1d timestep: 0.1s 2d timestep: 0.5s Simulation time: 35hr Time series output interval: 60s Map out interval: 300s
Catchment delineation	<ul style="list-style-type: none"> Model extent covering Waimakariri district 	<ul style="list-style-type: none"> Project extent covering Pegasus in the north and Kaiapoi in the south. Refer to Appendix A Catchment Delineation Section
Topography	<ul style="list-style-type: none"> Model grid element size: 5-m rectangular flexible mesh grid 5-m LiDAR DEM 2014 from WDC South Ashley Model 	<ul style="list-style-type: none"> Model grid element size: 4-m rectangular grid with sub-grid sampling 1-m LiDAR DEM 2020 from LINZ server Surveyed LiDAR for Kaiapoi Market Square pre-development
Hydrology		
Rainfall	<ul style="list-style-type: none"> 24-hr nested storm profile as derived from HIRDS v4 for the RCP 8.5 (2081-2100) climate change scenario. 	<ul style="list-style-type: none"> 24-hr nested storm profile for 100-year and 200-year ARI as extracted from WDC South Ashley Model
Initial Condition	<ul style="list-style-type: none"> Catchment is assumed dry initially 	<ul style="list-style-type: none"> Catchment is assumed dry initially
Boundary Condition	<ul style="list-style-type: none"> Constant water level downstream boundary of 1.4m RL at the confluence of Kaiapoi River and Waimakariri River Free outflow for the remaining areas downstream of the model 	<ul style="list-style-type: none"> Inflow boundaries (QT) applied upstream of the pipe network as extracted from WDC South Ashley Model Water level boundaries (HT) applied downstream as extracted from WDC South Ashley Model Refer to Appendix A Boundary Condition Section
Ground infiltration	<ul style="list-style-type: none"> Infiltration method: MIKE21 infiltration and leakage module Parameters such as initial infiltration, leakage, porosity, and initial saturation were applied 	<ul style="list-style-type: none"> Infiltration Method: TUFLOW Horton Parameters such as initial loss, initial loss rate, final loss rate, porosity, and initial moisture were applied as extracted from WDC South Ashley Model Exponential decay rate was applied as extracted from Waterways, Wetlands, and Drainage Guide of the Christchurch City Council Refer to Appendix A Ground Infiltration Section

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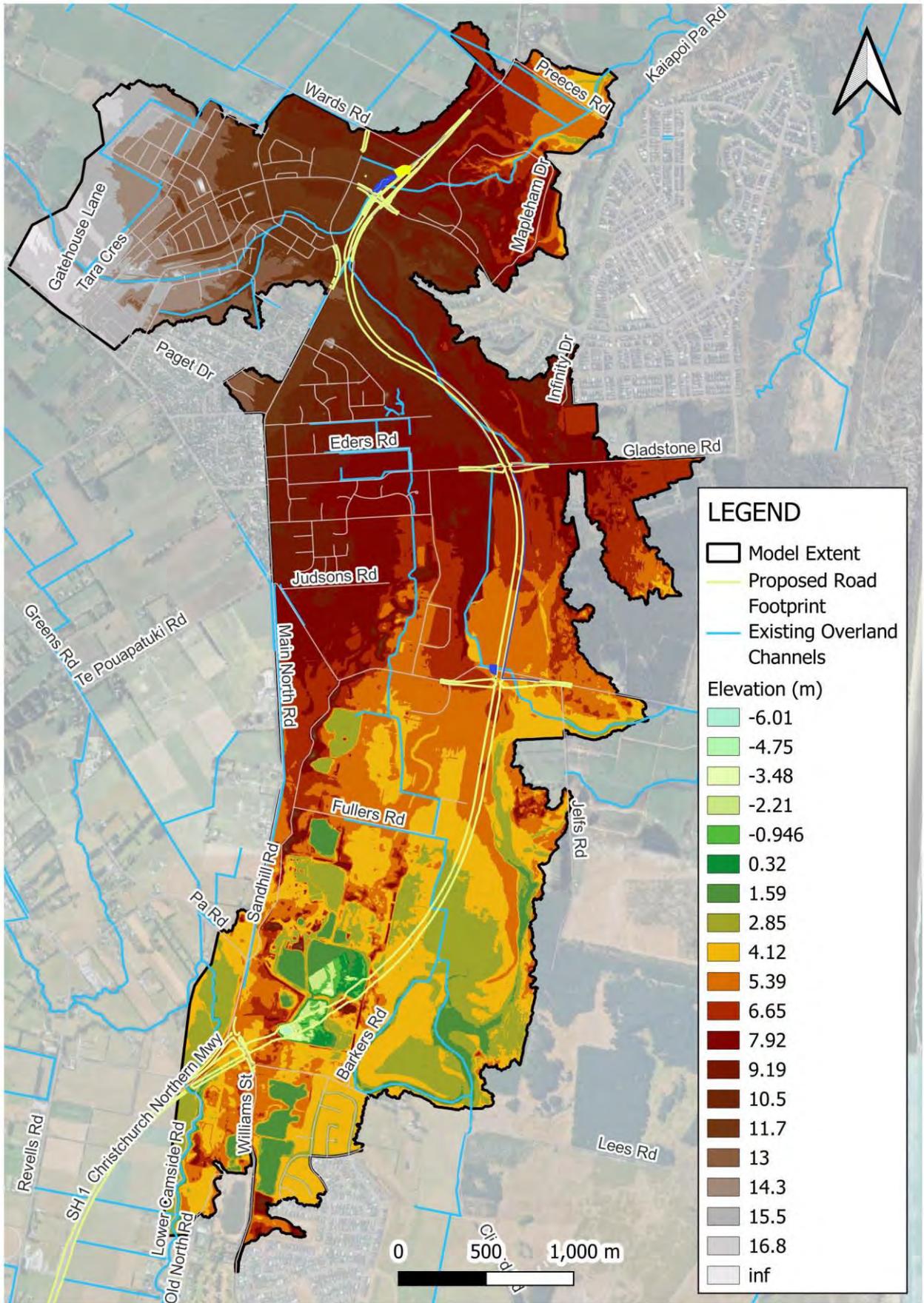
Parameter	WDC South Ashley Model	B2P Flood Model (PREDEV)
Surface roughness	<ul style="list-style-type: none"> Manning's surface roughness 'M' based on LCDB v4.1 database shapefiles 	<ul style="list-style-type: none"> Manning's surface roughness 'n' as extracted from WDC South Ashley Model Refer to Appendix A Surface Roughness Section
Stormwater network		
Pipe network & Culverts	<ul style="list-style-type: none"> Stormwater asset data covering the Waimakariri District Culverts are not defined in the model. Where flow path is blocked by existing road, existing road level has been lowered down to provide overland flow path 	<ul style="list-style-type: none"> Models were run with the assumption of 100% pipe blockage. For culvert modelling, refer to Section Stormwater Network and Culverts under Appendix A

Terrain

The topographic data used in the B2P Flood Model comprises of an on-going survey data collection and the 2020 LiDAR Digital Elevation Model (DEM) from LINZ. The survey covers the entire length of the designation of the proposed roadway bypass, including newly developed communities near the project site that were not covered in the 2020 LiDAR DEM. Once the survey data has been finalized, a new surface will be used to re-run the flood models. The Flood Mitigation Scenario Model will also be re-run with the finalised proposed roadway surface to analyse the effectivity of the measures with the ultimate design.

Catchment Delineation

The catchment was delineated using the 1m DEM LiDAR 2020 to determine the B2P Flood Model extent as shown in Appendix A Figure 1. The model extent is simplified by defining the catchment boundary covering the road alignment mostly in the towns of Pegasus, Woodend and Kaiapoi. Upper catchments were just represented as inflow boundary condition lines to avoid longer model runtime.



Appendix A Figure 1 B2P Flood Model catchment delineation

Hydrology

Rainfall

Rainfall was ingested into the model domain using a set of 50m x 50m resolution time varying 24-hour nested rainfall grid which was extracted from the WDC Flood Model. The rainfall grids have an hourly timestep with the first observation of rainfall starting at hour 1. As stated in Appendix A Table 1, the dataset was derived from HIRDS and incorporates a climate change scenario of RCP 8.5 for the period of 2081-2100.

Boundary Condition

The WDC Flood Model was the basis of all the boundary condition locations, where major drainage lines cross the extents of the model domain. Upstream flow BCs (QT) and downstream water level BCs (HT) were extracted also from the WDC Flood Model. Open boundaries, as represented by the slope, were calculated from the topographical data used in the TUFLOW model.

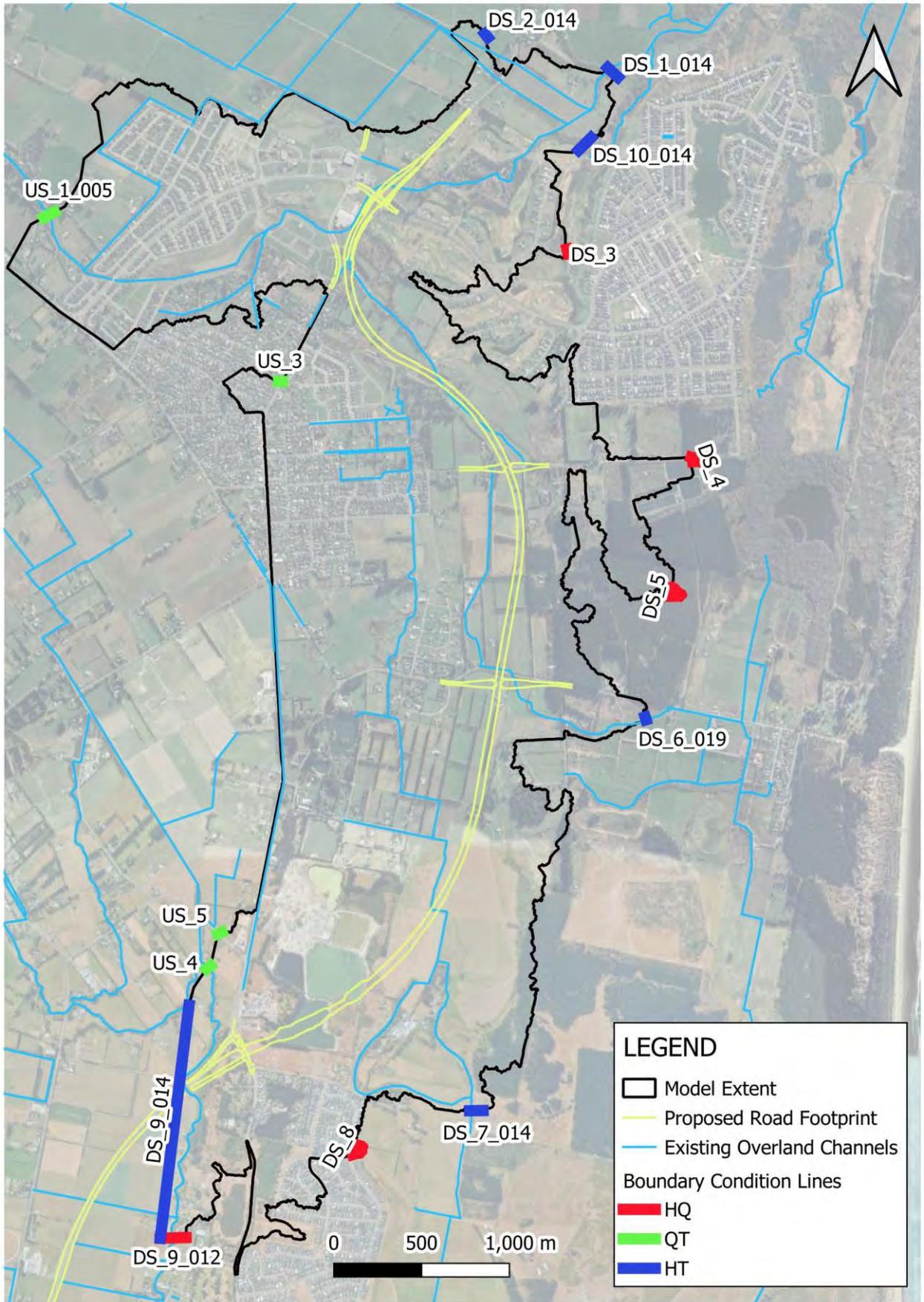
Flow hydrographs were used as an upstream boundary condition (US_1_005, US_3, US_4, US_5) along major drainage lines (e.g. rivers and streams) which are connected to upstream catchments and have been the source of water for the model domain. These are represented as a Flow vs. Time (QT) input with locations shown in Appendix A Figure 2. The 100- and 200-year ARI flow events are shown in Appendix A Figure 3.

Water level boundaries, Head vs Time (HT), are applied downstream of the model (DS_1_014, DS_2_014 and DS_10_014) at Waikuku to the north and at the western side of the Cam River (DS_9_014), as shown in Appendix A Table 2 and Appendix A Figure 4. These boundaries are influenced by other sources of water, specifically for areas near river or stream junctions that were not considered in the model domain. The same approach was applied to the floodplain at the southwestern boundary of the model (near Cam River) to simplify the movement of water since the WDC model shows that the area is a catch basin of water from different locations, apart from the Cam River.

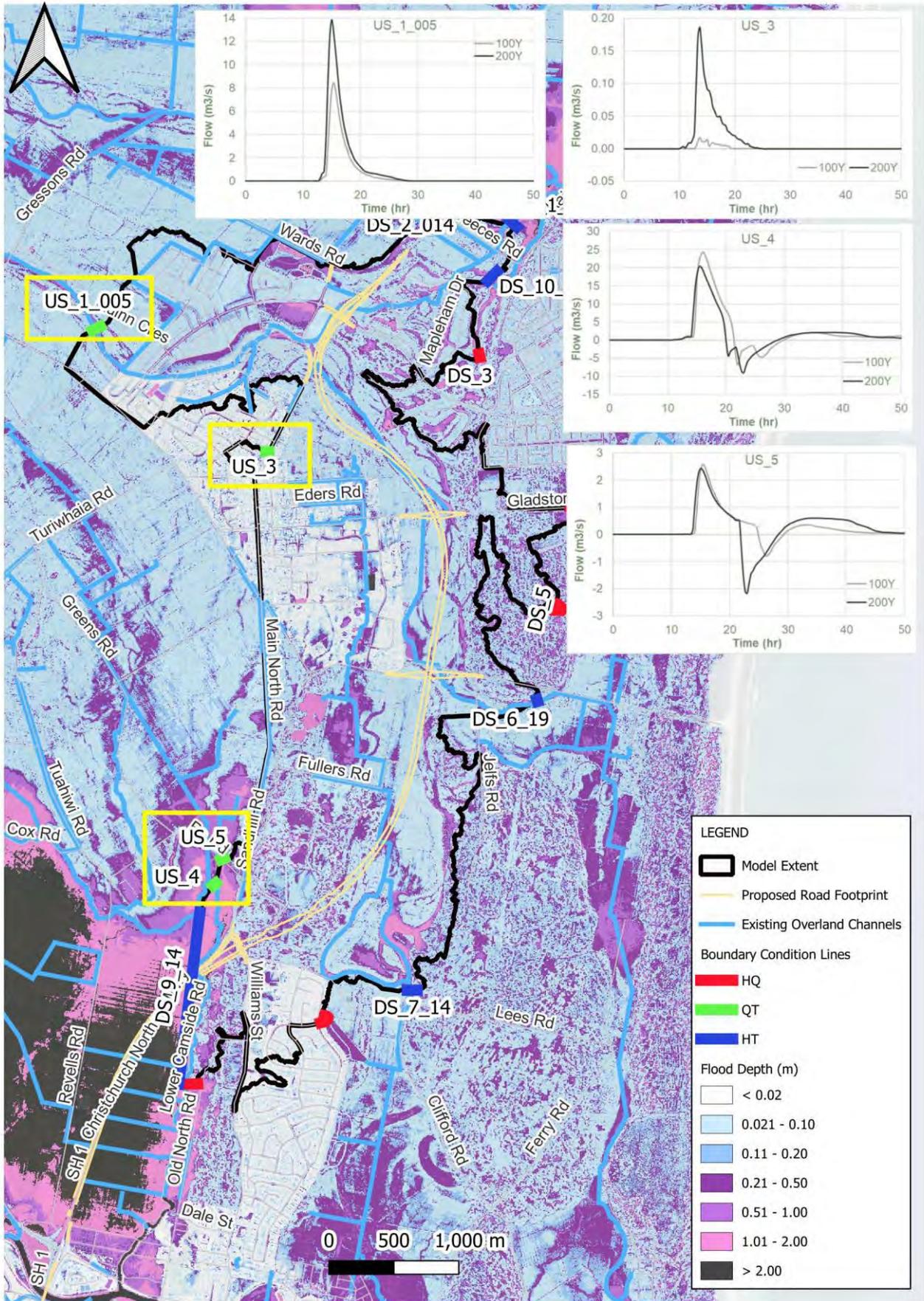
Water level boundaries Appendix A Figure 4 were also established at a major overland flow path discharging towards the east, near Woodend Beach Road (DS_6_019), and at a drain located east of quarry lake (DS_7_014). Both flow paths connect to a small drainage channel that can constrict flow in rare storm events, consequently funnelling water and producing tailwater conditions.

Free flow boundaries, as shown in

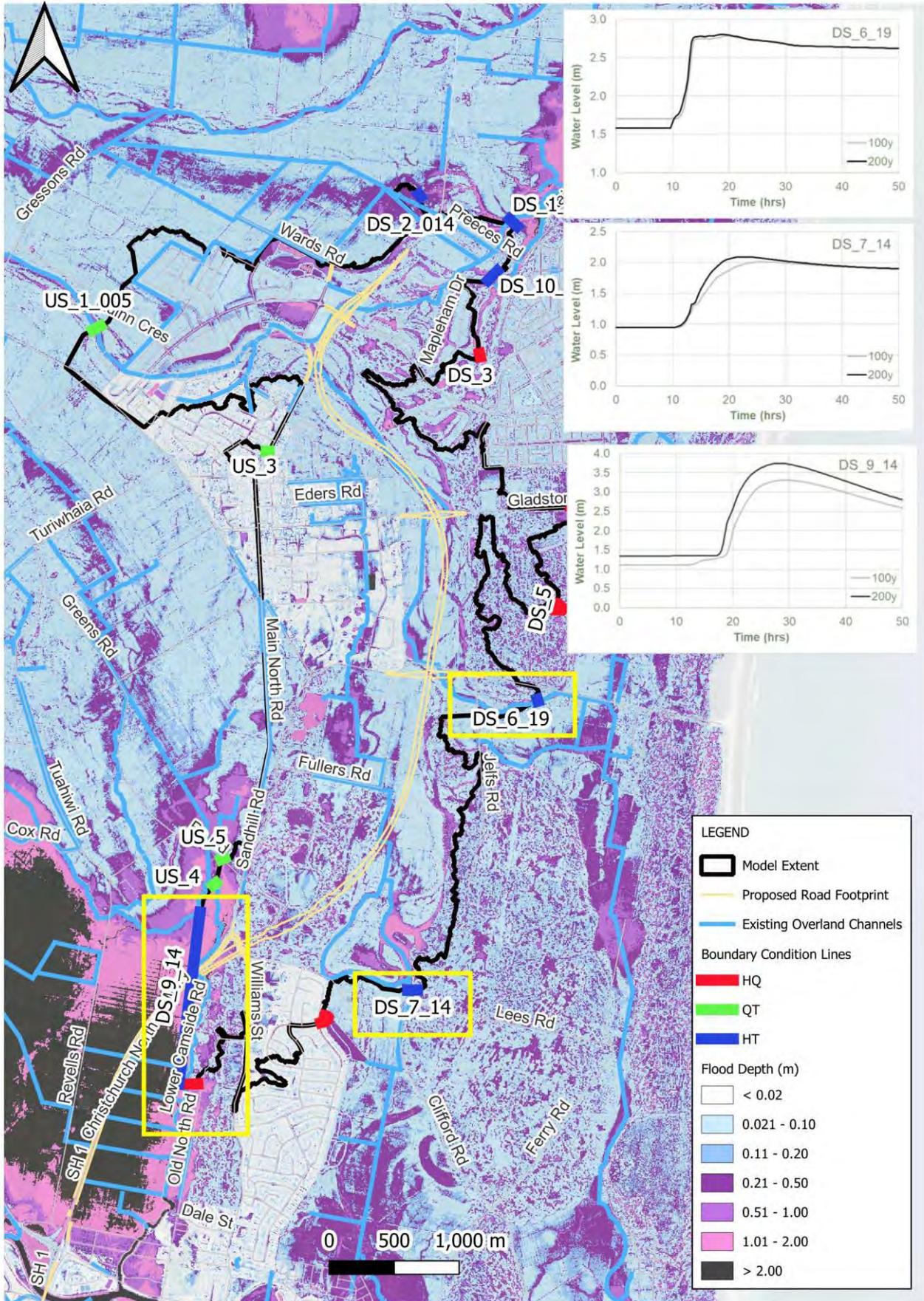
(HQ), have been placed at the downstream cross section of the Cam River (DS_9_012), and a few other streams that eventually discharges towards the east (DS_3, DS_4, DS_5, DS_8). These areas drain water freely out of the model domain.



Appendix A Figure 2 B2P Flood Model inflow and downstream boundaries overlaid on 100-year ARI flood depth result



Appendix A Figure 3 Boundary Conditions with Equivalent Inflow hydrographs



Appendix A Figure 4 Boundary Conditions with Equivalent Stage hydrographs

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Appendix A Table 2 Water Level Downstream Boundary Conditions

BC Line	100-year Level (m)	200-year Level (m)
DS_1_014	2.93	2.94
DS_2_014	5.31	5.31
DS_10_014	2.93	2.94
DS_6_019	Varying Water Level (Appendix A Figure 4)	
DS_7_014		
DS_9_014		

Appendix A Table 3 Normal Depth Downstream Boundary Conditions

BC Line	Slope
DS_3	0.0036
DS_4	0.0041
DS_5	0.0041
DS_8	0.0008
DS_9_012	0.0008

Ground Infiltration

The soils infiltration losses are applied to the B2P Flood Model using the parameters of the Horton method. Parameters such as the dry loss, initial loss rate, final loss rate, porosity, and initial moisture were extracted from WDC South Ashley Model. Detailed information on ground infiltration methodology can be referred to Section 3.2.2 of 'Flood Hazard Models Update' report.

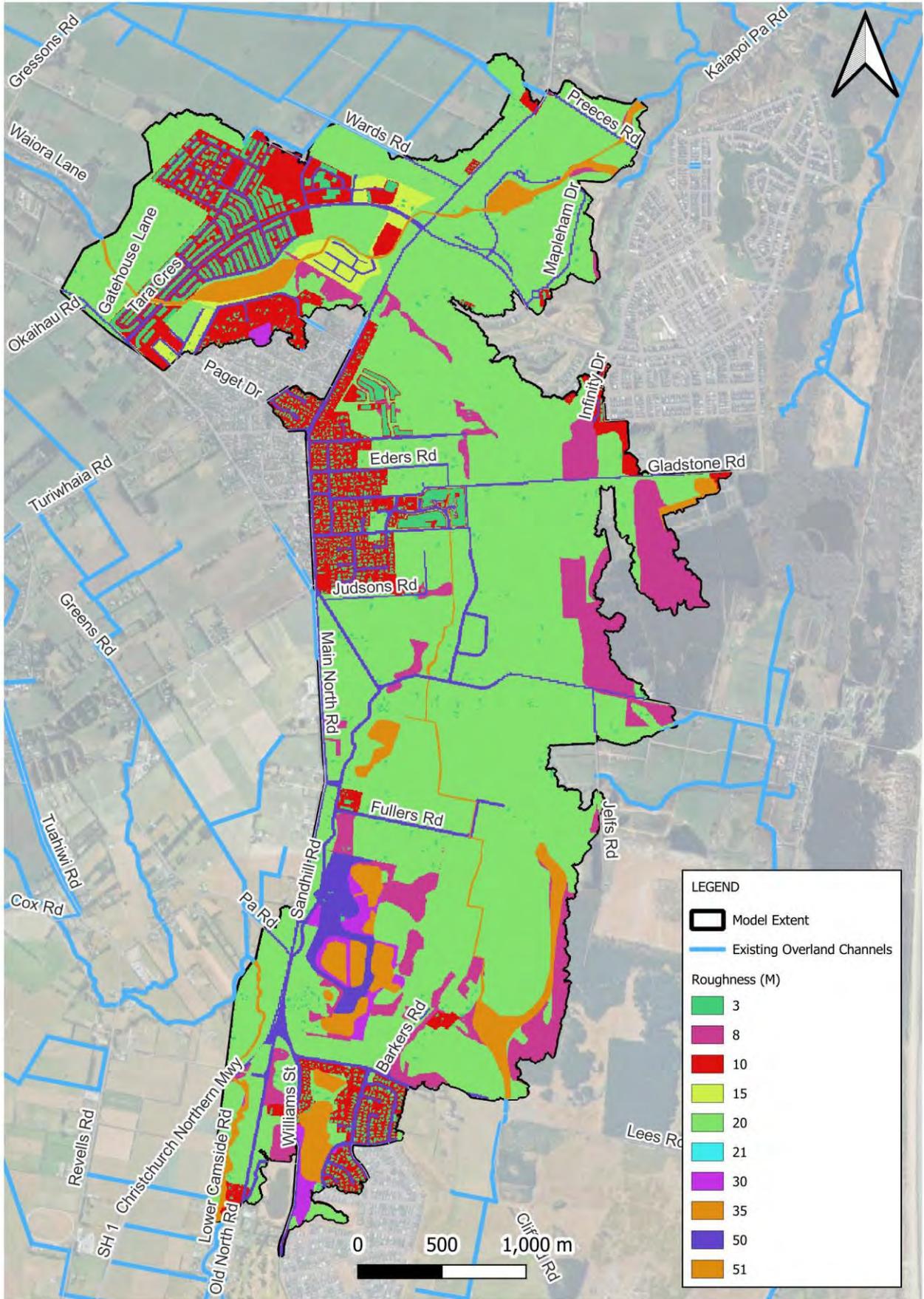
The exponential decay rate (k) parameter was determined based on the Waterways, Wetlands, and Drainage Guidelines (WWDG) of the Christchurch City Council (CCC), as detailed in Appendix A Table 4 decay rate was identified based on the initial infiltration rate extracted from WDC South Ashley Model.

Appendix A Table 4 Horton decay rate extracted from WWDG

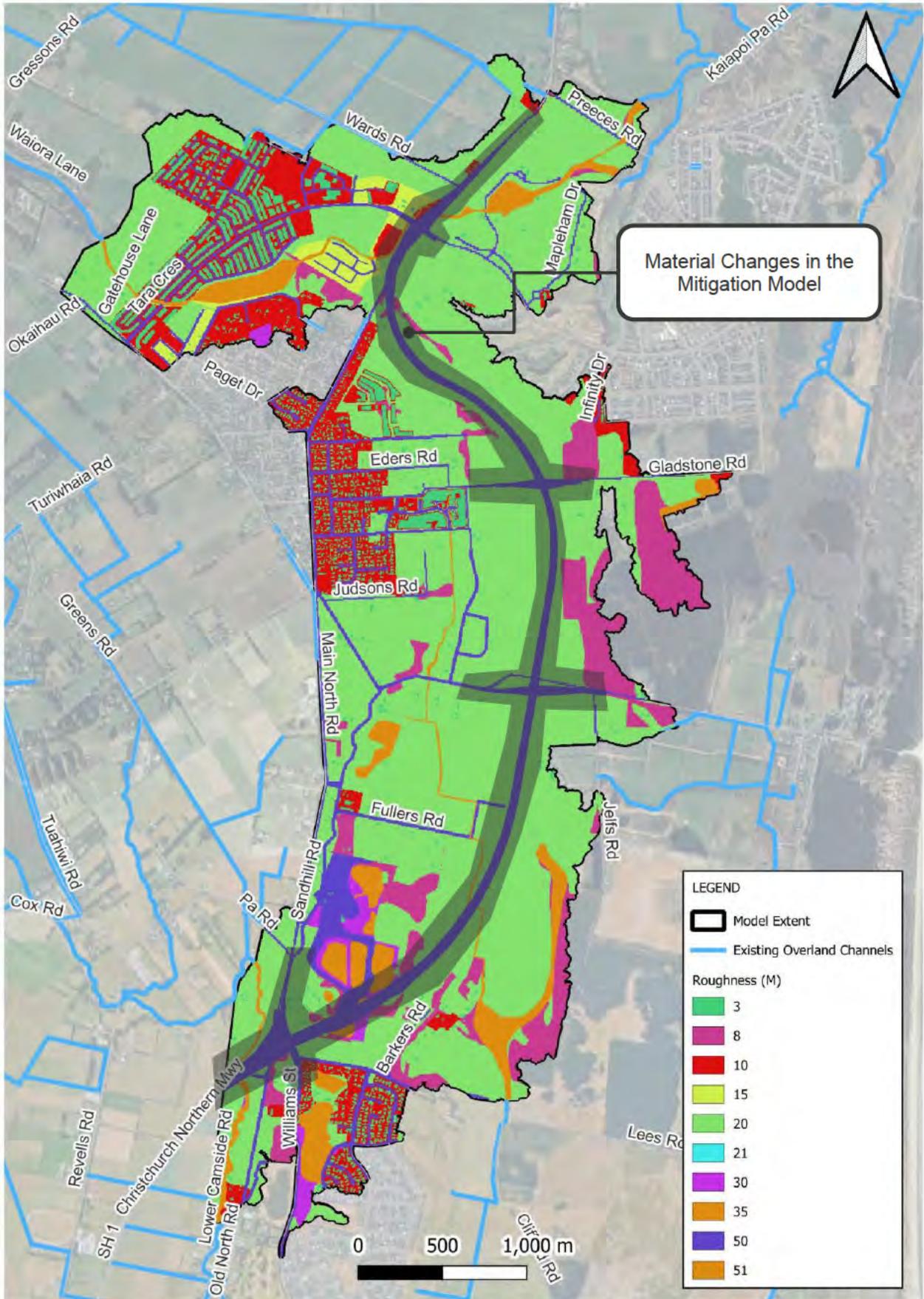
Initial infiltration rate (mm/hr)	Horton decay rate, k	Infiltration type
0 – 5	0.0015	Poor
5 – 10	0.0001	Moderate
10 – 15	0.00003	Free

Surface Roughness

The surface roughness as shown in Appendix A Figure 5 is applied to the B2P Flood Model. The surface roughness information is extracted from WDC South Ashley Model (refer to Appendix A Figure 7) A few changes to the surface roughness have been done in the Mitigation Scenario, to account for the proposed measures, such as the adjustment of the Taranaki Stream near Bob Robertson Drive (refer Appendix A Figure 6).



Appendix A Figure 5 Surface roughness applied in B2P Flood Models (Existing Scenario)



Appendix A Figure 6 Surface roughness applied in B2P Flood Models (Proposed Scenario)

Table 3-2: MIKE 21 roughness

Name_2012	Manning's M	Manning's n
Broadleaved Indigenous Hardwoods	8	0.125
Buildings	3	0.33
Built-up Area (settlement)	10	0.1
Deciduous Hardwoods	8	0.125
Depleted Grassland	50	0.02
Estuarine Open Water	35	0.029
Exotic Forest	8	0.125
Fernland	8	0.125
Flaxland	8	0.125
Forest - Harvested	8	0.125
Gorse and/or Broom	8	0.125
Gravel or Rock	50	0.02
Herbaceous Freshwater Vegetation	10	0.1
Herbaceous Saline Vegetation	10	0.1
High Producing Exotic Grassland	20	0.05
Indigenous Forest	8	0.125
Lake or Pond	35	0.029
Landslide	50	0.02
Low Producing Grassland	10	0.1
Manuka and/or Kanuka	8	0.125
Matagouri or Grey Scrub	10	0.1
Mixed Exotic Shrubland	20	0.05
Orchard, Vineyard or other Perennial Crop	20	0.05
River	35	0.029
Road	50	0.02
Sand or Gravel	50	0.02
Short-rotation Cropland	20	0.05
Sub Alpine Shrubland	20	0.05
Surface Mine or Dump	50	0.02
Tall Tussock Grassland	10	0.1
Transport Infrastructure	10	0.1
Urban Parkland/Open Space	20	0.05

Appendix A Figure 7 Surface roughness table extracted from 'Flood Hazard Models Update' report

Stormwater Network and Culverts

Appendix A Figure 8 shows the existing stormwater culverts along the major rivers and channels around the proposed development. For the B2P flood modelling purposes, urban pipe networks were assumed to be at full capacity during the 100-yr and 200-yr storm events, essentially not providing any storage and conveyance functionalities.

Geometric details of the pipes were extracted from the WDC database and were cross-referenced with the on-going topographical and drainage inventory survey along the designation of the proposed roadway. For areas that were not covered by the survey, details from the WDC database were considered absolute and were used whenever available since a few culverts lacked geometric details, such as the sizes and invert elevations.

Appendix A Table 5 shows the inventory of all the culverts modelled in the B2P Flood Model. It indicates which culvert were either new, maintained, adjusted, or removed in the Mitigation Scenario:

- Maintained – culverts were preserved from the Pre-Development Scenario Model since these were outside of the Proposed Roadway Designation and are not affected by the development.
- Adjusted – geometrical properties and/or alignment changes to the culvert. IDs of the adjusted culverts have been renamed in the Mitigation Model Scenario.
- Removed – decommissioned culverts due to changes of the overland flow path and have been affected by the Proposed Roadway Designation
- New Culvert – completely new culverts as part of the proposed mitigation measures

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The table also details the culverts that are present in each model scenario (Pre-Development, Post-Development, or Mitigation).

Appendix A Table 5 Modelled Culvert Inventory

ID	Size	No. of Barrels	Roughness (Manning's n)	Source	Dummy Geometry [Y/N]	Fish Passage [Y/N]	Model Scenario Present	MITIG Scenario Status
C001	DN525	1	0.013	Stormwater_Pipes -6254-SW007089	N	N	PREDEV, POSTDEV, MITIG	Maintained
C002	DN900	1	0.013	Stormwater_Pipes -4248-SW022584	N	N	PREDEV, POSTDEV, MITIG	Maintained
C003	DN1950	2	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
C004	DN600	1	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
C005	DN750	1	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
C006	DN525	1	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
C007	DN1800	2	0.0203	Survey	N	Y [300mm Embedment]	PREDEV, POSTDEV, MITIG	Maintained
C008	DN300	1	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
EC_01	DN750	1	0.013	Survey	N	N	PREDEV, MITIG	Adjusted (MITIG ID: EC_01)
R001	4.0m X 1.5m	1	0.013	Survey	N	N	PREDEV, MITIG	Adjusted (MITIG ID: NC_02)
R002	2.0m X 1.0m	1	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R003	2.4m X 1.2m	1	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R004	5.0m X 1.7m	1	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R005	4.0m X 1.0m	1	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R006	4.5m X 0.8m	1	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R007	1.95m X 1.95m	2	0.013	-	Y	N	PREDEV, POSTDEV, MITIG	Maintained
R008	1.25m X 0.5m	1	0.013	Survey	N	N	PREDEV, MITIG	Removed

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ID	Size	No. of Barrels	Roughness (Manning's n)	Source	Dummy Geometry [Y/N]	Fish Passage [Y/N]	Model Scenario Present	MITIG Scenario Status
R009	2.2m X 1.2m	1	0.013	Survey	N	N	PREDEV, MITIG	Adjusted (MITIG ID: NC_01a)
R010	1.7m X 2.5m	1	0.013	Survey	N	N	PREDEV, POSTDEV, MITIG	Maintained
NC_01a	2.7m X 1.2m	1	0.0233	-	-	Y [300mm Embedment]	MITIG	New Culvert
NC_02	4.0m X 1.5m	1	0.026	-	-	Y [300mm Embedment]	MITIG	New Culvert
NC_04	DN600	1	0.013	-	-	N	MITIG	New Culvert
NC_05	DN1050	2	0.013	-	-	N	MITIG	New Culvert
NC_06	DN1050	2	0.013	-	-	N	MITIG	New Culvert
NC_06b	2.0m X 1.0m	2	0.013	-	-	N	MITIG	New Culvert
NC_07	3.0m X 1.7m	2	0.0233	-	-	Y [300mm Embedment]	MITIG	New Culvert
NC_08	DN600	1	0.013	-	-	N	MITIG	New Culvert

Flood Modelling Scenarios

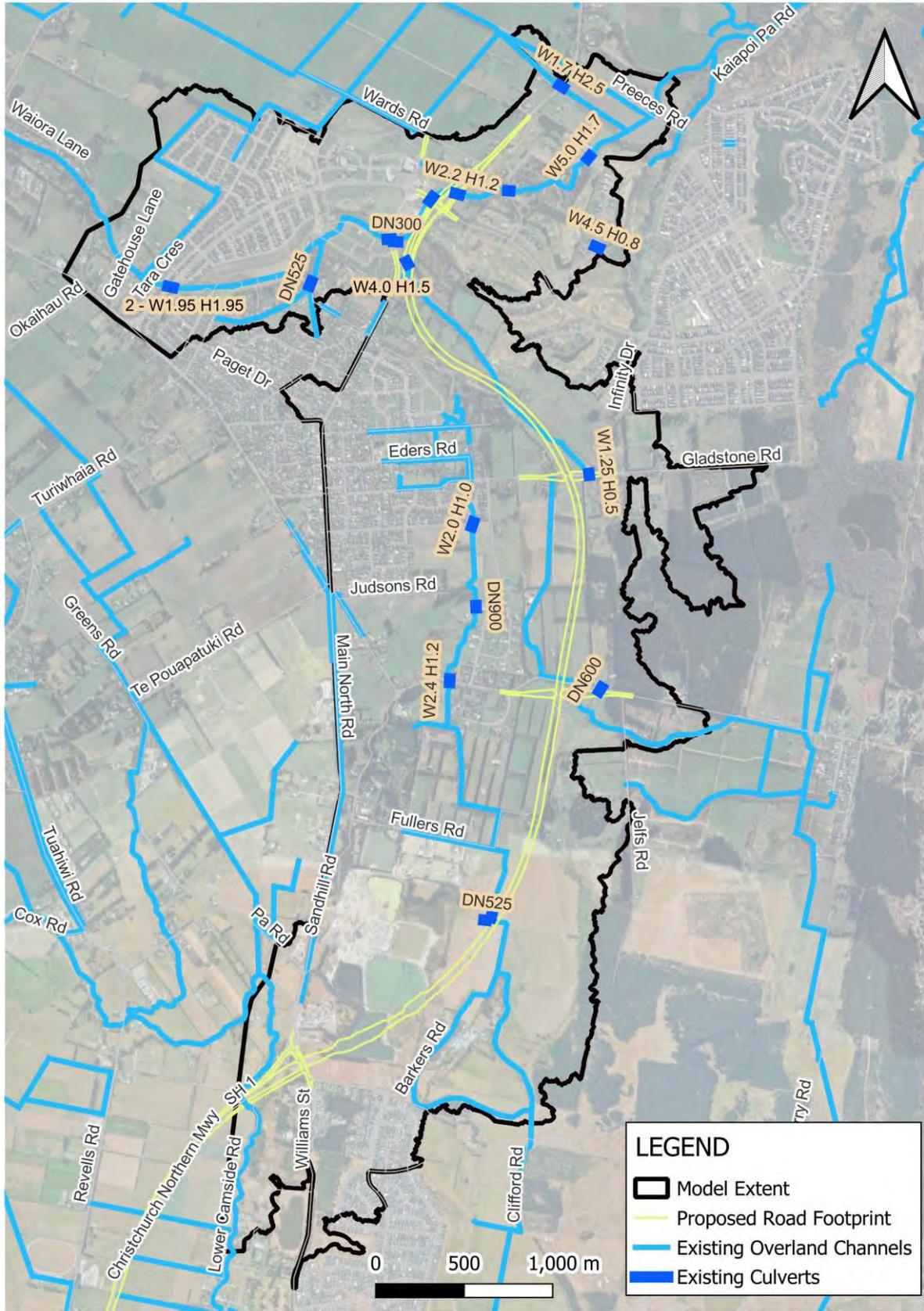
Appendix A Table 6 summarises the baseline and design scenarios that were modelled in the study for the flood impact assessment of the road development. This includes the details and corresponding changes in each modelled scenario, as well as figures for reference.

Appendix A Table 6 List of modelled scenarios

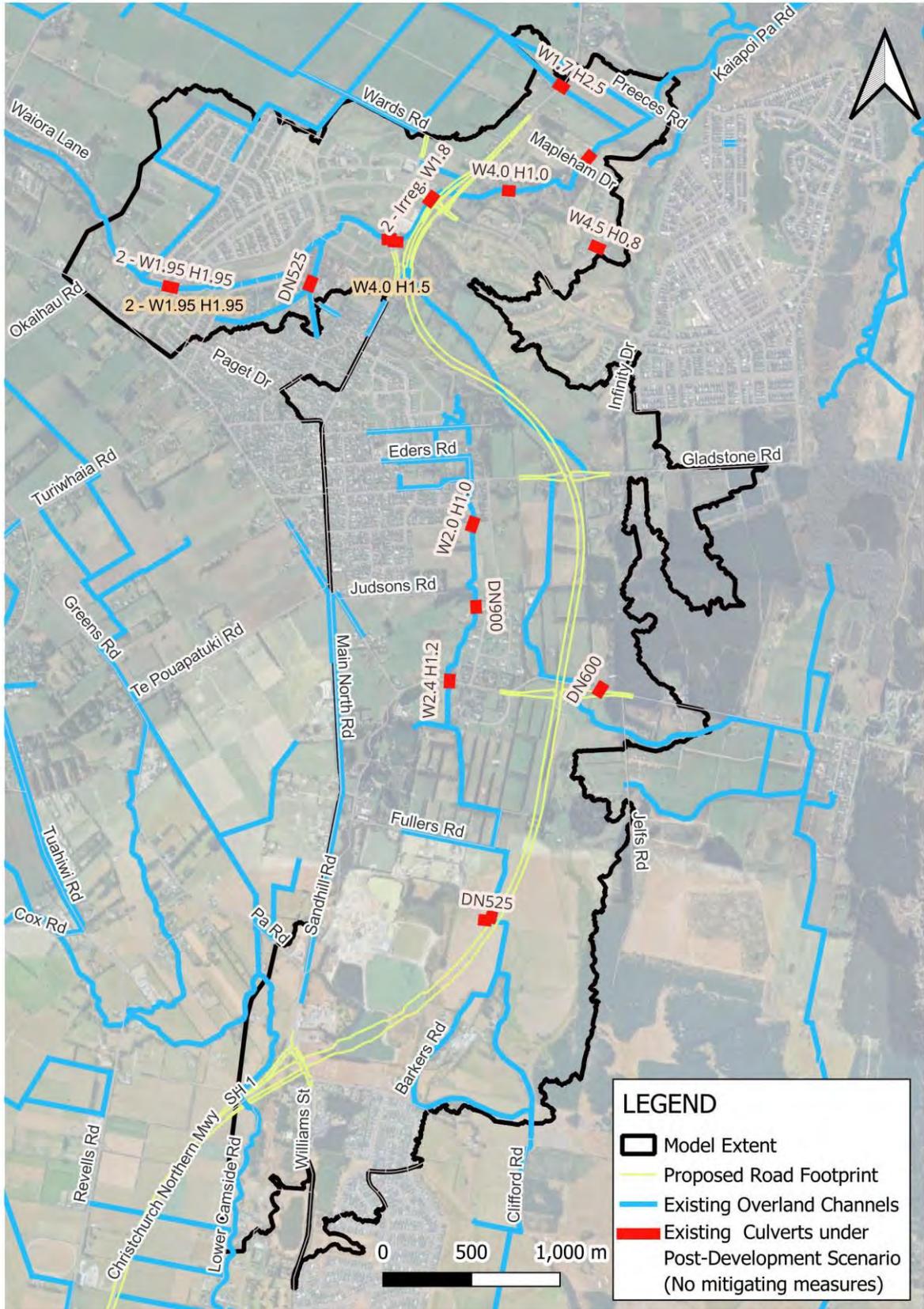
Item	Figure	Modelled Scenarios
1	Figure B-1	<p>PREDEV: Existing/pre-development scenario</p> <ul style="list-style-type: none"> • Baseline model for flood impact assessment • Refer to Table A-11 for B2P Flood Model setup
2	Figure B-2	<p>POSTDEV: Design/post-development scenario with proposed B2P road alignment included</p> <ul style="list-style-type: none"> • EXST with the following changes: <ul style="list-style-type: none"> ○ included design surface of proposed B2P road development ○ modifications on surface roughness to represent proposed B2P road alignment.
3	Figure B-3	<p>MITIG: Design/post-development scenario with mitigation solution implemented</p> <ul style="list-style-type: none"> • DES with the following changes: <ul style="list-style-type: none"> ○ Propose additional culverts ○ Propose additional flow path channels.

Appendix B

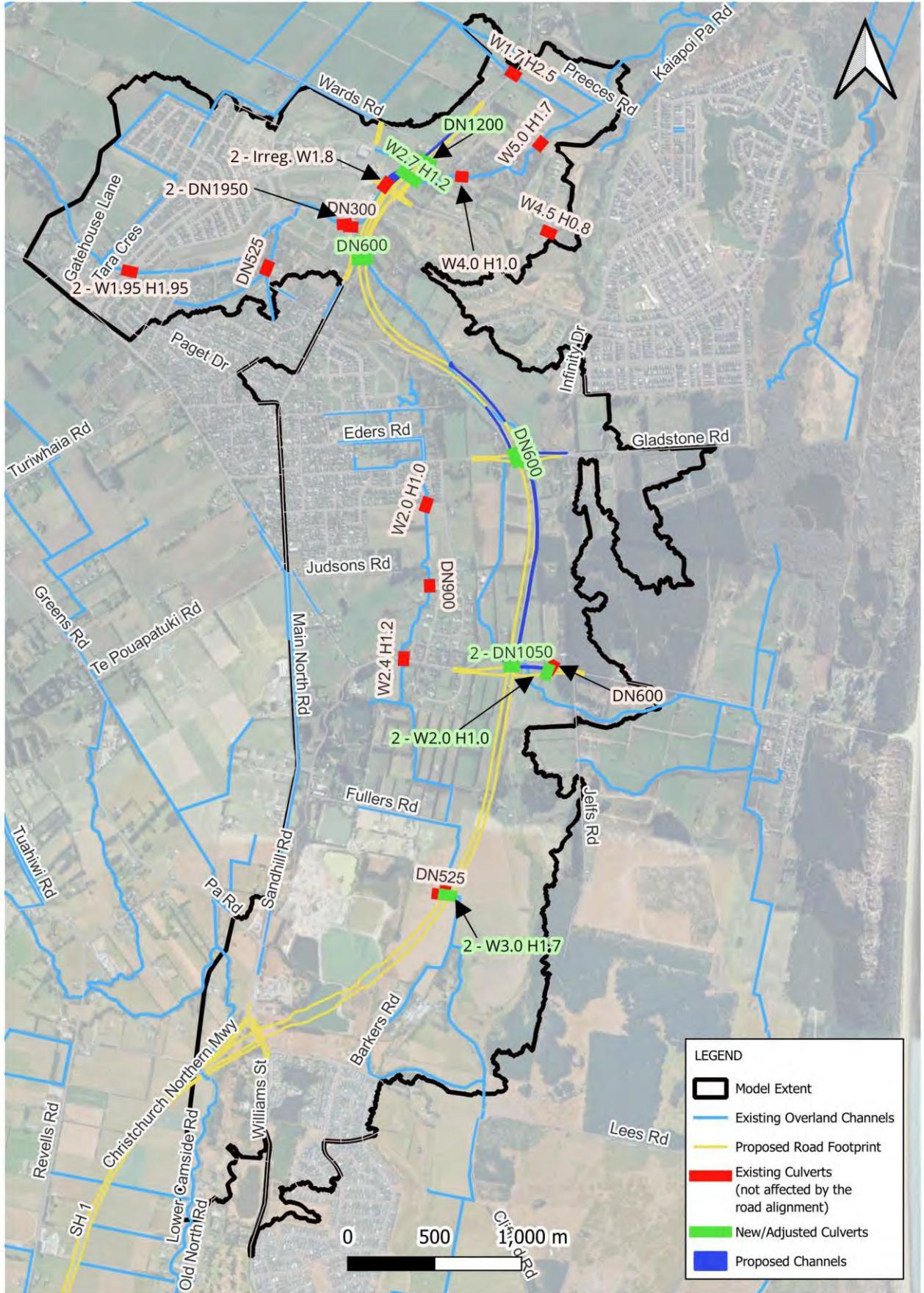
B2P Flood Model Modifications and Input Data



Appendix B Figure 1 Model Setup for the pre-development scenario



Appendix B Figure 2 Model Setup for the post-development scenario

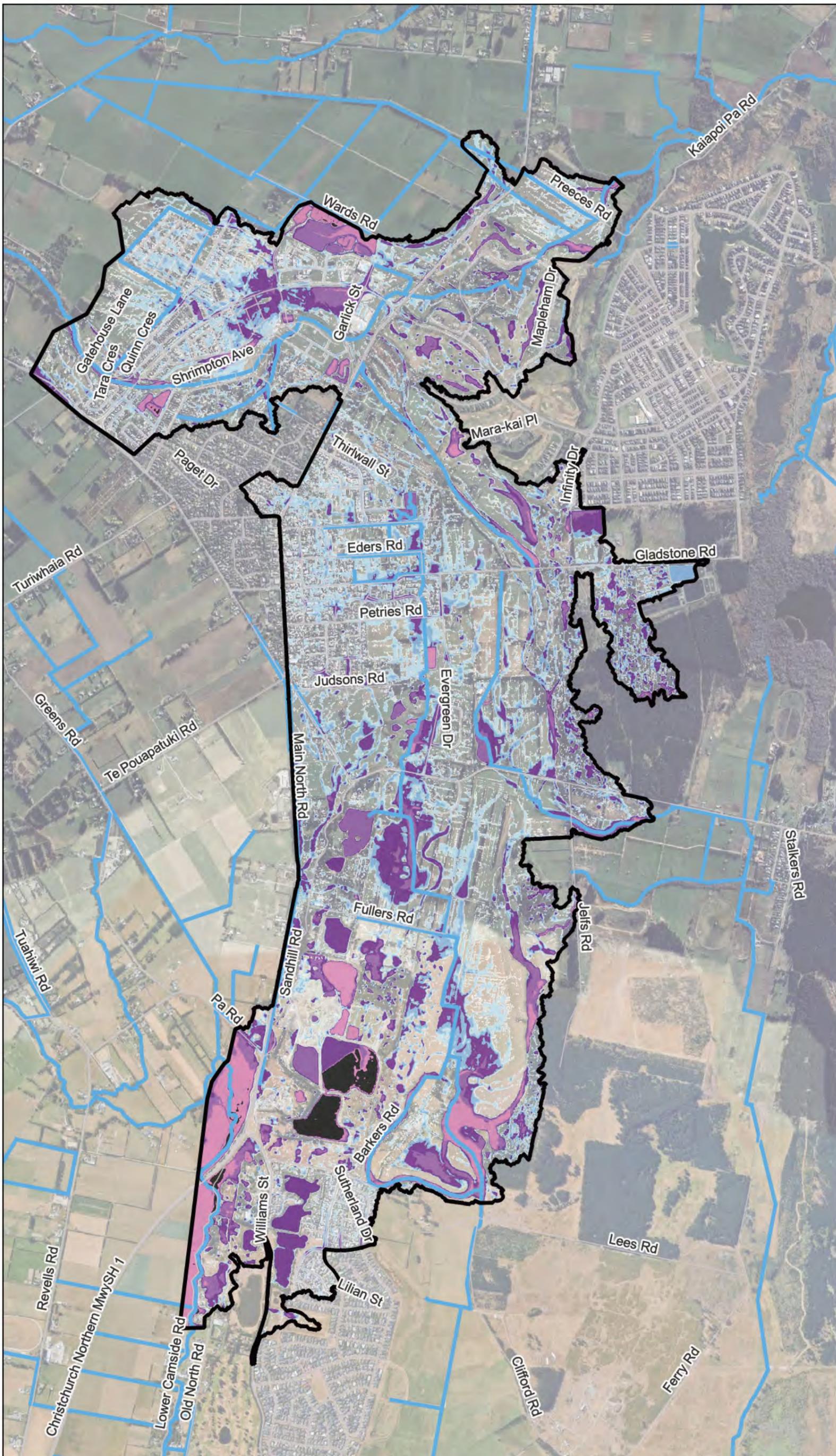


Appendix B Figure 3 Model Setup for the post-development with mitigation scenario

Appendix C

Woodend Flood Model Results

Item	Figure	Modelled Scenarios
1	Figure C-1	Pre-development Model (PREDEV) Flood Depth - 100yr ARI Storm
2	Figure C-2	Pre-development Model (PREDEV) Flood Level - 100yr ARI Storm
3	Figure C-3	Pre-development Model (PREDEV) Flood Depth – 200yr ARI Storm
4	Figure C-4	Pre-development Model (PREDEV) Flood Level – 200yr ARI Storm
5	Figure C-5	Post-development Model (POSTDEV) Flood Depth - 100yr ARI Storm
6	Figure C-6	Post-development Model (POSTDEV) Flood Level - 100yr ARI Storm
7	Figure C-7	Post-development Model (POSTDEV) Flood Depth – 200yr ARI Storm
8	Figure C-8	Post-development Model (POSTDEV) Flood Level – 200yr ARI Storm
9	Figure C-9	Flood Level Difference – Post-development (POSTDEV) minus Pre-development (PREDEV) - 100yr ARI Storm
10	Figure C-10	Flood Level Difference – Post-development (POSTDEV) minus Pre-development (PREDEV) – 200yr ARI Storm
11	Figure C-11	Post-development Model (MITIG) Flood Depth – 100yr ARI Storm
12	Figure C-12	Post-development Model (MITIG) Flood Level – 100yr ARI Storm
13	Figure C-13	Post-development Model (MITIG) Flood Depth – 200yr ARI Storm
14	Figure C-14	Post-development Model (MITIG) Flood Level – 200yr ARI Storm
15	Figure C-15	Flood Level Difference – Post-development (MITIG) minus Pre-development (PREDEV) – 100yr ARI Storm
16	Figure C-16	Flood Level Difference – Post-development (MITIG) minus Pre-development (PREDEV – 200yr ARI Storm



LEGEND

Model Extent

Flood Depth (m)

- < 0.02
- 0.021 - 0.10
- 0.11 - 0.20
- 0.21 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- > 2.00



Notes:
 Hydraulic TUFLOW Model

Model Cell Size:
 4m x 4m SGS with Quad Tree

LIDAR Cell Size:
 1m x 1m

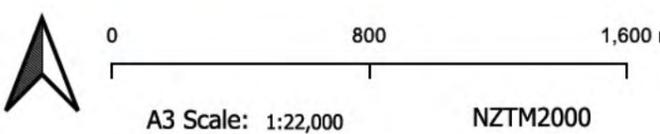
Output Grids Cell Size:
 1m x 1m

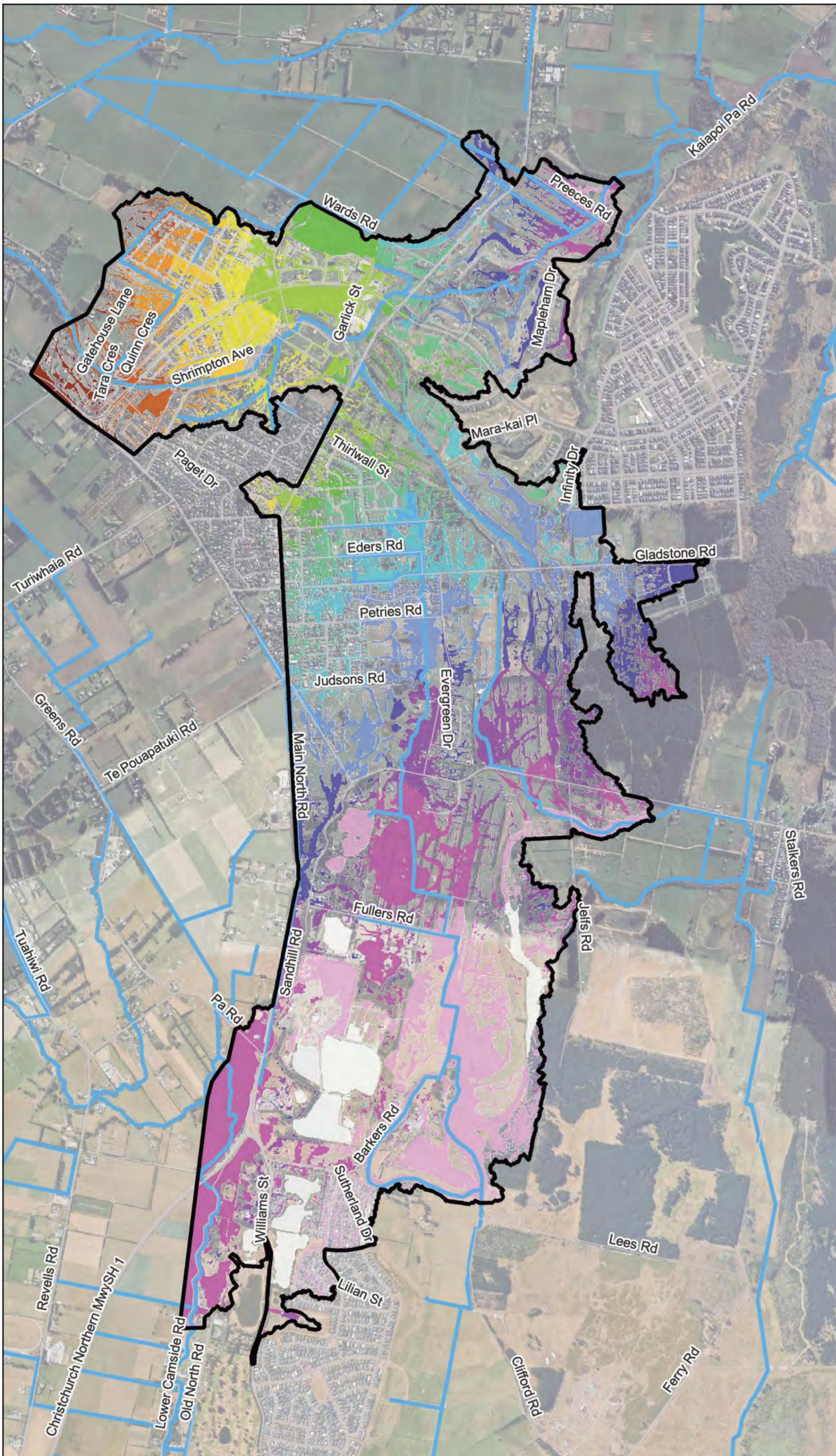
Run Scenarios:
 PREDEV - Existing topography

POSTDEV- Existing topography
 + Proposed Road
 Embankment

MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)

Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.



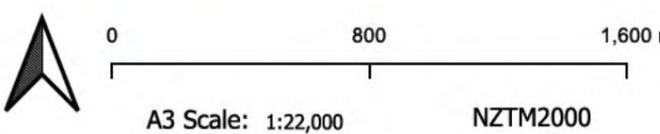


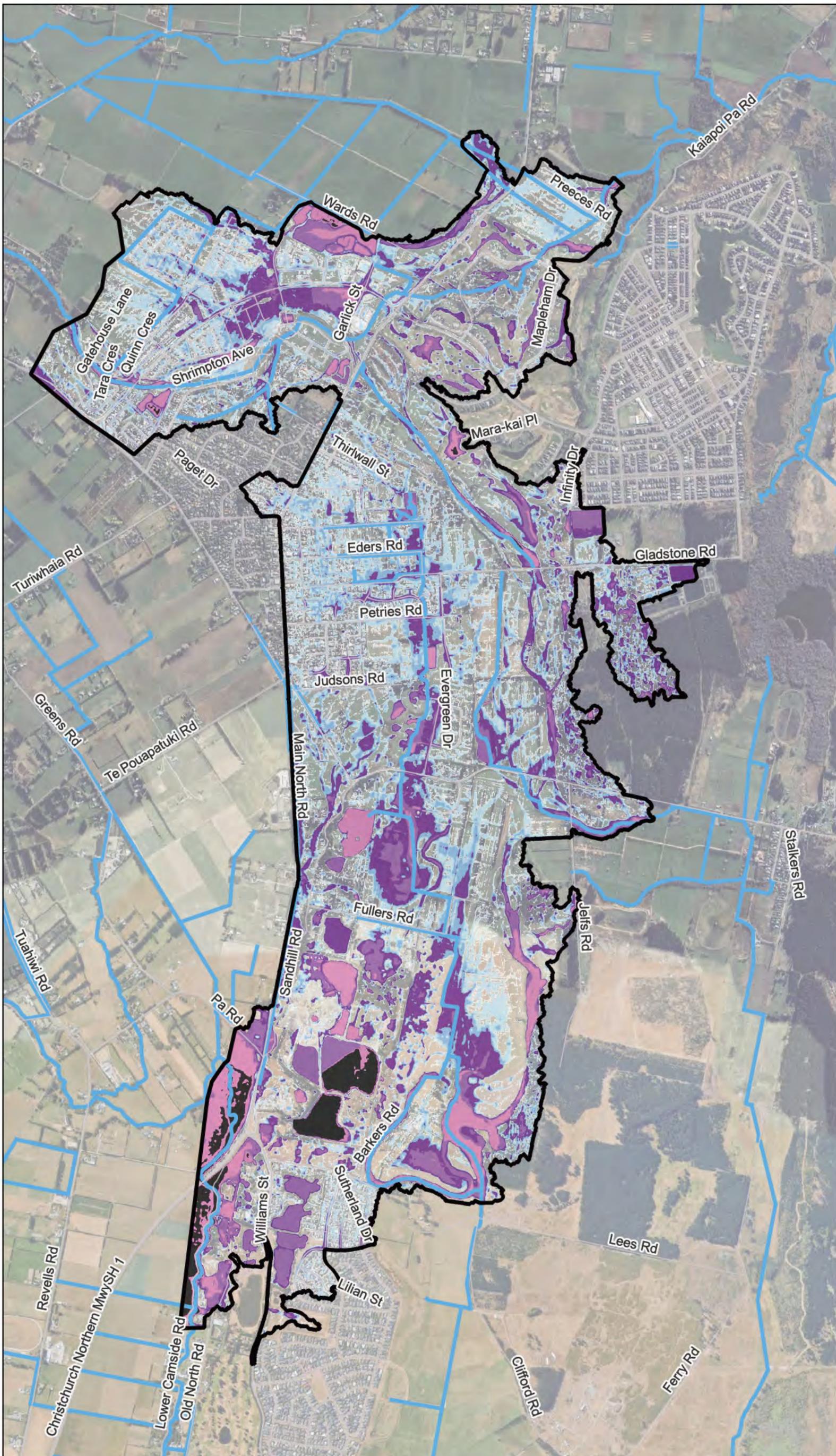
LEGEND

- Model Extent
- Roads
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
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 conditions.



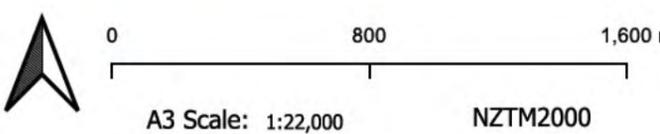


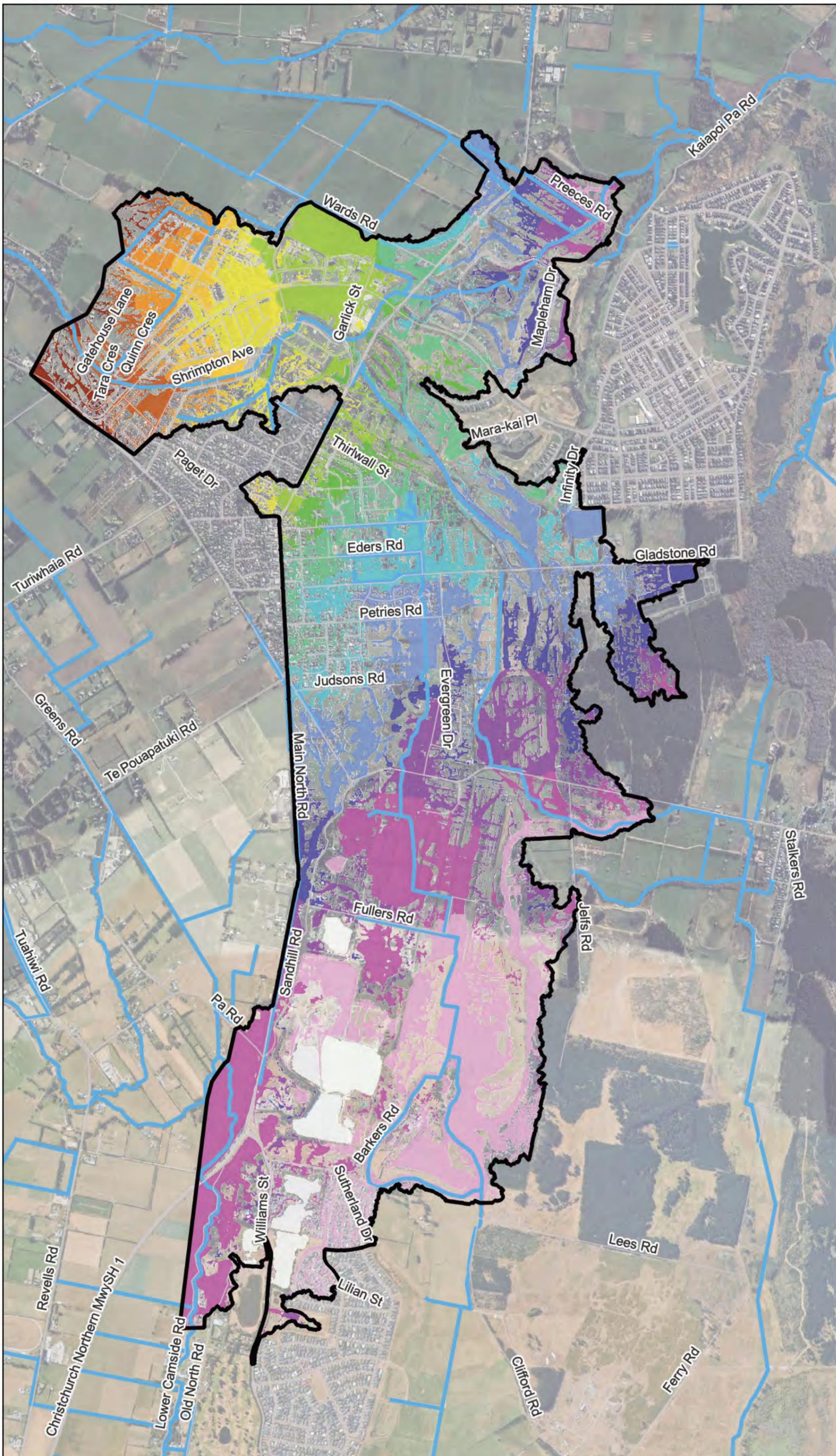
LEGEND

- Model Extent
- Roads
- Existing Overland Channels
- Flood Depth (m)
- < 0.02
- 0.021 - 0.10
- 0.11 - 0.20
- 0.21 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- > 2.00



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.



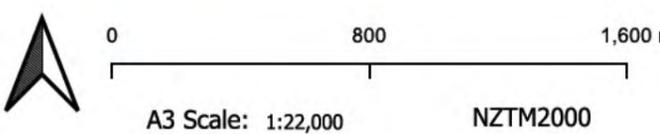


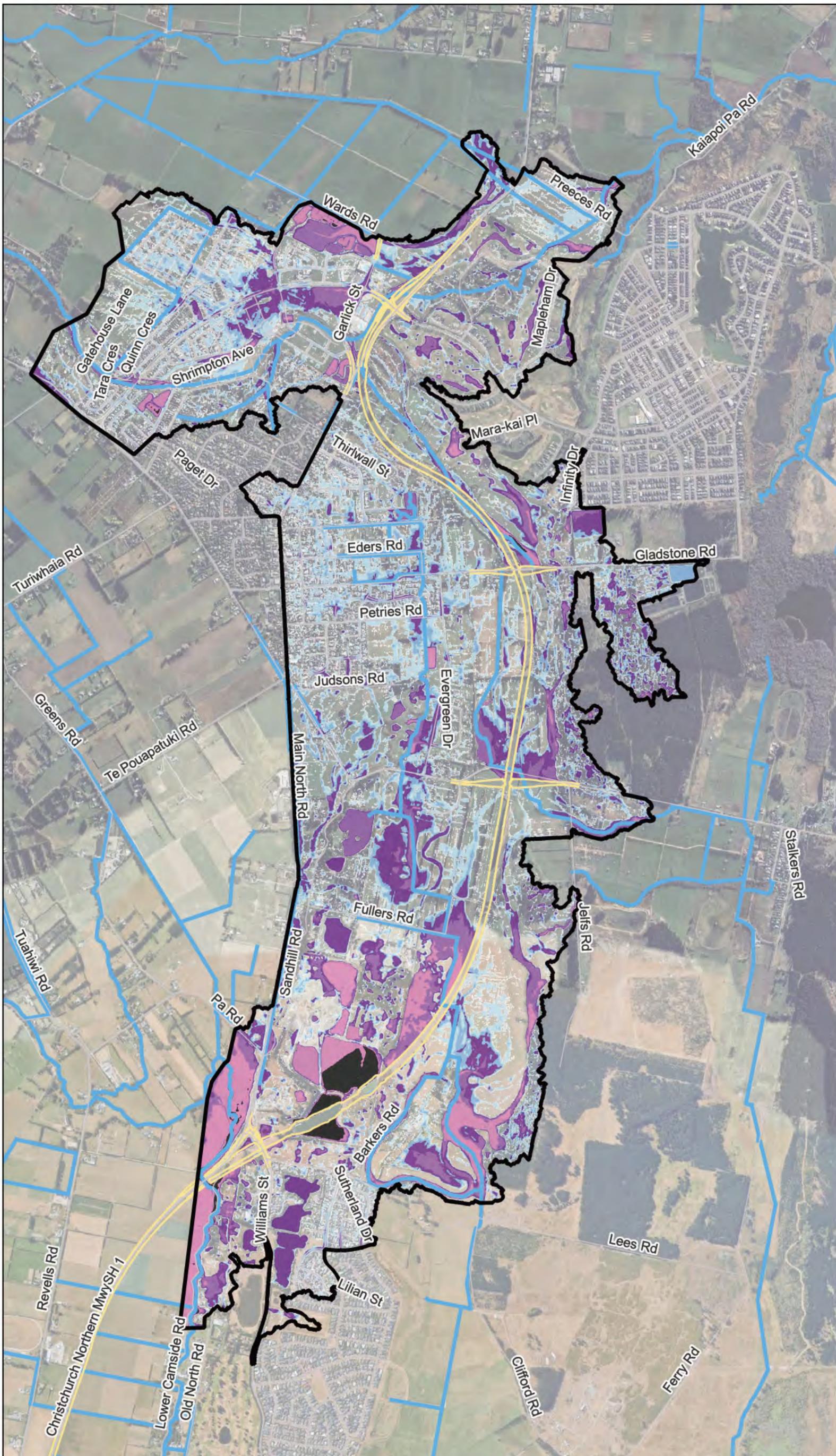
LEGEND

- Model Extent
- Roads
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.





LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Depth (m)
- < 0.02
- 0.021 - 0.10
- 0.11 - 0.20
- 0.21 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- > 2.00



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.

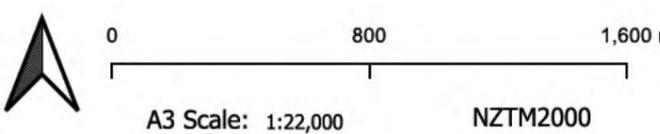
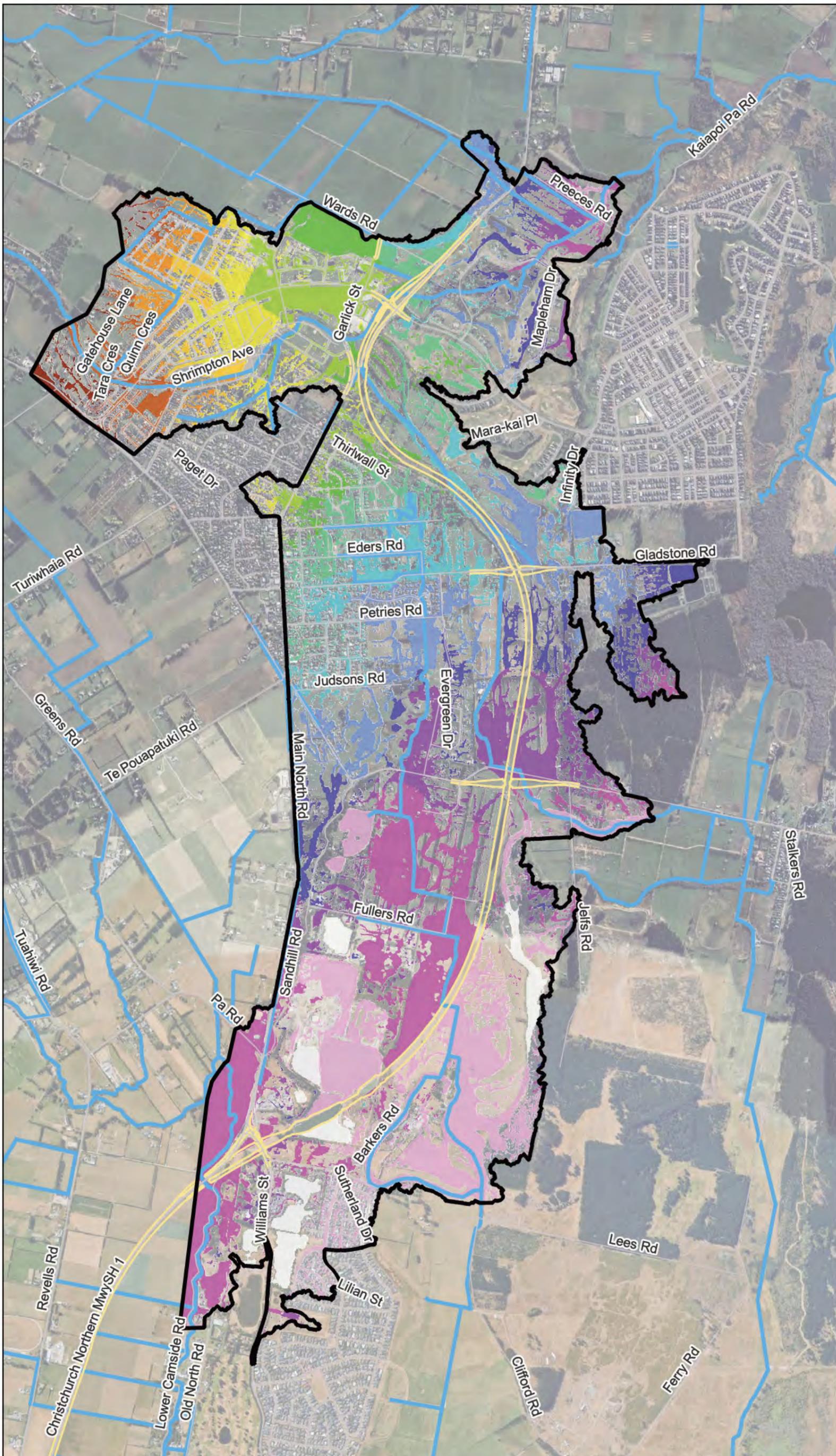


Figure C-5
 Woodend, Waimakariri District - POSTDEV

Post-development Model (POSTDEV) Flood Depth - 100yr ARI Storm

100yr ARI - Flood Depth (m)

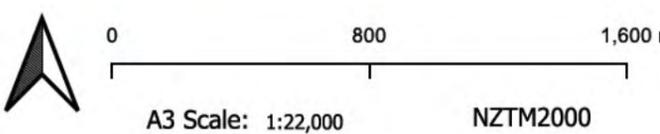


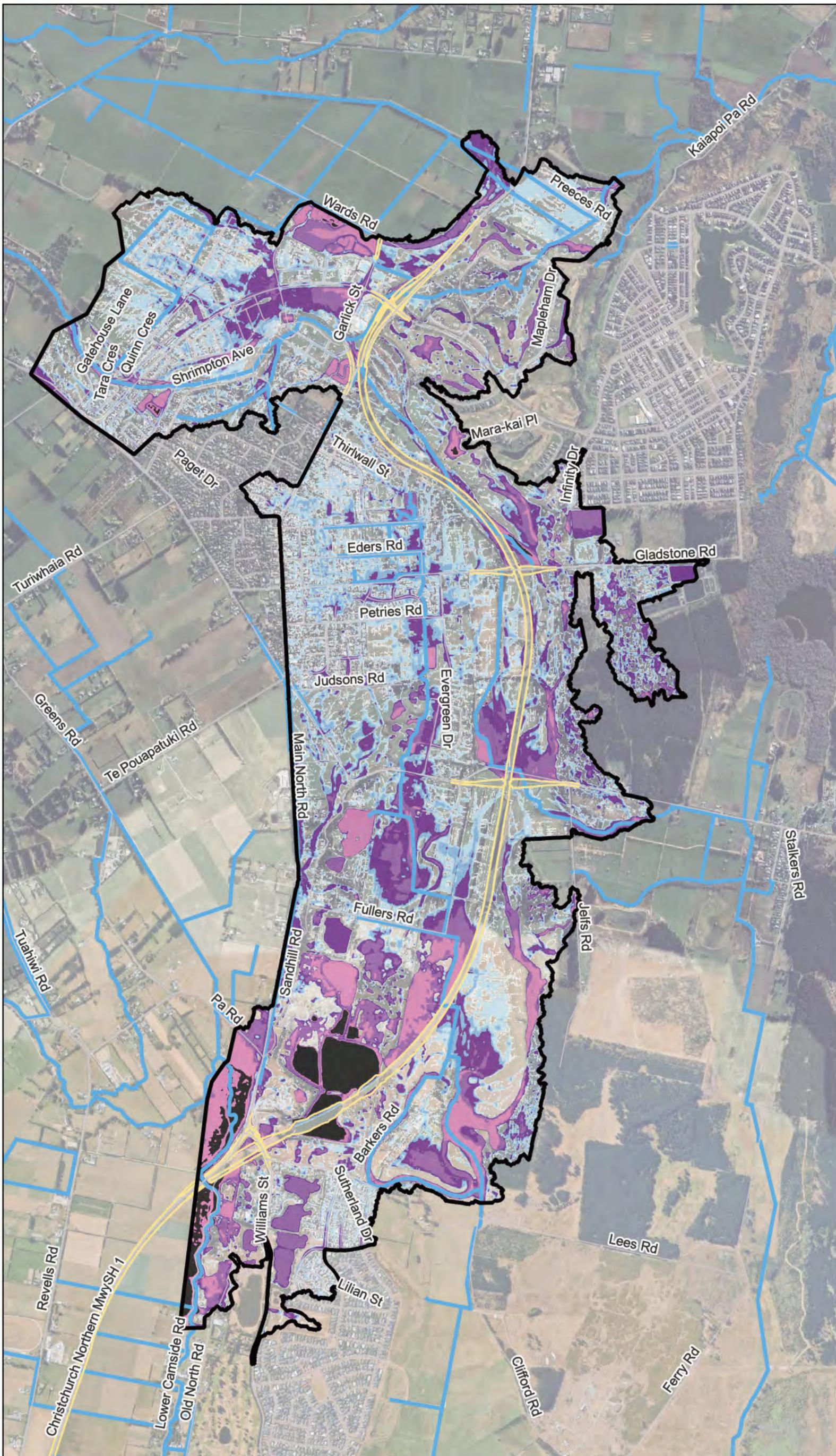
LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.





LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Depth (m)
- < 0.02
- 0.021 - 0.10
- 0.11 - 0.20
- 0.21 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- > 2.00



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.

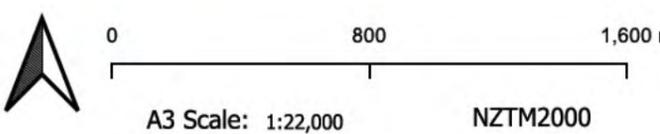
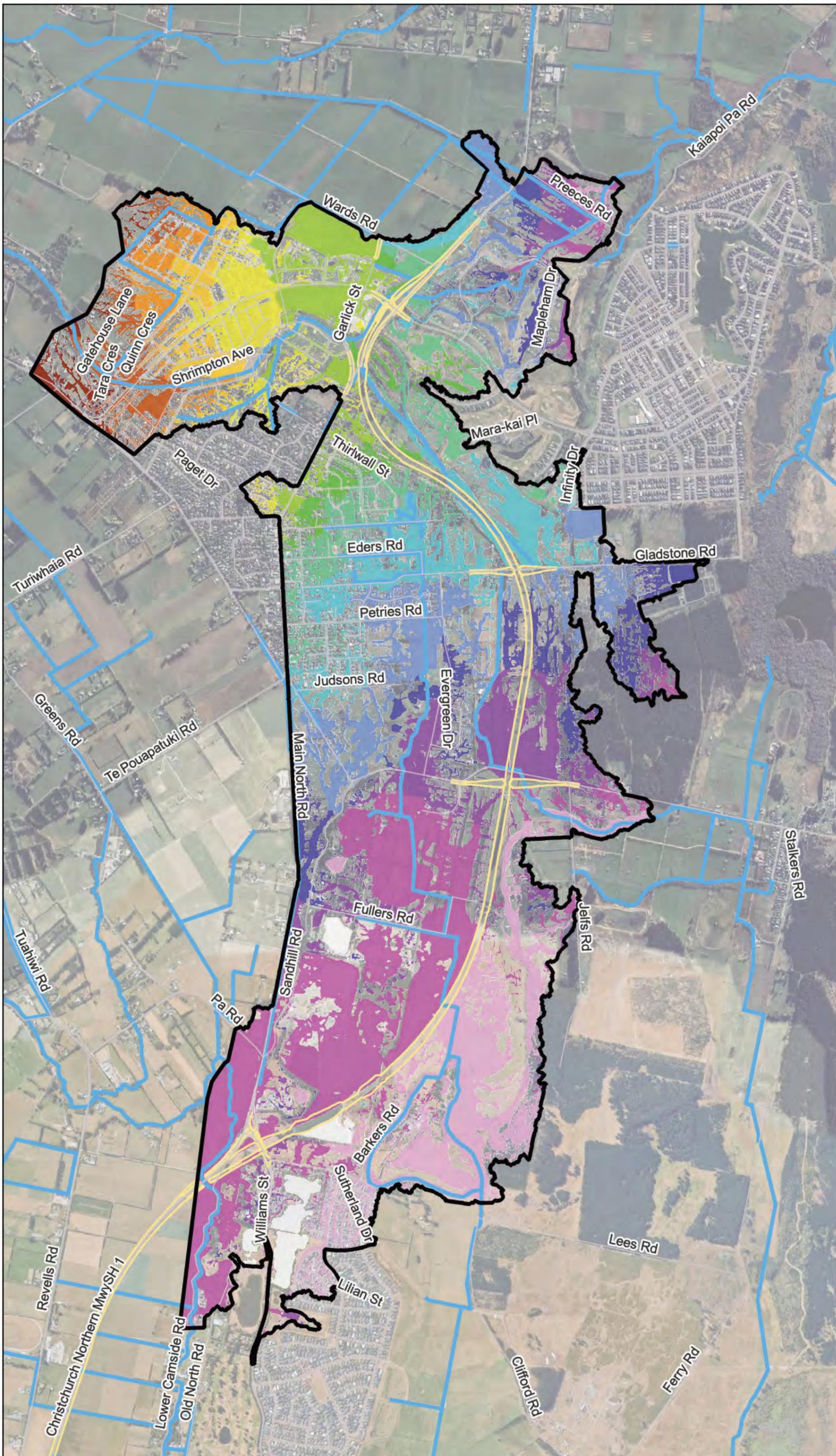


Figure C-7
 Woodend, Waimakariri District - POSTDEV

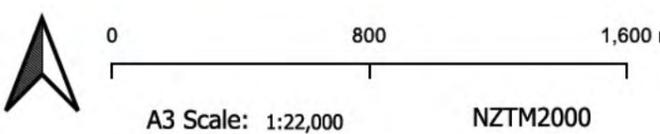


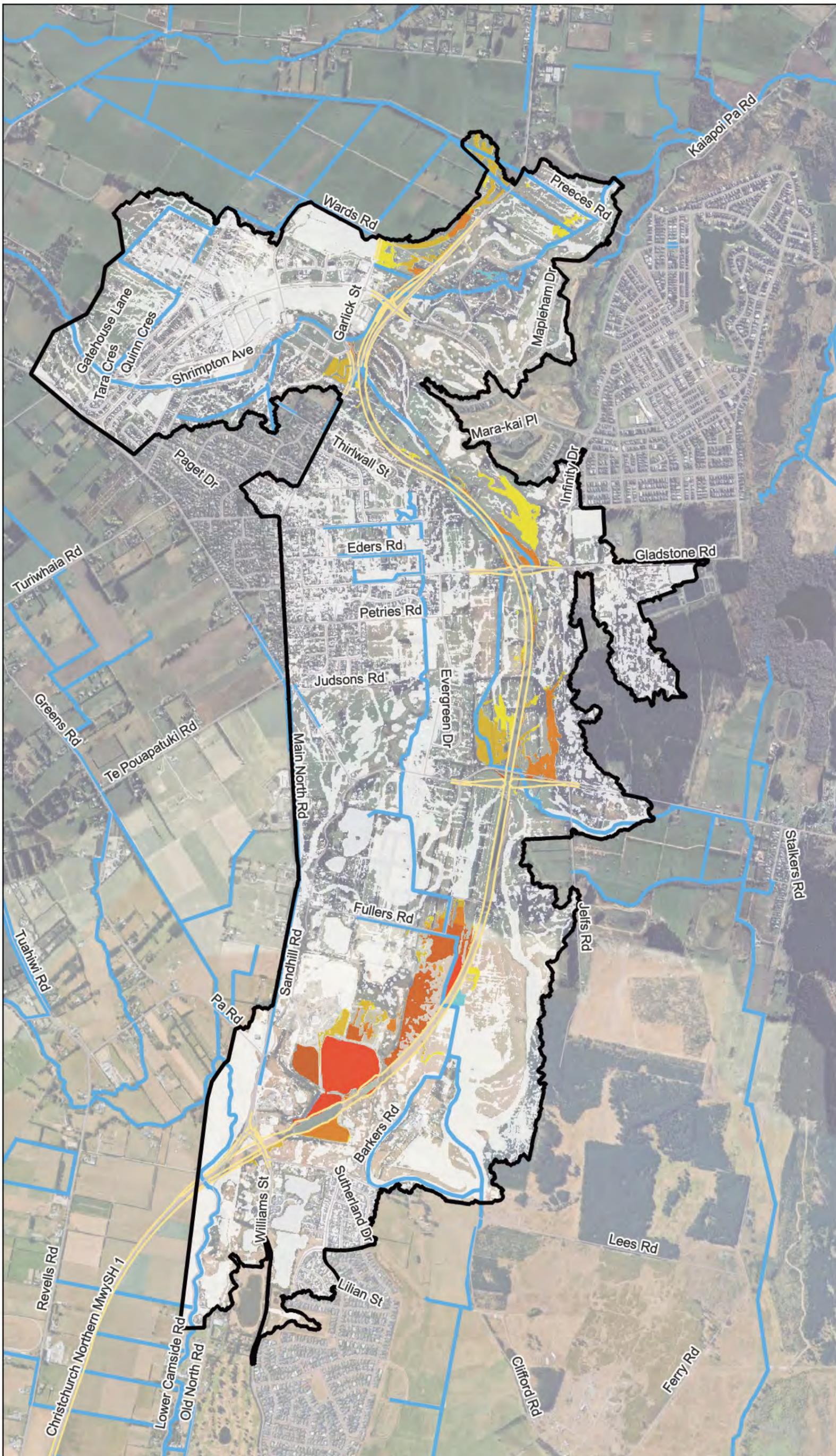
LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.



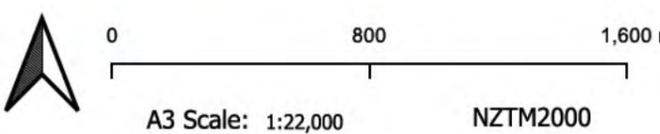


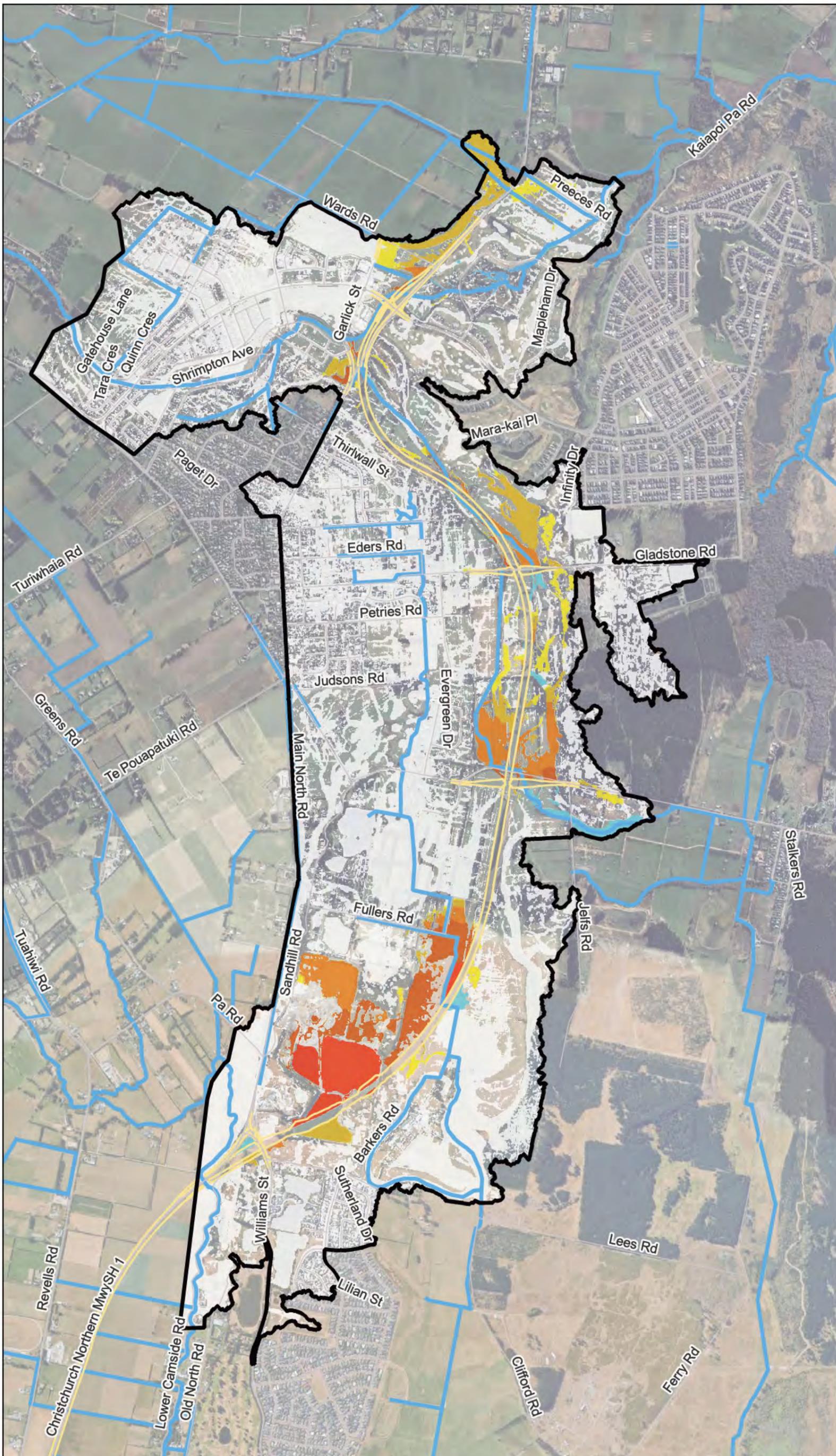
LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Afflux (m)
- <-1.000
- 0.999 to -0.500
- 0.499 to -0.250
- 0.249 to -0.020
- 0.020 to 0.020
- 0.021 to 0.100
- 0.101 to 0.250
- 0.251 to 0.500
- 0.501 to 1.000
- > 1.000



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.





LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Afflux (m)
- -1.000
- 0.999 to -0.500
- 0.499 to -0.250
- 0.249 to -0.020
- 0.020 to 0.020
- 0.021 to 0.100
- 0.101 to 0.250
- 0.251 to 0.500
- 0.501 to 1.000
- > 1.000



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.

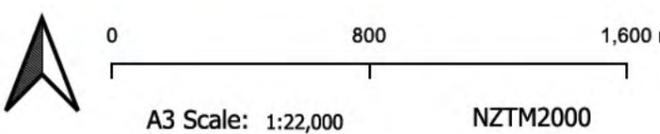
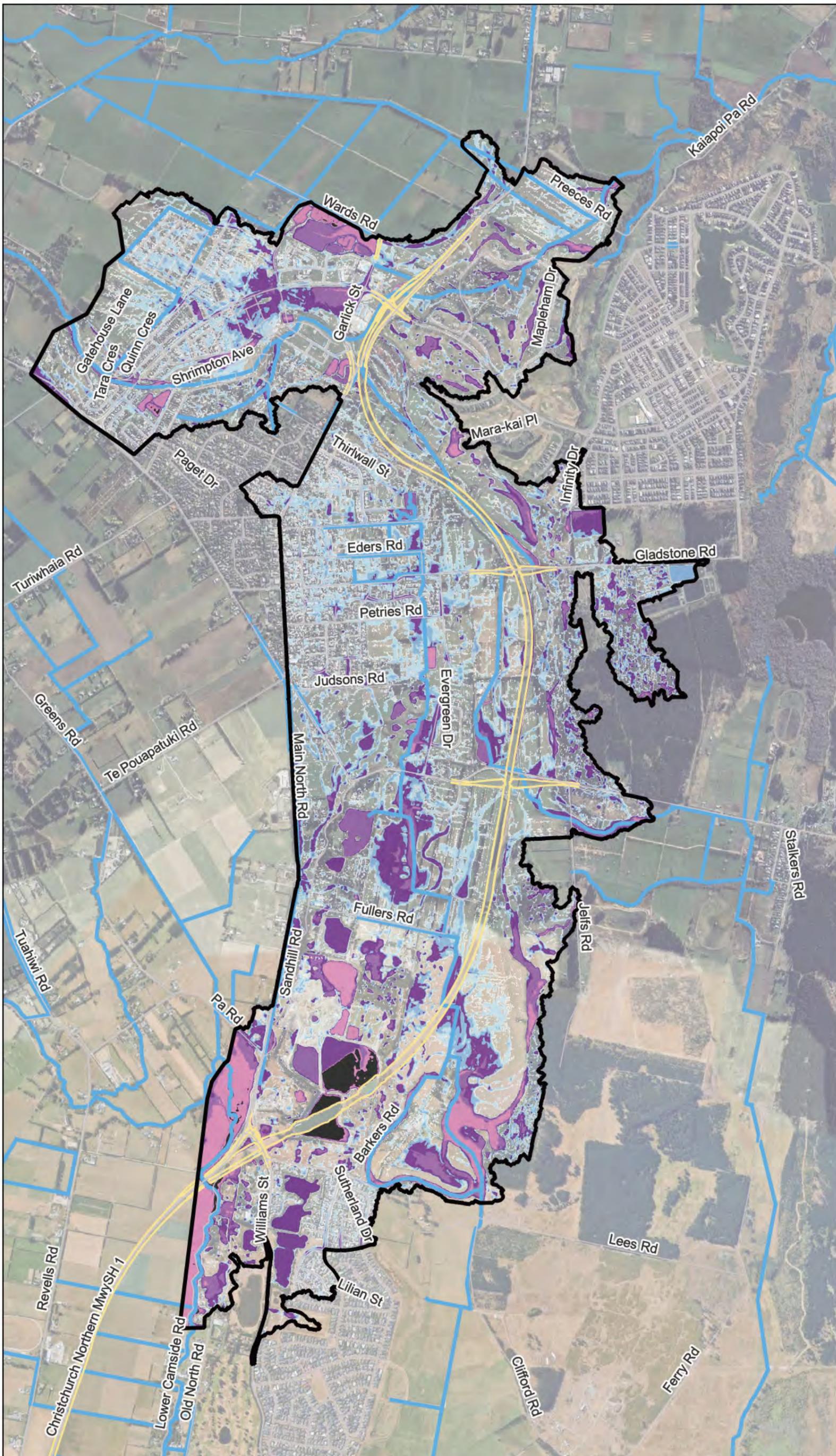


Figure C-10
 Woodend, Waimakariri District -

Flood Level Difference – Post-development (POSTDEV) minus Pre-development (PREDEV) - 200yr ARI Storm
 200yr ARI - Water Level Afflux (m)



LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Depth (m)
- <math>< 0.02</math>
- 0.021 - 0.10
- 0.11 - 0.20
- 0.21 - 0.50
- 0.51 - 1.00
- 1.01 - 2.00
- > 2.00



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.

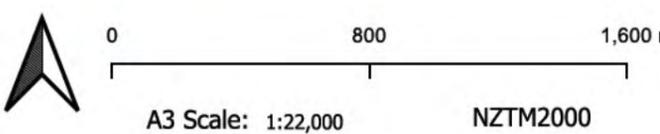
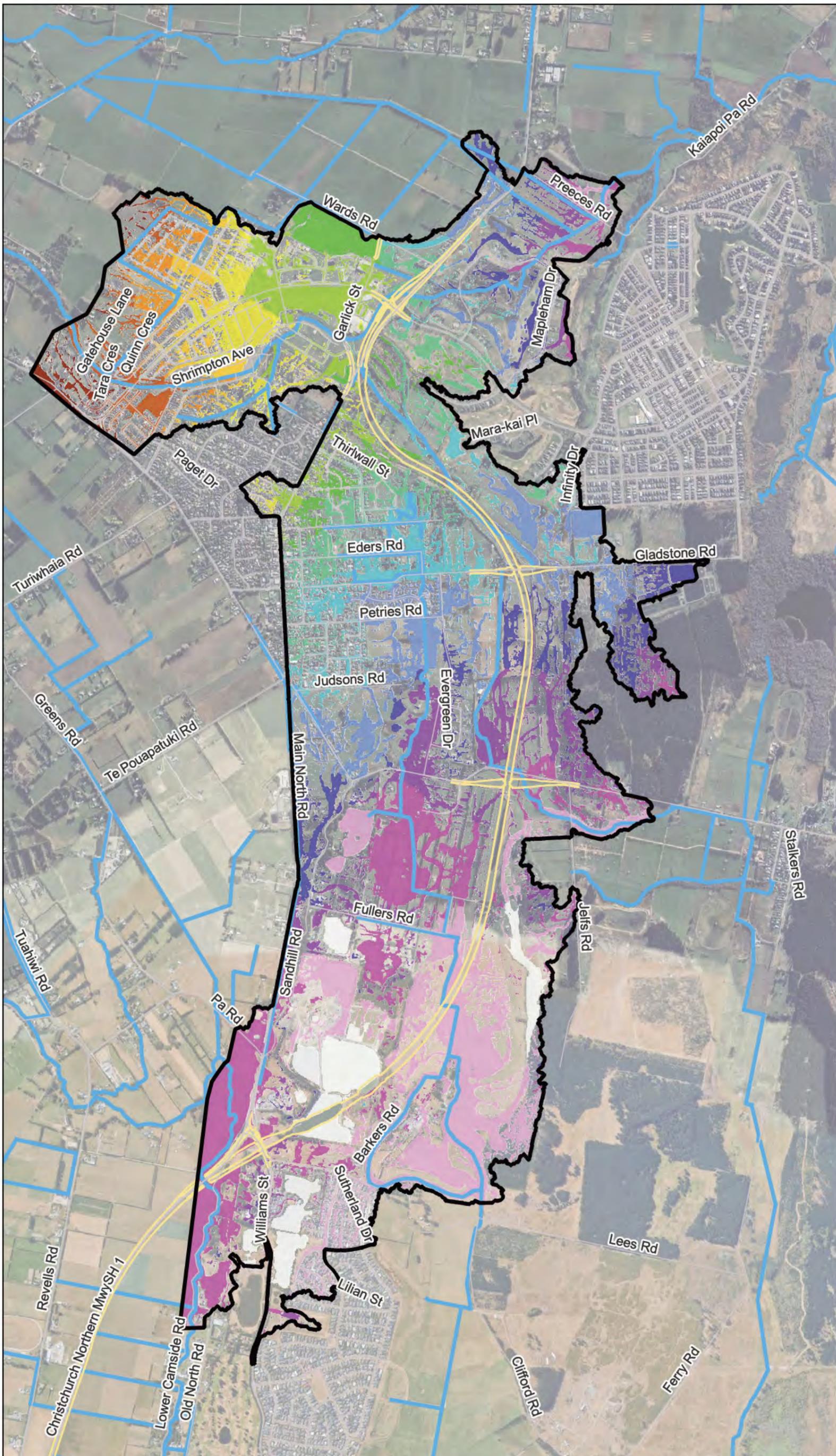


Figure C-11
 Woodend, Waimakariri District - MITIG

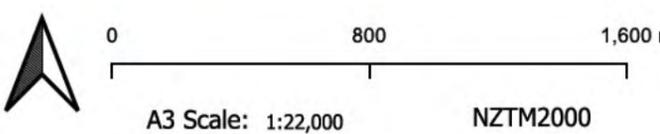


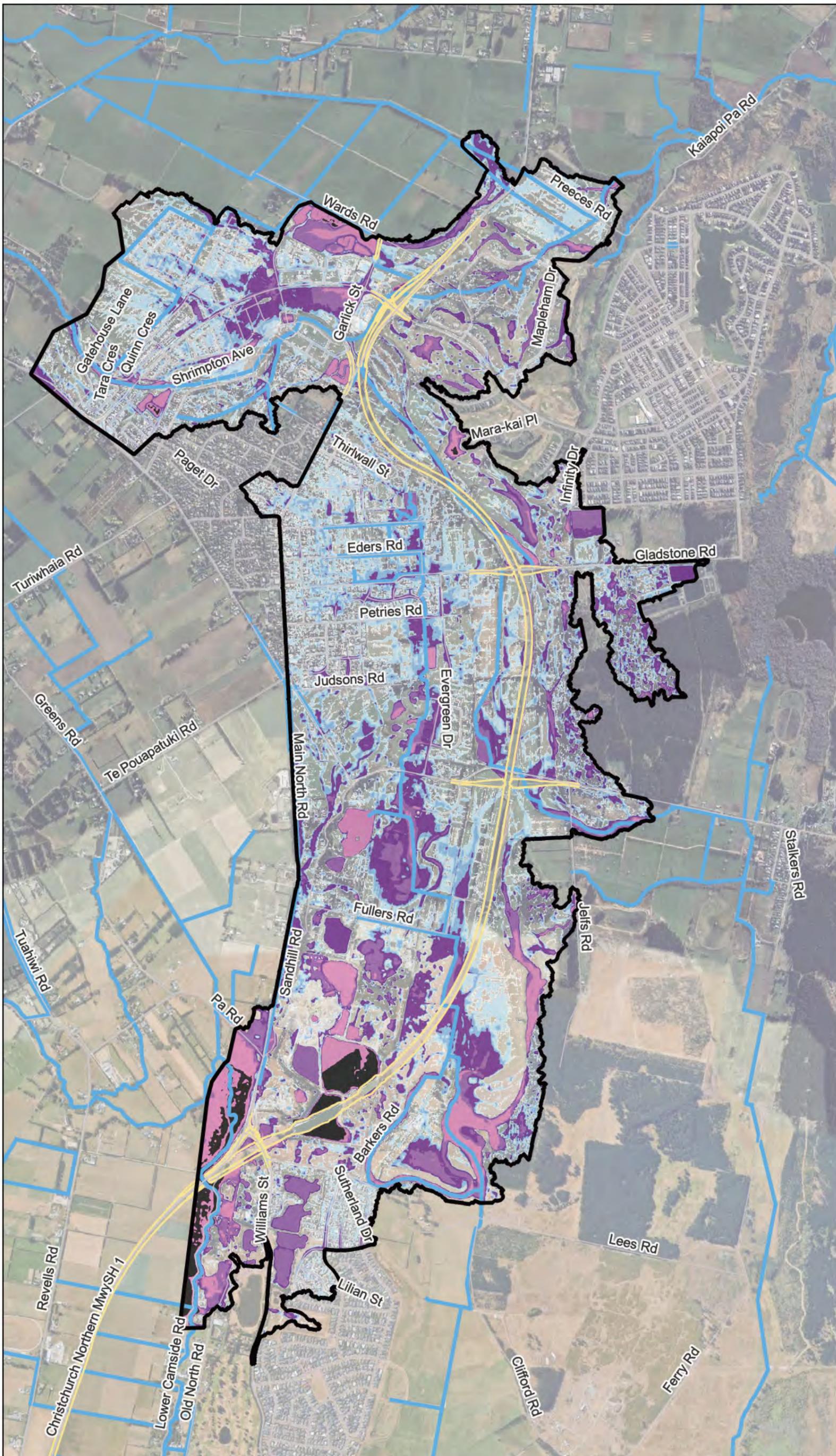
LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.





LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Depth (m)
 - < 0.02
 - 0.021 - 0.10
 - 0.11 - 0.20
 - 0.21 - 0.50
 - 0.51 - 1.00
 - 1.01 - 2.00
 - > 2.00



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
 displayed on the map when
 either the pre-development or
 mitigated/post-development
 scenarios indicate dry
 conditions.

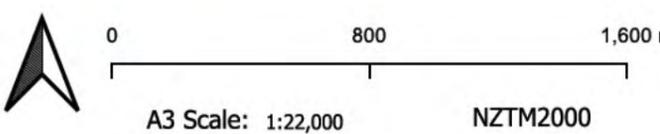
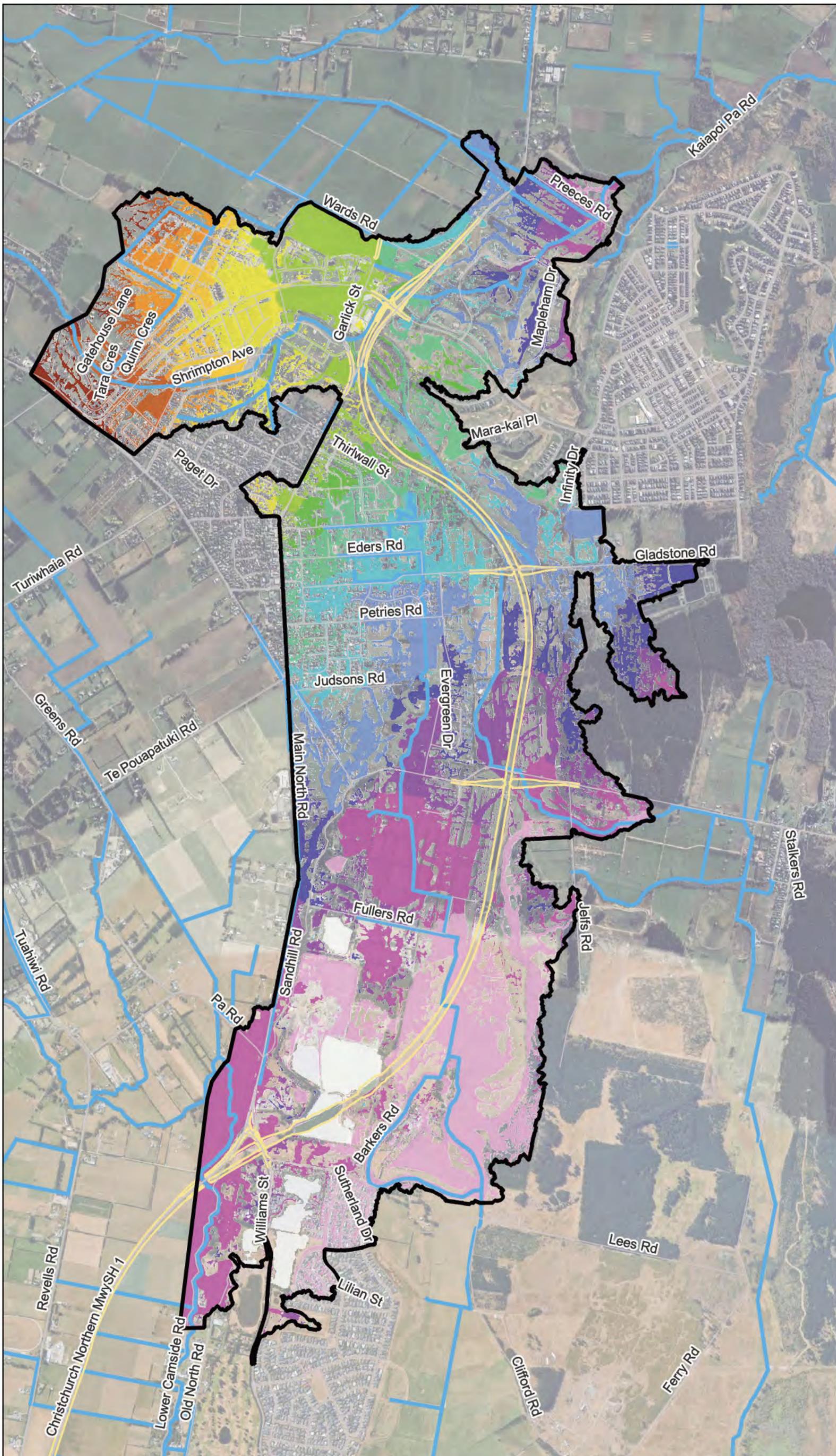


Figure C-13
 Woodend, Waimakariri District - MITIG



LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Flood Level (m)
- <= 2
- 2.001 - 3
- 3.001 - 4
- 4.001 - 5
- 5.001 - 6
- 6.001 - 7
- 7.001 - 8
- 8.001 - 9
- 9.001 - 10
- 10.001 - 11
- 11.001 - 12
- 12.001 - 13
- 13.001 - 14
- 14.001 - 15
- > 15



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.

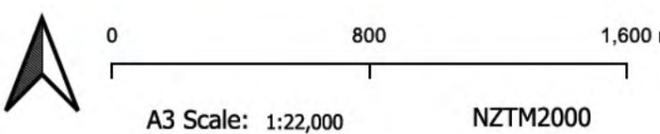
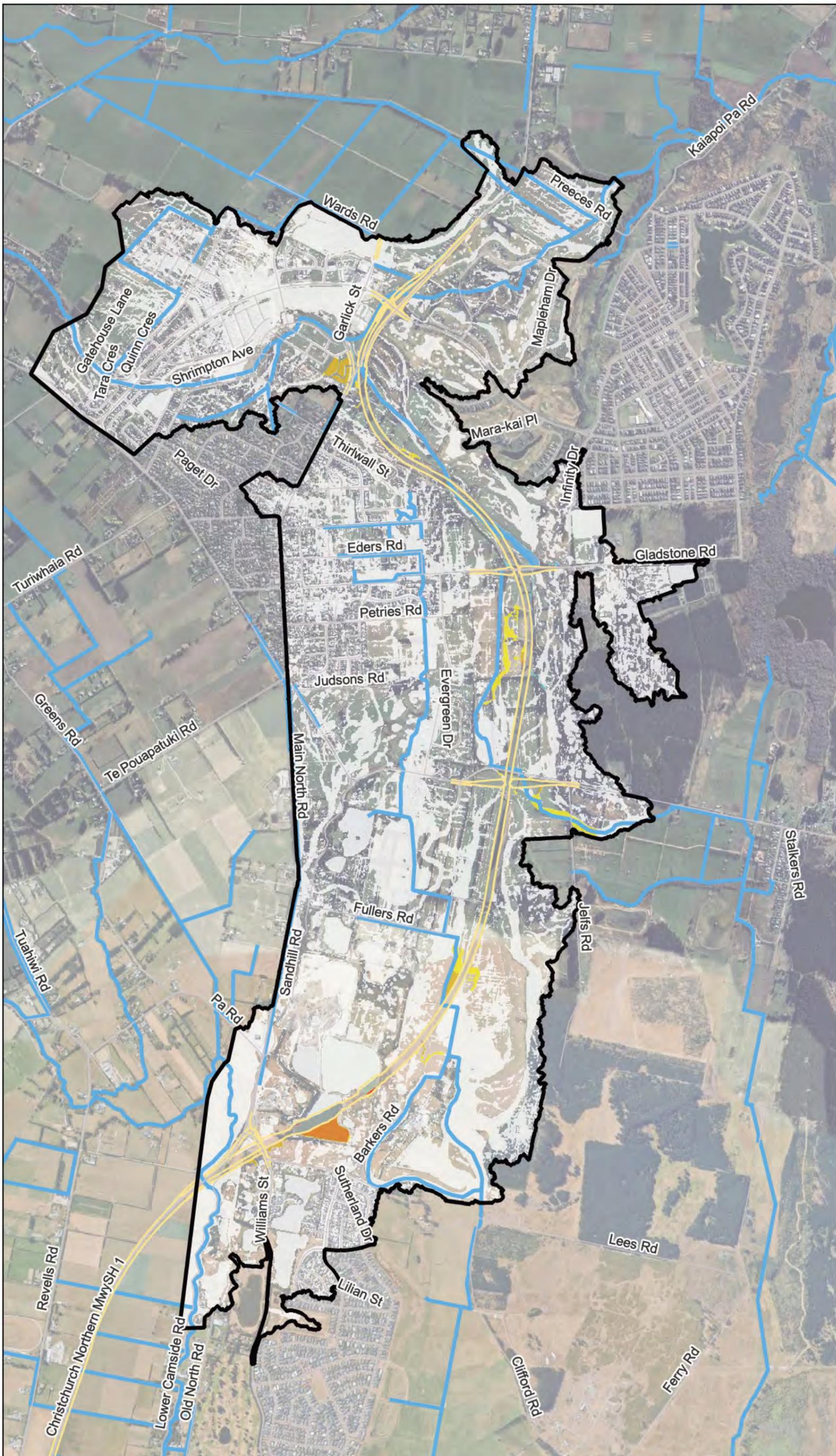


Figure C-14
 Woodend, Waimakariri District - MITIG

Post-development Model (MITIG) Flood Level – 200yr ARI Storm
 200yr ARI - Flood Level (m)



LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Afflux (m)
- <math><-1.000</math>
- -0.999 to -0.500
- -0.499 to -0.250
- -0.249 to -0.020
- -0.020 to 0.020
- 0.021 to 0.100
- 0.101 to 0.250
- 0.251 to 0.500
- 0.501 to 1.000
- > 1.000



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography + Proposed Road Embankment
 MITIG -Post-development scenario + mitigating measures (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not displayed on the map when either the pre-development or mitigated/post-development scenarios indicate dry conditions.

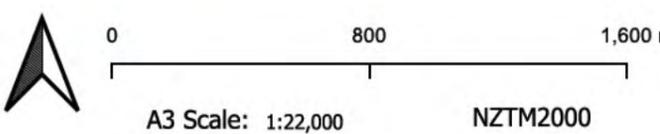
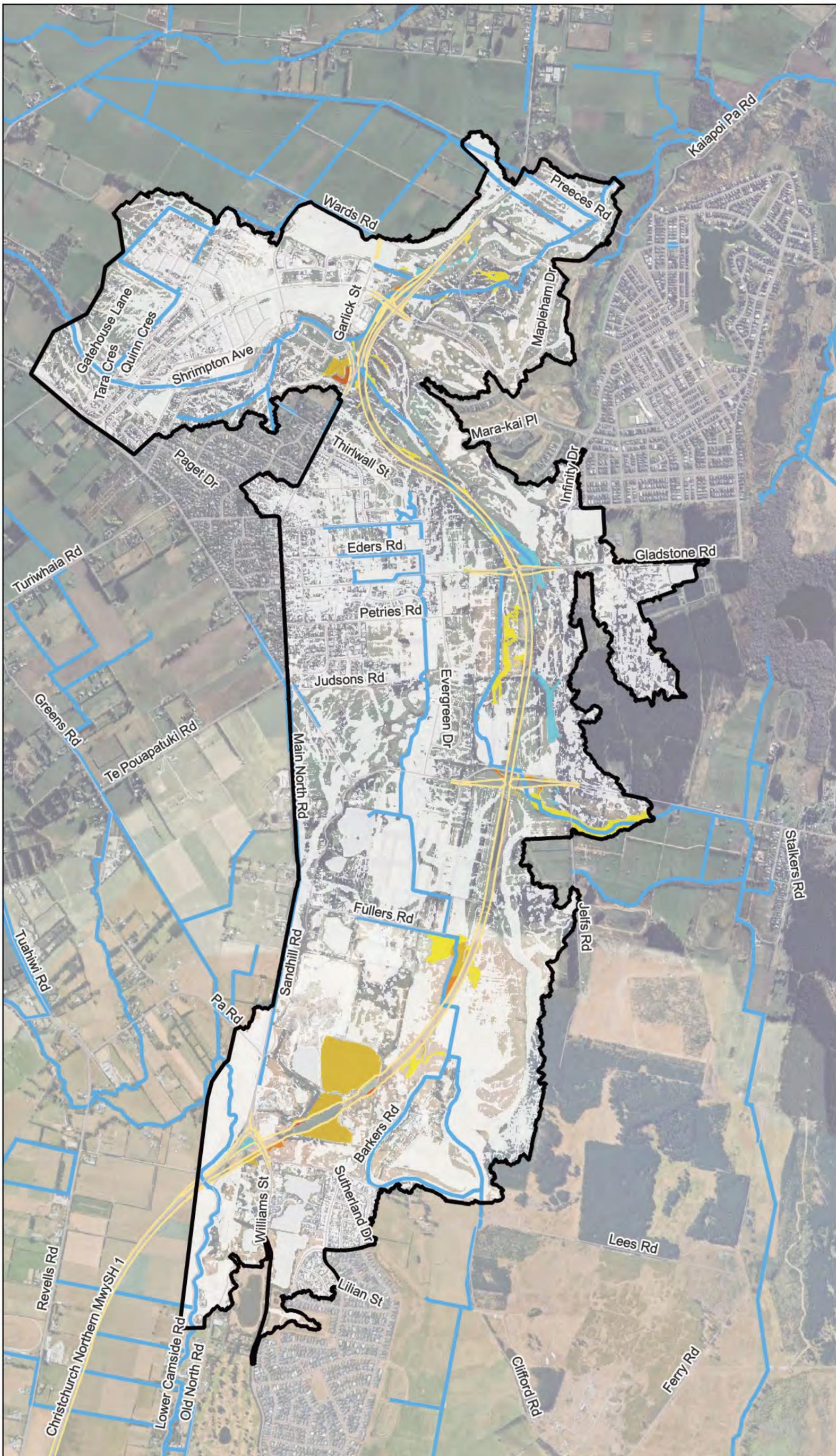


Figure C-15
 Woodend, Waimakariri District -

Flood Level Difference – Post-development (MITIG) minus Pre-development (PREDEV) – 100yr ARI Storm
 100yr ARI - Water Level Afflux (m)



LEGEND

- Model Extent
- Roads
- Proposed Road Footprint
- Existing Overland Channels
- Afflux (m)
- <-1.000
- 0.999 to -0.500
- 0.499 to -0.250
- 0.249 to -0.020
- 0.020 to 0.020
- 0.021 to 0.100
- 0.101 to 0.250
- 0.251 to 0.500
- 0.501 to 1.000
- > 1.000



Notes:
 Hydraulic TUFLOW Model
 Model Cell Size:
 4m x 4m SGS with Quad Tree
 LIDAR Cell Size:
 1m x 1m
 Output Grids Cell Size:
 1m x 1m
 Run Scenarios:
 PREDEV - Existing topography
 POSTDEV- Existing topography
 + Proposed Road
 Embankment
 MITIG -Post-development
 scenario + mitigating measures
 (add'l culverts, channels etc.)
 Water Level Differencing Notes:
 The water level afflux is not
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 mitigated/post-development
 scenarios indicate dry
 conditions.

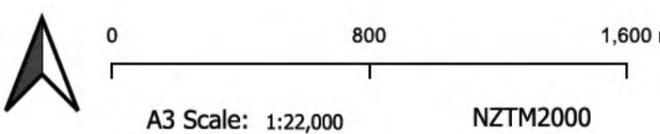


Figure C-16
 Woodend, Waimakariri District -

Flood Level Difference – Post-development (MITIG) minus
 Pre-development (PREDEV – 200yr ARI Storm
 200yr ARI - Water Level Afflux (m)

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