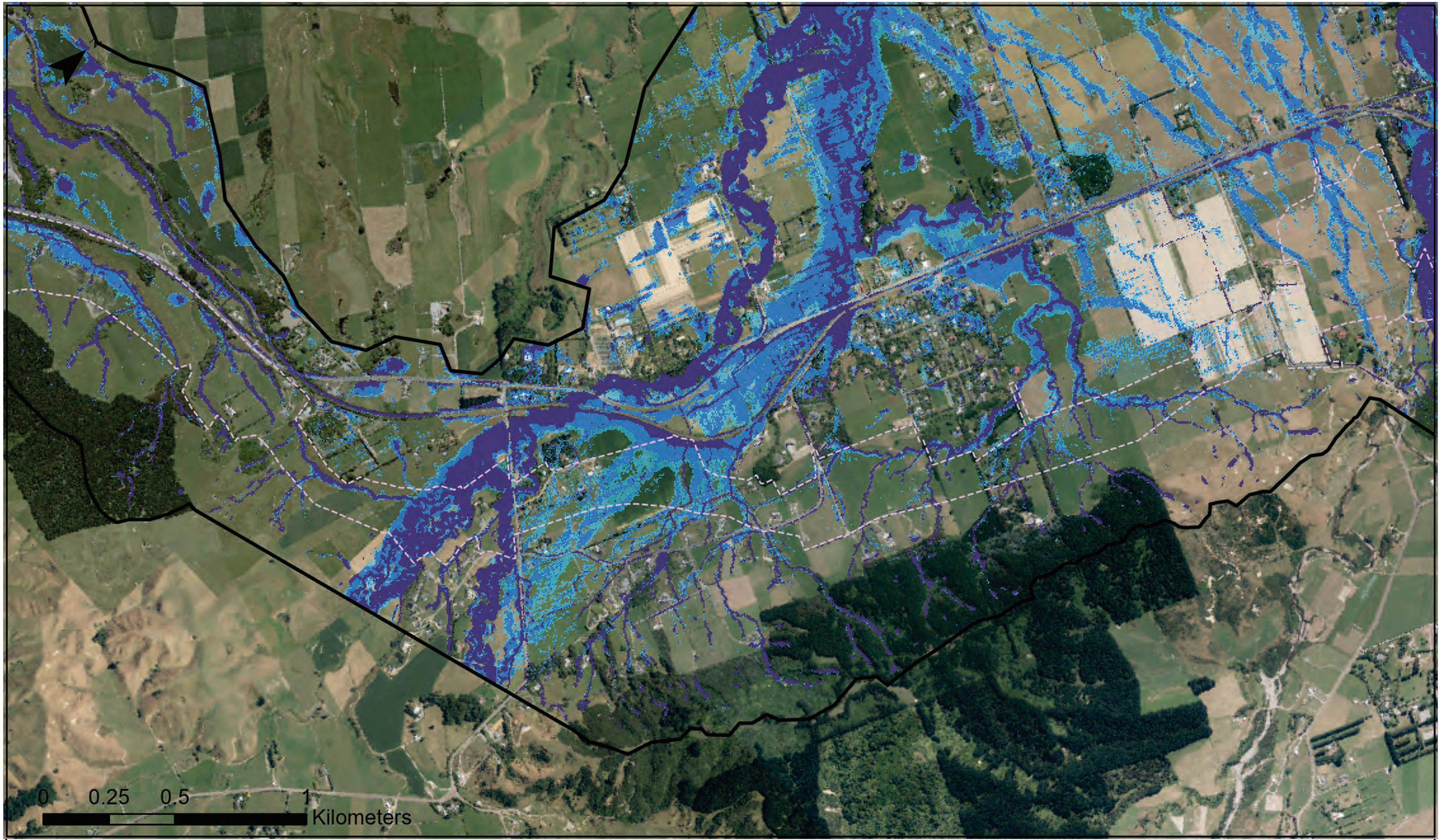


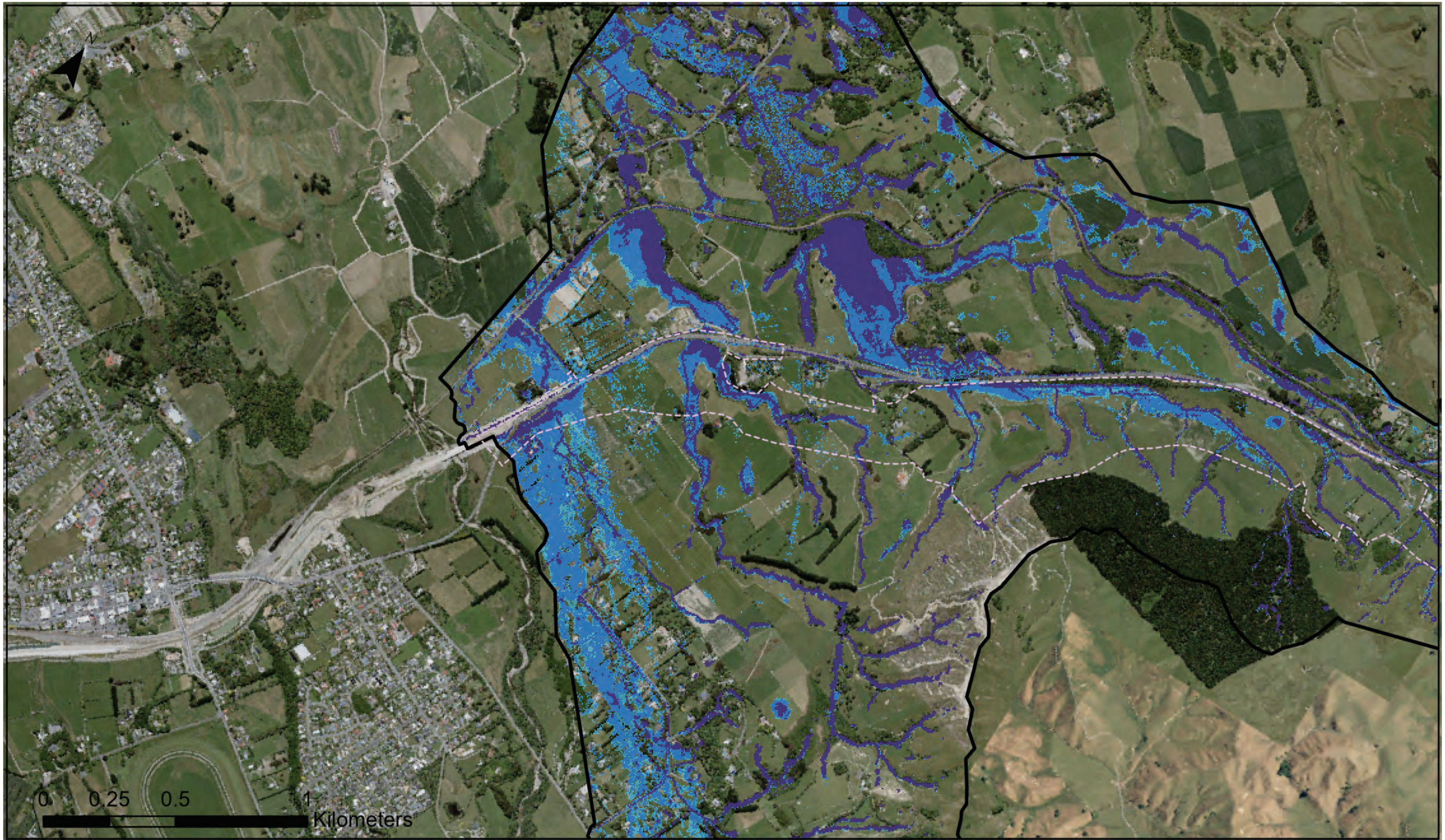
Model Results, Baseline Maximum Extents

This map shows maximum flood extents for various annual exceedance probabilities. No flood depths less than 0.05m are shown

- South Model Extent
- Ohau Model Extent
- North Model Extent
- Proposed Designation July 2022
- 1:10 AEP Current Climate
- 1:100 AEP RCP 6.0 2130
- 1:1500 AEP RCP 8.5 2130

Data Sources:Basemap Service Credits: LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors
Map displayed in NZGD 2000 New Zealand Transverse Mercator coordinate system.
Author: Stantec (2022)

Stantec



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APPENDIX F.2: WITH-SCHEME MODELLING REPORT

ŌTAKI TO NORTH OF LEVIN: WITH-SCHEME FLOOD ASSESSMENT REPORT

PREPARED FOR WAKA KOTAHI NZ TRANSPORT AGENCY

August 2022

Stantec

QUALITY STATEMENT

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REVISION SCHEDULE

Rev No.	Date	Status	Signature or Typed Name (documentation on file)			
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1.1	18/03/2022	Draft Final	AS	AC	JP	JP
1.2	18/08/2022	Final	AS	AC	JP	JP

Abbreviations

Abbreviation	Full Name
AEE	Assessment of Environmental Effects
ARF	Aerial Reduction Factor
AEP	Annual Exceedance Probability
DBC	Detailed Business Case
DEM	Digital Elevation Model
FFA	Flood Frequency Analysis
FSL	Fundamental Soil Layer
GWRC	Great Wellington Regional Council
HDC	Horowhenua District Council
HIRDS	High Intensity Rainfall Dataset
HRC	Horizons (Manawatū-Whanganui) Regional Council
h	Hour(s)
IPCC	International Panel on Climate Change
KCDC	Kapiti Coast District Council
LiDAR	Light Detection and Ranging (airborne survey to prepare DEM)
LINZ	Land Information New Zealand
NES-F	Resource Management (National Environmental Standard for Freshwater) Regulations 2020
MfE	Ministry for the Environment
Ō2NL	Ōtaki to North of Levin Project
PMP	Probable Maximum Precipitation
PP2Ō	Peka Peka to Ōtaki Expressway
RCP	Representative Concentration Pathway (IPCC climate scenario)
SLS	Serviceability Limit State
SH1	State Highway 1
SUP	Shared Use Path
ULS	Ultimate Limit State
Waka Kotahi	Waka Kotahi New Zealand Transport Agency

WAKA KOTAHI NZ Transport Agency

Ōtaki to North of Levin:
With-scheme Flood Assessment Report

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. Introduction

1.1 Background to the Project

Waka Kotahi NZ Transport Agency (Waka Kotahi) is planning a new 24km offline highway from Ōtaki to north of Levin (Ō2NL). The Project extends from the existing SH1 / Koputaroa Road intersection north of Levin, to south of Taylors Road near Ōtaki where it links with the Peka Peka to Ōtaki (PP2Ō) Expressway.

The with scheme hydraulic model has developed over time in parallel with the design process through 2020 and 2021. This report is written to present the latest hydraulic model that aligns with the consent design as at July 2022. Whilst some details are included in this report where they are pertinent to the hydraulic modelling, this report does not seek to present the full detail or drawings of the design. It is intended that this report be read in conjunction with the RMA consent application pack notably the Project Description (Volume II) and the Design and Construction Report (Volume II Appendices) plus the Drawings (Volume III). It is worth reiterating that the stage of design is intermediate, i.e., it is not as far advanced as a Specimen Design or Detailed Design for construction.

The Baseline Flood Assessment Report (Stantec, completed March 2022, selected figures updated August 2022) presents the latest understanding of the baseline flood risk near the Ō2NL Project corridor. All the work in this with-scheme report relates to the changes made to the hydraulic model relative to the baseline model presented in the baseline report. Similarly, the model results differences presented in this report are the differences between the with-scheme models and the pre-scheme baseline.

Similar to the baseline models, the with-scheme models receive the same hydrology, boundary conditions, rainfall scenarios, and is also split into the same three domains, namely: the North, Ōhau, and South models, as shown in Figure 1-1. The split of rainfall domains in the South model is explained later in this report.

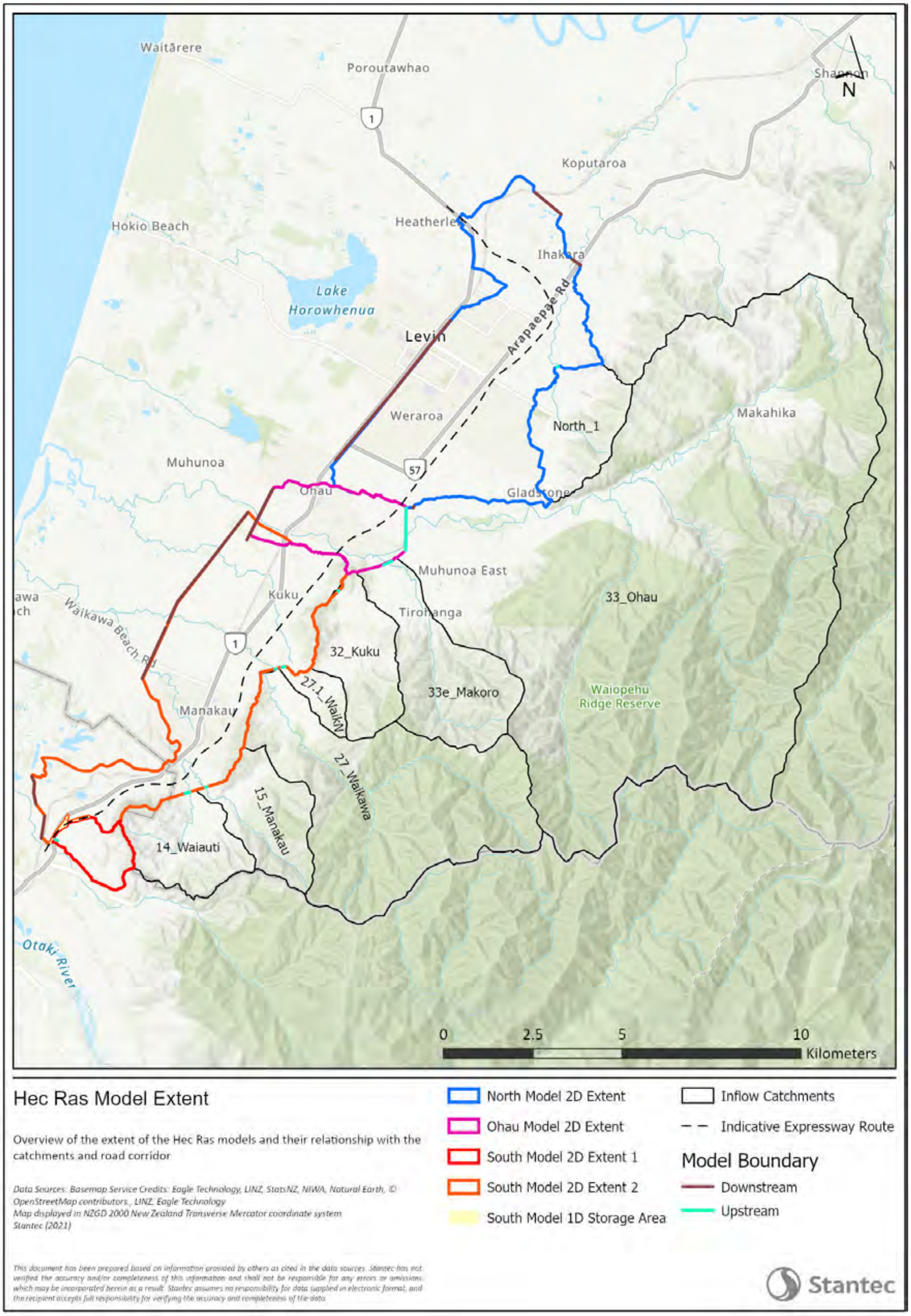


Figure 1-1: HEC-RAS 2D model extent for the three 2D hydraulic models

1.2 Purpose and Scope of this Assessment

It was required to prepare a model representation of the scheme to assess potential hydraulic effects of the Ō2NL Project. The schematisation choices and structure of the baseline model was designed to allow this outcome to be achieved by applying the infrastructure design into a copy of the baseline model.

A sample Consent design of the Ō2NL Project (as at July 2022) has been applied in the with-scheme hydraulic model, to test potential effects. The scheme will later go through detail design and the eventual scheme when built may differ from the sample Consent Design used for this assessment.

There will necessarily be some assumptions and limitations, due to information gaps or modelling processes and the stage of design. These have been captured through the baseline report and within this document where they relate to the scheme representation. Aspects of both the baseline and scheme representation and their uncertainties should be evaluated by the Detailed Design team to test whether the assumptions or limitations have bearing on the final design and whether any updates may be warranted.

1.3 Selection of Design Scenarios

The model scenarios are intended to inform key design decisions and/or assessment of effects. For design purposes, the highway classification (under the Waka Kotahi One Network Road Classification) has been selected as "IL3+ National (High Volume)". The associated serviceability and ultimate limit state design scenarios are provided in Table 2.1 of the NZ Bridge Manual, reproduced below:

Table 1-1: Design scenarios (reproduced from NZ Bridge Manual Table 2.1)

Bridge categorization	Importance level (as per AS/NZS 1170.0[(4)])	Bridge permanence*	Annual probability of exceedance for the ultimate limit state		Annual probability of exceedance for the serviceability limit state	
			ULS for wind, snow and floodwater actions	DCLS for earthquake actions	SLS 1 for wind, snow and floodwater actions	SLS 2 for floodwater actions
Bridges of high importance to post-disaster recovery (eg bridges in major urban areas providing direct access to hospitals and emergency services or to a major port or airport from within a 10km radius). Bridges with a construction cost (including associated ground improvements) exceeding $16 million (as at June 2018).	4	Permanent	1/2500	1/2500	1/25	1/100
		Temporary	1/1000	1/1000	1/25	1/100
Bridges on highways classified as National (High Volume in the One Network Road Classification (ONRC).	3+	Permanent	1/1500	1/1500	1/25	1/100
		Temporary	1/700	1/700	1/25	-
Bridges on highways classified as National, Regional, Arterial, Primary Collector or Secondary Collector in the ONRC.	3	Permanent	1/1000	1/1000	1/25	1/100
		Temporary	1/500	1/500	1/25	-

In accordance with the Bridge Manual, the design life (planning horizon) will be 100 years, from 2030 (estimated start of operation) to 2130. The design life is particularly relevant for climate change.

The Bridge Manual sets the IL3+ main traffic Serviceability Limit State SLS2 design scenario for flooding at 1:100 AEP with climate change. However, the Bridge Manual is not prescriptive on details of climate change allowances (e.g., epoch or emissions scenario). The climate scenario selected is RCP 6.0 extrapolated to 2130, is applied for the SLS2 1:100 AEP. This is a moderately conservative (medium-high) climate projection, which is considered suitable for the Ō2NL Project. Given the long design life and high cost to upgrade culverts or bridges during operational life, it would be impractical to follow a lower climate change scenario with the option to upgrade infrastructure at a later epoch if higher climate change transpires. The RCP 6.0 scenario was also applied for the recent Te Ahu a Turanga; Manawatū Tararua Highway Project, which further supports the decision to use this scenario.

The potential impacts of higher climate outcomes will be tested through the ULS case, namely the 1:1500 AEP with a more conservative RCP8.5 extrapolated to 2130. In summary, the following key scenarios will be used:

Table 1-2: Selected key scenarios

Annual Exceedance Probability		Climate Scenario	Description
1:10	10%	Current climate	Easier to relate to floods in recent history (or construction phase)
1:100	1%	RCP6.0 2130	SLS2, operationally functional
1:1500	0.067%	RCP8.5 2130	ULS, resilience case (damage limitation, avoiding collapse, quick recovery)

As discussed in the baseline flood report, a 4h storm duration is used for the fluvial (large stream) inflows for all model runs. For the North and Ōhau models, a 4h storm duration is also used for the direct rainfall zone, i.e., the same storm that generated the fluvial inflows. For the South model, the water level is taken from the maximum of a 4h storm across the whole model, and a hybrid 1h/4h storm (4h critical duration fluvial inflows and 1h high intensity rainfall with coincident rainfall centroid timing). The latter hybrid storm allows the critical peak flow to be captured in some of the small catchments toward the southern extent of the project. Taking the maximum of the 4h and hybrid 1h/4h storm for the south model was particularly important for the 1:100 AEP event with climate change, for assessment of effects.

The calculation of climate change growth factors for rainfall and river flow are discussed in the baseline flood report.

Outside of the Project area, the modelling for future epochs is based on current topography, drainage assets and estimated infiltration rates. These may change slightly in future through natural morphological change (including earthquakes and associated debris load in addition to gradual erosion and aggradation processes), and/or anthropological changes in land-use with associated impacts on infiltration/runoff. For the purposes of the modelling, it is assumed that hydrological catchment net response to any depth-duration rainfall event will remain similar to historic performance to up 1:100 AEP with climate change, despite future anthropological or morphological change. This is considered a reasonable assumption because plans submitted under the RMA seek to ensure hydraulic neutrality to avoid or minimise potential adverse effects.

2. Representation of Project in Hydraulic Model

The same HEC-RAS models used in the baseline modelling were used in this project, with modifications to represent the relevant features of the Project.

2.1 Hydrology

The same hydrological boundaries (inflows and direct rainfall for each respective AEP and storm duration) are applied to the with-scheme model as described in the baseline flood report and reflected in Figure 1-1.

Minor changes in the approach were the addition of infiltration regions and corresponding direct inflows to some stormwater ponds near the southern extent of the Project. These changes were added to represent key areas where the highway design utilises grey (piped) drainage infrastructure to convey road runoff to stormwater ponds, rather than open swales. As HEC-RAS is not well suited to model pipe networks, infiltration zones were added over the respective paved areas to remove the rainfall from the model surface. A HEC-HMS hydrological 1D catchment model for each paved area is used to provide direct inflows into the corresponding SW pond, see Figure 2-1. Summary details on the catchment parameters and culverts are shown below in Table 2-1.

Table 2-1: HEC-HMS 1D model catchment parameters

	Expressway Section 1	Expressway Section 2	Expressway Section 3	Expressway Section 4
Area (m2)	35,000	29,000	11,000	24000
Max Elevation (m)	33	33	25	60
Min Elevation (m)	21	27	21	52
Time of Concentration (min)	36	37	11	35

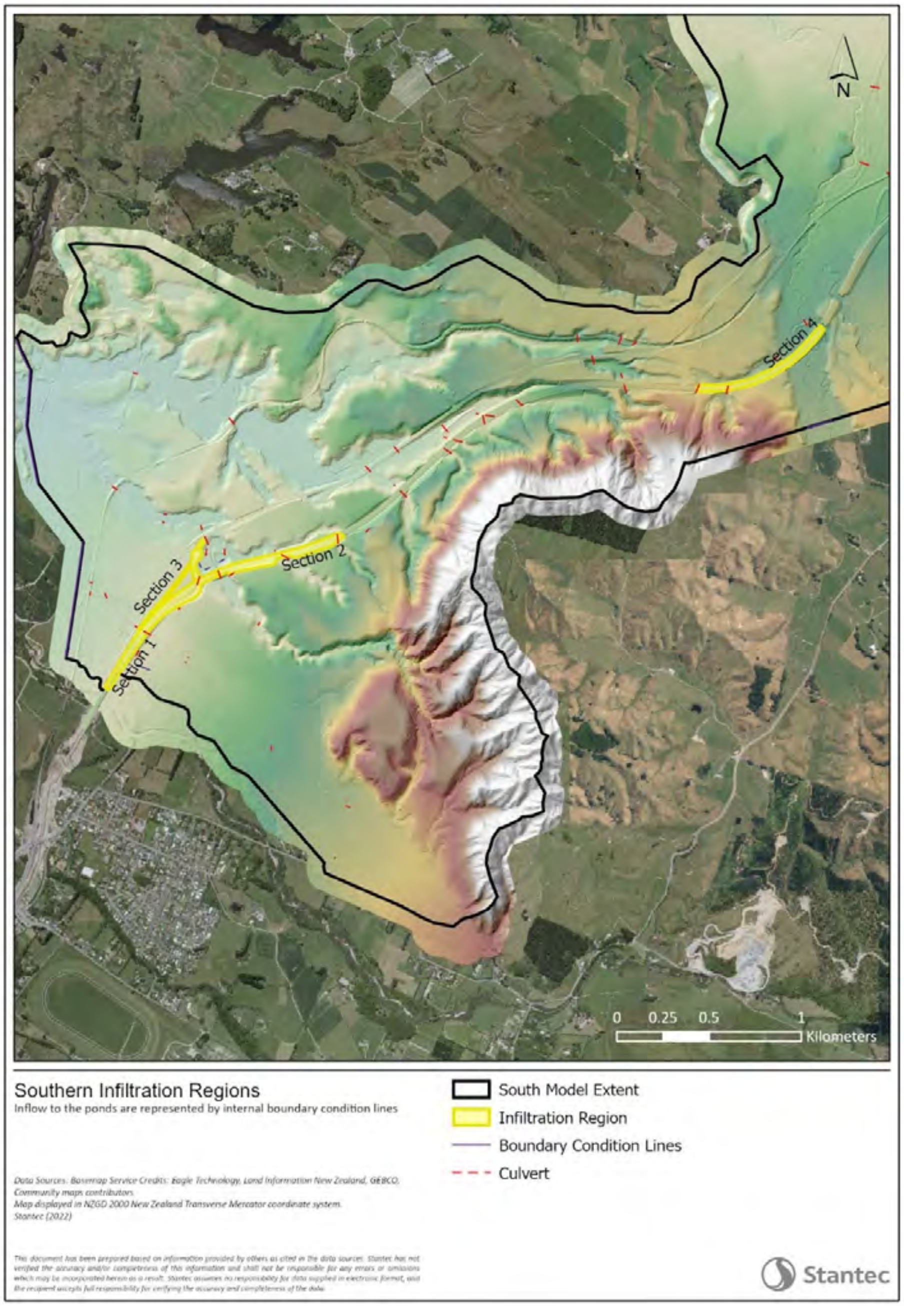


Figure 2-1: Southern grey highway infrastructure - 1D hydrology areas

2.2 Project Earthworks Design Surface

2.2.1 Model surface

The project design surfaces were obtained as OpenRoads 3D exports. These surfaces included finished highway levels, swales, cuts and fills, bridges, local roads (where modified in the design), and the SUP.

The decks of proposed bridges were de-selected from model preparation. This is because the openings through the bridges are modelled in HEC-RAS 2D without the soffit in place, since the soffits are designed to be well clear of the water surface (at least 0.6m in line with the Bridge Manual). The soffits also remain above the modelled water surface for the 1:1500 AEP event with climate change (RCP8.5 2130).

The selected design surface triangle files were imported into GlobalMapper software and converted to a raster grid (TIF) at 1m x 1m cell size to match the HEC-RAS model DEM resolution. This design surface was then superimposed onto the baseline model DEM to create a with-scheme DEM for use in the hydraulic model. The merging of the existing and proposed surfaces in GlobalMapper resulted in a slight horizontal shift of cell co-ordinates, which was corrected to ensure precise alignment with the cells in the baseline model. Otherwise, mis-aligned DEM's can detract from the water level comparison between the two models.

The exact volumes and final form of the material supply and spoil sites were not known at time of modelling and will remain somewhat uncertain until detailed design has occurred, and construction commences, because of potential material variability on site. The potential hydraulic behaviour and effects of the full development of these sites and their consequent rehabilitation (as show in the CEDF) will be inferred from the model results without representing their form in the hydraulic model.

2.2.2 Introduction to feature modifications and mesh refinements

Further modifications to the merged with-scheme DEM were conducted within the HRC-RAS model using the terrain modifications toolbox. This allows for changes to be made without having to create a separate full model surface each time. These use of terrain modifications when representing different features is discussed under each feature type below (first management of streams and overland flows, then longitudinal stormwater management).

Additional mesh refinements were required to allow the model to represent the Project and its hydraulic effect more accurately. Pertinent aspects of mesh refinements are discussed under each feature type below. The mesh refinements were then also copied back to the baseline model and re-run using the same computational mesh as the with-scheme model, to minimise the slight differences that can occur between models on account of different computational mesh, so that only the hydraulic effects of the Project are identified.

The modelling team worked closely with key members of the multi-disciplinary design team to ensure that modelling modifications and assumptions closely matched the design intent.

2.3 Proposed Bridges

2.3.1 Overview

Table 2-2 below lists the waterway bridges, which were modelled in the 2D domain without a bridge deck. This allows the model to include the natural stream bed and detect changes in velocities and depths through the structure due to the lateral constriction of flow. Details of the bridge structures and their hydraulic openings are provided in the design drawing pack (notably 310203848-400 set). Site specific commentary on the model approach is provided in the sub-sections that follow the table.

Where the drawing set indicated scour protection, these polygons were added as roughness patches with a new surface roughness of 0.055.

Breaklines and mesh refinement regions were added around the top edge of bridge abutments to reduce instabilities and improve model performance at the boundary of the road edge and the underlying ground level, see Figure 2-2.

Table 2-2: Proposed watercourse bridge information

Chainage (m)	Flow path ID	Location Name	Model Regime	Soffit clear of 1:1500 AEP (RCP8.5 2130)
22420	34	Ōhau floodplain	2D opening, no deck	Yes
22658	33	Ōhau River	2D opening, with piers, no deck	Yes
23808	32	Kuku Stream	2D opening, no deck	Yes
26440	27	Waikawa Stream	2D opening, with piers, no deck	Yes
30190	15	Manakau Stream	2D opening, no deck	Yes
30350	14	Waiauti Stream	2D opening, no deck	Yes

Figure 2-2: Example (Waikawa) 2D bridge with mesh and breaklines

2.3.2 Piers (Ōhau and Waikawa only)

Piers for the larger the Ōhau and Waikawa multi-span bridges were added as circular terrain modifications. A larger 4m diameter was used in the model preparation (as opposed to the 2m design diameter) to allow for reasonable size mesh cells around the pier and a dry hexagonal cell within the circle. This may result in slight over-estimation of energy losses and water levels and would be resolved more finely during detail design. The pier heights were set based on the approximate height of the bridge deck, which remains above the water surface in all model simulations. An infiltration surface was set on top of the pier to prevent rainfall ponding on top of the pier which can create appearance of curved water surfaces in nearby cells when interpolating results. The surface was brought in as raster cells with a 1m resolution and were drawn so they fell within the hexagon cell to prevent infiltration being applied to cells adjacent to the pier.

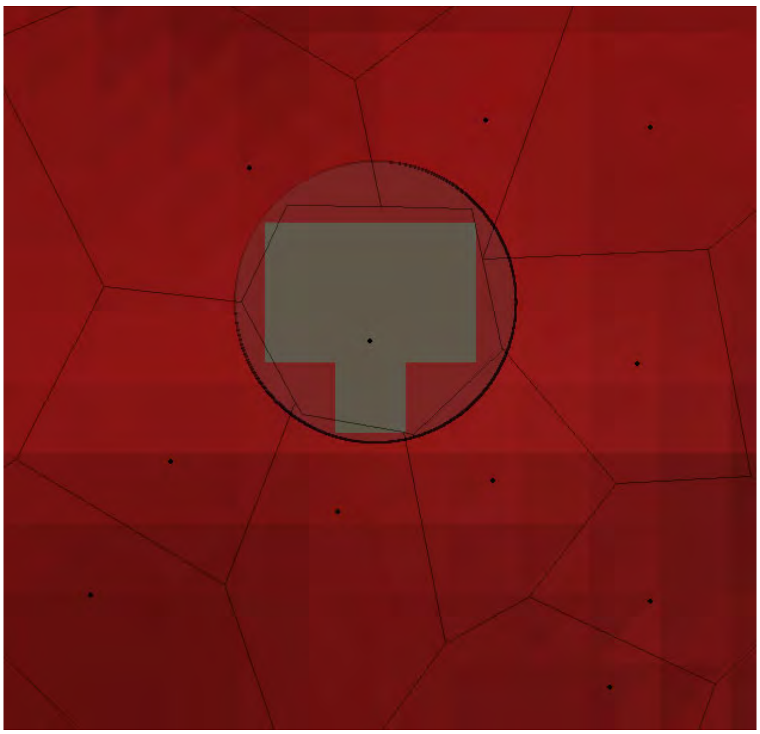


Figure 2-3: Example pier insertion and computational mesh

2.3.3 Ōhau flood relief bridge

The northern (right bank) of the Ōhau floodplain receives some Ōhau River flood flow from further upstream of the bridge, as in the baseline situation. This side of the floodplain slopes northwards away from the Ōhau River, see Figure 2-4. Therefore, a medium sized bridge with 35m top span (31m at floodplain level) is required to pass the flood flows that would otherwise cause a very large afflux (head loss or increase water levels) on the floodplain. A wide shallow scrape (terrain modification) is applied on the floodplain on the approach and throat of the flood relief bridge, which doesn't influence how much flow gets onto the floodplain but does improve the capacity of the bridge.

2.3.4 Ōhau River bridge

The total span (centres of bearings) of the main Ōhau bridge is 175m, although the effective width at floodplain level is reduced due to the spill-through abutments and the effect of piers.

Figure 2-4: Ōhau River bridge opening with piers

2.3.5 Kuku Stream bridge

The Kuku stream bridge in the F3 consent design 3D model (on which the hydraulic model is based) has a clear width of approximately 17m.

The existing culvert and access track at the location of the proposed bridge are removed for the scheme and stamped down to prevailing river elevations for the with-scheme model.

Small bunds were also added to the ends of swales and small trapezoidal channels were added at various sites around the ponds, swales and cut slopes as described in section 2.4, to steer the water in the intended directions. The modified topography is shown in Figure 2-5 below.

Figure 2-5: Kuku bridge terrain modifications

2.3.6 Waikawa Stream bridge

The total span (centres of bearings) of the main Waikawa bridge is 140m, although the effective width reduces at floodplain level due to the spill-through abutments and the effect of piers.

Piers were added as terrain modifications following the same process as described in section 2.3.2. Small channel modifications were also added as described in Section 2.4. The model terrain is shown in Figure 2-6 below.

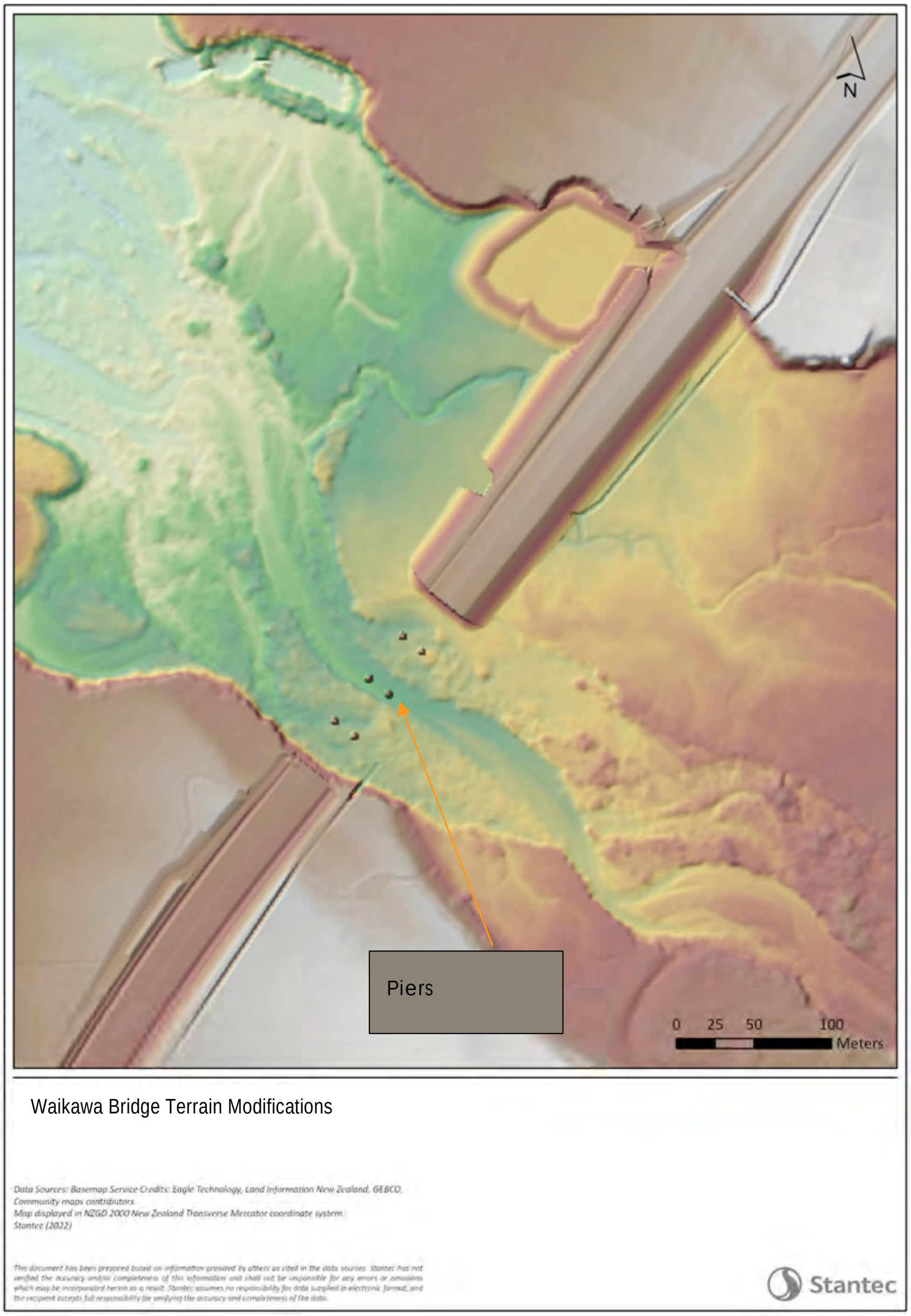


Figure 2-6: Waikawa Stream bridge opening with piers

2.3.7 Manakau Stream bridge

A stream realignment is applied in the model adjacent to South Manakau Road, as per the design drawings. Some flood flow occurs over the road in events above 1:10 AEP, and this behaviour is the same in both the scheme and baseline model. The total channel width of approximately 13m and road width of approximately 15m are combined in a single 28m bridge (bridge deck excluded from model).

Multiple terrain modifications using trapezoidal sections were added upstream and downstream for the new Manakau Bridge to help direct flows through the new structure and to smoothen irregularities in the existing DEM around the existing road. See Figure 2-7 in the next section.

As per the baseline model, the existing South Manakau road bridge over Manakau Stream was retained as a 1D structure. See the baseline flood report for more information.

2.3.8 Waiauti Stream bridge

The proposed Waiauti Stream bridge has been modelled with an opening between abutments of 20m. Stream realignments have been applied in the model as per the design, to maintain stream continuity where the Project footprint obstructs the existing stream. Two trapezoidal cross sections were used to stamp down the terrain to help the water flow through the bridge opening, see Figure 2-7 in the next section. The first trapezoidal shape had a base width of 4m, side slopes of 1 vertical to 5 horizontal units, and a top width of 10m. The second had a base width 20m, close to vertical side slopes of 1v to 0.1h and a max extent of 21m. The first trapezoid was created to model the low flow channel while the second was to model the floodplain under the bridge which sat slightly higher in invert.

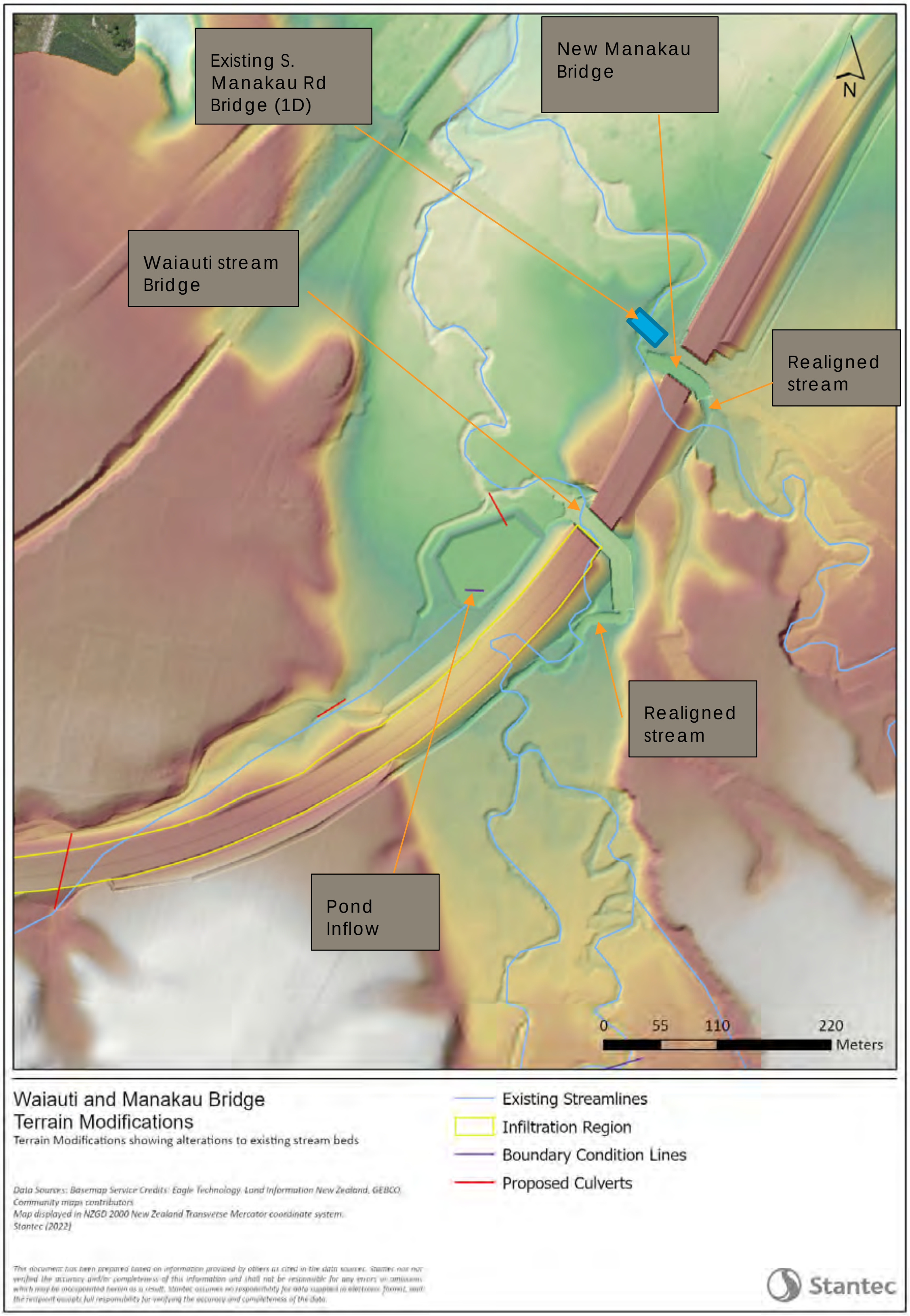


Figure 2-7: Example of terrain modifications and stream realignments around Waiauti Stream

2.4 Stream realignments and overland flow management

Stream realignments were added to the model as identified in the drainage design drawing set, to provide flow paths to culvert inlets and/or provide flow continuity where channels are disrupted by the proposed highway footprint. These stream realignments upstream and downstream of bridges have varied cross sections, based approximately on nearby channel topography. An example of some stream realignments is shown in Figure 2-7 above. See Section 2.3 above for more details.

Small open channel collector drains were added as per drainage design drawing set, to capture overland flows upstream of cut faces and to provide streamlined flow paths near toes of fill where necessary to prevent scour or ponding. These channels were modelled as modification lines with a trapezoidal cross section that typically had a top width of 2-3m, base width of 1-2m, side slopes of 1vertical to 2 horizontal units. A starting or minimum depth of ~0.3m was used as initial default, which was then deepened where necessary to retain forward slope in intended direction. Some of the channels were set back slightly further from the highway than shown in the design drawings, to allow hydraulic separation in the model mesh, but the model is still representative of the function of the consent design. The positioning, dimensions and gradients of the open channel collectors will be refined during detailed design.

Small low bunds were added in some locations to prevent water from flowing in unintended directions. For example, low bunds were added along the upstream side of some cut faces, that work in conjunction with the open channel collector to prevent water from spilling into the highway cutting, as shown in the typical cut-off section in drawing 310203848-01-300-C9100. Some bunds were also used to further raise the outside bank of some swales (relative to the 3D design model) to reduce spilling between natural overland flow and highway swales. All these bunds were constructed as raised trapezoidal shapes (like inverted stream modifications). The water being managed by these bunds is shallow, short duration flooding and only in rare events. The height of these bunds will be optimised in detailed design together with the open channel collector drains and highway swales.

Mesh breaklines were added to force cell edges along the top of banks, bunds, high points, and low channels so that water would not prematurely side-step these important features. HEC-RAS does all its calculations for flow at cell edges, thus hydraulic features that are not represented by cell edges could otherwise be missed in mesh cell calculations.

2.5 Proposed Culverts

Culverts were added to the model as indicated in the drainage plan set and culvert table (refer 310203848-300 drawing series). Culvert embedment was applied as shown in the table. The design philosophy for the culverts is reflected in the Design and Construction Report, and the effects are discussed in the consent application Technical Assessment #F.

At some locations, stream realignments or other small changes to mesh inverts were needed to allow model-compliant connectivity of inverts. However, these adjustments are small relative to the water depth upstream of the culvert, and do not impact on bore area of the culvert, and therefore the model is still considered representative of the consent design.

The culverts were assigned default entrance and exit loss factors of 0.5 and 1.0 respectively, assuming standard square edge headwalls for circular culverts and wingwalls (between 30 to 75 degrees) for rectangular culverts. All culverts were assumed to be made of concrete and backfilled with mixed substrate where shown for fish passage with a Manning's 'n' roughness of 0.05 along the bottom and 0.018 on the soffit of the culvert. If no embedment was required, the invert and soffit Manning's 'n' values were both set to 0.018. These are relatively high roughness values for a straight concrete culvert, to allow for some variation in sediment transport and energy dissipation along the length of the culvert. Roughness values may be reviewed during detailed design.

As specified in the culvert table, some culverts on ephemeral flow paths have a scruffy dome inlet to manhole drop structure at the inlet, to allow a straight culvert to pass underneath the highway and associated drainage. A low forward slope is still applied within the culvert, assuming that coarse sediment will be captured in upstream stilling basins and in the upstream manhole, so that forward velocity can maintain the pipes clear of sediment build-up. These culverts typically have a similar bubble-up structure at the downstream end, to return water to the surface along original overland flow paths.

2.6 Longitudinal stormwater management features

The longitudinal stormwater management features are intended to convey high intensity rainfall runoff from paved areas, for subsequent treatment and attenuation at the ponds. A key requirement for the hydraulic model is to keep reasonable separation between the longitudinal water and the natural transverse streams or overland flow paths, so that potential significant constraints or effects can be identified. The design and modelled representation of the stormwater system will need to be refined in detailed design stage. Since the stormwater ponds provide significant attenuation in a 1h or 4h storm, it is not required to model the depths or volumes within the longitudinal stormwater system with great precision at this stage for assessment of effects outside the designation.

2.6.1 Rain falling on the highway

Rain falling on paved areas of the highway, and unpaved areas of cut faces, road margins, swales, and fill faces, is modelled in HEC-RAS 2D using the same direct rainfall approach as the baseline model. For most of the Project, this water is captured in swales to lead to treatment and attenuation facilities, as discussed in subsequent subsections.

As discussed in section 2.1 there are a few small sections of the highway that were modelled using infiltration zones and direct inflows to approximate grey infrastructure. An approximation was required as HEC-RAS does not currently support underground pipe networks, and not all of the required detail is available at this stage in the design. However, the intention is reflected, namely that rainfall on the grey infrastructure will be routed efficiently to the appropriate pond for treatment and attenuation. The detailed design stage will provide more optimised and detailed stormwater component design, which can be tested in the hydraulic model where appropriate.

2.6.2 Swales

The swales in the design 3D consent model are based on parametric highway design and have minor deficiencies in conveyance continuity. These have addressed for the hydraulic model as follows:

- Closing the upstream ends of swales with a small bund to force water to flow along the swale in the directions intended in the design (since upstream ends of 3D swales were open ended sections in the design surface, which would otherwise allow a small quantity of backflow).
- Closing the downstream ends of swales with a small bund to force water to flow into the correct pond (since downstream ends of 3D swales were open ended sections in the design surface, which would otherwise allow flow over the end of the swale).
- Enforcing computational mesh lines along the outside edges of swale bunds, to prevent premature overtopping. In a few locations, these lines were also raised to prevent mixing with overland flows, which will be reviewed and refined in detailed design.
- At ‘kinks’ in the swales associated with maintenance bays, the invert of the swale was widened with a small terrain modification to provide continuity of flow.
- Minor widening of the swales under the new Muhunoa East overpass, where the narrowed 3D design conveyance swales were difficult to represent using the 1m model surface grid. This will not have a material impact on the model representation of the function of the swale conveying water to the appropriate treatment pond.

2.6.3 Swale cross connector culverts

Cross connections between swales were modelled as culverts following the input information provided in the drawing pack (310203848-300 series). These culverts were not embedded and were assigned a Manning’s ‘n’ of 0.018. Where the cross culverts were directly opposite the target pond, the cross culvert outlet was placed directly into the pond forebay to simplify model computation.

2.6.4 Swale to pond drop structures

Drop structures to take water from the swales to the SW ponds were not fully specified in the consent design and were therefore modelled as wide ‘spillways’ stamped down as a trapezoidal ramp / channel from the invert of the swale to connect to the invert of the pond.

Where ponds are on the outside of a highway curve (super-elevation) with no outside swale, for example at chainage 32400, the inside swale is directly connected to the pond via a cross culvert.

2.6.5 Treatment wetlands and attenuation ponds

The consent 3D design represents the pond volume as a combined treatment/attenuation storage area with a flat base and a surrounding bund. The separate volumes have been calculated for sediment forebay, wetland treatment pond and attenuation area, but the hydraulic model currently combines these as per the 3D design model.

Each pond was modelled in the 2D domain relying on the 3D terrain pond terrain and bunds. Break lines were applied along the tops of the pond bunds.

Outlet culverts were added to the model, to release flood flows at an attenuated rate.

Checks were completed against the stormwater calculation to confirm that the modelled ponds were attenuating the outflows approximately as intended for the 4h modelled storm.

2.6.6 Roundabouts, Local Roads, Accessways, and SUP

Roundabouts are generally designed with kerb and pit drainage to capture water for treatment, as shown on the drainage design plan set. However, apart from the southern interchange roundabout, all other roundabouts have been left in the hydraulic model direct rainfall zone with flow generating as per the design terrain slopes. Since the footprint of the roundabouts is relatively small, this minor simplification will not have a material impact on the accuracy of the hydraulic model for assessment of effects in the current stage of design. The representation can be improved during detailed design.

Similarly, local roads will generally have small stormwater management features (e.g. narrower infiltration swales) to approximately match existing local road drainage. These small features have not been explicitly included in the model. New or modified local roads that cross watercourses will have culverts as indicated in the drainage design plan drawing set.

Accessways in the form of pedestrian or vehicle underpasses beneath the new highway have not been explicitly modelled in the hydraulic model, as they do not convey significant flow. These features, including any associated bunds or drainage will be specified during detailed design.

The SUP crosses swales at many locations, and the size of the culverts or footbridges for these minor crossings have not yet been specified. For modelling purposes, these locations were represented either as estimated culverts or as 2D terrain modification (i.e., the deck of the SUP removed) to allow the swales to convey water unimpeded. This will be resolved during detailed design.

The southern section of the SUP that follows the existing SH1 was not modelled explicitly due to its distance from the new highway, and the small variations from the existing terrain are assumed to be insignificant. Any drainage requirements will be resolved in detail design.

2.7 Terrain stationarity and gravel mobility

For the purposes of the hydraulic modelling, it is assumed that topography and sediment remain at current levels and predominantly in 'equilibrium'. The small streams and ephemeral flow paths generally have finer sediment that is assumed to pass through the project culverts. The larger streams have some gravel and cobble bed load, which can pass through the bridges that typically span these streams. The combination of wide bridge spans and scour protection is assumed to provide adequate room for some migration, but bed elevations and flood elevations are assumed to remain similar to the current situation.

Terrain changes, including scour or injections of gravel and sediments due to earthquakes or major storm events are not considered in the hydraulic modelling.

2.8 Surface Friction

A roughness surface was developed for the baseline model following existing land use information, as discussed in the baseline flood report. Small modifications were added to the roughness layer in the with scheme model, for example where new open channels were constructed through dense vegetated areas. In these locations the roughness was set to be the same as the open space Manning's n value, namely 0.048.

The remainder of the roughness layer was left the same as the baseline models for the with scheme models, despite the increase in paved area on the expressway. Because the new paved areas drain to SW management features, the more rapid runoff is attenuated in the stormwater ponds. Only the outflows are relevant for assessment of potential downstream effects, in the 4h storm. The lack of infiltration in the HEC-RAS model, and the representation of the stormwater attenuation ponds, means that outflows can be reasonably reflected without specifically adjusting for infiltration or roughness within the paved areas when assessing downstream effects. The stormwater features are subject to design calculations outside of the HEC-RAS model to ensure appropriate performance across a range of event durations. The stormwater design performance will be further validated in the detailed design stage.

Scour protection details have not been modelled explicitly as roughness patches at this stage. The impact of scour protection on modelled water levels is expected to be minimal.

2.9 Run Parameters and Model Stability

The model used an adaptive time step based on courant formula with a maximum value of 2 and a minimum value of 0.5. The equation set used in all models was 'SWE_ELM Original'.

The three models have been simulated successfully across all AEP events, no major mass/volume balance errors.

3. Model results and differences from baseline

3.1 With-scheme model results

The scenarios modelled are the same as the baseline model, as discussed in Section 1.3.

The various AEP design event scenarios were applied to the models and run for 6 hours of simulation time to allow the peak value to pass the downstream boundary.

Appendix B presents modelled results for the with-scheme model. These can be compared with the modelled results in the baseline flood report appendices.

3.2 Scheme differences from baseline

Maps showing with-scheme differences (with-scheme model minus baseline model) are presented in Appendix B. Further discussion and evaluation of the difference maps is provided in Technical Assessment F.

3.3 Blockage risk assessment

A high-level assessment was carried out to evaluate the risks associated with culvert blockage, following the steps outlined below.

A desktop assessment of expected debris loads from contributing catchments and flow paths was performed, in line with AR&R (2015) Blockage Guidelines For Culverts And Small Bridges. This informed the preliminary recommendation for upstream debris arrestors (soldier piles or large screens) reflected in the culvert schedule. The debris loads and debris arrestors were not applied to the hydraulic model.

The concept design earthworks surface around each culvert was viewed in GIS and 3D views to ensure that in the event of blockage, water could either pass along the highway embankment to another nearby culverts or pass over the highway at shallow depth, without posing risk to upstream dwellings or preventing emergency services from passing through floodwaters.

Depressed low gradient culverts with dropped inlets and/or bubble-up outlets can sometimes be subject to reduced performance by blockage of debris arrestors and/or sediment deposition over time. The detailed design will provide upstream debris screens and stilling basins, plus safe maintenance options. For example, vehicle-mounted jec-vac systems that can evacuate sediment from stilling basins or from manholes via a small opening at the top of the scruffy dome without removing the screen. Periodic inspection or additional cleaning of the culverts can be carried out by removal of the screen and insertion of remote-controlled CCTV crawlers and/or cleaners. Further detail of the design and of monitoring and maintenance regimes will be established during detailed design.

3.4 Limitations and Residual Uncertainties

The modelling is a reasonable representation of the consent F3 design and can detect changes relative to baseline in flow rates and water levels on account of the proposed Ō2NL Project.

As indicated in the baseline model report, we have relied upon third party data sources when building the model. The source data and the hydrological and hydraulic modelling processes have followed industry best practice but still naturally contain some assumptions or uncertainties as normally anticipated. Depending on the changes after the consent design and criticality of decisions during detailed design, consideration could be given to reducing some of the residual uncertainties. Potential limitations and uncertainties to consider include:

- If using the model to optimise or validate the performance of the longitudinal stormwater management features, then shorter and longer duration storms would be required, in addition to other model refinements.

- Baseline hydrology limitations (refer to baseline flood report). The impact of this uncertainty is mitigated by applying the same hydrology to both pre and post project models, however the hydrological uncertainty could still influence some design decisions.
- There are ground model differences between the DEM (LiDAR data) on which the modelling was primarily based and the 2020 drone-based DEM on which the highway earthworks design is based. The differences could potentially be reduced by applying additional ground control survey to both datasets to reduce discontinuities and allow only one merged ground model to be used for modelling and detailed design. The onus will rest on the Detailed Design project stage to confirm suitability of the ground model and any associated hydraulic modelling for the final design and construction purposes.
- The representation of climate change is based on the IPCC 5th assessment global climate model predictions downscaled to New Zealand by NIWA (2018). Science from the new 6th assessment may become available to the project during detailed design.

Appendices

Appendix A Map Figures Data Source

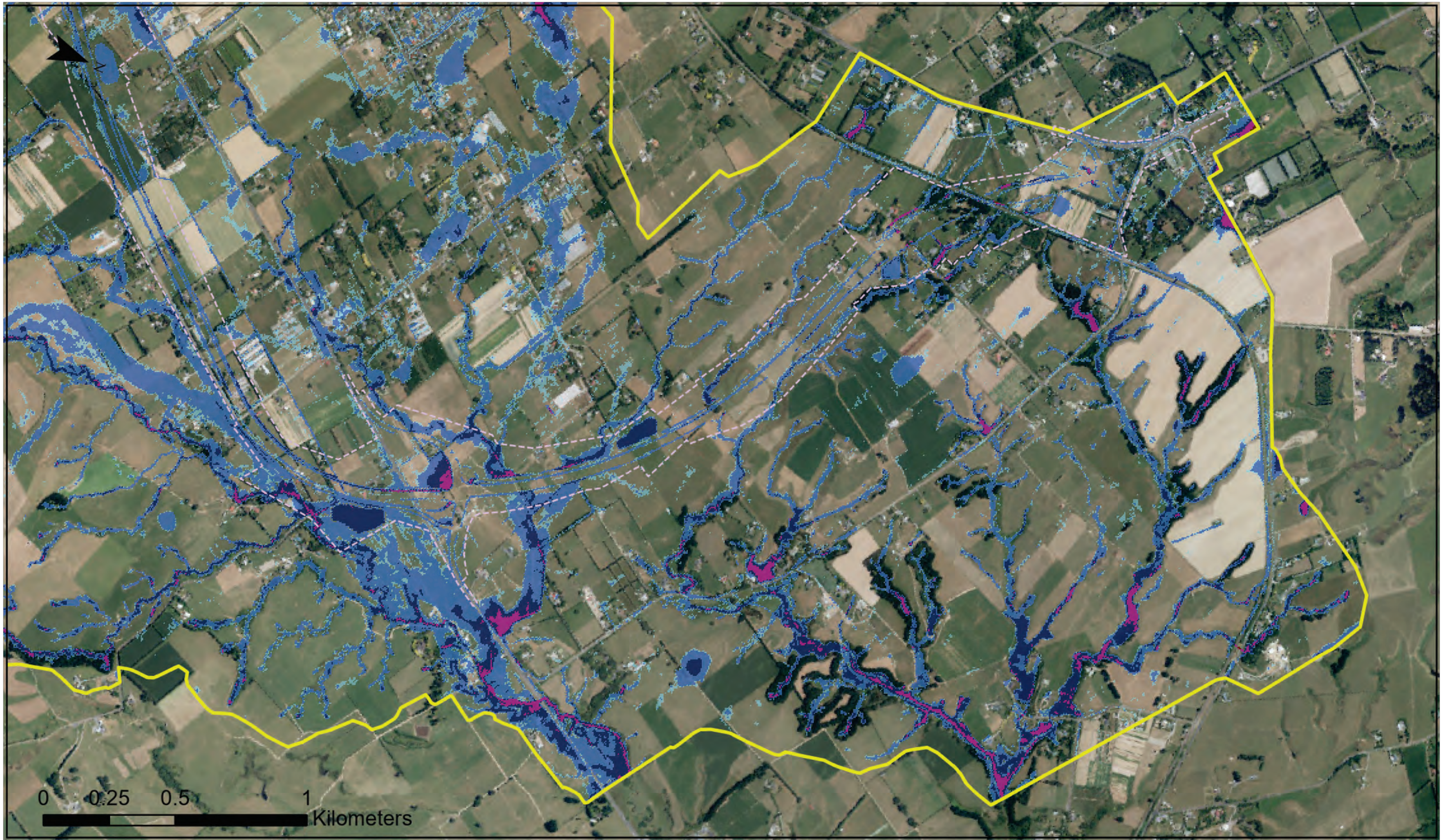
Data Sources: GWRC, HDC, HRC, KCDC, KiwiRail, LINZ, and Stantec NZ.

Basemap Service Credits: Eagle Technology, Esri, FAO, Garmin, HERE, LINZ, Natural Earth, NIWA, NOAA, © OpenStreetMap contributors, StatsNZ, USGS.

All maps displayed in NZGD 2000 New Zealand Transverse Mercator coordinate system unless otherwise specified.

All elevations relative to Wellington 1953 datum unless otherwise specified.

Appendix B Model Results



Model Results, Maximum Water Depths 1:100 AEP With Climate Change RCP 6.0 2130

Storm duration: 4hr for the Ohau and North models and max of 4hr and 1hr for the South model

- South Model Extent
- Ohau Model Extent
- North Model Extent
- Proposed Designation July 2022

Max. Water Depth (m)

- 0.05 to 0.1
- 0.1 to 0.5
- 0.5 to 1
- 1.0 to 3.0
- Greater than 3

Data Sources:Basemap Service Credits: LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors
Map displayed in NZGD 2000 New Zealand Transverse Mercator coordinate system.
Author: Stantec (2022)

Stantec

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Ohau Model Extent

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Proposed Designation July 2022

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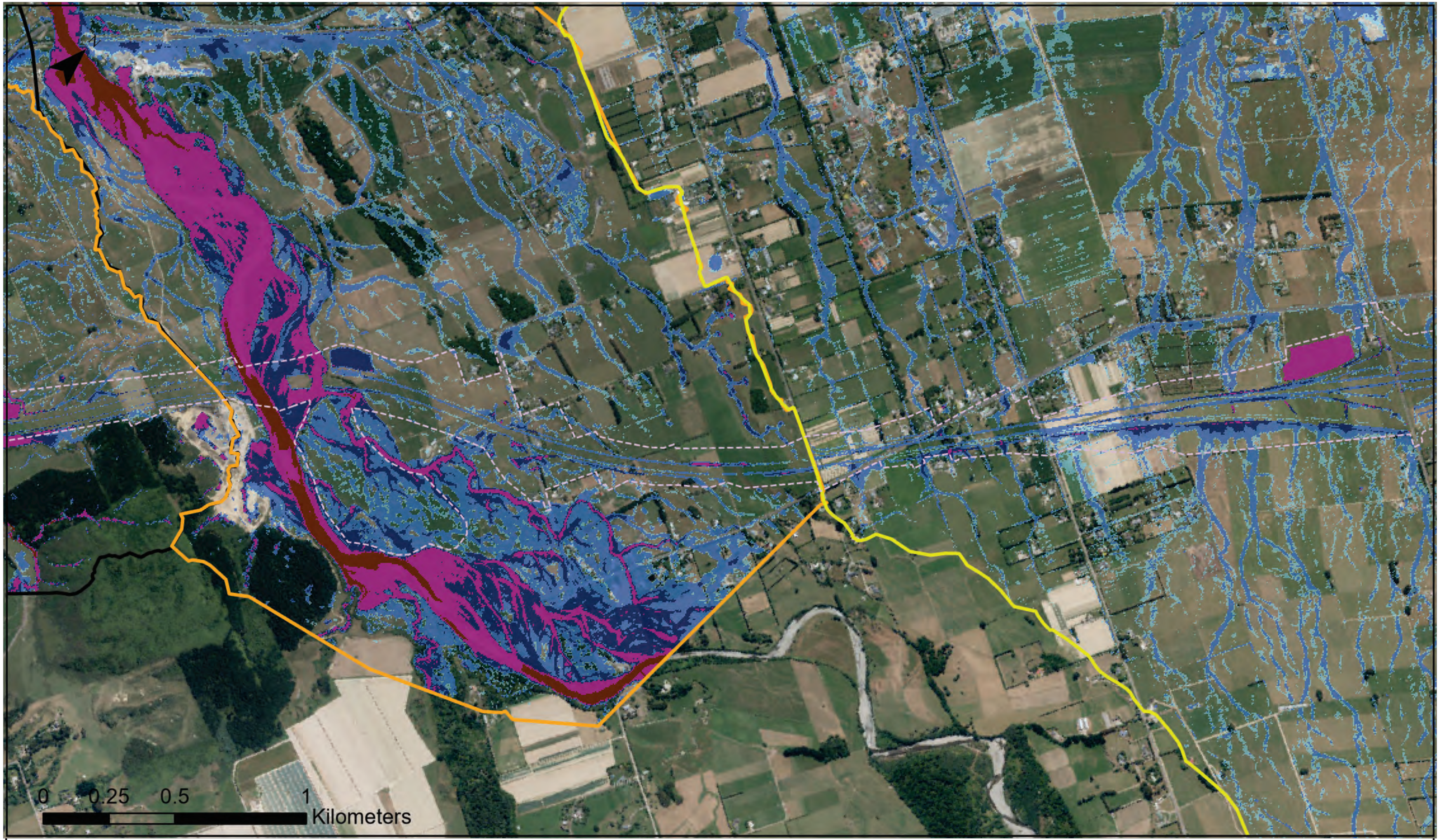

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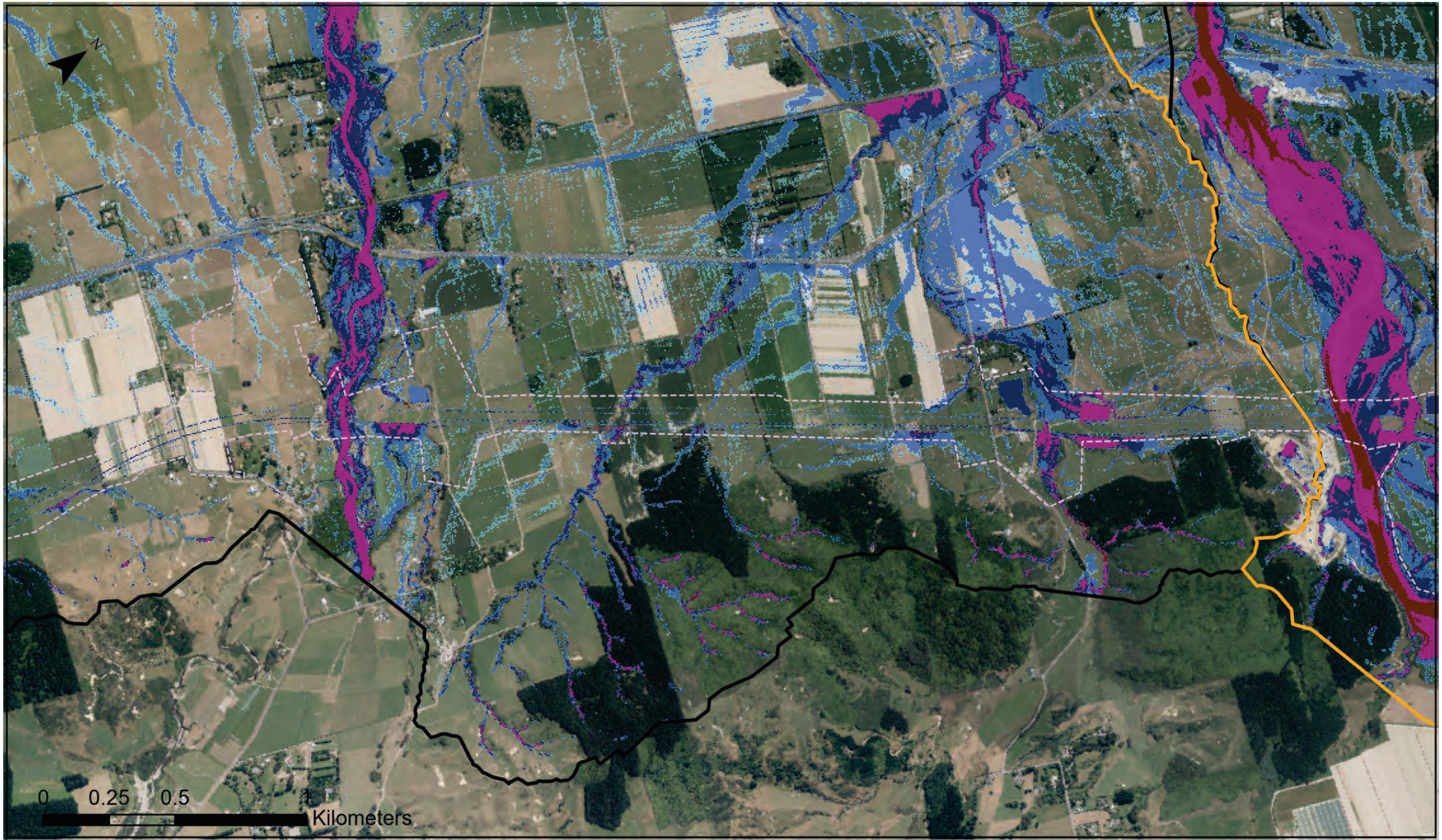

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Stantec

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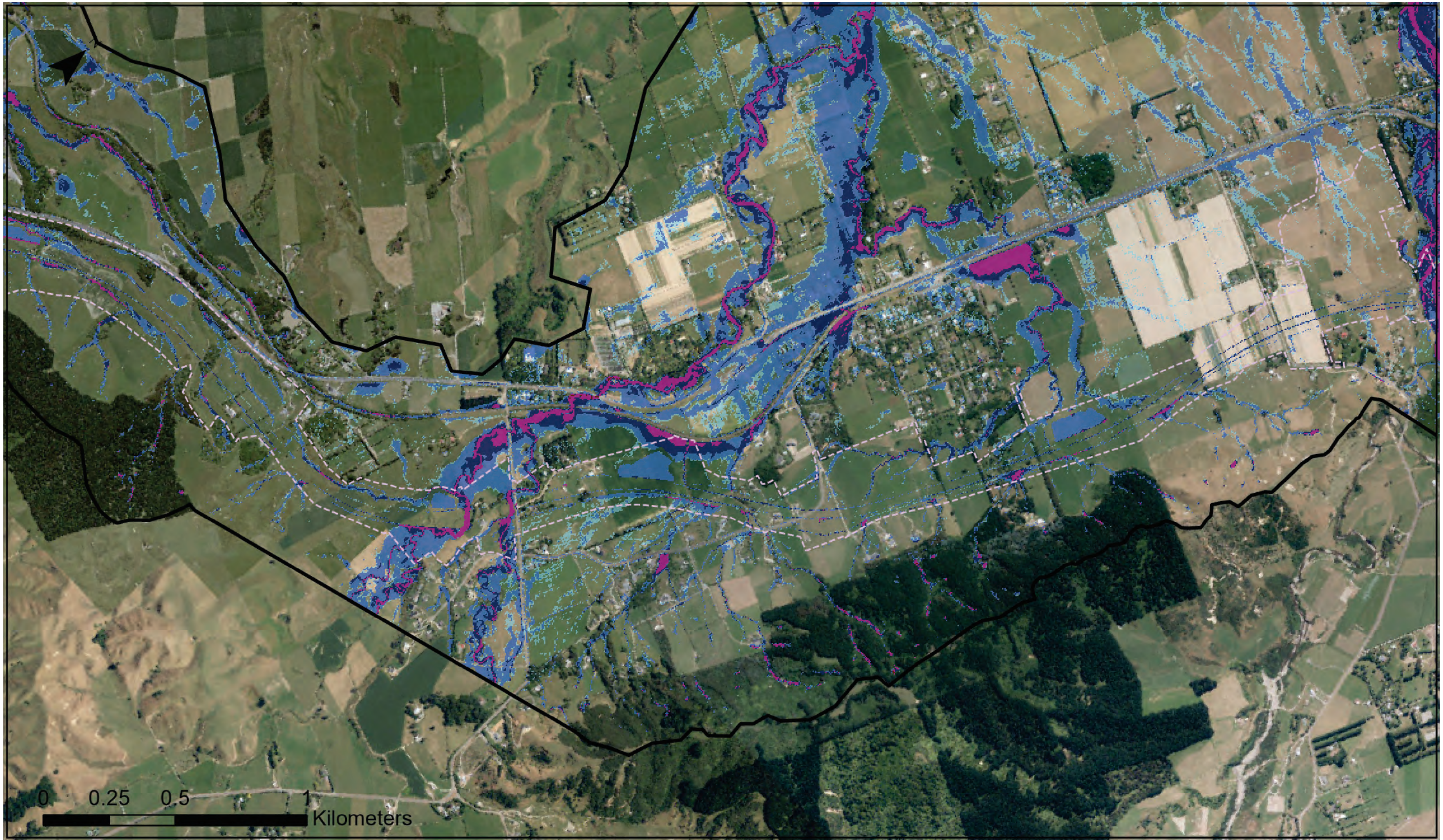

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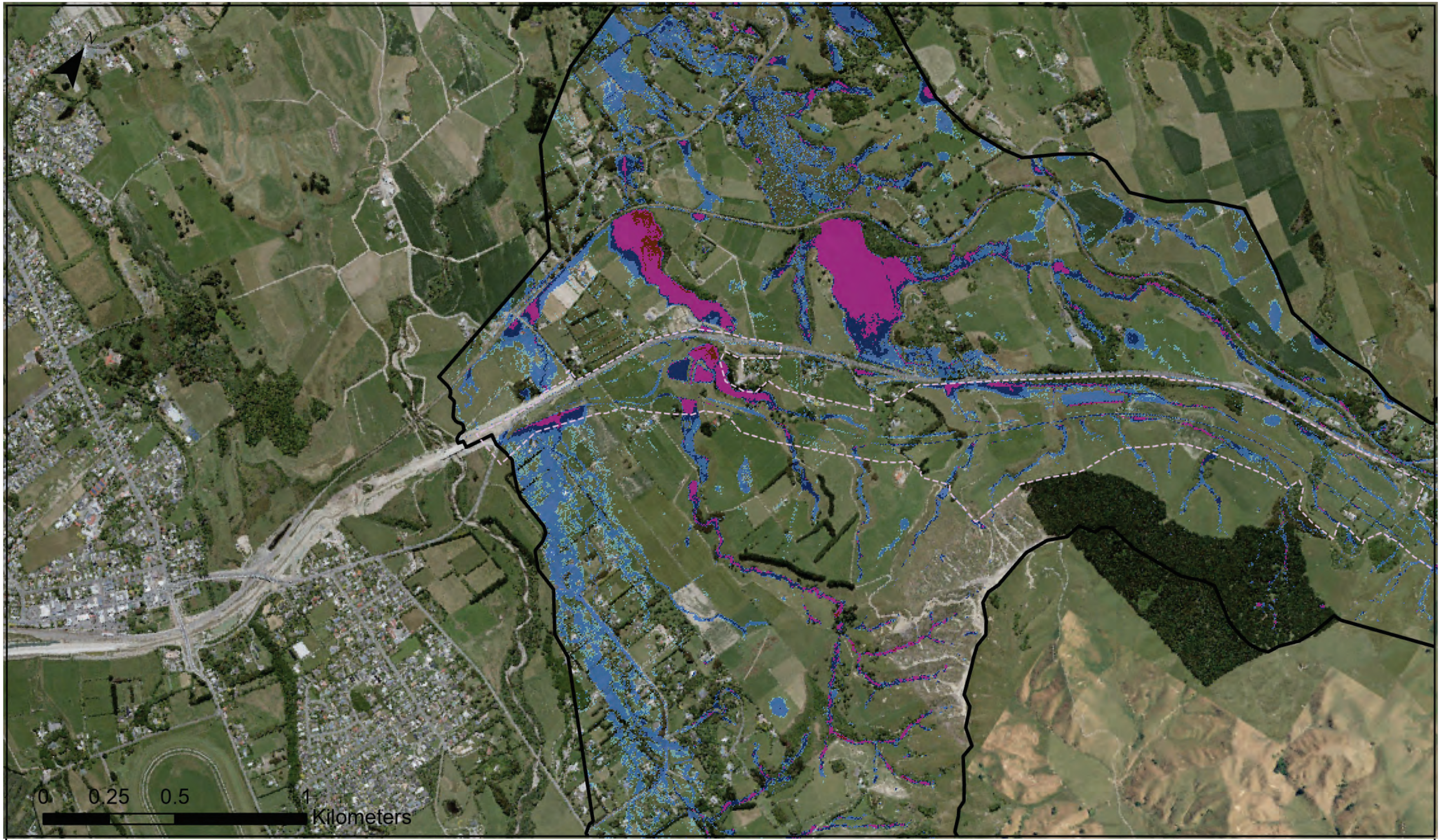

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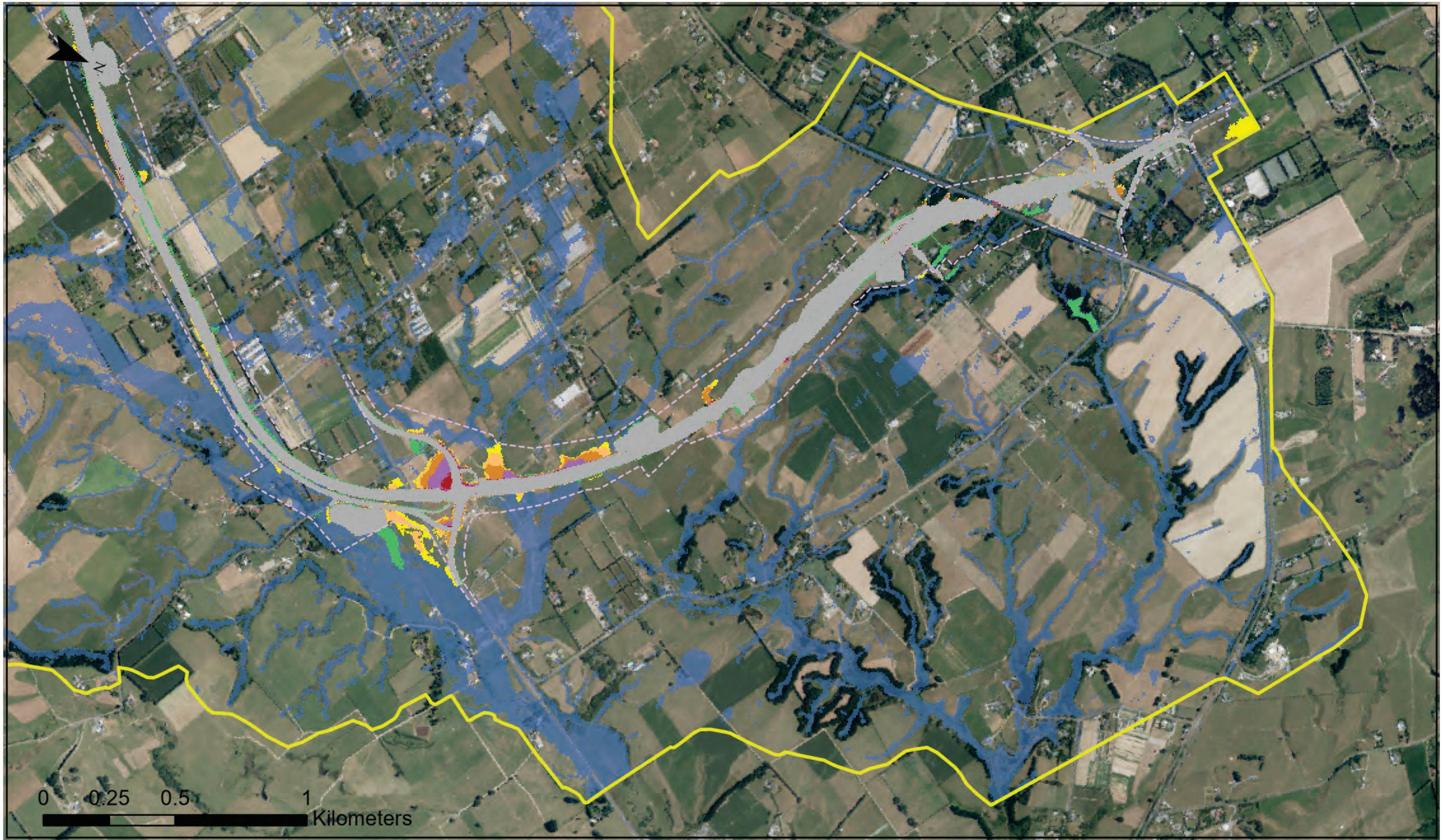

Model Results, 1:100 AEP Water Surface Elevation Difference, Scheme Minus Baseline

This map shows the difference in maximum water surface elevations for the 1:100 AEP event with RCP 6.0 2130 climate change considerations. The North and Ohau models show differences for a 4hr event, while the South model includes both 1hr and 4hr max elevation differences.

Stantec

Max WSE Difference (m)

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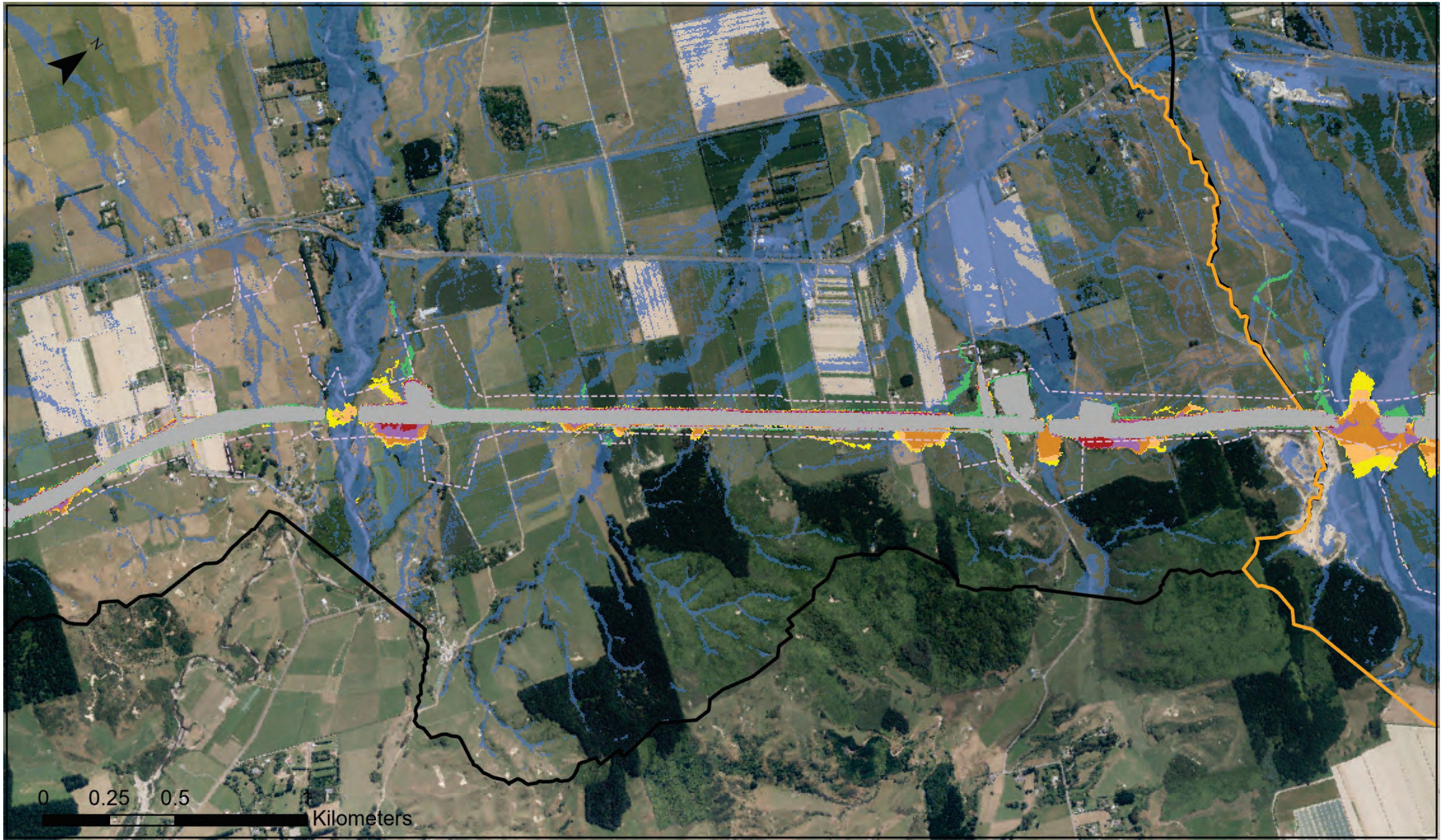

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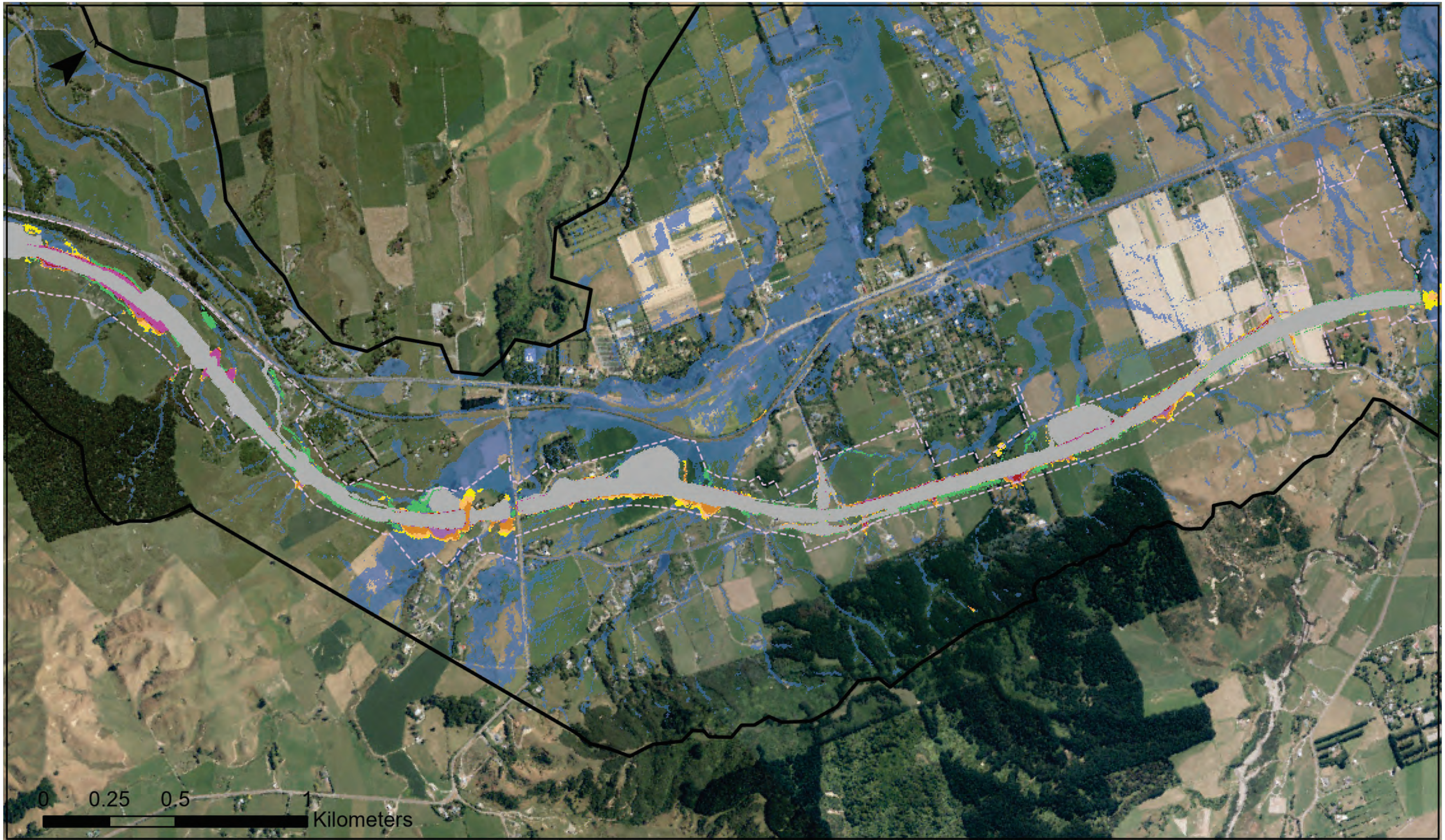

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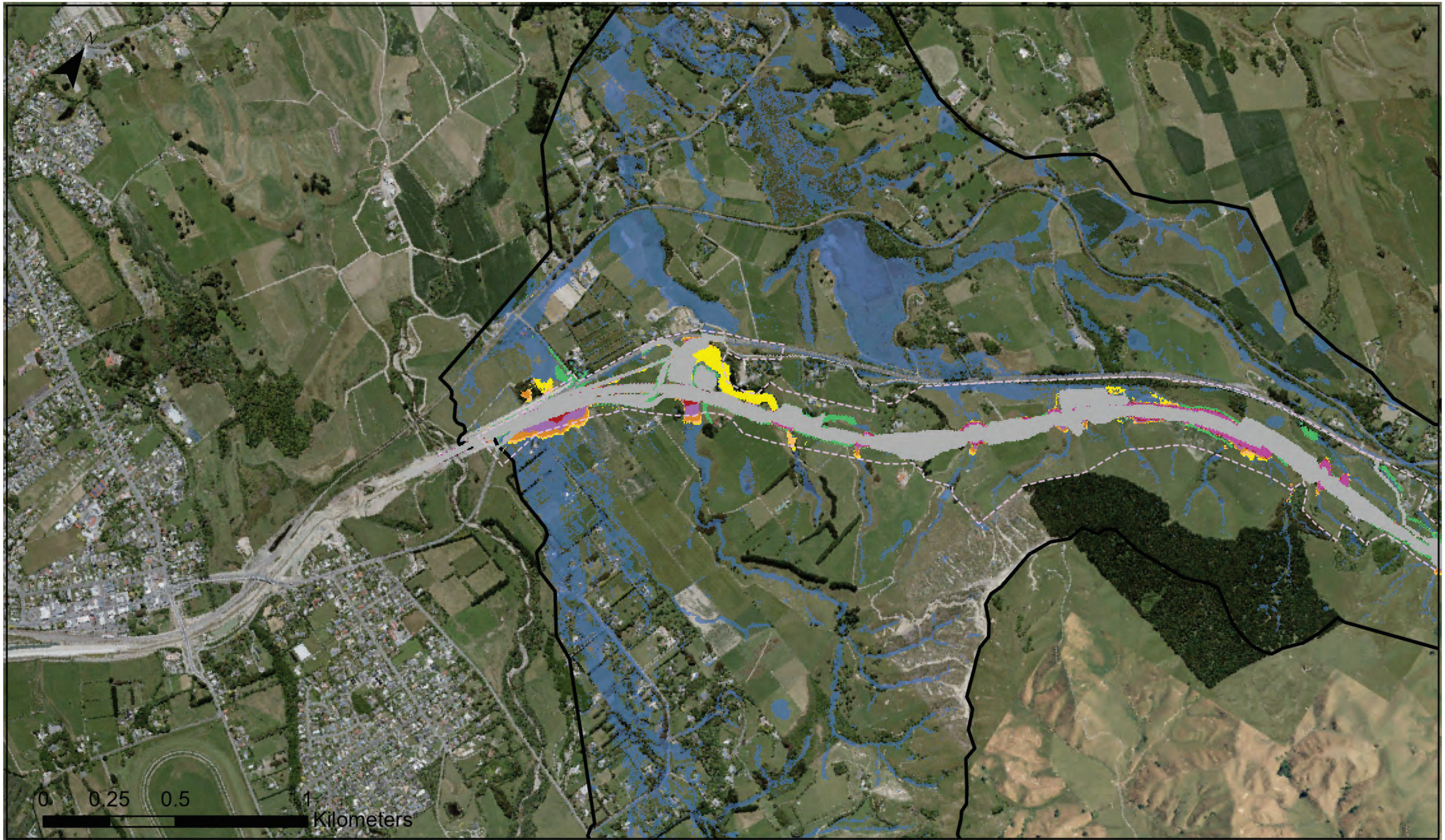

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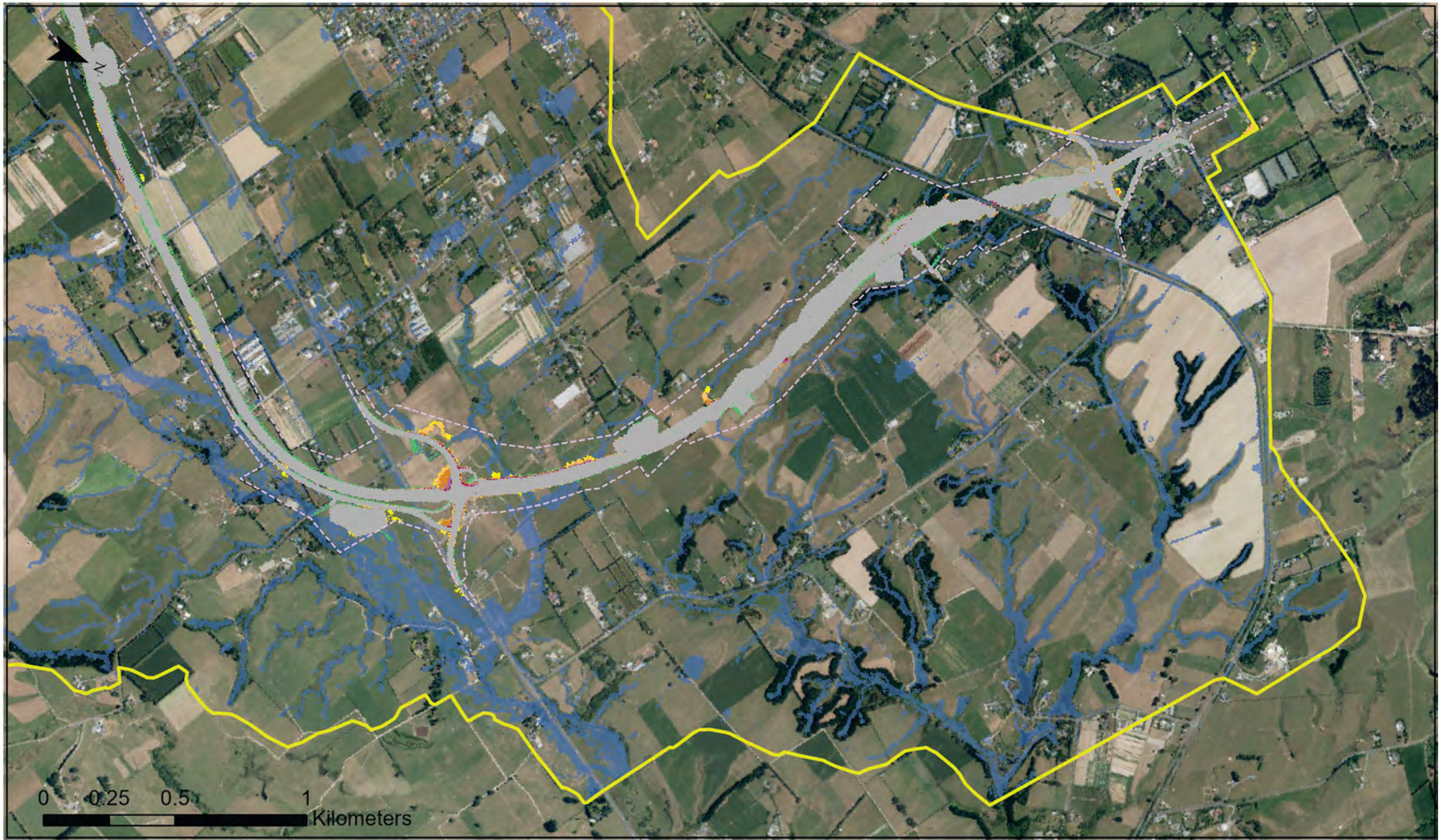

Model Results, 1:10 AEP Water Surface Elevation Difference, Scheme Minus Baseline

This map shows the difference in maximum water surface elevations for the 1:10 AEP event in existing climate. The North and Ohau models show differences for a 4hr event. The South model shows differences for a 1hr event

Stantec

Max WSE Difference (m)

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- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
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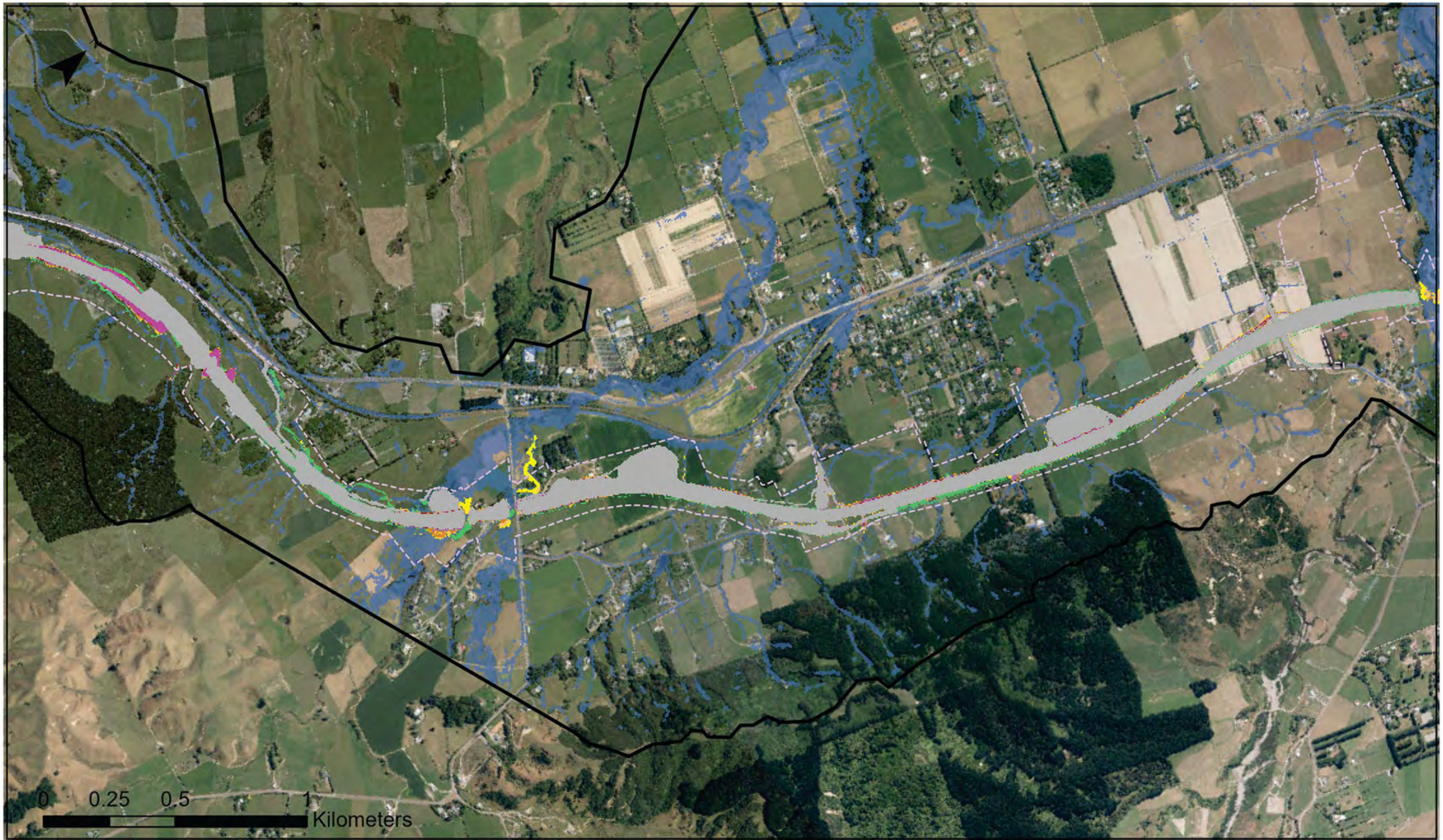

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- North Model Extent
- Proposed Designation July 2022
- Concept Design Footprint

Data Sources:Basemap Service Credits: LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors
Map displayed in NZGD 2000 New Zealand Transverse Mercator coordinate system.
Author: Stantec (2022)

Model Results, 1:10 AEP Water Surface Elevation Difference, Scheme Minus Baseline

This map shows the difference in maximum water surface elevations for the 1:10 AEP event in existing climate. The North and Ohau models show differences for a 4hr event. The South model shows differences for a 1hr event

Stantec

Max WSE Difference (m)

- Less than -0.1
- -0.1 to 0.05 (baseline no change)
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- Greater than 1.0

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APPENDIX F.3: PEER REVIEW MEMORANDUM PROVIDED BY DR MCCONCHIE

Memorandum

To:	Caitlin Kelly	**At:**	Ō2NL Project Team, Waka Kotahi
From:	Dr John (Jack) McConchie	**At:**	SLR Consulting NZ Limited
Date:	20 October 2022	**Ref:**	720.30017.00000 O2NL Hydrology Peer reviewer FINAL.docx
Subject:	Role as hydrology peer reviewer		

Introduction

I was asked by the Ō2NL Project team to provide independent peer reviews of the hydrology, results of the computational hydraulic modelling, and the assessment of environmental effects that underpin *Technical Assessment F – Hydrology and Flooding*. That assessment is part of a body of investigations and technical information that will support an application for the various resource consents and approvals necessary to construct the Ō2NL Project.

On other occasions, I have also been asked to provide advice on separate hydrology-related issues associated with the Ō2NL Project. These include:

- Options for the supply of the water necessary for construction of the Project;
- The hydrology of wetlands that might be considered for rehabilitation and for offsetting any potential adverse effects of the Ō2NL Project e.g., Kereru Wetland; and
- Options for potential material supply sites.

Background

My principal involvement in the Ō2NL Project has been related to groundwater. My background, skills and experience are summarised in *Technical Assessment G – Hydrogeology and Groundwater*. However, I also have skills and extensive experience in the areas of hydrology and flooding, and how these processes interact with infrastructure.

I have considerable experience working on major infrastructure projects including: the Hamilton North Bypass; Western Link Road; Kopu Bridge; Tauranga Eastern Link Road; Basin Bridge; Transmission Gully; Peka Peka to Ōtaki Expressway; Petone-Grenada Link Road; the realignment of SH3 at both Mt Messenger and Awakino Gorge; and Te Ahu a Turanga: Manawatū Tararua Highway. This experience gives me an in-depth understanding of climate, hydrology, and flooding and how they interact with infrastructure.

I have considerable local experience having worked on various hydrology-related projects in and around Horowhenua and Manawatū over the past 20 years; including the PP2Ō Expressway and Te Ahu a Turanga: Manawatū Tararua Highway. I provided technical evidence relating to the flood hazard and stormwater management at Tara-Ika during hearings into the proposed change to the Horowhenua District Plan. I have provided technical advice to Horizons on several applications for resource consents involving works related to streams and rivers. This experience has given me an in-depth understanding of climate, hydrology, and flood hazard in the area to be traversed by the Ō2NL Project.

Peer review

Any review of the potential effect of the Ō2NL Project must be undertaken within the context of the existing flood hazard of the area. In my opinion, the Project will not only increase the resilience and security of the State Highway but have a small, positive effect on reducing the existing flood hazard.

Regarding my independent peer reviews of *Technical Assessment F – Hydrology and Flooding*, I have:

- Reviewed the various hydrological inputs to the computational hydraulic modelling, including the design rainfalls and flows. This included undertaking an independent frequency analysis of the annual flood maxima from the various flow records. I believe that the inputs adopted are realistic but likely conservative i.e., the design flows, in my opinion, are likely to be slightly high;
- Considered the criteria adopted when defining the design events and believe that these are appropriate for the Ō2NL Project;
- Considered the inclusion of the potential effects of predicted climate change over the design life of the Ō2NL Project and believe that the approach adopted is appropriate;
- Not reviewed the detail of the computational hydraulic modelling, however, this has followed current industry practice and used an industry-standard suite of software;
- Considered the issue of calibration and validation of the computational hydraulic models. Given the extremely limited availability of empirical flow data, particularly for the very large design events modelled (apart from the 10% AEP event under current climate), a greater level of calibration and validation is not possible. However, this uncertainty is accommodated by adopting conservative flows (i.e., high) which exacerbates the impact of the Project and therefore any potential adverse effects;
- Considered the conceptual design for the Project incorporated within the computational hydraulic modelling and believe that it is realistic. In my opinion, once the Project has been refined and the design finalised, the effects of the Project on hydrology and flooding are likely to be less than assessed in Technical Assessment F;
- Considered the assessment of effects of the Project on the existing flood hazard. Again, I believe that a conservative approach has been adopted and that the effects that might eventuate from the Project will likely be less than stated; and
- Considered the feedback from Horizon's peer reviewer and the responses provided to the various matters raised.

Conclusion

Based on the information and materials that I have reviewed, and numerous discussions with Andrew Craig (Stantec), I believe that *Technical Assessment F – Hydrology and Flooding*:

- Has adopted industry standard methods and measures, and that these have been applied in an appropriate manner;
- Has included appropriate, although likely conservative (i.e., high), hydrological inputs to the computational hydraulic modelling;
- Has provided appropriate consideration of the future potential effects of climate change; and
- By considering a conceptual design, provides a realistic, although likely conservative (i.e., high) assessment of potential effects of the Project on hydrology and flooding. This assessment provides a realistic envelope of effects within which the final design and construction of the Project can be developed.

In summary, in my professional opinion, the methodologies, results and conclusions provided in *Technical Assessment F – Hydrology and Flooding* are realistic, but likely conservative i.e., high. That is, in my professional opinion and experience the effects of the Ō2NL Project on hydrology and flooding are likely to be less than assessed.