Attachment B Supplementary Flood Assessment

TE TUPU NGĀTAHI
SUPPORTING GROWTH

Te Tupu Ngātahi North Supplementary Flood Hazard Assessment

24/01/2024

Version 1.0

WAKA KOTAHI NZ TRANSPORT AGENCY

AT

New Zealand Government

Document Status

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Abbreviations

Acronym/Term	Description
AC	Auckland Council
AC HW	Auckland Council Healthy Waters
AEE	Assessment of Effects on the Environment
AEP	Annual Exceedance Probability
AT	Auckland Transport
AUP: OP	Auckland Unitary Plan Operative in Part
CEMP	Construction Environmental Management Plan
FUZ	Future Urban Zone
GD01	Auckland Council Guideline Document: Stormwater management devices in the Auckland region, GD2017/001 (an update of TP10)
GD05	Auckland Council Guideline Document: Erosion and Sediment Control Guide, GD2016/005
GIS	Geographic Information System
LGA	Local Government (Auckland Council) Act 2009
MfE	Ministry for the Environment
MPD	Maximum Probable Development
NES	National Environmental Standard
NPS	National Policy Statement
NPS: FM	National Policy Statement on Freshwater Management
NPS: UD	National Policy Statement on Urban Development 2020
NoR	Notice of Requirement (under the Resource Management Act 1991)
RCP	Representative Concentration Pathways
RMA	Resource Management Act 1991
SEA	Significant Ecological Area
SGA	Te Tupu Ngātahi Supporting Growth Alliance
SH1	State Highway 1
SMAF	Stormwater Management Area: Flow
SRP	Sediment Retention Pond
Te Tupu Ngātahi	Te Tupu Ngātahi Supporting Growth
Waka Kotahi	Waka Kotahi NZ Transport Agency

Glossary of Acronyms / Terms

Acronym/Term	Description
AT	Auckland Transport (an Auckland Council controlled organisation).
Auckland Council	Means the unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Freeboard	An allowance above the modelled flood level, be it road level or other features (e.g. existing floor level). For buildings freeboard shall be measured from the top water level to the finished floor level. The relevant design manual shall be referred to for the appropriate freeboard and method of calculation.
Lay down areas	An area that has been cleared for the temporary storage of materials and equipment and may include site compounds, stockpiles, sediment retention ponds.
MPD	Maximum Probable Development according to the AUP: OP zonings and the Auckland Council Healthy Waters technical memorandum dated 4/9/2019
Pre Project or Pre-development	Prior to construction of the Project
Post Project or Post-development	After construction of the Project
Stormwater Wetland	Constructed wetlands that store runoff and support conditions suitable for the growth of wetland plants. Stormwater wetlands provide enhanced water quality treatment of stormwater runoff through vegetation uptake, retention and settling. They can also be used for attenuation to reduce the predicted peak flow from a rainfall event and provide downstream erosion and flooding protection / mitigation.
Terrain	An elevation model which includes the ground levels based on 2016 LiDAR ground levels.

24/01/2024

Executive Summary

Overview

This Supplementary Flood Hazard Assessment provides additional clarification and assessment in relation to flood hazard effects of the Te Tupu Ngātahi North Projects in response to s92 questions and comments from Auckland Council (and Healthy Waters) on the lodged assessment of Flooding Effects and associated Flood Hazard Conditions.

The Te Tupu Ngātahi North Projects are a network of planned transport infrastructure with the purpose of responding to planned future growth in the North growth areas. The transport network is made of 13 Notices of Requirement (NoRs) including new corridors, existing road upgrades, rapid transit corridor, new stations and cycle / walkways.

Flooding is a natural hazard and has therefore been considered as part of the North NoRs to assess if the North Projects will impact that flooding (using the models that were recently updated by Te Tupu Ngātahi to understand the existing flood risks).

The NoRs address flooding and stormwater from the perspective of the suitability of land to provide transport corridors to support the growth of the Auckland region. The key provisions for NoRs/designations are those set out in RMA 171 of the Resource Management Act 1991, where relevant matters of the various policy and plans are to be considered, along with the effects of allowing the NoRs, consideration of alternative sites route and methods and whether the designation is reasonably necessary to achieve the Requiring Authorities' objectives. In terms of the Auckland Unitary Plan, Natural Hazards E36.2 (4), (5) and (6), relate to flooding and are considered relevant.

From a design perspective, and with consideration to effects to be considered by future resource consents, we paraphrase these issues as "can the future works be designed and constructed in a way that appropriately manages flooding effects" and "is there sufficient land to construct the future transport corridor and mitigate effects".

The models have been sent to Auckland Council Healthy Waters (AC HW) for draft review in 2020. The flood results have been compared to those published on the AC Geomaps site and compare well, particularly the latest 2023 version which uses the same AC modelling approach as Te Tupu Ngātahi.

The land required for construction areas and mitigating future stormwater impacts has also been considered; along with bridges and culverts, attenuation, and treatment of runoff from NoR impervious surfaces and impacts on stream diversions or flow paths.

In the context of this assessment, flood hazard risk may include changes to:

- the flood freeboard to existing habitable buildings, overland flow paths;
- the ability to access property by residents and emergency vehicles;
- the level of flooding to roads and flooding arising from the blockage of stormwater drainage; and
- effects to existing habitable buildings / infrastructure and potential future effects on upstream and downstream properties.

To limit the scale of effects on other property, we have identified flood performance outcomes in the proposed flood condition -, of which we consider the most important to be the reduction in freeboard to habitable floors that already flood or have limited freeboard. During future detailed design at the Outline Plan stage, both the change in head loss at the boundary (being up to 50mm) and the reduction in freeboard at the habitable floor level will need to be applied to identify which is the more restrictive case.

We have proposed some amendments to the lodged version of the Flood Hazard Condition as explained in the section 92 response and summarised in Section 2 of this Supplementary Flood Hazard report.

We consider that this condition addresses the key potential effects associated with flooding and means that it will appropriately address potential effects on other property. This condition has been framed so that there is a balance between appropriately managing effects while retaining a small amount of flexibility for the future designers. To retain flexibility outside the specified outcomes in the Flood Hazard condition, the final clause of the Flood Hazard Condition allows the Requiring Authority to negotiate a different outcome at a specific location with the landowner's agreement.

The design and authorisation of the transport corridors/stations is an ongoing process and one that will iterate with increasing understanding of constraints, effects and design certainty alongside the consenting strategy.

The future regional resource consent process gives Council another opportunity to review the potential effects in the future. Our view is that consents would currently be required under section 13, 14 and 15 of the Resource Management Act 1991 (RMA) for stormwater diversion and discharge and the AUP, and that similar requirements are likely with future consenting legislation.

Regardless we expect that the future consenting process will consider structures in streams, stormwater diversion and discharges in more detail and will require Waka Kotahi and Auckland Transport to address stormwater management requirements and effects relating to water quantity attenuation, flood mitigation, overland flow, storm water quality and retention and detention. Auckland Council will therefore be able to review the proposed works and effects at that stage in greater detail and consider the application of the planning and engineering criteria that apply at that time.

Assessment undertaken.

The assessment of flooding effects has involved the following steps:

- Desktop assessment to identify potential flooding locations
- Modelling of the pre-Project (base case) scenario
- Producing flood extent maps for the pre-Project scenario to show the flood levels (greater than 50 mm deep)
- Overlaying the pre-Project flood results on GIS with aerial photographs, land use zones, contours, and the proposed work footprint to identify potential effects; and inspection and review of flood maps at key locations such as proposed bridges, culverts, wetlands, and major earthworks to identify potential flooding effects
- Where we identified existing buildings were within the existing flood plain from aerial photographs, there is potential for a building to have insufficient freeboard. We initiated a

series of site inspections to estimate the amount of existing freeboard and decided, based on the proximity of the building to the building corridor and whether the corridor works were likely to cause an effect. Where we decided there was potential for an effect, we then considered whether such an effect could be avoided – primarily this meant that if the conveyance capacity under the corridor could be increased (via additional culverts or a longer bridge), the effect could be avoided. In situations where we considered there was a greater loss of flood plain storage due to a road embankment, we made a judgement on whether this needed to be avoided by putting the works on a bridge, and

- Flood modelling of the concept design terrain was undertaken (i.e. the post Project scenario) for areas that are identified as having the greatest potential change to flood risk outside the proposed designation. The locations identified were near the predicted overtopping of Dairy Flat Highway (NoR 8) to the west of the existing Bawden Road intersection and both sides of the Green Road intersection; the realigned Bawden Road and bridge (NoR 12); and the Upgrade to Pine Valley Road (NoR 7).

Stormwater effects (stormwater quantity and quality) and structures in streams are regional plan issues which will be subject to a future regional consenting process during later stages. Provision was made for the potential future stormwater effects by identifying the space required for stormwater management devices (i.e. treatment and/or attenuation wetlands) and incorporating land for that purpose into the NoR and designations.

The pre-Project (base case) scenario relates to the existing network model <u>without</u> the terrain amendments for the North Projects, but with future catchment development impervious allowances (as per the AUP: OP zonings and the AC Healthy Waters memo of 4 Sept 2019), 2016 terrain, larger existing pipes, or bridges with the 1% Annual Exceedance Probability (AEP) return period future storms including climate change scenarios of 2.1 and 3.8° temperature increases. The base case scenario provides water levels and flow paths to identify the vertical alignment of the concept design – i.e. to set the levels of carriageway and bridges with appropriate freeboard above the flood levels.

Apart from NoR 7, NoR 8 and 12, the post-development scenario <u>with</u> the proposed terrain for the North Projects design added to the flood model <u>has not been assessed using flood modelling at this stage</u> and is proposed to be done at the later detailed design and modelling stage. This is because we considered the potential effects for the majority of the NoRs were able to be assessed qualitatively such that potential effects would be able to be mitigated.

For NoR 7, 8 and 12, the post development scenario was modelled because the area had flatter hydraulic grades and it was more difficult to determine the extent of likely effects. Modelling the post development scenario confirmed that, subject to design development, the designation area provides sufficient room so the proposed NoR condition can be met in the future. This also provides confidence that the condition can be met in other parts of the study area which have not been modelled post development - because the areas that have not undergone modelling of the post development scenario typically have steeper existing hydraulic grades and additional cross conveyance capacity can be used to address potential effects.

The modelling undertaken to date is for the purposes of assessing potential effects and identifying whether those effects can likely be mitigated. Further flood modelling will be carried out for the Outline Plan to demonstrate that the detailed design complies with the proposed flood hazard conditions. In addition, this does not preclude additional flood requirements, such as the future

Auckland Council Code of Practice requirements being used in the assessment of future regional resource consents.

Results of assessment and recommended measures

The main positive effects associated with the North Project NoRs are:

- proposed new transport corridors / stations will be above the predicted future flood plains (including allowance for climate change)
- proposed widened and improved corridors are to be above the predicted future floodplains, particularly existing overtopping roads which provides improved resilience for these roads (allowing emergency vehicles to get through and avoid traffic disruption effects)
- ability to convey flows without worsening flooding impacts upstream or downstream of the works within the proposed designation conditions, and
- added water quality treatment and attenuation of the total roadway impervious area as opposed to just the additional roadway area for upgraded roads.

Construction effects

The proposed construction works which could potentially result in flooding effects include raised road formations, temporary works for proposed bridges and culverts restricting flows, interruption of flow paths by new wetlands and temporary laydown or construction areas.

The management and mitigation measures for construction flooding effects are:

- Setting the earthwork construction period during typically drier periods
- Locating lay down and construction areas outside of flooding and overland flow paths
- Temporary diversions for bridge, culvert, and wetland construction
- Managing overland flow paths to reduce the risk of increased flooding
- Construction methodology planning along with contingency planning for large rainfall events during construction including rainfall monitoring, and
- Construction Environmental Management Plans developed and implemented, including continuous improvement as necessary.

The proposed designation conditions require that the Construction Environmental Management Plan (CEMP) includes measures to mitigate flood hazard effects such as siting stockpiles out of floodplains, minimising obstruction to flood flows, and actions to respond to warnings of heavy rain.

Operational effects

In summary, the potential operational effects are:

- Changing bridge or culvert crossing capacity can increase or decrease upstream and downstream flow rates and therefore potentially impact flood levels.
- Widening embankments will increase the length of existing culverts which can increase upstream water levels due to inlet inverts being higher if widened on the inlet side and the culvert extended on the existing grade. If formation widening on the downstream side the upstream water level will also increase due to greater culvert friction losses due to the increased culvert length.

- Widening the carriageway width will increase the channel length under existing bridges and if the waterway area is maintained it will increase upstream water levels due to greater bridge waterway friction losses.
- Embankments built within floodplains will reduce flood storage and increase predicted water levels.
- Altering or obstructing existing overland flow paths which can lengthen flow paths or create flood prone areas.
- Increased impervious area within the NoR corridor to treat for treatment, attenuation or both dependent on the location of the device in the catchment.

The key flooding effects and controls within the North Projects area are associated with changing the flow characteristics at key watercourses crossing the NoRs. The locations listed below are considered to have a greater potential for flooding effects:

- The area upstream of East Coast Road on the south branch of the Okura River. Increasing culvert capacity under East Coast Road would reduce the existing flooding problems.
- The area around chainage 4700 on State Highway 1 where an overland flow path runs through 1513 East Coast Road.
- The upper reaches of the Dairy Stream around chainage 7100 on State Highway 1, where flow is attenuated upstream of East Coast Road and SH1 before running to the west through FUZ.
- The area south of the Silverdale Interchange. On the west side flooding could be increased on the FUZ land unless peak flows from the new corridor are mitigated. One way of doing that mitigation, and potentially reducing existing flood risk on the west side, is to divert peak flows in a channel along the east side of SH1 – but this must be balanced with the potential for effects on the existing commercial properties to the south-east of the Silverdale interchange.
- Raising the existing alignment of Pine Valley Road improves road resilience but must be done in conjunction with providing enough cross conveyance to mitigate changes to flood levels.
- The three bridges near intersection of Dairy Flat Highway (NoR8) and Bawden Road (NoR 12). Modelling shows that the two upstream bridges on Bawden Road and Dairy Flat Highway can be constructed with little change to upstream flood levels by leaving the existing crossing at chainage 2750 nominally as it is. There is potential to reduce the upstream flooding effects on the FUZ land by letting water pass downstream if this is appropriate in terms of downstream effects.

No locations have been identified where potential effects cannot be appropriately mitigated.

We note that if catchment wide mitigation approaches were developed by AC and private landowners and which required changes to the flow characteristics at waterway crossings, there is potential for these to be implemented in conjunction with any changes to the bridges and culverts required to mitigate the effects of the Project works. There are several areas of existing flooding that present this opportunity.

The proposed Flood Hazard condition will require the future detailed design of the transport corridors to be designed to achieve specific flood risk outcomes. The condition requires flood modelling of the pre-Project and post-Project 1% AEP flood levels (for Maximum Probable Development land use and including climate change) and that the design meets specific outcomes. The condition has been revised and updated in December 2023 as set out below and explained in the section 92 response.

Proposed Flood Hazard Condition (updated Dec 2023)

a) *The Project shall be designed to achieve the following flood risk outcomes:*

   i. *no increase in flood levels in a 1% AEP event for existing authorised habitable floors that are already subject to flooding or have a freeboard less than 500mm;*

   ii. *no increase in 1% AEP flood levels for existing authorised community, commercial, industrial and network utility building floors that are already subject to flooding or have a freeboard of less than 300mm;*

   iii. *maximum of 50mm increase in water level in a 1% AEP event outside and adjacent to the designation boundaries between the pre and post Project scenarios;*

   iv. *no new flood prone areas; and*

   v. *No increase of flood hazard for main vehicle access to authorised habitable dwellings existing at time the Outline Plan is submitted. The assessment shall be undertaken for the 1% AEP rainfall event. Where Flood Hazard is:*

      a) *Velocity x depth > = 0.6 or*
      b) *depth > 0.5m, or*
      c) *velocity >2m/s.*

b) *Compliance with this condition shall be demonstrated in the Outline Plan, which shall include flood modelling of the pre-Project and post-Project 1% AEP flood levels (for Maximum Probable Development land use and including climate change).*

c) *Where the above outcomes can be achieved through alternative measures outside of the designation such as flood stop banks, flood walls, raising existing authorised habitable floor level and new overland flow paths or varied through agreement with the relevant landowner, the Outline Plan shall include confirmation that any necessary landowner and statutory approvals have been obtained for that work or alternative outcome.*

Mitigation measures which may be implemented to meet these outcomes include:

- Providing wider bridge spans or additional culvert capacity at existing waterway crossings
- Optimising bridges, culverts, and wetlands to assess cumulative effects of upstream NoRs on downstream NoRs
- Designing bridge and culvert locations / sizes so that the predicted upstream and downstream water level differences between the 1% AEP pre and post development scenarios comply with the NoR flood hazard conditions (the Outcomes)
- Providing overland flow paths to avoid creating new flood prone areas
- Installing drains at the toe of the embankment sloping towards the culverts can also provide additional storage to decrease the velocity and peak flow through the culvert crossings
- Installing drains at the top of cuttings to reduce water entering the cutting and thus need conveying through the cutting. This can also be improved using benches in deep cuttings to further reduce the flow entering the cutting base drain, and

- Providing space for wetlands for treatment and attenuation as needed.

Conclusions

We conclude from our assessment of the potential flooding effects that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

We consider that the proposed flood condition sets appropriate outcomes for managing future flooding effects due to the Project Works and subject to these being designed and implemented, the effects can be minor or less. Flood modelling will be required at the Outline Plan phase to confirm the detailed design will comply with the NoR conditions.

The modelling undertaken to date is for the purposes of assessing potential effects and identifying whether those effects can be mitigated. Further flood modelling will be carried out for the Outline Plan to demonstrate that the detailed design complies with the proposed flood condition. In addition, this does not preclude additional flood requirements, such as may be set out in future Auckland Council, Waka Kotahi and Auckland Transport Codes of Practice being used in the development of the design or assessment of future regional resource consents.

The positive flooding effects are primarily associated with raising existing roads out of the floodplain that are currently predicted to flood in the future 1% AEP events plus treatment of existing roads that are widened. However, raising roads needs to be accompanied by providing sufficient new cross drainage capacity so that upstream flood levels are not increased.

The assessed Post Project flooding hazard can be managed by adjusting the proposed road geometry and changing the culvert and bridge opening areas during detailed design so that the proposed NoR conditions will be met.

The detailed design of stormwater treatment and management and structures in streams will be also subject to regional consenting requirements where further flooding criteria applicable at the time they are processed can be considered.

24/01/2024

1 Introduction

This is a supplementary report to the Assessment of Flooding Effects that was prepared for the Te Tupu Ngātahi Supporting Growth Alliance, North Projects in August 2023. It provides information to support the response to Section 92 request for information from Auckland Council (and Healthy Waters).

There are 13 Notices of Requirement (NoRs) for Auckland Transport (AT) and Waka Kotahi NZ Transport Agency (WK) as the requiring authorities under the Resource Management Act 1991 (RMA). The NoRs are to designate land for future strategic transport corridors and two rapid transit corridor stations to enable the future construction, operation, and maintenance of transport infrastructure in the North area of Auckland.

The North Projects area extends from Albany to Ōrewa through the growth areas of Dairy Flat, Silverdale West, Wainui East, and Redvale.

Refer to the main Assessment of Effects on the Environment (AEE) for a more detailed project description.

During the later outline plan and regional consenting phases, additional detailed modelling and design will be completed to refine the concept NoR designs and achieve the proposed flood hazard condition and treatment / attenuation requirements.

2 Flood hazard condition

To limit the scale of effects on other property, we have identified flood performance outcomes in the proposed flood hazard condition - of which we consider the most important to be the reduction in freeboard to habitable floors that already flood or have limited freeboard. During future detailed design at the Outline Plan stage, both the change in head loss at the boundary (being up to 50mm) and the reduction in freeboard at the habitable floor level will need to be applied to identify which is the more restrictive case.

We have proposed some amendments to the lodged version of the Flood Hazard Condition as explained in the section 92 response and summarised here.

We consider that this condition addresses the key potential effects associated with flooding and means that it will appropriately address potential effects on other property. This condition has been framed so that there is a balance between appropriately managing effects while retaining a small amount of flexibility for the future designers. To retain flexibility outside the specified outcomes in the Flood Hazard condition, the final clause of the Flood Hazard Condition allows the Requiring Authority to negotiate a different outcome at a specific location with the landowner's agreement.

The design and authorisation of the transport corridors/stations is an established process and one that will iterate with increasing understanding of constraints, effects, and design certainty alongside the consenting strategy.

We note that there are requirements for consents under AUP Section E8 (A5 – diversion and discharge from an impervious area of more than 5000m^2 – Restricted Discretionary), E9 (A7, A9 - development of a new high use road greater than 5000m^2 – Controlled, Discretionary), E10 (A3, A4 – development of a new road greater than 50 m^2 in a SMAF 1 or SMAF 2 – Restricted Discretionary/Discretionary) and E36 (A33 – construction of land drainage devices and flood mitigation works in the 1% AEP flood plain- Restricted Discretionary and A37 – new structures in the 1% AEP floodplain – Restricted Discretionary). Although there could be changes to the rules, planning framework and legislation prior to implementation of these projects, we expect that there will be similar requirements in the future.

The future regional resource consent process gives Council another opportunity to review the potential effects in the future. Our view is that consents would currently be required under sections 13, 14 and 15 of the Resource Management Act 1991 (RMA) for structures in streams or stormwater diversion and discharge and flood diversion and the AUP, and that similar requirements are likely with future consenting legislation.

We expect that this future consenting process will consider stormwater diversion and discharges in more detail and will require Waka Kotahi and Auckland Transport to address stormwater management requirements and effects relating to water quantity attenuation, flood mitigation, overland flow, stormwater quality, and retention / detention. Auckland Council will therefore be able to review the proposed works and effects at that stage in greater detail and consider the application of the planning and engineering criteria that apply at that time.

3 Assessment Methodology

3.1 General

The Assessment of Flooding Effects involved the following steps:

- Desktop assessment to identify potential flooding locations using the Auckland Council (AC) Geomaps.
- Flood modelling of the pre – Project (base case) scenario using either existing Auckland Council (AC) models or updating of the models using the latest AC LiDAR, Waka Kotahi, and Auckland Transport asset data – with catchment hydrology set for future imperviousness and AUP land-use.
- Overlaying the pre-Project flood results on GIS with aerial photographs, land use zones, contours, and the proposed work footprint to identify potential effects. The overlays allow us to see where the flooding overtops the existing road alignment, how the flood water interacts with the existing topography (i.e. a change in flood level could be limited in steeper terrain or widespread in extent in a wide flat floodplain) and where the new works could restrict flows where waterways or overland flow paths cross the alignment or occupy space in the floodplain (potential effects associated with the post Project).
- The pre-Project flood model also gave us water levels along the alignment which allowed us to see whether the hydraulic grade is flatter or steeper at the proposed crossing points and therefore whether the upstream and downstream floodplain is wide and flat and likely to be more sensitive to change. Refer Appendix 1 of the lodged (August 2023) Assessment of Flooding Effects for flood levels extracted from the pre-Project model at various points.
- Inspection and review of flood maps at key locations such as proposed bridges, culverts, wetlands, and major earthworks.
- Where we decided there was potential for an effect, we considered whether such an effect could be avoided – primarily this meant that if the conveyance capacity across the corridor could be increased to be equivalent to the pre-Project scenario, the effect could be avoided.
- Where the flood plain was flatter and it was uncertain whether the post Project works could be mitigated, modelling of the post Project concept design terrain was undertaken. This occurred at the Dairy Flat Highway / Bawden Rd intersection (part of NoRs 8 and 12) and Pine Valley Rd upgrade (NoR 7). Both locations were identified to overtop in the pre-Project scenario, and with road widening and raising, upstream flood risk could be increased unless sufficient capacity beneath the new road formation was proposed.

Recently as part of this Supplementary Assessment, further site assessments of floor levels near or within floodplains were compared to the predicted pre-Project water levels for the 1% Annual Exceedance Probability (AEP) 2.1° and 3.8° to assess if the freeboard of 150 or 500mm made a difference to the number of existing floors at risk of flooding. Refer to Appendix 1 of this supplementary report. Colour coded maps were developed for the 1% AEP event, with freeboard for each site assessed. Building footprints were red if the floor is flooded or within 150mm of flooding, yellow if within 150 to 500mm of flooding, and green if > 500m between the site assessed floor level and the predicted floodplain.

3.2 Models used for the assessment of flooding effects.

There are six Auckland Council stormwater catchments (outlined in yellow in the figures below) that impact the North Projects area as shown in Figure 3-1 below.

The stormwater catchments from south to north and NoRs that may impact them are:

- Lucas Creek covering NoR 1 and 4;
- Okura North covering NoR 1, 4, 9 and 13;
- Dairy Flat covering NoR 1, 4, 5, 8, 9, 10, 11, 12 and 13;
- Silverdale South covering NOR 1, 4, 8, 11 and 13;
- Pine Valley covering NoR 1, 3, 4, 7 and 8;
- Orewa River West covering NoR 1, 2, 4, 6 and 10.

For the Silverdale South and Pine Valley catchments a single stormwater pre-Project flood model was developed as both catchments discharge to the same downstream outlet.

Figure 3-**1:** North catchment boundaries taken from AC Geomaps.

3.3 Pre-Project (base case) models

Pre-Project future models (<u>without the terrain for each NoR</u>) were developed based on the AC Rapid Flood Hazard Assessment (RFHA) August 2012 approach for each catchment with common aspects being:

- Future rainfall was based on the historical TP108 1% AEP rainfall in the catchment with climate change of 2.1 and 3.8°applied equally across the catchment. 2.1° of climate change is the current AC Code of Practice (Ver 3 Jan 2021) design standard although 3.8° is what AT and Waka Kotahi require to understand the flood risk of increased climate change.

- The ARC TP108 methodology uses two rainfall loss parameters, the Soil Conservation Service (SCS) Curve Number (CN) and Initial Abstraction (Ia), to describe rainfall losses. Runoff timing, using the parameters lag time or time of concentration, is used to describe the runoff routing process. These parameters provide attenuation and lag of rainfall-runoff within the catchment. ARC TP108 has derived CN and Ia values for use in the Auckland Region. These are tabulated as a function of soil type and land use.
- Ground model terrain: The ground model grid elevation was defined using the AC 2016 LiDAR Digital Elevation Model (DEM) which was assumed to be the same in future, as it is unknown at this stage what the future landform will take. The DEM is based on a 1m grid with elevation values at the centre of each grid.
- Ground roughness: The AUP: OP was used to define the areas of varying Manning's roughness coefficients throughout the model. Mannings's coefficients used were roads and other impervious areas 0.05, existing buildings 1 and other areas 0.1. These values were applied in each catchment to give an average Manning's ground roughness.
- Existing culverts over certain sizes were added to the models as discussed under each model catchment section below.
- Models linked the 1D culverts with the ground model except for Lucas Creek. Bridges were added in some catchments or cut into the terrain as defined by LiDAR also as discussed below.

Note that the only difference between the pre-Project model and the post-Project model is that the post Project model has the terrain modified to include the shape of the proposed physical works. This tests whether the proposed works constrict or release flows across the corridor and exacerbate flooding upstream or downstream. Both models use the same hydrology and catchment development assumptions – namely full development in accordance with the AUP and 1% AEP rainfall including 2.1 degrees of climate change.

Where the post development terrain has been modelled, the effects are the relative change in flood levels. The use of 2.1° or 3.8° climate change hydrology makes little difference to the change in flood levels for wide flood plains.

3.3.1 Lucas Creek

The Lucas Creek model was different to the other models as it was a one-dimensional (1D) model only. The Lucas Creek catchment area is shown in Figure 3-2 below.

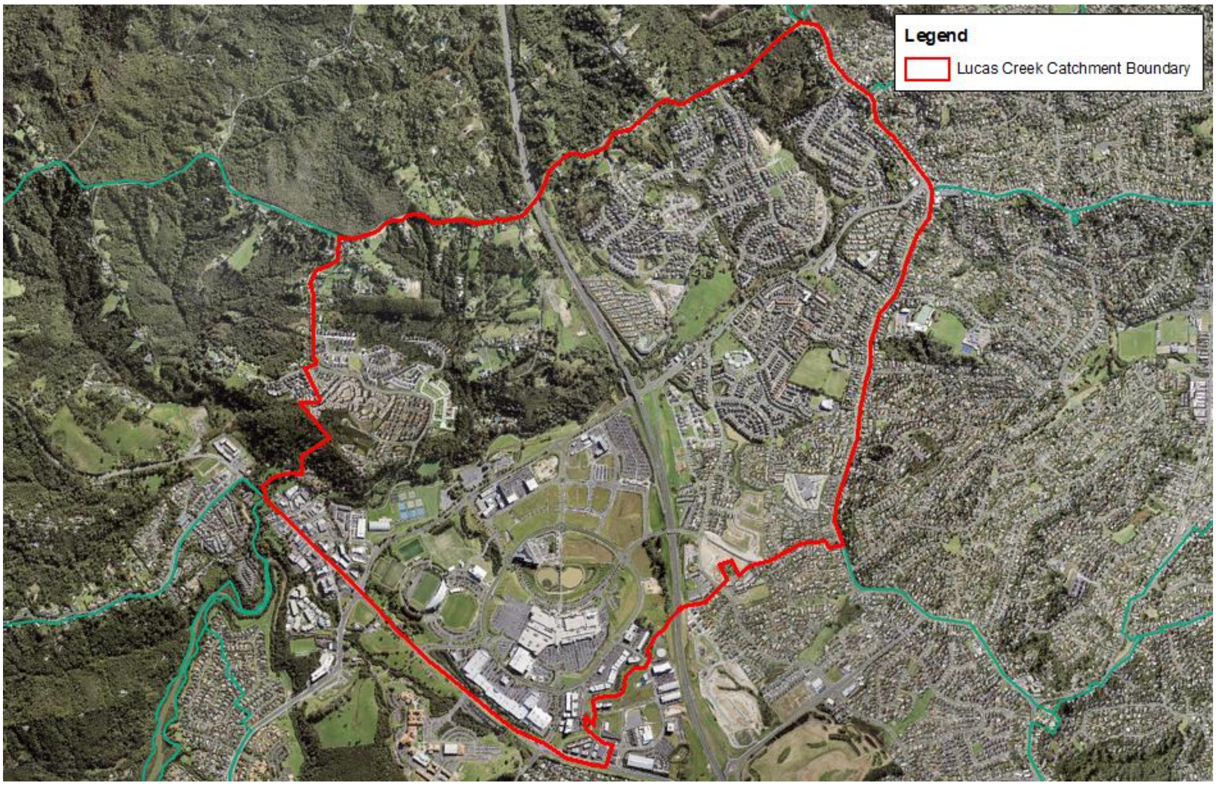


Figure 3-2: Lucas Creek catchment boundary.

Previous model

A 1D hydraulic model was developed for the Lucas Creek catchment for Auckland Council in 2009 by AWT NZ Ltd (AWT). The model was built in MOUSE modelling software based on 1D free surface gradually varied unsteady flow equations. As part of the Northern Corridor Improvements (NCI) project, the AWT model was converted to a 1D DHI MIKE Urban model by Jacobs in 2018 for flood assessment in accordance with Auckland Council's Stormwater Flood Modelling specifications dated December 2012.

Updated model

The 2018 model was used as the basis of the pre-Project (base case) model with the following changes implemented:

- Three additional bridges were included:
  - Fairview Avenue bridge
  - SH1 Lucas Creek off-ramp bridge: NZTA ID- 4101
  - SH1 Lucas Creek on-ramp bridge: NZTA ID- 410
  - The cross-sections under the above bridges were based on surveyed cross-sections. The bridge deck and soffit levels were sourced from the existing NZTA bridge information and the above ground points data at the location of the above bridges.
- Rainfall. For Lucas Creek the existing 1% AEP rainfall depth was taken as 220mm.
- The time of concentration for the catchment was estimated using the empirical lag equation given in ARC TP108, derived from a regression analysis of data from the Auckland Region. A minimum time of concentration of 0.17 hours (10 minutes) was used, as per TP108 guidelines. A majority of the Lucas Creek sub-catchments are small in area. Therefore, the minimum lag time of 0.17 hours has been used.

- A channelisation factor of 0.6 was applied to piped systems and 0.8 to other areas.
- Assuming Class C soil for Lucas Creek catchment, CN values of 98 and 74 have been applied to all impervious areas and pervious areas (representing lawns in good condition), respectively.
- The Maximum Probable Development (MPD) percentage area of each sub-catchment within the Lucas Creek catchment has been estimated based on the most recent publication of the Auckland Unitary Plan Zones as of 23rd June 2020 along with the Healthy Waters memorandum of 4 Sept 2019 indicating the impervious coverage to utilise for each future zone.

3.3.2 Okura North

Previous model

The Okura North RFHA catchment model was developed for Auckland Council in 2009 by DHI using Mike21 with large grid size (10 x 10m) and no climate change allowance.

Updated SGA model

Given the age of the model, grid size and lack of climate change, a new RFHA model was built using TUFLOW (version 2020-01- AB) using the rain-on-grid approach.

Ground model

The existing grid elevation was defined using the AC 2016 LiDAR Digital Elevation Model (DEM). The model consists of a 4m grid using a sub grid sampling (SGS) of 1m. Utilising SGS allows the model to make better use of the 1m DEM at a sub-cell level to provide better representation of the LiDAR ground model. The 4m grid consisted of 1,135,790 cells.

2D ground roughness

Roads were included within the 2D model as defined in the AUP. Building footprints are not defined within the AUP, as such, areas not defined as roads are defined as other areas. Roads and other impervious areas utilised a roughness of 0.05, existing buildings 1 and other areas 0.1.

Design rainfall

The Okura North catchment and TP108 rainfall contours are shown in Figure 3-3 below.

Design rainfall depth was applied across the catchment based on the RFHA formula. Existing rainfall depth = ($Rain_{min}$ + ($Rain_{max}$ – $Rain_{min}$)*0.8) giving a daily rainfall value of 224mm for the historical 1% AEP event. This equates to 261.6mm for the 1% AEP with 2.1° of climate change (16.8% increase over historical rainfall) and 297.2mm for the 3.8°of climate change (32.7% increase).

The TP108 24hr rainfall hyetograph shape was utilised.

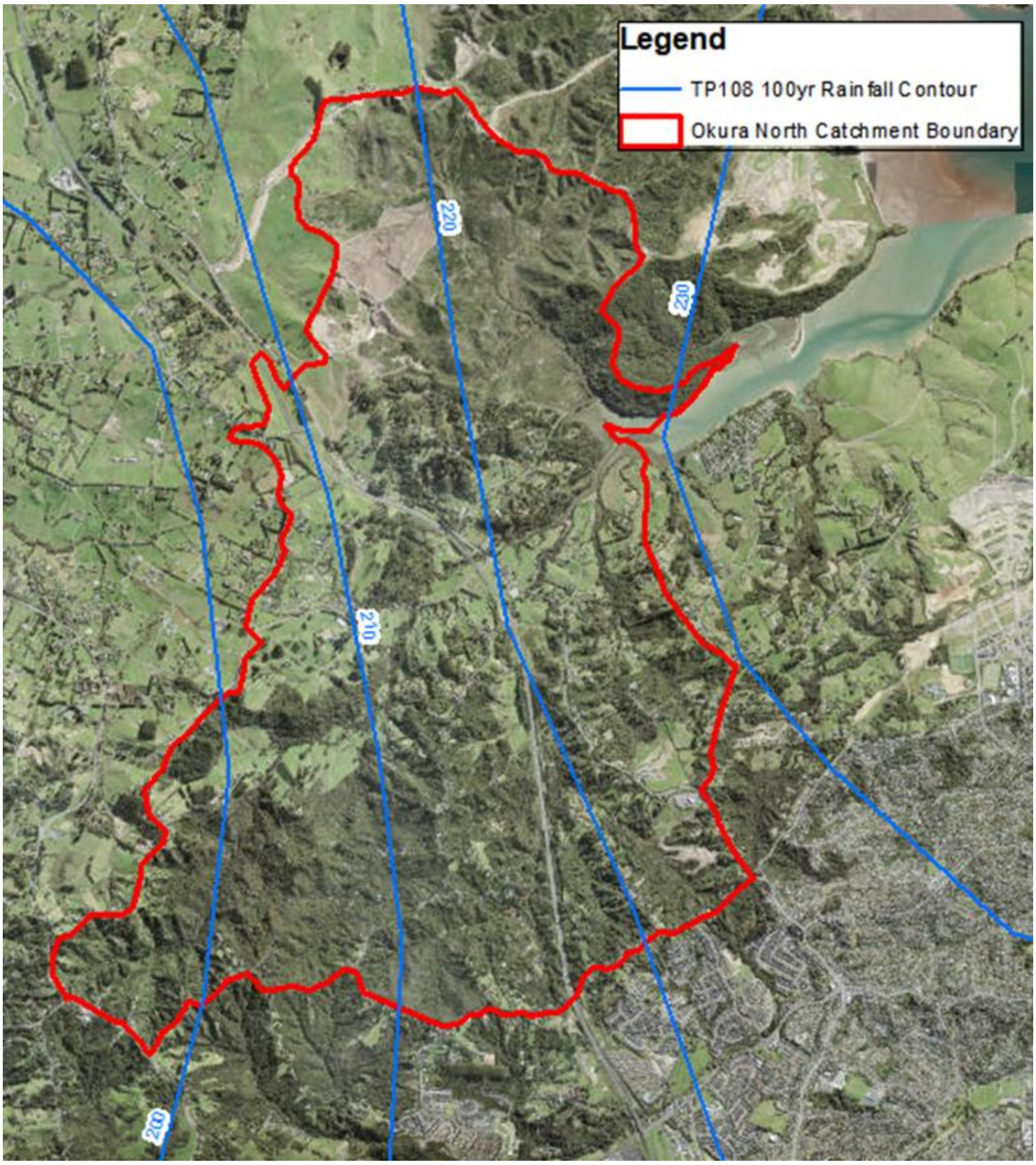


Figure 3-3: Lucas Creek catchment boundary.

<u>Existing structures</u>

The previous modelling did not include any culverts or bridges, just the terrain.

Larger existing culverts (greater than 675 mm) have been added into the model as 1D structures. A total of 12 culverts greater than 675mm were identified within the Okura North catchment. The culverts were identified from the Road Assessment and Maintenance Management (RAMM) database and Auckland City Council (ACC) database. The culverts were modelled in 1D. The size and material of the culverts were sourced from the RAMM and ACC databases. The upstream and downstream inverts were interpolated from LiDAR ground levels where not available.

The AC 2016 LiDAR DEM does not include the above ground points (linear features) at the locations of large bridge structures. Therefore, no modifications to the 2D bathymetry were undertaken at the bridge structures rather the opening in the terrain were maintained to replicate the bridge without the bridge soffit.

Surface depressions within the 2D bathymetry were filled using an initial water level created from a hot start run of the model which is conservative.

Downstream boundary

Downstream future tidal boundary condition of 2.49m was applied at the outlet of the Okura North catchment which included 1m of sea level rise.

Impervious coverage

Significant Ecological Areas (SEAs) are present within the Okura North catchment. SEAs within the Countryside Living (CLZ) zones suggests that there may be little opportunity for these areas to be developed in future. As such, these areas of CLZ are unlikely to reach an imperviousness percent of 25% as suggested by Auckland Council.

An assessment of the current imperviousness of the SEA areas shows that the areas have an imperviousness of 5.5% and 8.8% using Auckland Council data and Land Information New Zealand (LINZ) respectively. The imperviousness of the CLZ areas where SEAs are present between Wright Road and SH1 was reduced to 10% to provide a better representation of likely MPD imperviousness in the area. By reducing the imperviousness in the area, excess rainfall flowing towards SH1 is reduced.

TP108 checks

The TP108 graphical method was used to estimate the MPD 1% AEP with 2.1° of climate change peak flow and total runoff volume for comparison with that calculated from the Okura North RFHA model at the main catchment outlet by East Coast Road. The RFHA model overpredicted the peak flow by 12% and underpredicted the volume by 5% both of which are acceptable for this type of model.

3.3.3 Dairy Flat catchment

Previous model

A 1D/2D coupled MIKEFLOOD model was developed for the Dairy Flat and Rangitopuni Catchments in 2009 for Auckland Council (AC) by DHI. As part of the Dairy Flat / Silverdale structure plan process, the model was updated in 2019 to assess the impact of the proposed land use changes. The model bathymetry was based on 10mx10m grids derived from the 2006 LiDAR survey data. There are significant uncertainties associated with the model results due to potential terrain errors. Given the age, large grid size and uncertainty of the model, a new RFHA model was built as discussed below.

Updated model

TUFLOW hydraulic modelling software (HPC version 2020-01-AB-iSP-w64) was used to undertake the Dairy Flat Catchment RFHA modelling. A two-dimensional (2D) effective (after loss) rain-on-grid modelling approach was used to identify the extent of overland flow paths including flow depth and velocities within the Dairy Flat Catchment.

The TUFLOW sub-grid sampling (SGS) feature was used in the Dairy Flat RFHA model. SGS utilised the finer details of the underlying DEMs / TINs based on detailed survey in the hydraulic calculations. SGS has excellent cell size convergence and has ability to rotate a regular grid in any direction.

Ground model

The ground model consists of the 2D ground surface Digital Elevation Model (DEM) created from the 2016 Light Detection and Ranging (LiDAR) Digital Terrain Model (DTM). The 2D model grid used for the Dairy Flat Catchment is 3,084,821 cells with a grid cell size of 4m. The dimension of the 2D ground surface (the grid size) is an important parameter as it sets the spatial resolution of the resultant floodplain. A Sub-Grid-Sampling (SGS) grid sample distance of 1m was used to utilise the 1m grid 2016 LiDAR survey data in the RFHA model hydraulic calculations.

A "hot start simulation" was carried out by running an initial 300mm rainfall profile, over a 24hour period to flood the surface depressions within the 2D terrain zone. The end state of the hot start simulation was used as initial water level conditions in the RFHA model.

<u>2D model roughness</u>

The current AC impervious surface and building footprints layer do not contain any data within the Dairy Flat Catchment. Roads with a constant Manning's roughness coefficient value of 0.05 were included within the 2D model as defined in the AUP. A constant Manning's roughness coefficient value of 0.10 was used for the remaining areas of the RFHA 2D domain.

<u>Existing structures</u>

A total of 35 culverts with sizes 900mm or greater were modelled within the Dairy Flat Catchment.

A total of 7 culverts including sizes and invert levels based on the previous MIKE11 model was included in the SGA RFHA model. The remaining 28 culverts were identified from the AT and NZTA Road Assessment and Maintenance Management (RAMM) databases. The size and material of the culverts were sourced from the RAMM databases. The upstream and downstream inverts were estimated from 2016 LiDAR ground levels. The length of the culverts was measured in Geographic Information System (GIS).

A total of three bridges were modelled based on the previous MIKE11 model. The 2016 LiDAR DEM does not include the above ground points (linear features) at the locations of large bridge structures within the Dairy Flat Catchment. Therefore, modifications of the 2D bathymetry were undertaken at these three bridge structures to include bridge deck overtopping in 2D model. The remaining bridges within the Dairy Flat Catchment were not modelled explicitly as 1D network structures as no bridge data was available.

<u>Design rainfall</u>

There is spatial variation in the rainfall depths across the Dairy Flat catchment, representative of the ARC TP108 1% AEP rainfall contour depths. Following the AC Stormwater Rapid Flood Hazard Assessment Modelling Specification, the minimum daily rainfall was 190mm and the maximum daily rainfall 210mm which gave an average catchment total rainfall depth of 206mm.

The entire Dairy Flat catchment was modelled using two rainfalls as shown in Figure 3-4 below.

The Dairy Flat Catchment comprises mainly a Group C hydrological soil group that relates to the Waitemata Residual soil type having low infiltration losses. A SCS CN of 74 was used for pervious areas. The impervious areas were assigned with a SCS CN of 98 and an initial abstraction loss of 0.0mm. The pervious areas were assigned with an initial abstraction loss of 5.0mm.

The entire Dairy Flat Catchment was modelled with two rainfall zones with their weighted curve number (CN) estimated based on the soil and AUP land use zones (see figure 3-4). The rainfall Zone 1 covers mostly future urban land use and the rainfall Zone 2 covers mostly rural land use areas.

The 1% AEP effective rainfall hyetograph (i.e. after losses) was calculated using the HEC-HMS hydrological modelling software according to the ARC TP108 rainfall-runoff methodology based on the weighted SCS CN, weighted initial abstraction, the AUP maximum allowable imperviousness for various land use zones and the 1% AEP climate change design rainfall temporal profile.

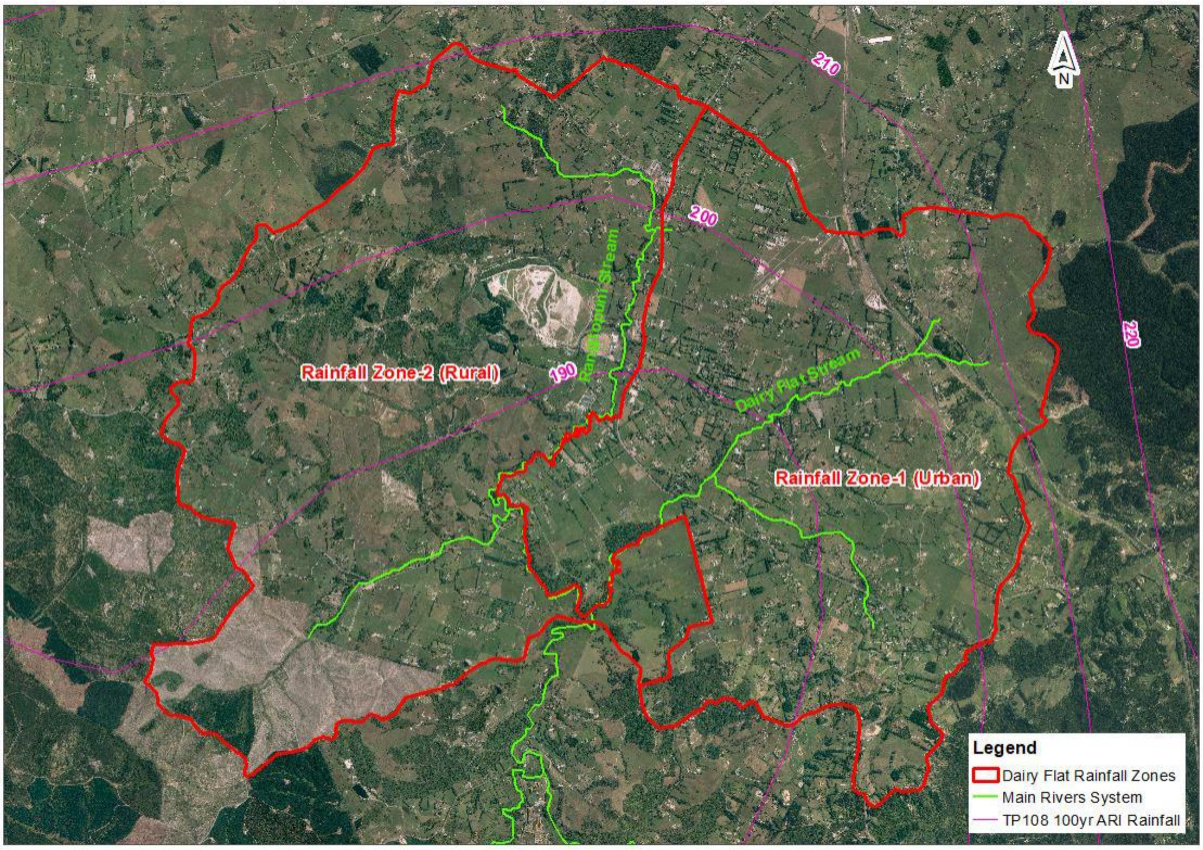


Figure 3-4: Dairy Flat rainfall zones

Downstream boundary

The Rangitopuni Stream crosses the Diary Flat Catchment southern boundary after joining the Dairy Stream. A normal depth with a water surface slope of 0.003 was assigned as a downstream water level boundary condition at the Dairy Flat Catchment southern boundary based on the previous MIKEFLOOD model results.

Impervious coverage

The MPD percentage area of each rainfall zone in the Dairy Flat catchment was estimated based on the most recent publication of the AUP Zones (23rd June 2020). AUP land use zones with maximum allowable imperviousness for the MPD scenario within the Dairy Flat catchment were calculated as 68.3% for Zone 1 and 15.3% for Zone 2.

TP108 checks

It shows small differences between the TP108 graphical method and RFHA modelled total runoff volume (1%). The difference in peak flows (25.6%) is likely due to smaller lag time of the TUFLOW RFHA model compared to the lag time calculated by ARC TP108 empirical lag equation method. The faster runoff in the TUFLOW RFHA model results in a higher peak flow.

3.3.4 Silverdale South – Pine Valley Catchment

Previous model

A rapid flood hazard model was developed for the Silverdale South catchment for Auckland Council in 2017 by AECOM. The model was built in MIKE FLOOD 2014 with a classic grid created for the entire catchment using 2013 LiDAR. Model development details are provided in the AECOM RFHA report (2017).

Due to the age of the model, long run times, older LiDAR the model was updated and combined with the Pine Valley model to develop a complete model discharging downstream of SGA NoR 4.

Updated model

A new RFHA model has been built for the Silverdale South- Pine Valley catchment using TUFLOW (version 2020-01-AB). A two-dimensional (2D) effective (after loss) rainfall-on-grid modelling approach was used to identify the extent of overland flow paths, including flow depth, flow rate and velocities, in the catchment.

Ground model

The ground model consists of the 2D ground surface Digital Elevation Model (DEM) created from the 2016 Light Detection and Ranging (LiDAR) Digital Terrain Model (DTM). The 2D model grid used for the Silverdale South catchment consists of 1,406,153 4m by 4m cells. The dimension of the 2D ground surface (the grid size) is an important parameter as it sets the spatial resolution of the resultant floodplain. A Sub-Grid-Sampling (SGS) grid sample distance of 1m was used to utilise the 1m grid 2016 LiDAR survey data in the RFHA model hydraulic calculations. All surface depressions within the 2D zone were filled using a hot start simulation by using a 300 mm rainfall profile, over a 24-hour period to flood the depressions. The end state of the hot start simulation was used as initial water level conditions in the RFHA model – this is a conservative approach as there is more runoff.

2D model roughness

Roads were included within the 2D model as defined in the AUP. Building footprints are not defined within the AUP, as such, areas not defined as roads are defined as other areas. Roads and other impervious areas utilised a roughness of 0.05, existing buildings 1 and other areas 0.1.

Design rainfall

There is spatial variation in the rainfall depths across the Silverdale South catchment, representative of the TP108 rainfall 1% AEP contour depths.

Following the AC Stormwater RFHA Specification, a design rainfall depth of 218 mm was estimated as the 1% AEP 24hour current design rainfall depth for the catchment.

The 1% AEP design rainfall with 2.1° of climate change depth was estimated to be 254.6 mm.

This catchment comprised of mainly the Group C hydrological soil group. A SCS CN of 74 and an initial abstraction loss of 5.0 mm was used for pervious areas. This is considered a conservative approach. The impervious areas were assigned an SCS CN of 98 and an initial abstraction loss of 0.0 mm.

The TP108 24hr rainfall hydrograph shape was utilised.

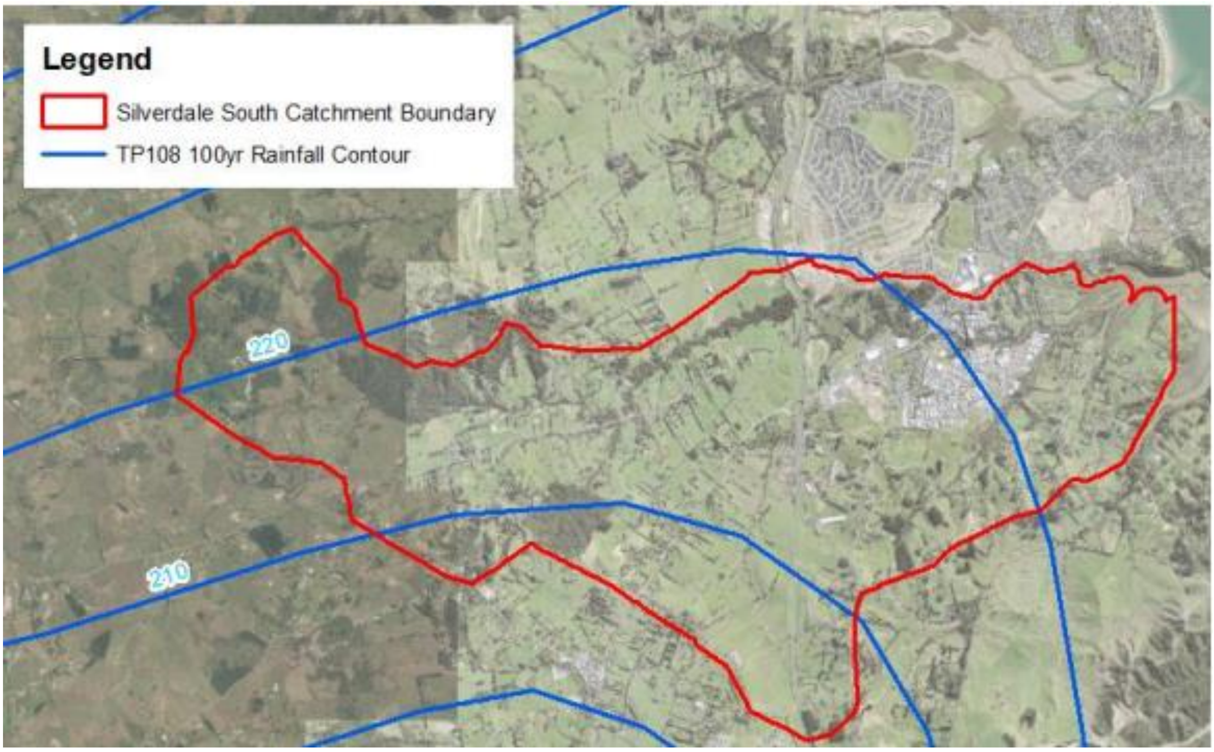


Figure 3-5: Silverdale South – Pine Vally catchment area and TP108 rainfall contours

Excess rainfall for the catchment was generated following HEC-HMS rainfall run-off parameters. The Silverdale South Catchment was modelled with two rainfall zones (see Figure 3-6) with their area-weighted curve number (CN) estimated based on the soil and AUP land use zones. The division of these two zones was based on the Dairy Flat and Silverdale West Structure Plan. Zone 1 covers mostly rural land use areas and falls outside of the Structure Plan zone. Zone 2 covers mostly future urban zones and falls within the Structure Plan zone.

The 24hour 1% AEP effective rainfall depth was calculated as 214.5 mm for rainfall Zone 1 and 241.9 mm for rainfall Zone 2 using the 24hour 1% AEP future design rainfall depth of 254.6 mm for 2.1°of climate change. For 3.8°of climate change the rainfall becomes 243.7mm for zone 1 and 289.3mm for zone 2.

<u>Existing structures</u>

Large existing culverts (greater than 675 mm) have been included in the model as 1D structures. A total of 27 culverts with a diameter were identified in the Silverdale South catchment. Of the 27 culverts, 15 culverts, including sizes and invert levels, were based on the previous RFHA 2017 model. Some minor modifications to the model set up of the existing culverts was undertaken, where appropriate, to rectify instabilities and convergence issues within the existing culverts. The remaining 12 culverts were identified and added from the Auckland Transport (AT) and New Zealand Transport Agency (NZTA) Road Assessment and Maintenance Management (RAMM) databases. The size and material of the culverts were sourced from the RAMM databases. Where invert levels were not available in RAMM the inverts were estimated from the 2016 LiDAR ground levels. The length of the culverts was measured in GIS based on aerial photos (inlets and outlets) and compared to the RAMM data.

The AC 2016 LiDAR DEM does not include the above ground points (linear features) at the locations of large bridge structures. Therefore, no modifications to the 2D bathymetry were undertaken at the bridge structures rather the opening in the terrain were maintained to replicate the bridge without the bridge soffit.

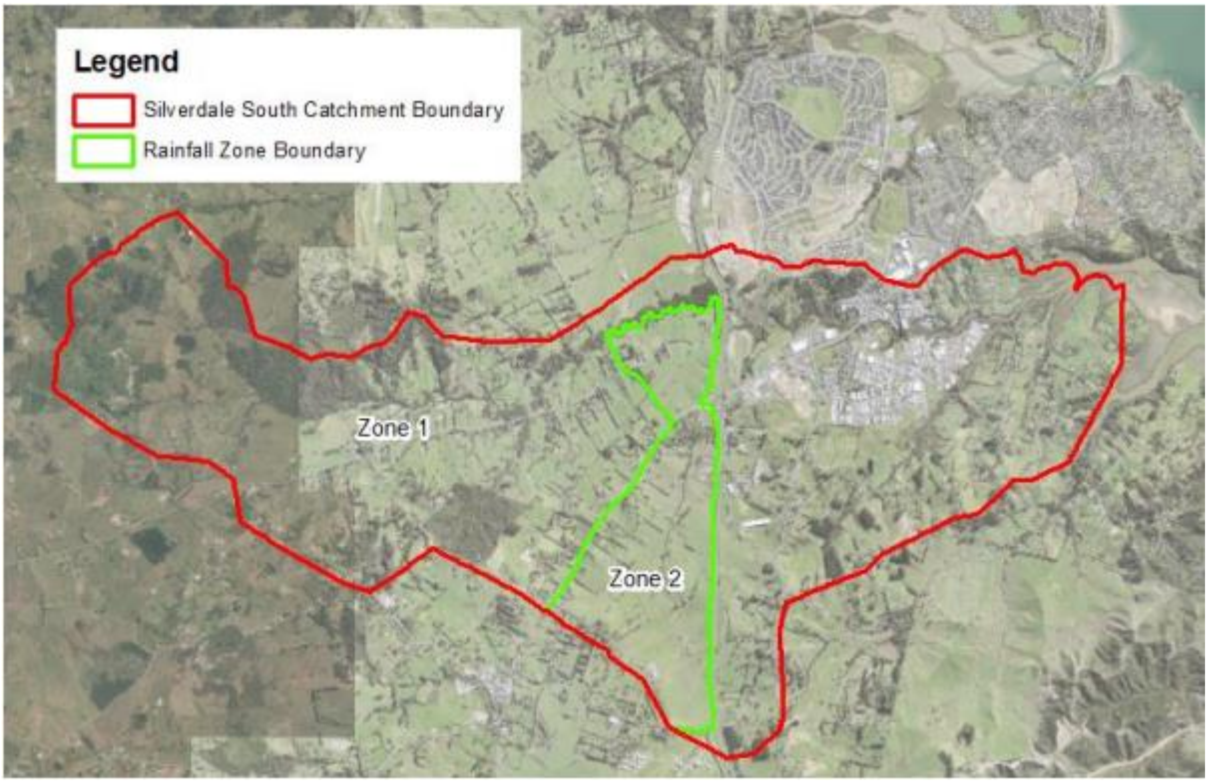


Figure 3-6: Silverdale South – Pine Vally rainfall zones

Boundary conditions

The boundary condition used for the MPD scenario was based on the existing Mean High-Water Spring (MHWS) level included in the AC Coastal Marine Area Boundary for the Auckland Region plus 1m for climate change effects. This equated to a downstream boundary condition of 2.60 m reduced level (RL) for the Silverdale South catchment.

Impervious coverage

The MPD percentage area of each rainfall zones in the Silverdale South – Pine Valley catchment was estimated based on the most recent publication of the AUP Zones (23rd June 2020). AUP land use zones with maximum allowable imperviousness for the MPD scenario within the catchment were calculated as 44.9% for Zone 1 and 88.1% for Zone 2.

TP108 checks

The TUFLOW RFHA model demonstrates a peak flow 14.56% larger than calculated through TP108. This is likely due to smaller peak time of the TUFLOW RFHA model compared to the peak time calculated through ARC TP108. The faster runoff in the TUFLOW RFHA model results in a larger peak flow.

The volume check showed Tuflow was 8.8% lower which is acceptable for this type of model.

3.3.5 Orewa River West Catchment

Previous model

A rapid flood hazard model was developed for the Orewa River West catchment for Auckland Council in 2016 by Opus. The model was built in Infoworks ICM v 5.5.1.1 with a flexible mesh created for the entire catchment using 2010 LiDAR. Model development details are provided in the Opus Orewa West Catchment RFHA report (2016).

Updated model

The following model updates have been carried out on the existing model provided by Auckland Council. Where updates below have not been described the Orewa West RFHA 2016 modelling elements and assumptions have been applied. The RFHA model has been updated and simulated in Infoworks ICM v 9.5.3.

Ground model

The ground model consists of the 2D triangular mesh (Digital Elevation Model), assigning an elevation to each vertex. The ground model included in the Orewa West RFHA 2016 modelling was the 2010 LiDAR digital terrain model (DTM).

The ground model was updated as part of this assessment using the 2016 LiDAR DTM to create the 2D triangular mesh.

Surface depressions within the 2D bathymetry were filled using an initial water level created from a hot start run of the model which is conservative.

2D model roughness

Buildings were previously included in the Orewa West 2016 RFHA modelling as roughness zones with a Manning’s roughness of 0.4. The manning’s roughness value of these buildings was updated to 1.0 in line with AC Stormwater RFHA Modelling Specification.

The existing building roughness zones were also reviewed in line the roads roughness zones, as some of the buildings included in the previous Orewa West RFHA 2016 model have been demolished.

Areas where building roughness zones were removed during these model updates were located around the developing Orewa urban area.

Roads were not previously included in the 2D mesh as roughness zones in the Orewa West 2016 RFHA model. Roads have therefore been included as part of the model updates, as defined in the Unitary Plan mapping which reflects the existing and more recently developed road network, along with the impervious surfaces layer (dating back to 2011) which also includes a number of local residential roads.

A visual check was carried out against the most recently available aerial imagery to amend any roughness zones where roads have been removed, realigned or not yet built as per the Unitary Plan or within the Impervious Surface dataset.

Design rainfall

There is spatial variation in the rainfall depths across the Silverdale South catchment, representative of the TP108 rainfall 1% AEP contour depths.

Following the AC Stormwater RFHA Specification, a design rainfall depth of 218 mm was estimated as the 1% AEP 24hour current design rainfall depth for the catchment.

The 1% AEP design rainfall with 2.1° of climate change depth was estimated to be 254.6 mm.

This catchment comprised of mainly the Group C hydrological soil group. A SCS CN of 74 and an initial abstraction loss of 5.0 mm was used for pervious areas. This is considered a conservative approach. The impervious areas were assigned an SCS CN of 98 and an initial abstraction loss of 0.0 mm.

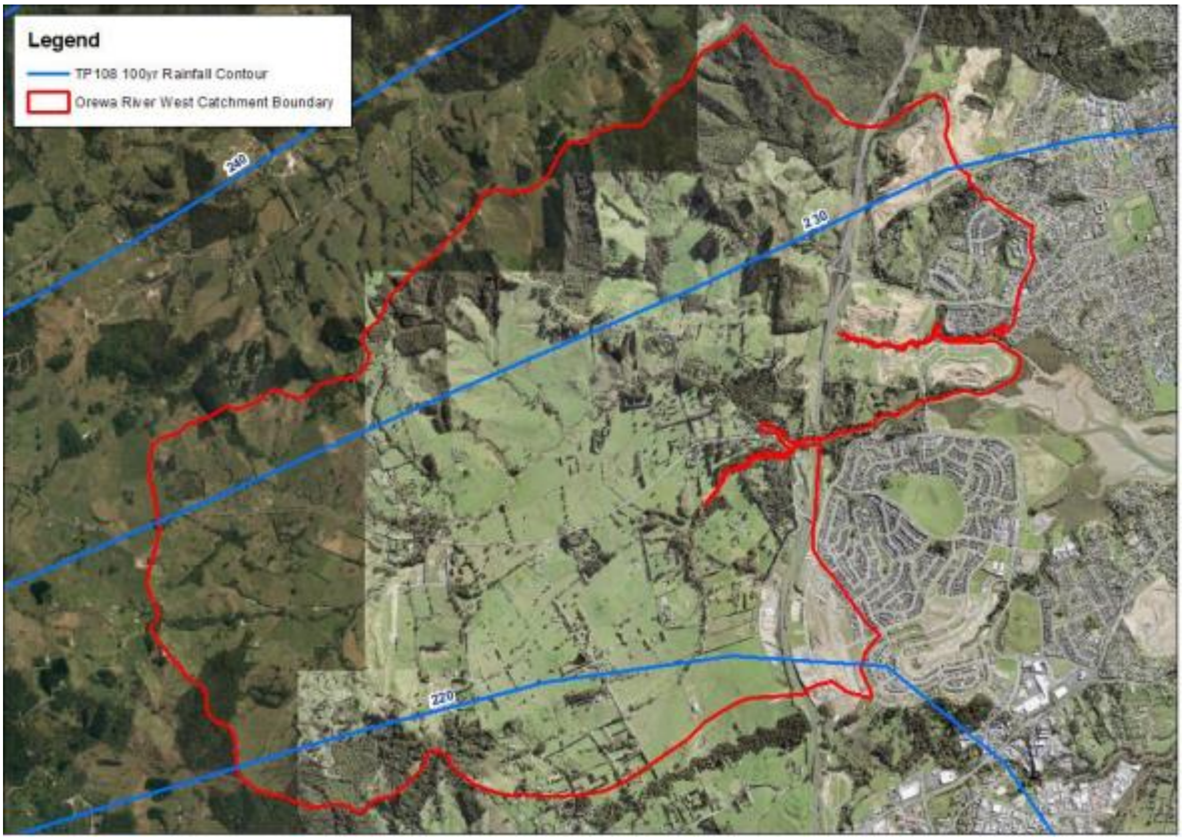


Figure 3-7: Orewa River West catchment area and TP108 rainfall contours

Excess rainfall for the catchment was generated following HEC-HMS rainfall run-off parameters.

The existing 24hour 1% AEP effective rainfall depth was calculated as 228mm for rainfall and 266.3mm for 2.1°of climate change. For 3.8°of climate change the rainfall becomes 302.6mm.

The TP108 24hr rainfall hydrograph shape was utilised.

<u>Existing structures</u>

A total of seven existing culverts were included in the previous RFHA 2016 model, located under SH1, Wainui Road and Grand Drive. Some minor modifications to the model set up of the existing culverts was undertaken, where appropriate, to rectify instabilities and convergence issues within the existing culverts.

Culverts 675 mm and greater were added to the model. Therefore, the model needed to be re-meshed and this was done on the same basis as the previous 2016 modelling. The AC 2016 LiDAR

DEM does not include the above ground points (linear features) at the locations of large bridge structures.

An additional 15 culverts have been included as part of these RFHA model updates, based on a review of available information from the NZTA and AT Road Assessment and Maintenance Management (RAMM) databases where culverts are 675 mm or greater in diameter.

The size and material of the culverts were sourced from the RAMM databases. Where invert levels were not available in RAMM the inverts were estimated from the 2016 LiDAR ground levels. The length of the culverts was measured in GIS based on aerial photos (inlets and outlets) and compared to the RAMM data.

Boundary conditions

The future MHWS is calculated from the existing MHWS plus 1 m, equating to a downstream boundary condition of 2.44 m RL in the Orewa River West catchment.

Impervious coverage

The MPD percentage area of each rainfall zones in the Silverdale South – Pine Valley catchment was estimated based on the most recent publication of the AUP Zones (23rd June 2020). AUP land use zones with maximum allowable imperviousness for the MPD scenario within the catchment were calculated as 44.9% for Zone 1 and 88.1% for Zone 2.

TP108 checks

The RFHA model demonstrates a peak flow 34% larger than calculated through TP108. The differences in peak flows are due to the differences in lag time between the RFHA model and TP108 estimates using an empirical lag equation.

The volume check showed 8% lower which is acceptable for this type of model.

3.3.6 Post Project models

Two post project models were developed to understand what options could be refined to achieve the proposed flood conditions.

The two locations were Dairy Flat Highway / Bawden Road (part of NoRs 8 and 12) and Pine Valley Rd (NoR 7). These are discussed further in Appendices A and B of the August 2023 Flood Effects AEE**.** Results for a further run of the Pine Valley Road model was undertaken recently with results included in Appendix 2 of this supplementary report.

The Dairy Flat Highway model showed that the flood conditions required by the proposed flood hazard condition were very close to being achieved and this could be improved by recontouring the land downstream of Dairy Flat Highway (DFH) and the old and proposed Bawden Roads to provide flow conveyance equivalent to the flow over topping DFH and flowing through the existing bridge.

The recent run of the Pine Valley model showed that with upgraded culverts across the route, effects were limited to within 10mm of the Pre-Project works a short distance from the route.

3.3.7 Model Limitations

- The effective rainfall estimation is limited by the ARC TP108 rainfall-runoff model which is expected to be within ± 25% at a confidence level of 90% for the 1% AEP storm event (ARC, 1999).
- The extents of flooding and ponding areas were mapped based on 2016 LiDAR data. No specific survey was conducted for flood extent mapping. Therefore, the accuracy of the flood extent maps depends on the compound effects of uncertainties in the TP108 rainfall-runoff model, uncertainties in the hydraulic model parameters, and the accuracy of the LiDAR ground model.
- Hydrological processes are represented in a uniform way without accounting for spatial distribution within the catchment and with losses pre-applied to the rainfall time-series.
- Watercourses are not accurately resolved in the rapid flood hazard assessment model as capacity may be understated due to LiDAR issues.
- Culvert inlet and outlet invert levels have been interpolated from LiDAR where not available.
- The model has not been calibrated to recorded events. TP108 rainfall runoff sense checks have been done.

3.3.8 Model Assumptions

- It is assumed the culverts and bridges included in the 1D model are fully operating with no blockages restricting flows.
- Apart from the culverts included in the 1D models as explained in sections 3.3.1 to 3.3.5 above, all other culverts in the catchment are assumed blocked in the 1% AEP rainfall with climate change scenario.
- Some smaller bridges have not been modelled which will create artificial ponding areas upstream of the bridge site. The assumption is that there is a higher risk of the bridge being blocked with debris.

4 Site assessment of floor levels

Habitable floors within or near the predicted pre-Project 1% AEP with 2.1° of climate change flood extent were visited in July and December 2023 to assess the relative distance between the existing ground level and the authorised habitable floor level (site assessed freeboard). Authorised habitable floors were assumed to be the floor level at the front entrance doorway.

It should be noted that in some cases the flood extent is greater than the floodplain as the flood extent has not been trimmed according to the AC floodplain criteria. Some of the properties identified as being at risk of flooding may be due to smaller overland flows (< $2m^3/s$) and not flooding, thus freeboard requirements differ.

The site assessed floor level was completed from public land (roadways or reserves) and no entry to private property occurred. The location of the site-assessed ground to floor level distance was noted on a plan so that the ground level could be established later from 2016 LiDAR. This LiDAR ground level then provides an estimate of the habitable floor level by adding the LiDAR ground level and the site assessed freeboard. It is accepted this method is not as accurate as topographical survey, but it still provides a good estimate, which is considered appropriate for the purpose of this assessment.

In future, existing buildings within future development areas may well be demolished or moved; therefore, this site floor level assessment may only be useful to understand which floors may be at risk of flooding or within freeboard conditions now.

Future habitable floors will be built to the appropriate code of practice and standards at that time and at the Outline Plan stage all authorised habitable floors and other approved floors (community, commercial etc) that may be at risk of flooding will require topographical floor level and ground survey to establish the exact floor level and actual freeboard.

The mapping of assessed floor levels compared to floor levels (refer Appendix 1 of this supplementary report) showed that there were existing habitable floors near the proposed designation that were predicted to flood or be within 150mm of the 1% AEP with 2.1°of climate change. These floors would then control the flood condition needed to be achieved for the future Outline Plan flood conditions; and whether 150 or 500mm was utilised as a freeboard makes no difference to the flood condition control requirements.

5 North NoRs – summary information on operational effects

Overall

5.1.1 Positive flooding and stormwater effects

The main positive effects of the North NoRs relating to flooding are:

- The widened and improved transport corridors are typically proposed to be above the predicted future flood levels, particularly where existing roads are overtopped
- The corridors cand convey cross flows without worsening flooding impacts upstream or downstream of the works to achieve the proposed flood conditions, by appropriately sizing of culverts and bridges
- There is an opportunity to add water quality treatment and attenuation of the total transport corridor impervious area as opposed to just the additional area for existing upgraded roads.

We note that there are opportunities to work with AC in its catchment management role and achieve better catchment outcomes by removing flow constrictions at waterway crossings / reducing upstream flood levels. These include: reducing flood flows into the area west of SH1 and south of the Silverdale Interchange, upgrading the culvert on the southern branch of the Okura stream under East Coast Road , upgrading the bridges on Dairy Flat Highway near Bawden Road and upgrading cross conveyance on Pine Valley Road and Argent Lane – all of which could reduce effects on upstream developable land and improve development potential.

5.1.2 Assessment of potential operational effects

There are a range of operational effects that are common to all NoRs, particularly from the formation of proposed road crossings (embankments, cuttings, bridges, and culverts).

The physical works that could cause flooding effects during the operational phase are:

- Changing bridge or culvert crossing capacity can increase or decrease upstream and downstream flow rates and therefore potentially impact flood levels.
- Widening embankments will increase the length of existing culverts which can increase upstream water levels due to inlet inverts being higher if widened on the inlet side and the culvert extended on the existing grade. If formation widening occurs on the downstream side the upstream water level will also increase due to greater culvert friction losses due to the increased culvert length.
- Widening the carriageway width will increase the channel length under existing bridges and if the waterway area is maintained it will increase upstream water levels due to greater bridge waterway friction losses.
- Embankments built within floodplains can reduce flood storage and increase water levels.
- Altering or obstructing existing overland flow paths can lengthen flow paths or create flood prone areas.
- Increased impervious area within the NoR corridor may require attenuation to avoid increasing peak flows from the road corridor (dependent on the location of the discharge point in the catchment relative to the overall catchment peak flow).

- Where an existing road overtops, improving the capacity for flows under the road can reduce upstream flood levels but possibly increase flood levels at properties further downstream. The predicted flooding impacts should however revert to the predicted pre-Project flood levels within a short distance of the NoR as the peak flows will not change and the downstream terrain will be the same.

The development of the concept design considered:

- Where new culverts and bridges would be required to maintain flow patterns. Note these were generally not sized.
- Minimising areas where new road embankments would encroach on to floodplains or flood prone land and take up flood storage, thereby potentially changing routing relationships and changing discharge rates. Note this was assessed qualitatively and used as an input to when modelling of the post Project terrain would be carried out.
- The length of potential bridge spans – which were set qualitatively based on a proportion of floodplain width.
- The extent of land required for stormwater wetlands based on preliminary stormwater management device sizing (including considering the need for retention/treatment and the need for flow attenuation) and then 3d modelling to work out the earthworks geometry of the device within the terrain.
- Whether there was potential for off-site overland flows to enter the corridor and the need for them to be diverted around the Project works.
- The location and level of properties and buildings adjacent to the Project works relative to the terrain and existing flood levels – and therefore whether the Project works were likely to exacerbate or cause flooding.

5.1.3 Recommended measures to avoid, remedy or mitigate operational effects.

In addition to stormwater and flooding design, the future design process will require multiple engineering specialties (such as geotechnical, transport geometry, transportation planning, structural elements, environmental management, construction methodology and cost optimisation). This will be an interactive, iterative process that will consider multiple constraints and likely take significant time. The design will refine the design of formations, culverts, and bridge crossings.

The flood modelling undertaken to date is for the purposes of assessing potential effects and identifying whether those effects can likely be mitigated. Further flood modelling will be carried out and will refine/change the design for the Outline Plan to demonstrate that the detailed design complies with the proposed flood hazard conditions. In addition, this does not preclude additional flood requirements, such as may be set out in future Auckland Council, Waka Kotahi and AT Codes of Practice being used in the development of the design or assessment of future regional resource consents.

Mitigation measures which may be implemented to achieve the flood hazard outcomes set out in the proposed flood hazard conditions (detailed in section 2) include:

- Upgrading existing culverts or duplicating culverts to manage upstream water level changes.
- Increasing bridge spans to reduce upstream water level changes.
- Creating new overland flow path diversions to discharge to nearby overland flow paths or streams to mitigate ponding and decrease flood levels at affected properties.

- Using bridges or retaining walls to reduce earthworks volumes that displace water within the existing floodplain.
- Culvert sizing to have freeboard of 0.5m at the upstream inlet and setting bridge levels to have 0.6m or 1.2m freeboard (dependent on risk of debris).
- Upgrading culverts by adding additional culverts to create a balance between the flood level differences upstream and downstream, particularly for existing road sites that overtop and are to be raised and existing culverts that are lengthened.
- Reducing cutting conveyance requirements at the toe of the cutting by using benches and cut off drains to convey flows to either end of the cutting.
- Installing drains at the toe of the embankment sloping towards the culverts which can also allow for additional storage to decrease the velocity and peak flow through the culvert crossings.
- Installing treatment wetlands in optimum locations to reduce conveyance to and treatment areas to the wetlands. Fewer optimised wetlands can reduce future maintenance costs along with pipe networks to convey flows to the wetlands.

Regional stormwater consents will also be required closer to construction which will address flooding, water quality (treatment and attenuation), erosion and sediment control.

5.1.4 Summary

The main positive effects that could be designed in the future works for the North NoRs are:

- proposed new roadways to be above the predicted future flood levels;
- proposed widened and improved roadways to be above the predicted future flood levels, particularly existing overtopping roads, thereby improving road resilience and ensuring there are lifeline routes for emergency vehicles and minimising disruption to other traffic;
- added water quality treatment and attenuation of the total roadway impervious area as opposed to just the additional roadway area for upgraded roads;
- conveying water across existing corridors with less headwater so that upstream flood effects are reduced (subject to checks on downstream flooding effects).

We conclude from our Supplementary Flood Hazard Assessment that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

We consider that the proposed flood hazard condition sets appropriate outcomes for managing future flooding effects due to the North Project works. Flood modelling will be required at the Outline Plan phase to confirm the detailed design will comply with the NoR conditions.

5.2 NOR 1 – New Rapid Transit Corridor (RTC) between Albany and Milldale

The following physical works may cause / exacerbate flooding effects (without appropriate mitigation):

- The relocated wetland at chainage 300 near Lucas Creek;
- Bridge crossings over the Huruhuru (Dairy – chainage 9300) and tributaries of the Rangitopuni (chainage 11350) and Wēiti (chainage 13600m) Streams, which need to be sized to optimise upstream and downstream water levels to within NOR conditions;

- construction of new road formation reduces flood storage volume, which could increase tailwater effects and reduce the culvert and bridge capacities; and
- deep cuttings (south of Bawden Rd – chainage 6900 to 8700) which may generate relatively large flows at the cutting outlets.

Our site assessment of floor levels (refer Appendix 1 in this supplementary report) has identified the following buildings near the NoR 1 Project works:

- Building 15 (99 Bawden Road) adjacent to the Dairy Stream may have less than 150mm of freeboard; and
- Buildings 29 (1320 Dairy Flat Highway) and 33 (117 Postman Road) near a tributary of the Rangitopuni Stream may have less than 150mm of freeboard.

We consider that the following locations may be more susceptible to flood effects because there are flooding effects in the Pre-project scenario:

- The Dairy Stream crosses the RTC alignment at chainage 9300m. A 300m length (approx.) bridge has been modelled over the Bawden Road underpass and the Dairy Stream crossing and shows limited increase in upstream flood levels. This is near the building at 99 Bawden Road.
- The culvert crossing at chainage 10500 will need to convey flow while considering effects on the building at 117 Postman Road.
- The Rangitopuni Stream tributary crosses the RTC alignment at chainage 11350. The western embankment is within the floodplain and therefore removes storage and has the potential to increase flood levels (the building at 1320 Dairy Flat Highway is to the west). Modelling has shown the change in flood levels is 20 mm at the proposed NoR boundary.

The general mitigation measures in Section 5.1.3 are proposed to apply to this NoR, with the main ones being:

- Appropriate sizing of the bridge span at chainage 9300
- Appropriate sizing of the culvert at chainage 10500
- Diversion of flows along the west side of the embankment at chainage 11350
- Conveyance through deep cuttings at the toe of the cut face can be improved through use of cut off and bench drains
- Appropriate sizing of the bridge span at chainage 13600, and
- Attenuation of flows from new impervious areas within the corridor within the Silverdale South and Dairy Stream catchments

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.3 NOR 2 - New Milldale Station and Associated Facilities

There is a potential diversion of a minor overland flow path due to the proposed physical works for NoR 2.

Our site assessment of floor levels (refer Appendix 1 in this supplementary report) has not identified any buildings that may be at risk of effects being exacerbated due to the NoR 2 Project works.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.4 NOR 3 – New Pine Valley East Station and Associated Facilities

There is a potential diversion of a minor overland flow path due to the proposed physical works for NoR 3.

Our site assessment of floor levels (refer Appendix 1) has not identified any buildings outside of the proposed NoR that may be at risk of effects being exacerbated due to the NoR 3 Project works.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.5 NOR 4 – SH1 Improvements

The concept design for this NoR allows for the SH1 Improvements to widen existing bridge crossings of the Orewa River, Wēiti Stream, Huruhuru (Dairy Stream) and Ōkura River by means of a bridge or viaduct.

The features for this NoR that could exacerbate flooding relate to the earthworks, flood storage volume loss, construction of bridges over the streams, extension of existing culverts, and formation / wetland construction adjacent or within the predicted floodplains.

In particular, the following physical works could give rise to potential operational effects (without appropriate mitigation):

- The embankment at chainage 2,500 encroaching on the nearby floodplain and potentially exacerbating flooding on the building at 1226 East Coast Road
- Stormwater wetlands (as potential alternatives to swales) at chainage 3,200 and 3,600m being close to or within floodplains
- Diversion of the overland flow path at chainage 4,700 and potentially affecting the building at 1513 East Coast Road
- Diversion of overland flow paths near the O Mahurangi Penlink Interchange at chainage 6,300 to 6,800
- Diversion of the stream due to the cycleway around the SH1 Motorway Service Centre (Dairy Flat BP site) at chainage 7,400

- Increasing the span of the bridge at chainage 7,100 could remove a constriction on the Dairy Stream which could release flow downstream. The existing crossing has 1.8m of head loss, and
- Diversion of overland flow on the eastern side of the corridor.

Our site assessment of floor levels (refer Appendix 1) has identified the following buildings near the project works:

- Buildings within the floodplain in the Okura South catchment at 1226 East Coast Road (which we are unable to estimate a freeboard for)
- Building 6 (1370 East Coast Road) in the Okura South catchment may have less than 150mm of freeboard
- Building 15 (1513 East Coast Road) in the Okura North catchment may have less than 500mm of freeboard
- Building 19 (87 Small Road) in the Silverdale South catchment may have 150-500mm of freeboard
- A building at 91 Top Road is within the floodplain downstream of the new crossing of SH1 at chainage 7,100, and
- The existing crossing of East Coast Road at chainage 450 (near chainage 7100 on SH1) overtops and has 2.0m of head loss through the structure. Downstream the existing crossing of SH1 has a further 1.8m of head loss. A building in between East Coast Road and SH1 (1746 East Coast Road) may have limited freeboard.

There is also Future Urban Zoned land on the south-west side of SH1 Silverdale Interchange and alongside the Dairy Stream west of SH1 which is affected by Pre-project flooding.

We consider that the following locations may be more susceptible to flood effects because there are flooding effects in the Pre-project scenario:

- Ponding on east side of SH1 2,300 to 2,500 is caused by limited capacity in the culvert at NoR 4 chainage 2,500. The proposed embankment extends east, partially into the existing ponding area, where there is a house within the existing floodplain (1226 East Coast Road). If flood mitigation for the project is required, additional culvert capacity could be provided at chainage 2500 to reduce/maintain existing flood levels. This could require additional capacity for downstream culverts also.
- At the Okura Stream South branch under East Coast Road near chainage 3,400, the stream (east of SH1 and on the south-west side of East Coast Road) overtops its banks (but not across East Coast Road) and runs north toward existing glasshouses (building 15, 1370 East Coast Road) due to limited capacity in the culvert under East Coast Road (4.42m existing head loss). The nearby house may have limited freeboard. A construction yard and treatment device may be constructed for the Project nearby. If required to mitigate flooding effects, additional culvert capacity could be provided under East Coast Road to reduce/maintain existing flood levels.
- Overland flow crosses SH1 and East Coast Rd at chainage 4,700 SH1 and runs through 1513 East Coast Road. The Project works maintain the existing eastern boundary of SH1. Diversion of the overland flow within the NoR is required without increasing flood levels on the property at 1513 East Coast Road.
- The catchment around East Coast Road at the SH1 / O Mahurangi Penlink interchange (chainage 6,400) runs north and connects with the upper Dairy Stream which crosses at chainage 7,100. The

proposed SH1 southbound off ramp route for NoR 4 is through the floodplain of the channel from Penlink. A diversion drain has been allowed for in the Project works.
- The proposed cycleway embankment for NoR 4 is routed over the existing stream immediately west of the SH1 Motorway Service Centre (BP site), between chainage 7,400 to 7,500. The western embankment for NoR 5 also diverts a downstream section of the channel. Space for a rerouted stream alignment or boardwalk has been allowed.
- From the Wilks Road interchange, flow runs north on both the east and west sides of SH1, with the western side having a wider flood extent on relatively gentle terrain. The proposed alignment does not encroach on the flooding on the western side except near the southern side of the Silverdale Interchange (chainage 11,100 to 11,300m). To accommodate the additional lanes and the cycle way and not exacerbate existing flooding, the culverts will be extended and capacity set to maintain the existing hydrology. To the east of SH1, the additional lane may encroach on an existing channel and restrict flow between chainage 8800 and 9000m. At chainages 10,000, 10,100 and 10,650, culverts (which will need to be lengthened) allow water to run from east to west and may need to be adjusted in size to compensate for the additional friction caused by lengthening. Flows from new impervious areas will be attenuated to maintain peak flows from the corridor. Space for a new diversion drain between chainage 8,800 and 10,650 has been allowed for to realign the eastern channel and distribute flow if this is necessary to mitigate effects. Between chainage 10,650 and 11,300, further space for a diversion drain is allowed for, to enable a portion of peak flow to be diverted further north if required.

The general mitigation measures in Section 5.1.3 are proposed to apply to this NoR, with the main ones being:

- Increasing the capacity of the culvert under East Coast Road to lower the tailwater for upstream culverts
- Appropriate sizing of the diversion at chainage 4,700
- Appropriate sizing of the diversions at chainage 6,300 to 6,800
- Appropriate sizing of the bridge at chainage 7,100 to not exacerbate Pre-project flooding at dwellings outside the Corridor
- Appropriate sizing of the stream diversion at chainage 7,400 (in conjunction with NoR 5),
- Appropriate sizing of culverts that convey flow from east to west from chainage 8,800 to 10,650 to maintain the existing hydrology, and
- Attenuation of flows from new impervious areas within the corridor within the Dairy Stream and Silverdale South catchments

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.6 NoR 5- New SH1 crossing at Dairy Stream

The concept design for NoR 5 allows for a new bridge over SH1 near Dairy Stream.

The site features and works for this NoR that could cause flooding relates to the earthworks, stream diversion, flood storage volume loss, construction of a culvert over a Dairy Stream tributary and formation / wetland construction adjacent or within the floodplain.

In particular, the following physical works could give rise to potential effects (without appropriate mitigation):

- The roundabout with East Coast Road diverts a tributary of the Dairy Stream but is not near any buildings.
- The culvert and embankment for the western abutment diverts a second tributary of the Dairy Stream and there are approximately three residential buildings nearby downstream and one nearby upstream.

The buildings at 109, 112 and 127 Top Road (downstream) and 142 Top Road (upstream) are close to the NoR 5 Project works. The building at 127 Top Road was the only one to have its freeboard assessed and it was identified to have 500mm freeboard.

We expect that the building at 142 Top Road has the potential for greater risk as the culvert and diversion are more likely to exacerbate upstream flood levels, in which case the culvert needs to be sized to minimise head loss and maintain freeboard in accordance with the flood condition.

The general mitigation measures in Section 5.1.3 are proposed to apply to this NoR, with the main one being maintaining the pre-project peak flow regime so that Pre-project flood levels affecting buildings are not exacerbated.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.7 NOR 6 – New Connection between Milldale and Grand Drive

A new connection is proposed between Wainui Road and Grand Drive (NoR 6):

- The southern part of the route follows the existing Upper Orewa Road, where there is a culvert which causes water to overtop the road, and a bridge over the Orewa River. The bridge will be widened, and the culvert extended.
- At the intersection with Russell Road, the new route turns east with a further bridge and two more culverts are envisaged.

The following potential operational effects are associated with the proposed NoR concept design (without appropriate mitigation):

- Upsizing of the existing culvert crossing (upstream catchment area approximately 68 ha) at chainage 1850m which could create upstream or downstream flood level differences if not sized appropriately.
- A relatively short reduction in the length of the open permanent stream due to culverting.
- Construction of new road formation which would slightly reduce flood storage volume, which could increase inlet effects or divert flows.

There is FUZ land over the majority of the route.

Our site assessment of floor levels (refer Appendix 1) has identified the following buildings in the Orewa West catchment near the proposed works:

- Building 12 (42 Kowhai Road) which is about 800m downstream of the proposed works, is estimated to have no freeboard.

- Building 14 (29 Upper Orewa Road) in the Orewa West catchment has an estimated freeboard of more than 500mm.
- There is new subdivision on land just upstream of the new section of road.

Building 14 at 29 Upper Orewa Road is the greatest known risk and it can be managed with appropriate sizing of the bridge. The new section of the route traverses steeper land and therefore increases in upstream flood level should be able to be appropriately managed.

The general mitigation measures in Section 5.1.3 are proposed to apply to this NoR, with the main ones being:

- Increasing the capacity of the existing culvert under Upper Orewa Road to improve road resilience (stopping the road overtopping) while minimising changes to upstream flood levels.
- Appropriate sizing of the bridge and two culverts on the new section of road
- Attenuation of flows from new impervious areas within the corridor.

There is also potential to reduce the extent of upstream flooding at the existing culvert and existing bridge, by increasing the flow capacity, subject to maintaining any downstream freeboard requirements.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.8 NOR 7 – Upgrade to Pine Valley Road

The concept design entails an upgrade to the existing Pine Valley Road to join to the proposed new intersection with Argent Lane in the east.

The Wēiti Stream flows from west to east along the northern side of Pine Valley Road. A tributary also runs along the south side until Young Access Road where it crosses to the north side. The road embankment is located within the floodplain between chainage 0 to 400m, existing culverts are undersized and stretches of the existing road overtop in the 1% AEP event. The road is to be raised to improve resilience (eliminate overtopping). Two bridges are envisaged (at chainage 900m and on Young Access Road over the main stem of the Wēiti Stream) along with new / upgraded culverts.

The potential flooding effects for this NoR relate to the earthworks, road raising, flood storage volume loss, overland flow path impacts, construction of widened bridges and lengthened culverts over existing streams and embankment formation adjacent or within the floodplain.

The following physical works may have potential operational effects (without appropriate mitigation):

- Extending the existing culvert crossings combined with raising the road could create upstream flooding
- Widened bridge crossings over existing streams which need to be sized to manage potential flood level changes
- A relatively short length reduction of an open permanent stream due to culverting of the stream, and
- Construction of new road formation reduces flood storage volume, which could increase upstream water levels.

Our site assessment of floor levels (refer Appendix 1) has identified the following buildings in the Wēiti Stream catchment near the NoR 7 Project works:

- Buildings 6, 7, 9, 14, 16, 18 (158, 165, 202, 257A, 320, 357 Pine Valley Road) may have less than 150mm of freeboard.
- Buildings 8, 17 (195, 346 Pine Valley Road) may have between 1560 and 500mm of freeboard.

Given that the existing road overtops, and that there is a number of nearby buildings, we consider that there is potential for effects at many of the crossings along the route. The post Project terrain was therefore assessed in the flood model.

Modelling showed that changes in flood level can be maintained to +/- 10mm in the main tributary south of the road and then the main channel north of the road by appropriate sizing of bridges. The existing culverts are undersized and will need to be upgraded to minimise changes in flood levels for cross corridor flows via culverts into the main stream. Refer to Figure 5 in the "Silverdale South – Pine Valley Design Flood Modelling" memorandum, 31/08/2023 in Appendix 3 of the lodged Assessment of Flooding Effects. Further modelling was carried out to identify the extent of the culvert upgrades / new culvert sizes required on the new corridor alignment. The work is reported in Appendix 2 to this supplementary report. It shows that it is possible to provide suitable cross drainage to manage effects to between 10 and 50mm adjacent to the corridor.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR, with the main ones being:

- Appropriate sizing of culverts under the road between chainage 0 to 400 to manage potential flood level increases upstream to the north (near buildings 16 and 17)
- A section of retaining wall may be needed near chainage 100 to allow road formation that does not impinge on the stream tributary
- A bridge is envisaged at chainage 900m (near building 14) and needs to be sized to manage upstream flooding effects
- Appropriate sizing of the culvert(s) at chainage 1,050 and 1,450 to manage upstream flooding effects
- Attenuation of flows from new impervious areas within the corridor, and
- Further flood modelling and iterations of the design geometry and the road formation and flow crossings will be important for this stretch of road where flooding could be exacerbated by road level raising alone.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.9 NOR 8 – Upgrade to Dairy Flat Highway between Silverdale and Dairy Flat

The concept design entails an upgrade to the existing Dairy Flat Highway between Durey Road and the SH1 Silverdale Interchange in the north.

The route crosses several tributaries of the Dairy Stream south of Blackbridge Road and several tributaries of the Rangitopuni Stream north of that. The existing road is overtopped in numerous locations in both catchments. The road is to be raised to improve resilience (eliminate or reduce overtopping). Three bridges are envisaged over tributaries of the Dairy Stream (at chainages 600m, 1,900 and 2,750) and two bridges are proposed over tributaries of the Rangitopuni Stream (at chainages 4,650 and 5,900). There will also be new / upgraded culverts.

The potential flooding effects for this NoR relate to the earthworks, road raising, flood storage volume loss, overland flow path impacts, construction of widened bridges and lengthened culverts over existing streams and embankment formation adjacent or within the floodplain.

- The existing Dairy Flat Highway crossings have the following hydraulic characteristics:
  - Chainage 1900 m has 980mm of head loss (RL 38.33 upstream)
  - Chainage 2,750 currently overtops and has 2.16m of head loss (RL 36.28 upstream)
  - Chainage 4,300 has 2.76m of head loss (RL 49.49 upstream)
  - Chainage 4,650 currently overtops and has 270mm of head loss (RL 48.25 upstream), and
  - Chainage 5,900 currently overtops and 1.29m of head loss (RL 53.29 upstream).

Around the intersection with Bawden Road (chainage 1,900 to 2,750) our site assessment of floor levels (refer Appendix 1) identified the following buildings in the Dairy Stream catchment that may be at risk of effects being exacerbated due to the NoR 8 Project works:

- Buildings 9, 10, 13, 14 (1016, 1005A Dairy Flat Highway and 38, 77 Bawden Road) may have less than 150mm of freeboard.
- Buildings 31, (20A Green Road) downstream of the bridge at chainage 2750 may have between 150 and 500mm of freeboard.

Within the Rangitopuni catchment, our site assessment of floor levels (refer Appendix 1) has identified the following buildings may be at risk of effects being exacerbated due to the NoR 8 Project works:

- Building 37 (Dairy Flat School) and building 6 (1284 Dairy Flat Highway) may have less than 150mm of freeboard.
- Building 7 (1256 Dairy Flat Highway) may have between 150 and 500mm of freeboard.

We consider that the following locations may be more susceptible to flood effects because there are flooding effects in the Pre-project scenario:

- The bridge over the stream at chainage 600 where there are buildings nearby upstream
- Exacerbating existing flooding where the existing road is overtopped around the intersection of Dairy Flat Highway and Bawden Road. The stream diversions and bridges at chainage 1,900m and 2,750 – in conjunction with the proposed nearby bridge on Bawden Road (part of NoR 12). There are buildings on both sides of the route at both bridges
- The culvert at chainage 4,350 near Dairy Flat School, where there are existing flooding issues upstream (building 37), and
- The bridge abutment and wetland at chainage 5,950 being sited partly within the floodplain with buildings 6 and 7 upstream.

The predicted overtopping of Dairy Flat Highway (chainage 1,900) to the west of the existing Bawden Road intersection and both sides of the Green Road intersection, along with the realigned Bawden Road and bridge were considered sufficient to warrant modelling of the post Project terrain. This modelling revealed that additional land was needed in the triangle between the old and new Bawden Road alignment and Dairy Flat Highway for ground recontouring. Therefore, the designation was updated to include a small section of land alongside the old Bawden Road alignment. The modelling also showed that the designation conditions should be achieved with further design refinement at the outline plan stage. The modelling and results are discussed in Appendix B to the lodged Assessment of Flooding Effects report.

At the crossings noted above:

- The existing road and bridge at chainage 2,750 overtop, with a predicted 2.16m of head difference either side of the road. Modelling has used the existing terrain and a limited bridge opening for the stretch of road between chainage 2,440 and 3,000m. On this basis the road continues to overtop and there is no change to the existing flood levels. There is potential for improvement in the upstream flood levels upstream by increasing the bridge span.
- The existing road at chainage 1,900 currently overtops and has 1.02m of head difference either side of the road. Modelling shows that the proposed bridge at chainage 1,900 can convey water through the crossing with a +/- 10mm difference in water level outside the designation boundary. There is potential for improvement in the upstream flood levels upstream (south of the crossing) also – the current configuration showed a 10 to 50mm reduction in flood water levels upstream of chainage 1,900m. Refer to Figure 5 in the “Dairy Flat Design Flood Modelling” memorandum, 31/08/2023 in Appendix 2 of the lodged Assessment of Flooding Effects.
- A culvert at chainage 4,300 near Dairy Flat School has limited capacity with 2.74m of head difference either side of the road in the pre-Project model. Sufficient cross conveyance capacity will be provided to limit upstream effects. There is potential for improvement in the Pre-Project upstream flood levels by increasing the size of the culvert and there is space within the proposed NoR area to achieve this.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR, with the main ones being:

- Bridges envisaged at chainage 1,900m and 2,750 need to be considered in conjunction with the NoR 12 works and need to be sized to manage upstream and downstream flooding effects,
- Appropriate sizing of the culvert(s) at chainage 4,300 so as to not exacerbate upstream flooding effects,
- Appropriate sizing of the bridge span at chainages 4,650 and 5,950 to manage upstream flooding effects,
- Attenuation of flows from new impervious areas within the corridor, and
- Future flood modelling and iterations of the design geometry and the road formation and crossings will be important for this stretch of road as there are a number of buildings where flooding could be exacerbated.

We consider that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

5.10 NOR 9 – Upgrade to Dairy Flat Highway between Dairy Flat and Albany

The Dairy Flat Highway between Albany and Durey Road is to be upgraded.

The route is generally along a relatively steeply sided ridge with no nearby floodplains. Overland flow may run along the road at chainage 550 to 650 and cross the existing road at chainage 4,700 and 5,000m.

There are potentially some large cut and fill extents on the road but as they are near the ridge there is limited interaction with overland flow paths.

There is a building on the upstream side of the culvert at chainage 4700 that could be potentially affected by diversion of flow or extension of the culvert, but this is a minor issue that can be appropriately addressed by sizing the culvert. There is potential to reduce the existing upstream ponding.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR, with the main ones being:

- Appropriately sizing the overland flow path diversion at chainage 550 to 650
- Appropriately sizing the culvert at chainage 4,700 to not exacerbate upstream flooding effects.

We conclude that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

5.11 NOR 10 – Upgrade to Wainui Road

Wainui Road between the SH1 overbridge and Lysnar Road is to be upgraded.

The route is generally along a ridge with one side falling steeply down to Waterloo Creek (a tributary of the Orewa River). There are limited minor overland flow paths with the only significant feature being a bridge over the creek.

The concept design allows for a longer bridge and there is no encroachment on the Orewa River or the Waterloo Creek.

At the bridge, our site assessment of floor levels (refer Appendix 1) has identified the following nearby buildings adjacent to the Orewa River:

- Building 12 (42 Kowhai Road), on the opposite side of the river, may have less than 150mm of freeboard.
- Building 18 (330 Wainui Road) downstream of the bridge at chainage 2750 is estimated to have more than 2.5m of freeboard.

The general mitigation measures in Section 5.1.3 are proposed to apply to this NoR, with the main ones being:

- Appropriately sizing the bridge abutments and span to not exacerbate flood levels on nearby buildings.

We conclude that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

5.12 NOR 11 – Connection from Dairy Flat Highway to Wilks Road

A new connection is proposed between Dairy Flat Highway (at Kahikatea Road) to Wilks Road and a new crossing of State Highway 1 (as part of NoR 4 - which then joins on to East Coast Road near Jackson Way). There is no existing road over most of the route.

There are two culvert crossings (at chainages 250 and 1,050) on overland flow paths in the upper Dairy Stream catchment that could cause effects (without appropriate mitigation).

There is FUZ land over both sides of the route.

Our site assessment of floor levels (refer Appendix 1) has identified the following buildings nearby:

- Buildings 2 and 3 (235 and 343 Postman Road) near chainage 1050, are estimated to have less than 150 mm freeboard.
- The building at 1444 Dairy Flat Highway upstream of chainage 250, is approximately 3m above the flood level.

The building upstream of the culvert at chainage 1,050 is likely to have the greater risk of flooding being exacerbated by the works – if the culvert is not appropriately sized.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR with the main ones being appropriately sizing the two culverts to manage upstream flood levels.

We conclude that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

5.13 NOR 12 – Upgrade and Extension to Bawden Road

The concept design entails an upgrade to the existing Bawden Road route between Dairy Flat Highway and the new O Mahurangi Penlink interchange with State Highway 1.

The route crosses three tributaries of the Dairy Stream, with the larger ones at chainage 1,650 and 3,100. The existing road is predicted to overtop and will be raised to improve resilience (eliminate or reduce overtopping). Two bridges are envisaged over tributaries of the Dairy Stream (at chainages 1,650 and 3,100). There will also be three new/upgraded culverts.

The potential flooding effects for this NoR relate to the earthworks, road raising, flood storage volume loss, overland flow path impacts, construction of bridge abutments within the floodplain, lengthened culverts and embankment formation adjacent or within the floodplain.

- The existing Bawden Road crossings have the following hydraulic characteristics:
  - Chainage 1,650 m has 610mm of head loss (RL 39.87m upstream), and
  - Chainage 3,100 currently overtops and has only 10mm of head difference either side of the road. (RL 35.75m upstream).

Around the intersection with Dairy Flat Highway our site assessment of floor levels (refer Appendix 1) has identified the following buildings in the Dairy Stream catchment near to the NoR 8 and NoR 12 Project works:

- Buildings 9, 10, 13, 14 (1016, 1005A Dairy Flat Highway and 38, 77 Bawden Road) may have less than 150mm of freeboard.
- Buildings 31 (20A Green Road) downstream of the Dairy Flat Highway bridge at chainage 2750 may have between 150 and 500mm of freeboard.

Along the remainder of the route, our site assessment of floor levels (refer Appendix 1) has identified the following buildings near the NoR 12 Project works:

- Buildings 17, 19, 20, and 36 (120, 216, 218, 200B Bawden Road) may have less than 150mm of freeboard.
- Building 16, 18 (119 and 135 Bawden Road) may have between 150 and 500mm of freeboard.

We consider that the following locations may be more susceptible to flood effects because there are flooding effects in the Pre-project scenario:

- The bridge at chainage 1,650 where there are buildings nearby upstream
- The culvert at chainage 2,150 where there are buildings both upstream and downstream, and
- The stream diversion and bridge at chainage 3,100 – in conjunction with the proposed two nearby bridges on Dairy Flat Highway (part of NoR 8). There are buildings on both sides of the Bawden Road bridge.

The predicted overtopping of Dairy Flat Highway to the west of the existing Bawden Road intersection and both sides of the Green Road intersection (NoR 8), along with the realigned Bawden Road and bridge were considered sufficient to warrant modelling of the post Project case. This modelling revealed that additional land was needed in the triangle between the old and new Bawden Road alignment and Dairy Flat Highway for ground recontouring. Therefore, the designation was updated to include a small section of land alongside the old Bawden Road alignment. The modelling and results are discussed in Appendix B to the lodged Assessment of Flooding Effects report.

In summary:

- At the bridge at chainage 1,650 there is some increase in upstream flood levels and the bridge span will need to be increased.
- The bridge at chainage 3,100 has been modelled in conjunction with the works on the RTC (NoR 1) and Dairy Flat Highway (NoR 8). Modelling shows that the proposed bridge can convey water through the crossing with a +/- 10mm difference in water level outside the designation boundary. Refer to Figure 5 in the "Dairy Flat Design Flood Modelling" memorandum, 31/08/2023 in Appendix 2 of the lodged Assessment of Flooding Effects.

The results showed that with refinements, the proposed flood condition outcomes were very close to being achieved, and with future refinements available (such as recontouring adjacent to the existing stream), the flood hazard risk can be further improved to within the outcomes sought in the proposed designation conditions. The main issue that needs to be resolved is the span of the Bawden Rd bridge over the Dairy Stream tributary the extent of recontouring required around the waterway between the proposed cul-de-sac head and the proposed Bawden Rd embankment.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR, with the main ones being:

- The bridges envisaged at chainage 3,100 need to be considered in conjunction with the NoR 8 works and needs to be sized to manage upstream and downstream flooding effects
- Appropriate sizing of the culvert(s) at chainage 2,150 to manage upstream flooding effects
- Appropriate sizing of the bridge span at chainage 1,650 to manage upstream flooding effects, and
- Attenuation of flows from new impervious areas within the corridor.

Future flood modelling and iterations of the design geometry and the road formation and crossings will be important for this stretch of road as there are some buildings where flooding could be exacerbated.

We conclude that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

5.14 NOR 13 – Upgrade to East Coast Road between Silverdale and Ō Mahurangi Penlink (Redvale) Interchange

East Coast Road is to be upgraded between the new interchange with O Mahurangi Penlink and Silverdale. The route generally follows a ridge and there is limited interaction with any flooding or overland flow paths.

The concept design for NoR 13 allows for a new bridge crossing and diversion of the Dairy Stream – which is associated with a new intersection for a new crossing of State Highway 1 (NoR 5).

The existing crossing of East Coast Road at chainage overtops and has 2.0m of head loss through the structure. Downstream the existing crossing of SH1 has a further 1.8m of head loss.

The site features and works for this NoR that could cause flooding relates to the span of the bridge over the Dairy Stream and earthworks and stream diversion. The roundabout on East Coast Road diverts a tributary of the Dairy Stream but is not near any buildings and we have not identified potential effects. A building has been identified within the floodplain downstream of SH1 at 91 Top Road.

There is FUZ land downstream which the Dairy Stream runs through.

The general mitigation measures proposed in Section 5.1.3 apply to this NoR with the main ones being:

- Managing the capacity of the crossing of East Coast Road such that potential effects on downstream properties are appropriately mitigated; and
- At detailed design, flood modelling of the post Project geometry will be required to check the potential effects downstream.

This potential effect is considered low risk as there is sufficient room available within the designation to design a solution to achieve the flooding conditions.

We conclude that the expected changes in flood levels due to the North Project works on adjoining property can be appropriately managed.

6 Conclusions

We conclude from our assessment of the potential flooding effects that the expected changes in flood levels and effects due to the Project works can be managed appropriately.

We consider that the proposed flood condition sets appropriate outcomes for managing future flooding effects due to the Project Works and subject to these being designed and implemented, the effects can be minor or less. Flood modelling will be required at the Outline Plan phase to confirm the detailed design will comply with the NOR conditions.

The modelling undertaken to date is for the purposes of assessing potential effects and identifying whether those effects can be mitigated. Further flood modelling will be carried out for the Outline Plan to demonstrate that the detailed design complies with the proposed flood condition. In addition, this does not preclude additional flood requirements, such as may be set out in future Auckland Council, Waka Kotahi and Auckland Transport Codes of Practice being used in the development of the design or assessment of future regional resource consents.

The positive flooding effects are primarily associated with raising existing roads out of the flood plain that are currently predicted to flood in the future 1% AEP events plus treatment of existing roads that are widened. However, raising roads needs to be accompanied by providing sufficient new cross drainage capacity so that upstream flood levels are not increased. If catchment wide flood mitigation approaches are developed by Auckland Council and land-owners to reduce Pre-Project flooding, there are opportunities to implement these in conjunction with works to mitigate the effects of the Project works.

The key flooding effects and controls within the North Projects area are associated with changing the flow characteristics at key watercourses crossing the NoRs. The locations listed below are considered to have a greater potential for flooding effects:

- The area upstream of East Coast Road on the south branch of the Okura River. Increasing culvert capacity under East Coast Road would reduce the existing flooding problems.
- The area around chainage 4700 on State Highway 1 where an overland flow path runs through 1513 East Coast Road.
- The upper reaches of the Dairy Stream around chainage 7100 on State Highway 1, where flow is attenuated upstream of East Coast Road and SH1 before running to the west through FUZ.
- The area south of the Silverdale Interchange. On the west side flooding could be increased on the FUZ land unless peak flows from the new corridor are mitigated. One way of doing that mitigation, and potentially reducing existing flood risk on the west side, is to divert peak flows in a channel along the east side of SH1 – but this must be balanced with the potential for effects on the existing commercial properties to the south-east of the Silverdale interchange.
- Raising the existing alignment of Pine Valley Road improves road resilience but must be done in conjunction with providing enough cross conveyance to mitigate change sot flood levels.
- The three bridges near intersection of Dairy Flat Highway (NoR8) and Bawden Road (NoR 12). Modelling shows that the two upstream bridges on Bawden Road and Dairy Flat Highway can be constructed with little change to upstream flood levels by leaving the existing crossing at chainage 2750 nominally as it is. There is potential to reduce the upstream

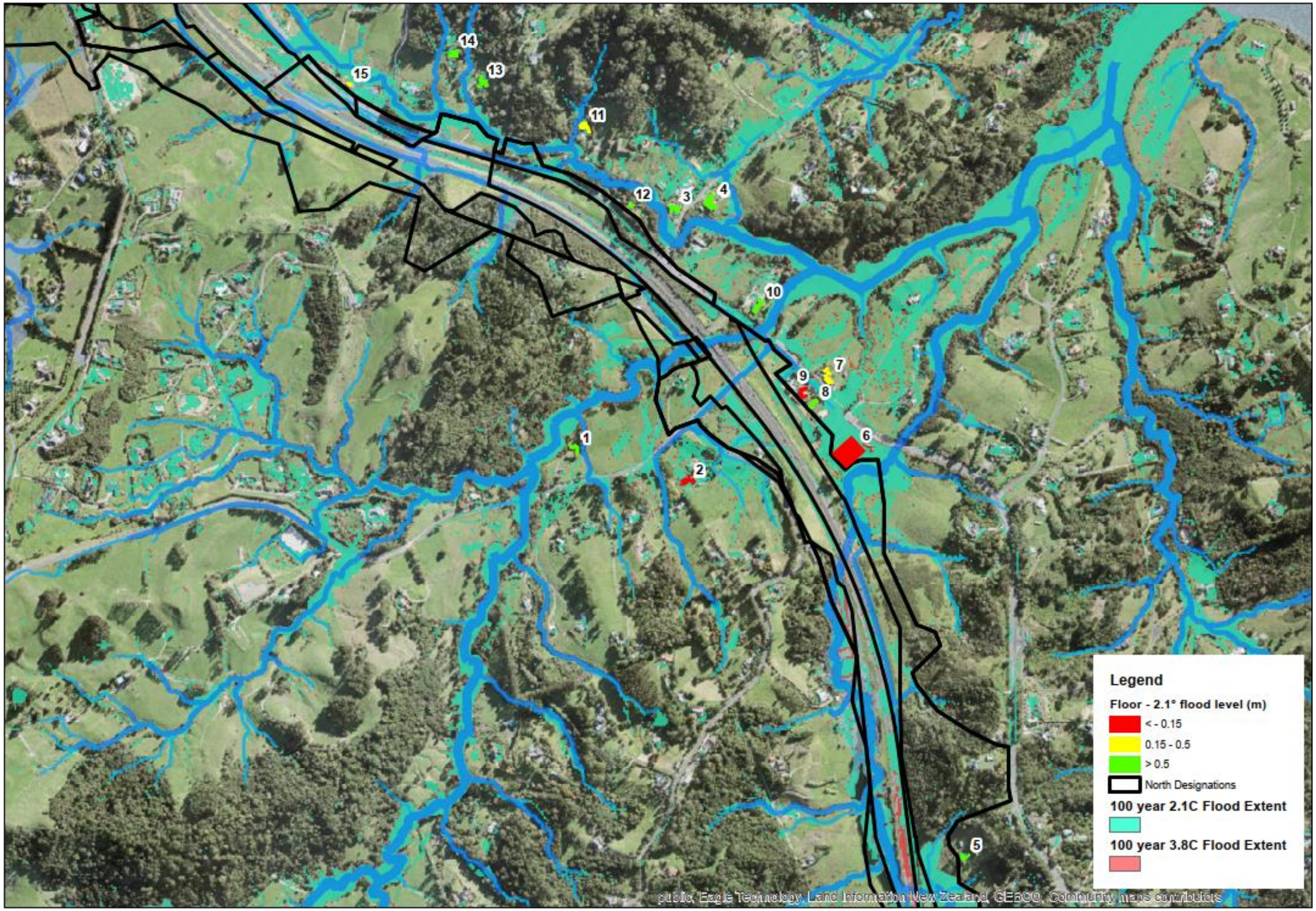
flooding effects on the FUZ land by letting water pass downstream if this is appropriate in terms of downstream effects.

These potential issues can be mitigated by adding extra flow capacity under the road (either by increasing the span of a bridge or increasing the culvert area). Adjusting the proposed road geometry can also help. Together, these methods can refine the design and be checked with further flood modelling to demonstrate that the NOR flood conditions are met.

Appendix 1 Maps and spreadsheet of North area existing site assessed floors with associated flood risk.

Okura North

Street	Number	Estimated by site assessment: Estimated freeboard (m)	Ground level (from LiDAR)	Est. floor level	Existing flooding: Property within or near AC Geomaps 2023 floodplain	Existing floor within or near AC Geomaps 2023 floodplain	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level	Floor - 2.1° flood level (m)	Floor flooding
Awanohi Road	56	0.05	13.25	13.3	Yes	No	9.4	9.78	3.90	No
Wright Road	8	0.1	16.68	16.78	Yes	No	16.68	16.69	0.10	No
Haigh Access Road	11	0.2	15.16	15.36	Yes	No	14.72	14.72	0.64	No
	20	0	14.05	14.05	Yes	No	12.33	12.34	1.72	No
East Coast Road	1262	0.1	36.29	36.39	Yes	No	22.23	22.33	14.16	No
	1370	0	10.95	10.95	Yes	Yes	11.33	11.39	-0.38	Yes
	1373	0.05	10.79	10.84	Yes	No	10.63	10.64	0.21	No
	1374	0.7	12	12.7	Yes	Yes	11.91	11.91	0.79	No
	1384	0.1	12.47	12.57	Yes	No	12.42	12.43	0.15	No
	1401	0.1	10.52	10.62	No	No	5.07	5.32	5.55	No
	1425	0.4	21.81	22.21	No	No	21.34	21.34	0.87	No
	1451	0.4	20.17	20.57	Yes	Yes	20.28	20.28	0.29	No
	1469	0.55	24.31	24.86	Yes	No	24.21	24.21	0.65	No
	1473	0.55	24.3	24.85	Yes	No	24.15	24.16	0.7	No
	1513	0.3	22.74	23.04	Yes	Yes	22.73	22.73	0.31	No



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North Designations
100 year 2.1C Flood Extent
100 year 3.8C Flood Extent
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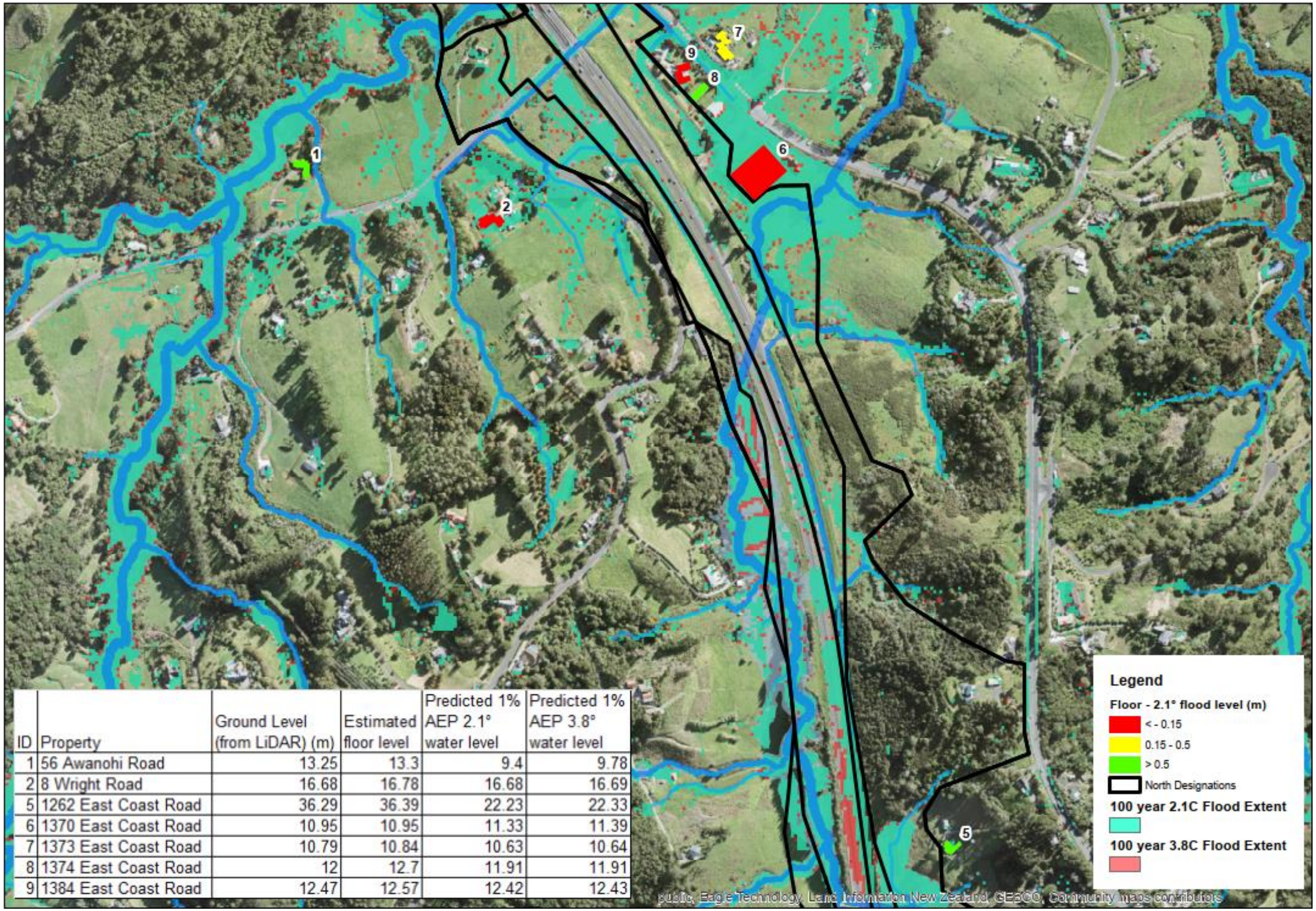
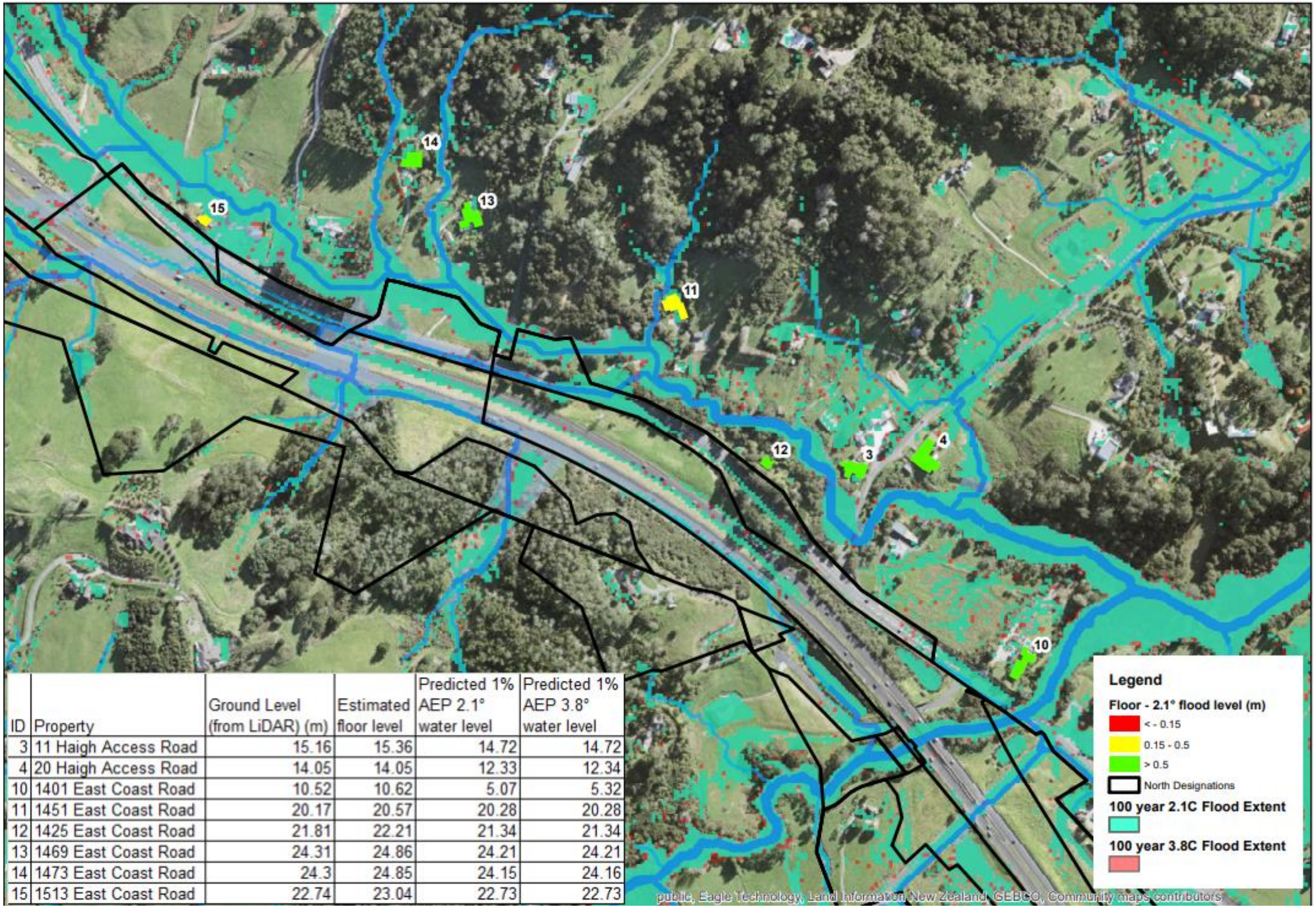


ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
1	56 Awanohi Road	13.25	13.3	9.4	9.78
2	8 Wright Road	16.68	16.78	16.68	16.69
5	1262 East Coast Road	36.29	36.39	22.23	22.33
6	1370 East Coast Road	10.95	10.95	11.33	11.39
7	1373 East Coast Road	10.79	10.84	10.63	10.64
8	1374 East Coast Road	12	12.7	11.91	11.91
9	1384 East Coast Road	12.47	12.57	12.42	12.43



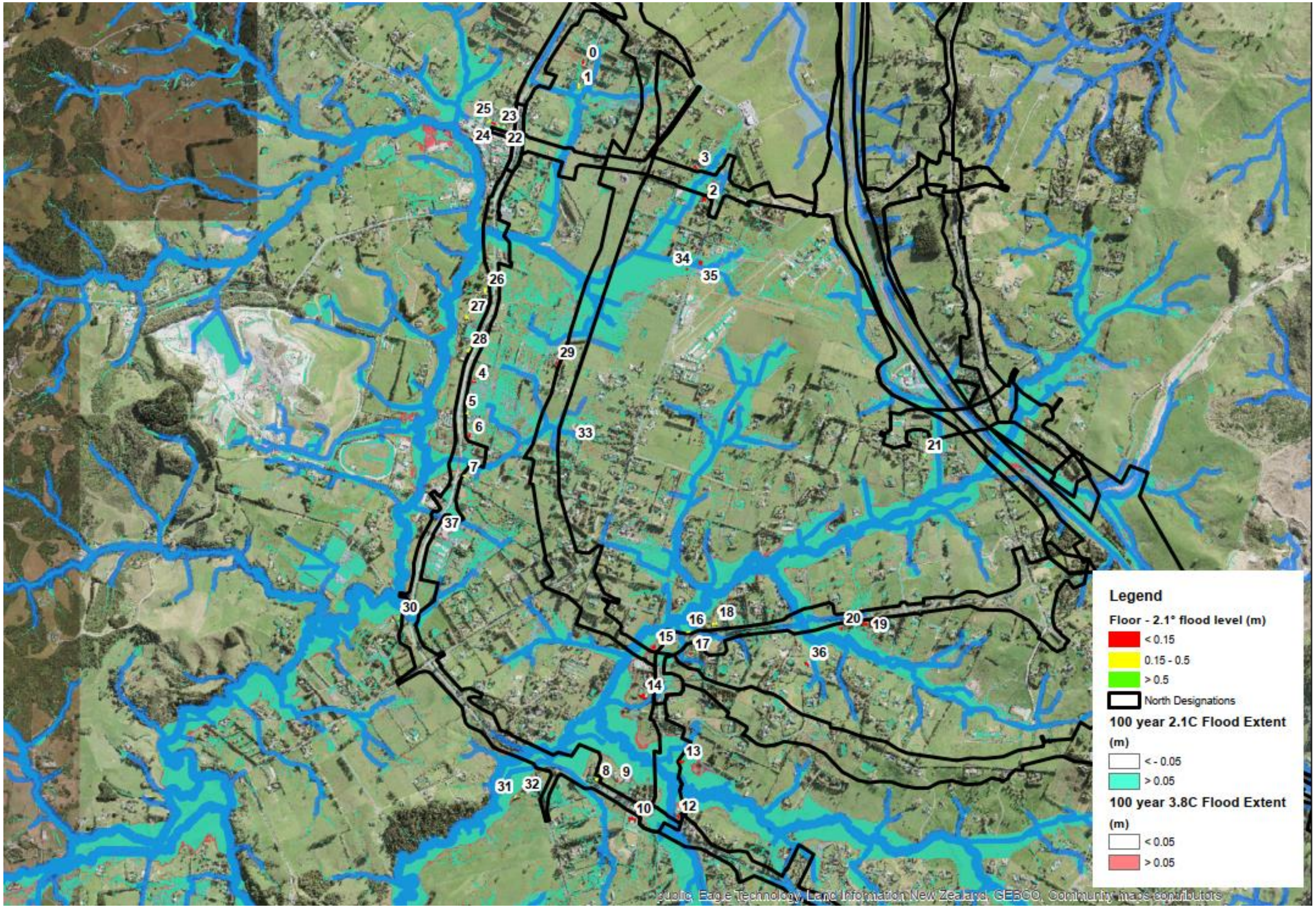
ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
3	11 Haigh Access Road	15.16	15.36	14.72	14.72
4	20 Haigh Access Road	14.05	14.05	12.33	12.34
10	1401 East Coast Road	10.52	10.62	5.07	5.32
11	1451 East Coast Road	20.17	20.57	20.28	20.28
12	1425 East Coast Road	21.81	22.21	21.34	21.34
13	1469 East Coast Road	24.31	24.86	24.21	24.21
14	1473 East Coast Road	24.3	24.85	24.15	24.16
15	1513 East Coast Road	22.74	23.04	22.73	22.73

Dairy Flat catchment

Street	Number	Estimated existing by site assessment			Zoning			Existing flooding					
Street	Number	Freeboard (m)	Ground level (from LiDAR)	Floor level (FL)	Zoning	Property within or near AC Geomaps 2023 floodplain	Existing floor within or near AC Geomaps 2023	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level	Floor - 2.1° flood level (m)	Floor flooding	Floor - 3.8° flood level (m)	3.8° Floor flooding
Lascelles Drive	28	0	58.58	58.58	Future Urban Zone	Yes	No	58.61	58.63	-0.03	Yes	-0.05	Yes
	38	0.5	55.93	56.43	Future Urban Zone	Yes	Yes	56.2	56.25	0.23	No	0.18	No
Postman Road	177	0.1	53.14	53.24	Future Urban Zone	Yes	Yes	53.29	53.32	-0.05	Yes	-0.08	Yes
	293	0.15	55.98	56.13	Future Urban Zone	Yes	Yes	56.23	56.19	-0.1	Yes	-0.06	Yes
	300	0	56.79	56.79	Special Purpose - Airports and Airfields Zone	Yes	Yes	57.09	57.14	-0.3	Yes	-0.35	Yes
	325	0	59.48	59.48	Future Urban Zone	Yes	Yes	59.46	59.47	0.02	No	0.01	No
	343	0	60.43	60.43	Future Urban Zone	Yes	No	60.45	60.46	-0.02	Yes	-0.03	Yes
Dairy Flat Highway	1005A	0	38.44	38.44	Future Urban Zone	No	No	38.43	38.44	0.01	No	0	No
	1016	0.2	38.11	38.31	Future Urban Zone	Yes	No	38.18	38.18	0.13	No	0.13	No
	1032	0.4	37.15	37.55	Future Urban Zone	Yes	No	37.2	37.21	0.35	No	0.34	No
	1220	0	49.97	49.97	Future Urban Zone	Yes	Yes	49.99	49.99	-0.02	Yes	-0.02	Yes
	1256	0.2	50.27	50.47	Future Urban Zone	Yes	No	50.26	50.26	0.21	No	0.21	No
	1284	0.15	52.14	52.29	Future Urban Zone	No	No	52.15	52.16	0.14	No	0.13	No
	1286	0.4	52.76	53.16	Future Urban Zone	Yes	Yes	52.88	52.9	0.28	No	0.26	No
	1306	0	53.89	53.89	Future Urban Zone	Yes	Yes	53.9	53.9	-0.01	Yes	-0.01	Yes
	1320	0.3	56.49	56.79	Future Urban Zone	Yes	Yes	56.84	56.5	-0.05	Yes	0.29	No
	1321	0.3	54.65	54.95	Rural - Mixed Rural Zone	Yes	No	54.7	54.71	0.25	No	0.24	No
	1327	0.2	55.7	55.9	Rural - Mixed Rural Zone	Yes	No	55.45	55.46	0.45	No	0.44	No
	1355	0.25	56.88	57.13	Rural - Mixed Rural Zone	Yes	Yes	56.95	56.97	0.18	No	0.16	No

Dairy Flat catchment

Street	Number	Estimated existing by site assessment: Freeboard (m)	Ground level (from LiDAR)	Floor level (FL)	Zoning	Property within or near AC Geomaps 2023 floodplain	Existing floor within or near AC Geomaps 2023	Existing flooding: Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level	Floor - 2.1° flood level (m)	Floor flooding	Floor - 3.8° flood level (m)	3.8° Floor flooding
Bawden Road	9	0.15	39.61	39.76	Future Urban Zone	Yes	No	39.67	39.67	0.09	No	0.09	No
	38	0	35.59	35.59	Future Urban Zone	Yes	Yes	35.8	36.1	-0.21	Yes	-0.51	Yes
	77	0	37.7	37.7	Future Urban Zone	Yes	Yes	37.73	37.74	-0.03	Yes	-0.04	Yes
	99	0	36.22	36.22	Future Urban Zone	Yes	Yes	36.26	36.4	-0.04	Yes	-0.18	Yes
	119	0.25	36.97	37.22	Future Urban Zone	Yes	Yes	36.93	37.22	0.29	No	0	No
	120	0.15	38.98	39.13	Future Urban Zone	Yes	No	39.02	39.02	0.11	No	0.11	No
	135	0.2	40.07	40.27	Future Urban Zone	Yes	No	40.1	40.1	0.17	No	0.17	No
	200b	0	41.32	41.32	Future Urban Zone	Yes	No	41.46	41.48	-0.14	Yes	-0.16	Yes
	216	0	41.68	41.68	Future Urban Zone	Yes	Yes	42.03	42.04	-0.35	Yes	-0.36	Yes
	218	0	40.74	40.74	Future Urban Zone	Yes	Yes	40.81	40.82	-0.07	Yes	-0.08	Yes
Top Road	127	0.3	45.88	46.18	Future Urban Zone	Yes	No	45.67	45.68	0.51	No	0.5	No
Kahikatea Flat Road	10	0.6	62.91	63.51	Business - Light Industry Zone	Yes	Yes	63.08	63.11	0.43	No	0.4	No
	12	0.3	63.15	63.45	Business - Light Industry Zone	Yes	Yes	63.07	63.09	0.38	No	0.36	No
	14	0	62.84	62.84	Business - Light Industry Zone	Yes	Yes	62.97	62.98	-0.13	Yes	-0.14	Yes
	16	0.35	62.9	63.25	Business - Light Industry Zone	Yes	Yes	62.87	62.88	0.38	No	0.37	No
Richards Road	1	0	45.63	45.63	Future Urban Zone	Yes	Yes	44.4	44.69	1.23	No	0.94	No
Green Road	20	0.3	34.67	34.97	Future Urban Zone	Yes	Yes	34.39	34.4	0.58	No	0.57	No
	20a	0.3	33.78	34.08	Future Urban Zone	Yes	Yes	33.84	33.85	0.24	No	0.23	No


Legend
Floor - 2.1° flood level (m)
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North Designations
100 year 2.1C Flood Extent (m)
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> 0.05
100 year 3.8C Flood Extent (m)
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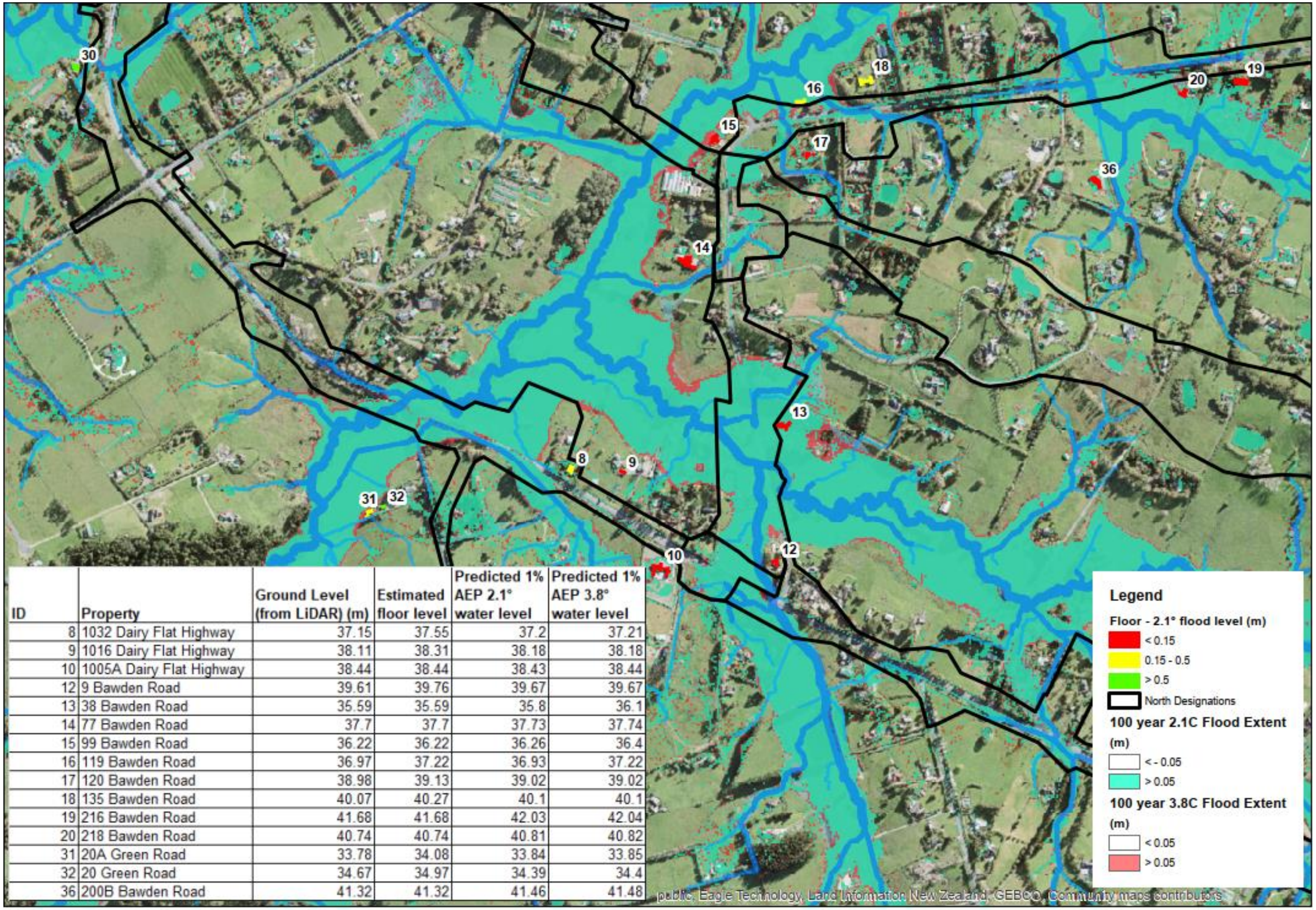
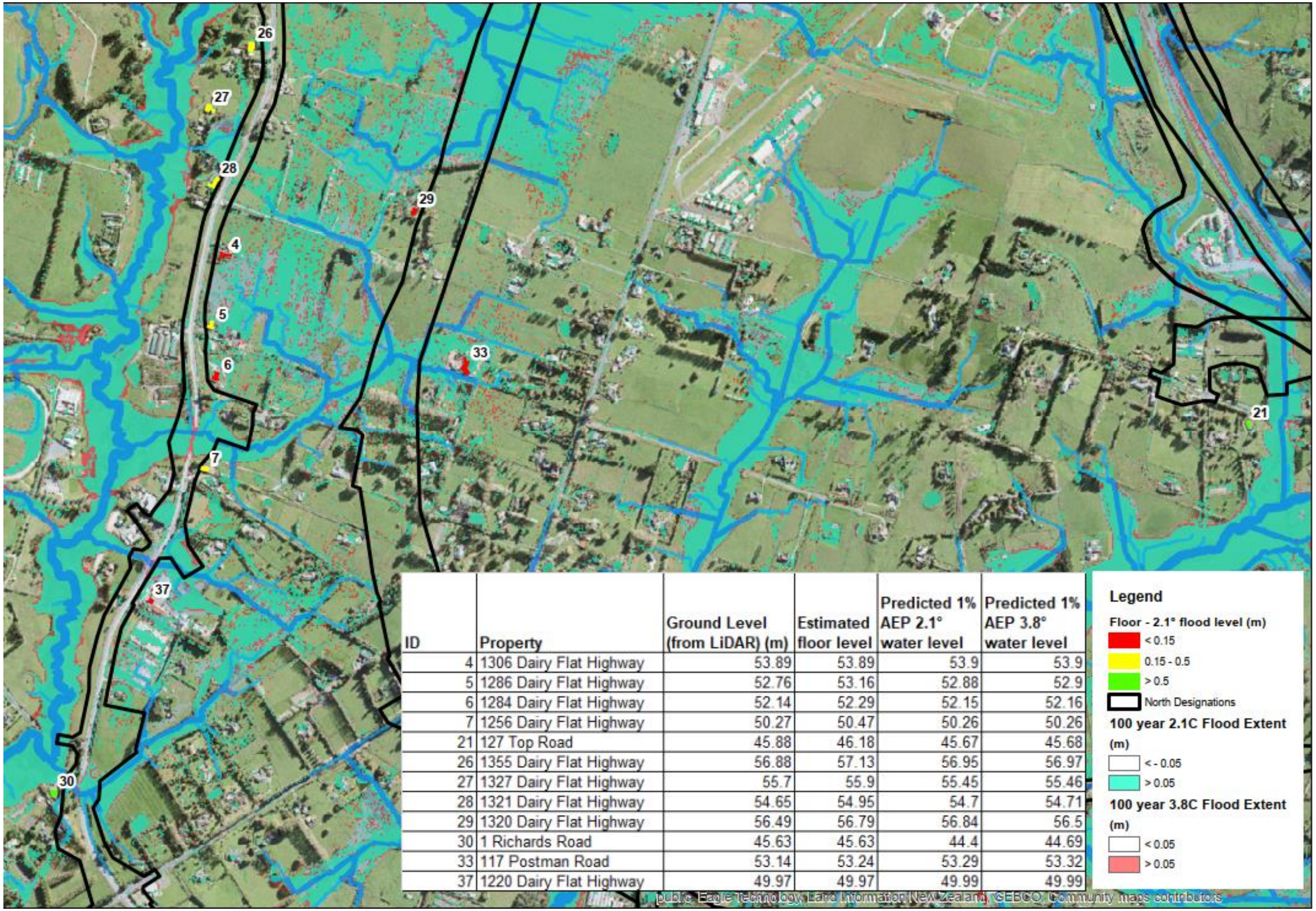
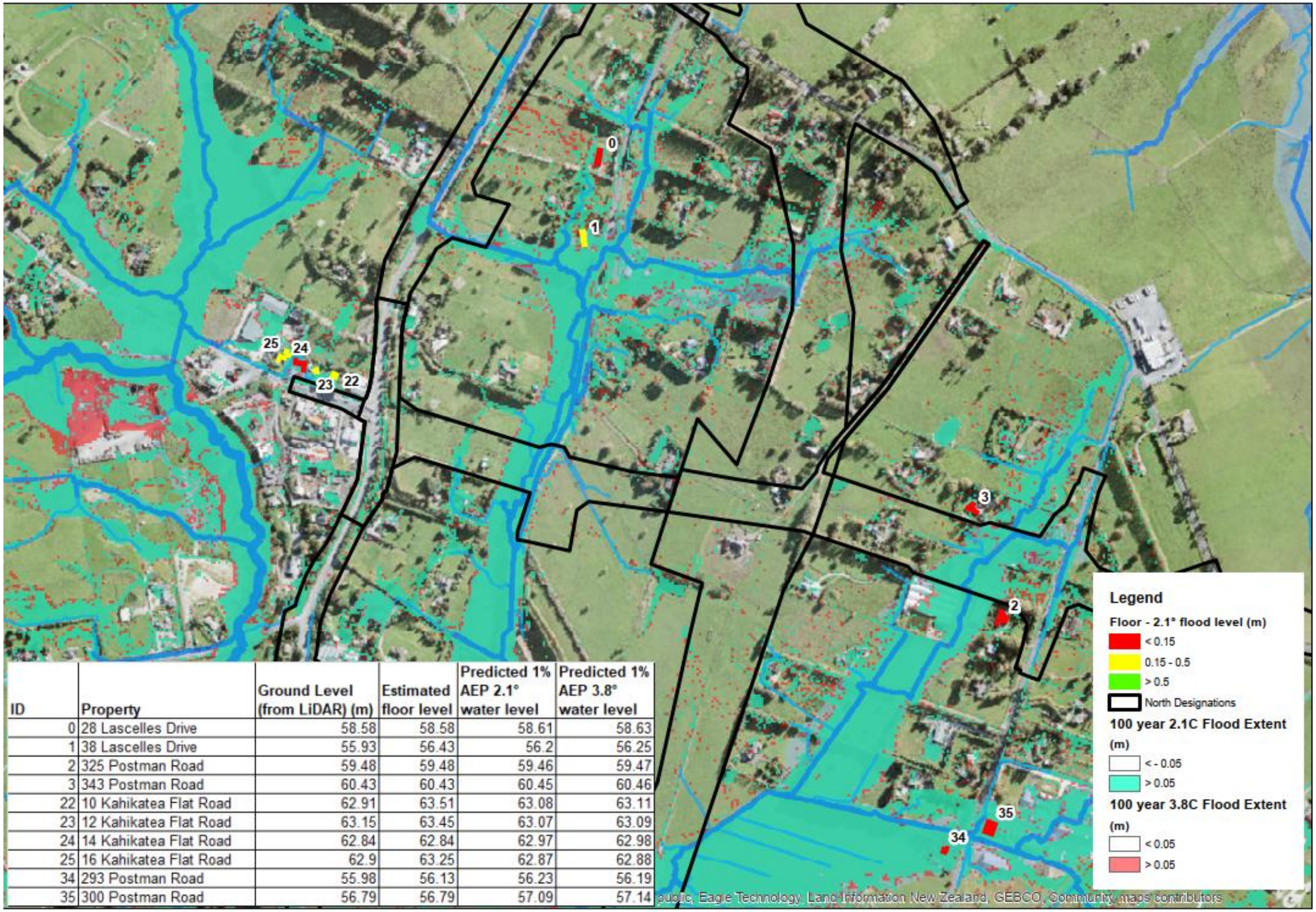
Esri, Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
8	1032 Dairy Flat Highway	37.15	37.55	37.2	37.21
9	1016 Dairy Flat Highway	38.11	38.31	38.18	38.18
10	1005A Dairy Flat Highway	38.44	38.44	38.43	38.44
12	9 Bawden Road	39.61	39.76	39.67	39.67
13	38 Bawden Road	35.59	35.59	35.8	36.1
14	77 Bawden Road	37.7	37.7	37.73	37.74
15	99 Bawden Road	36.22	36.22	36.26	36.4
16	119 Bawden Road	36.97	37.22	36.93	37.22
17	120 Bawden Road	38.98	39.13	39.02	39.02
18	135 Bawden Road	40.07	40.27	40.1	40.1
19	216 Bawden Road	41.68	41.68	42.03	42.04
20	218 Bawden Road	40.74	40.74	40.81	40.82
31	20A Green Road	33.78	34.08	33.84	33.85
32	20 Green Road	34.67	34.97	34.39	34.4
36	200B Bawden Road	41.32	41.32	41.46	41.48



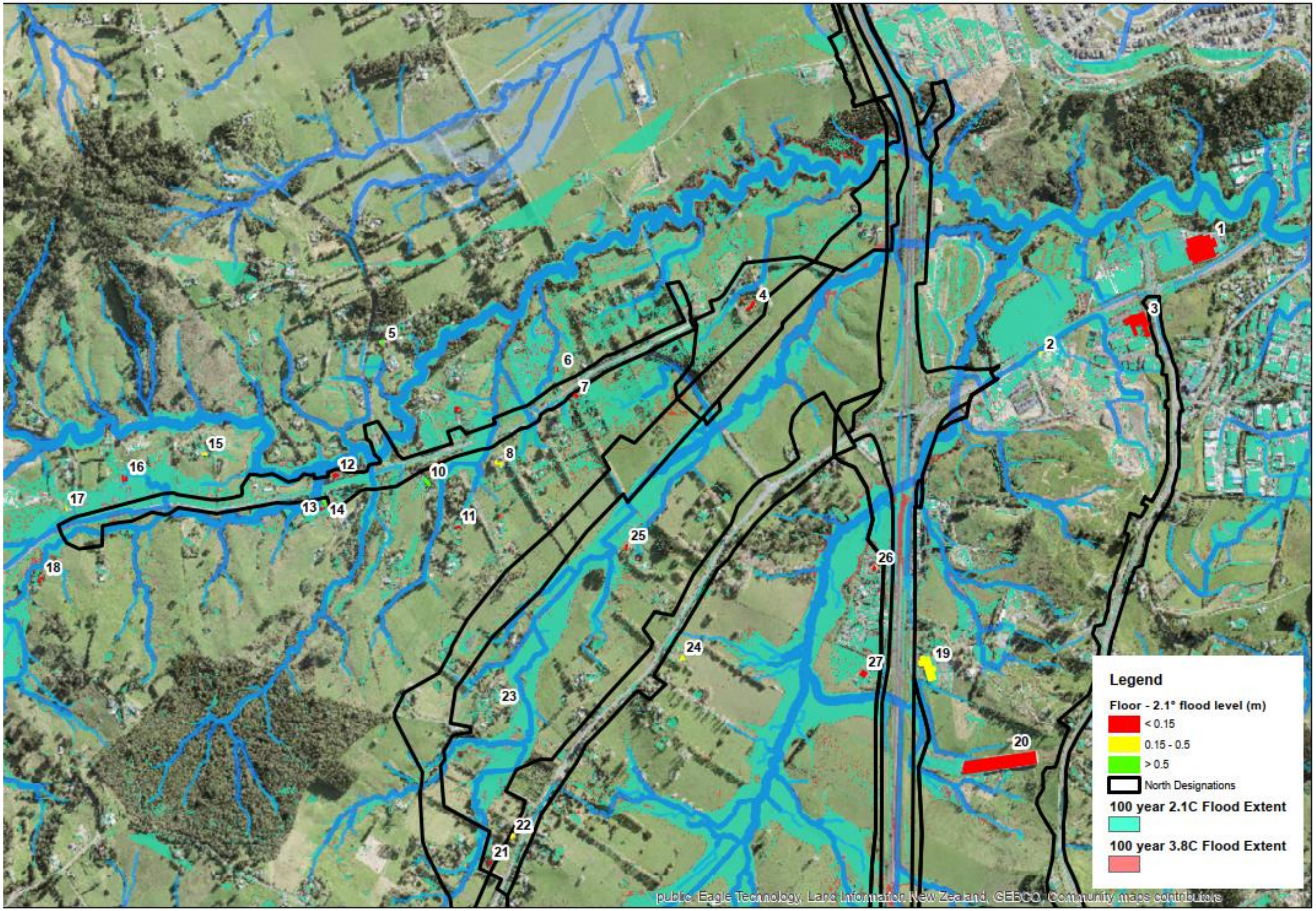
ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
4	1306 Dairy Flat Highway	53.89	53.89	53.9	53.9
5	1286 Dairy Flat Highway	52.76	53.16	52.88	52.9
6	1284 Dairy Flat Highway	52.14	52.29	52.15	52.16
7	1256 Dairy Flat Highway	50.27	50.47	50.26	50.26
21	127 Top Road	45.88	46.18	45.67	45.68
26	1355 Dairy Flat Highway	56.88	57.13	56.95	56.97
27	1327 Dairy Flat Highway	55.7	55.9	55.45	55.46
28	1321 Dairy Flat Highway	54.65	54.95	54.7	54.71
29	1320 Dairy Flat Highway	56.49	56.79	56.84	56.5
30	1 Richards Road	45.63	45.63	44.4	44.69
33	117 Postman Road	53.14	53.24	53.29	53.32
37	1220 Dairy Flat Highway	49.97	49.97	49.99	49.99



ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
0	28 Lascelles Drive	58.58	58.58	58.61	58.63
1	38 Lascelles Drive	55.93	56.43	56.2	56.25
2	325 Postman Road	59.48	59.48	59.46	59.47
3	343 Postman Road	60.43	60.43	60.45	60.46
22	10 Kahikatea Flat Road	62.91	63.51	63.08	63.11
23	12 Kahikatea Flat Road	63.15	63.45	63.07	63.09
24	14 Kahikatea Flat Road	62.84	62.84	62.97	62.98
25	16 Kahikatea Flat Road	62.9	63.25	62.87	62.88
34	293 Postman Road	55.98	56.13	56.23	56.19
35	300 Postman Road	56.79	56.79	57.09	57.14

Silverdale South - Pine Valley

		Estimated by site assessment			Existing flooding							
Street	Number	Estimated freeboard (m)	Ground level (from LiDAR)	Est. floor level	Property within or near AC Geomaps 2023 floodplain	Existing floor within or near AC Geomaps 2023 floodplain	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level	Floor - 2.1° flood level (m)	Floor flooding	Floor - 3.8° flood level (m)	3.8° Floor flooding
Hibiscus Coast Highway	3	0.15	20.74	20.89	Yes	Yes	20.69	20.69	0.20	No	0.20	No
	17	0	24.32	24.32	Yes	Yes	24.34	24.35	-0.02	Yes	-0.03	Yes
	20	0	17.91	17.91	Yes	Yes	17.95	17.95	-0.04	Yes	-0.04	Yes
Old Pine Valley Road	36	0.1	27.52	27.62	Yes	No	27.53	27.53	0.09	No	0.09	No
Young Access Road	26	2	35.6	37.6	Yes	No	35.24	35.25	2.36	No	2.35	No
Pine Valley Road	158	0	23.76	23.76	Yes	No	23.67	23.7	0.09	No	0.06	No
	165	0	28.67	28.67	Yes	No	28.68	28.69	-0.01	Yes	-0.02	Yes
	195	0.2	31.19	31.39	Yes	No	30.97	30.98	0.42	No	0.41	No
	202	0	25.6	25.6	Yes	No	25.55	25.56	0.05	No	0.04	No
	223	0.3	31.72	32.02	Yes	No	31.28	31.28	0.74	No	0.74	No
	225	0	33.22	33.22	Yes	No	33.24	33.26	-0.02	Yes	-0.04	Yes
	240	0.15	27.66	27.81	Yes	Yes	27.8	27.8	0.01	No	0.01	No
	257A	0	24.69	24.69	Yes	Yes	27.24	27.39	-2.55	Yes	-2.7	Yes
	257	0.7	27.76	28.46	Yes	Yes	27.37	27.45	1.09	No	1.01	No
	302	0.2	35.63	35.83	Yes	No	35.41	35.42	0.42	No	0.41	No
	320	0	31.6	31.6	Yes	Yes	31.8	31.82	-0.2	Yes	-0.22	Yes
	346	0.3	33.34	33.64	Yes	No	33.38	33.43	0.26	No	0.21	No
	357	0.15	35.27	35.42	Yes	Yes	35.47	35.48	-0.05	Yes	-0.06	Yes
Small Road	87	0	25.53	25.53	Yes	No	25.21	25.22	0.32	No	0.31	No
	91	0	30.63	30.63	Yes	Yes	30.55	30.56	0.08	No	0.07	No
Dairy Flat Highway	1561	0	48.03	48.03	Yes	No	48.1	48.11	-0.07	Yes	-0.08	Yes
	1579	0	52.49	52.49	Yes	No	52	52.02	0.49	No	0.47	No
	1609	0.3	39.03	39.33	Yes	No	38.85	38.87	0.48	No	0.46	No
	1660	0.3	48.23	48.53	Yes	No	48.29	48.29	0.24	No	0.24	No
	1669	0.15	26.55	26.7	Yes	No	26.59	26.6	0.11	No	0.1	No
	1744	0	20.91	20.91	Yes	No	20.81	20.81	0.1	No	0.1	No
	1748a	0	21.82	21.82	Yes	Yes	21.74	21.74	0.08	No	0.08	No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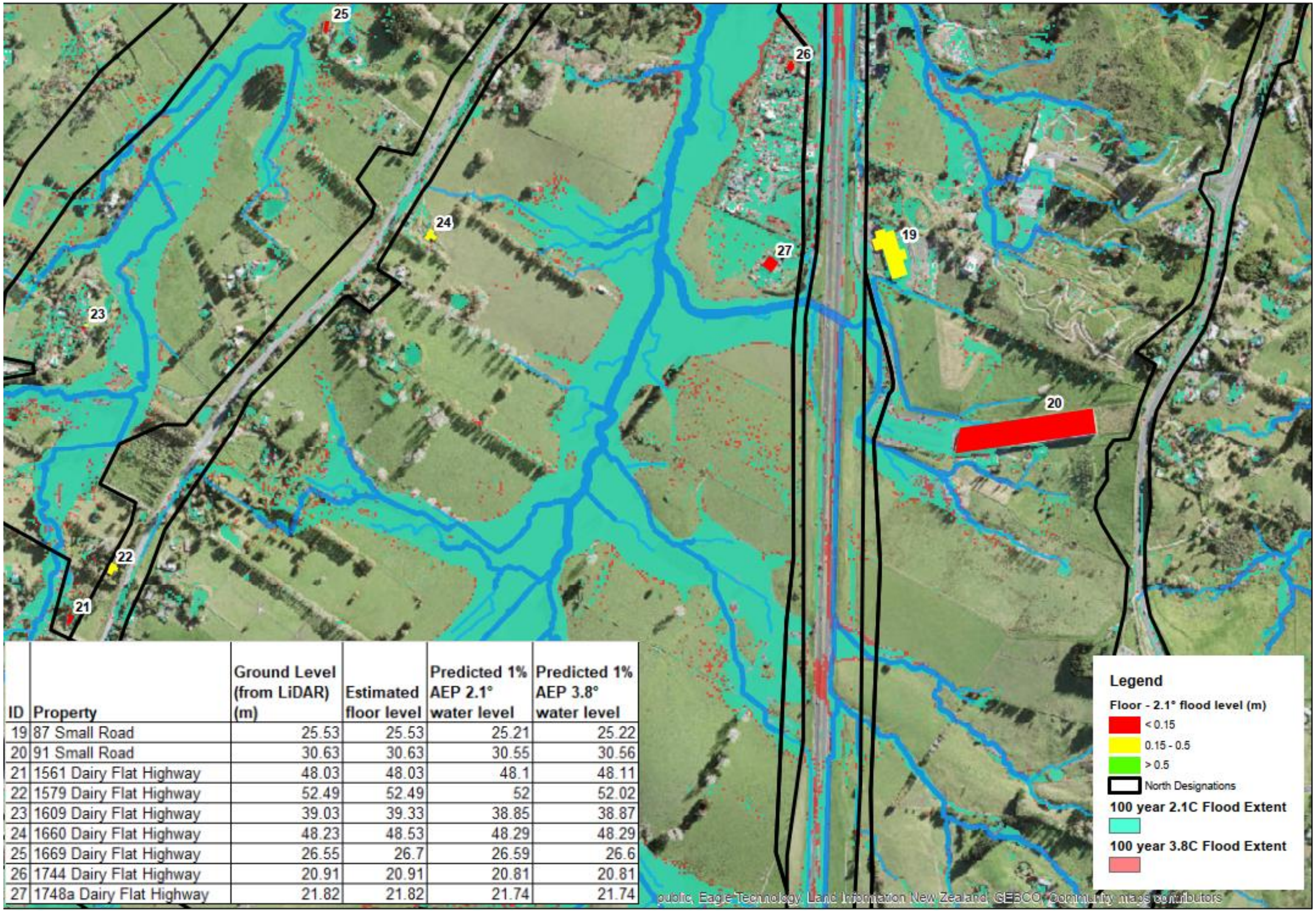
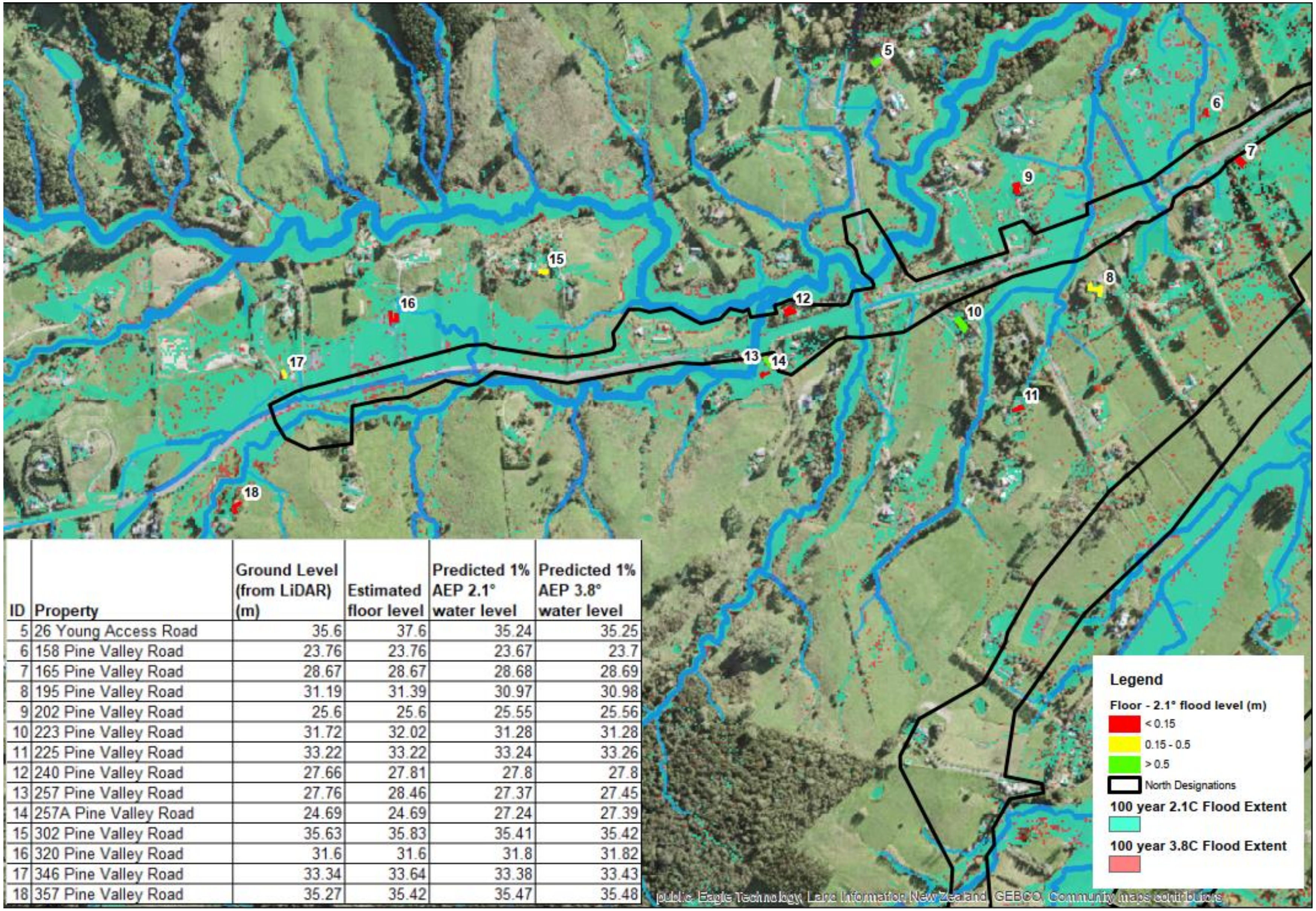
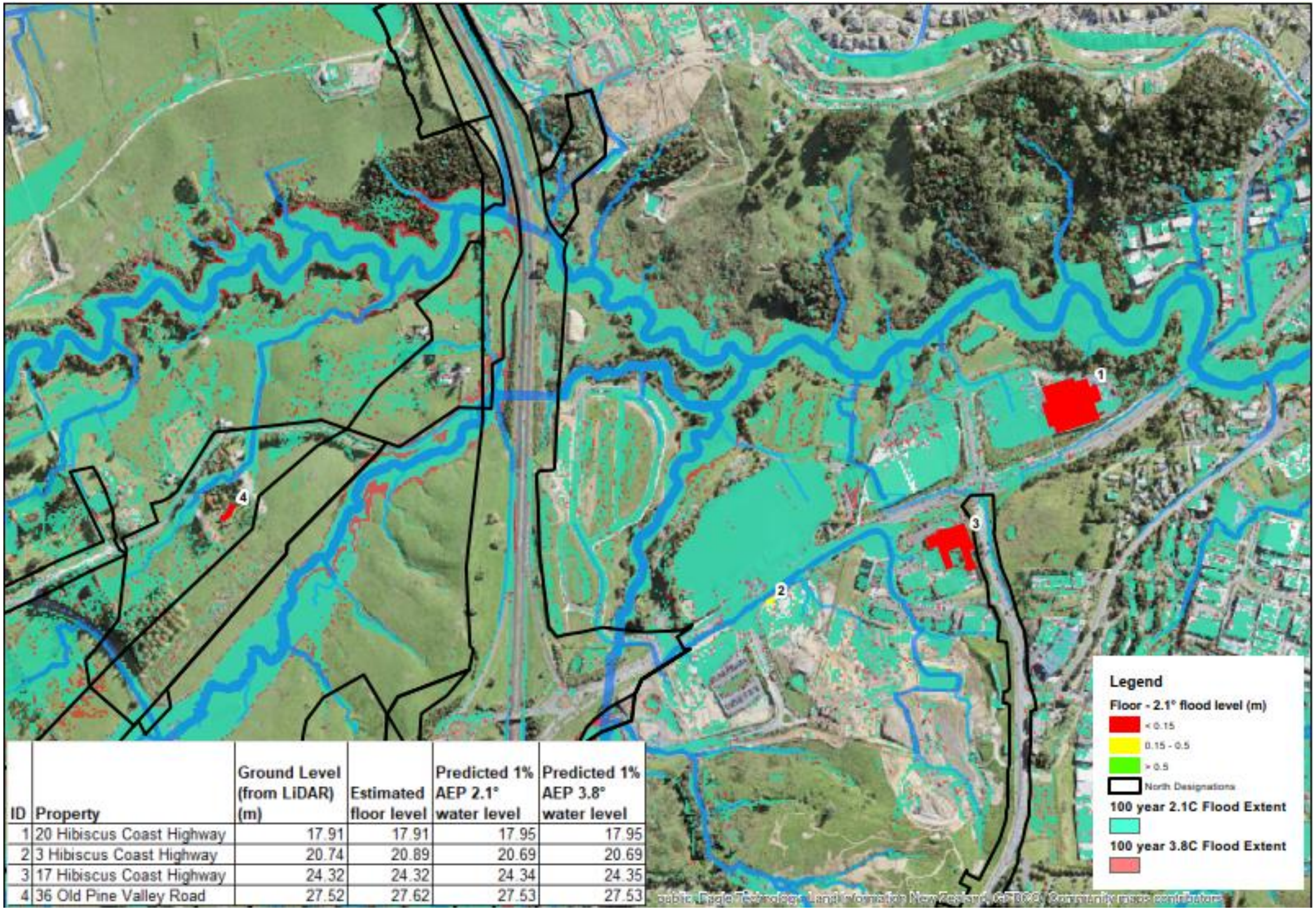
Legend
Floor - 2.1° flood level (m)
< 0.15
0.15 - 0.5
> 0.5
North Designations
100 year 2.1C Flood Extent
100 year 3.8C Flood Extent
public, Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors



ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
19	87 Small Road	25.53	25.53	25.21	25.22
20	91 Small Road	30.63	30.63	30.55	30.56
21	1561 Dairy Flat Highway	48.03	48.03	48.1	48.11
22	1579 Dairy Flat Highway	52.49	52.49	52	52.02
23	1609 Dairy Flat Highway	39.03	39.33	38.85	38.87
24	1660 Dairy Flat Highway	48.23	48.53	48.29	48.29
25	1669 Dairy Flat Highway	26.55	26.7	26.59	26.6
26	1744 Dairy Flat Highway	20.91	20.91	20.81	20.81
27	1748a Dairy Flat Highway	21.82	21.82	21.74	21.74



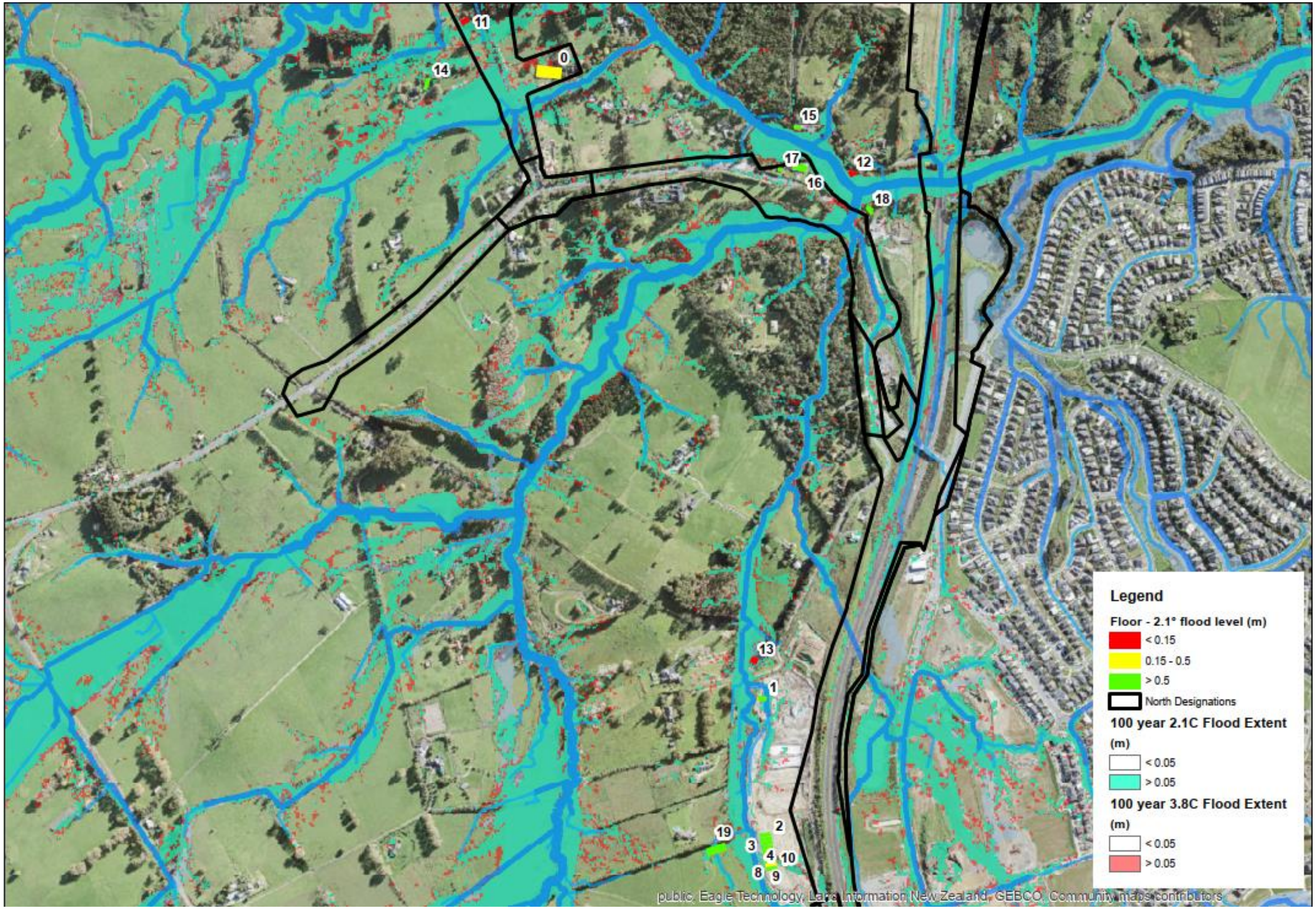
ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
5	26 Young Access Road	35.6	37.6	35.24	35.25
6	158 Pine Valley Road	23.76	23.76	23.67	23.7
7	165 Pine Valley Road	28.67	28.67	28.68	28.69
8	195 Pine Valley Road	31.19	31.39	30.97	30.98
9	202 Pine Valley Road	25.6	25.6	25.55	25.56
10	223 Pine Valley Road	31.72	32.02	31.28	31.28
11	225 Pine Valley Road	33.22	33.22	33.24	33.26
12	240 Pine Valley Road	27.66	27.81	27.8	27.8
13	257 Pine Valley Road	27.76	28.46	27.37	27.45
14	257A Pine Valley Road	24.69	24.69	27.24	27.39
15	302 Pine Valley Road	35.63	35.83	35.41	35.42
16	320 Pine Valley Road	31.6	31.6	31.8	31.82
17	346 Pine Valley Road	33.34	33.64	33.38	33.43
18	357 Pine Valley Road	35.27	35.42	35.47	35.48



ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
1	20 Hibiscus Coast Highway	17.91	17.91	17.95	17.95
2	3 Hibiscus Coast Highway	20.74	20.89	20.69	20.69
3	17 Hibiscus Coast Highway	24.32	24.32	24.34	24.35
4	36 Old Pine Valley Road	27.52	27.62	27.53	27.53

Orewa River West

Street	Number	Estimated by site assessment			Existing flooding							
		Estimated freeboard (m)	Ground level (from LiDAR)	Est. floor level	Property within or near AC Geomaps 2023 floodplain	Existing floor within or near AC Geomaps 2023 floodplain	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level	Floor - 2.1° flood level (m)	2.1 ° Floor flooding	Floor - 3.8° flood level (m)	3.8° Floor flooding
Upper Orewa Road	24	0	13.96	13.96	Yes	Yes	13.55	13.66	0.41	No	0.30	No
	29	0.2	16.1	16.3	Yes	No	15.7	15.72	0.60	No	0.58	No
	37	0	14.79	14.79	Yes	No	14.86	14.88	-0.07	Yes	-0.09	Yes
Kowhai Rd	20	0	12.23	12.23	Yes	Yes	5.68	6.33	6.55	No	5.90	No
	42	0	5.04	5.04	Yes	Yes	5.45	6.08	-0.41	Yes	-1.04	Yes
Wainui Road	348	0	8.6	8.6	Yes	No	5.6	6.35	3.00	No	2.25	No
	348A	0.1	9.19	9.29	Yes	No	5.71	6.36	3.58	No	2.93	No
	330	0	8.13	8.13	Yes	No	5.44	6.05	2.69	No	2.08	No
Endsley Rise	15	0	18.17	18.17	Yes	No	18.05	18.15	0.12	No	0.02	No
Archibald Drive	2	0	25.01	25.01	Yes	Yes	23.68	23.74	1.33	No	1.27	No
Ahutoetoe Road	16	0.1	19.83	19.93	Yes	Yes	19.16	19.24	0.77	No	0.69	No
	45	0.1	25.12	25.22	Yes	Yes	23.6	23.65	1.62	No	1.57	No
	47	0.1	25.11	25.21	Yes	Yes	23.63	23.69	1.58	No	1.52	No
	49	0.1	25.16	25.26	Yes	Yes	23.66	23.72	1.6	No	1.54	No
	51	0.1	24.89	24.99	Yes	Yes	23.67	23.73	1.32	No	1.26	No
	53	0.1	24.81	24.91	Yes	Yes	23.72	23.78	1.19	No	1.13	No
	55	0.1	23.8	23.9	Yes	Yes	23.72	23.79	0.18	No	0.11	No
	57	0.1	24.31	24.41	Yes	Yes	23.75	23.81	0.66	No	0.6	No
	59	0.1	23.92	24.02	Yes	Yes	23.8	23.85	0.22	No	0.17	No
	61	0.1	24.66	24.76	Yes	No	24.06	24.09	0.7	No	0.67	No



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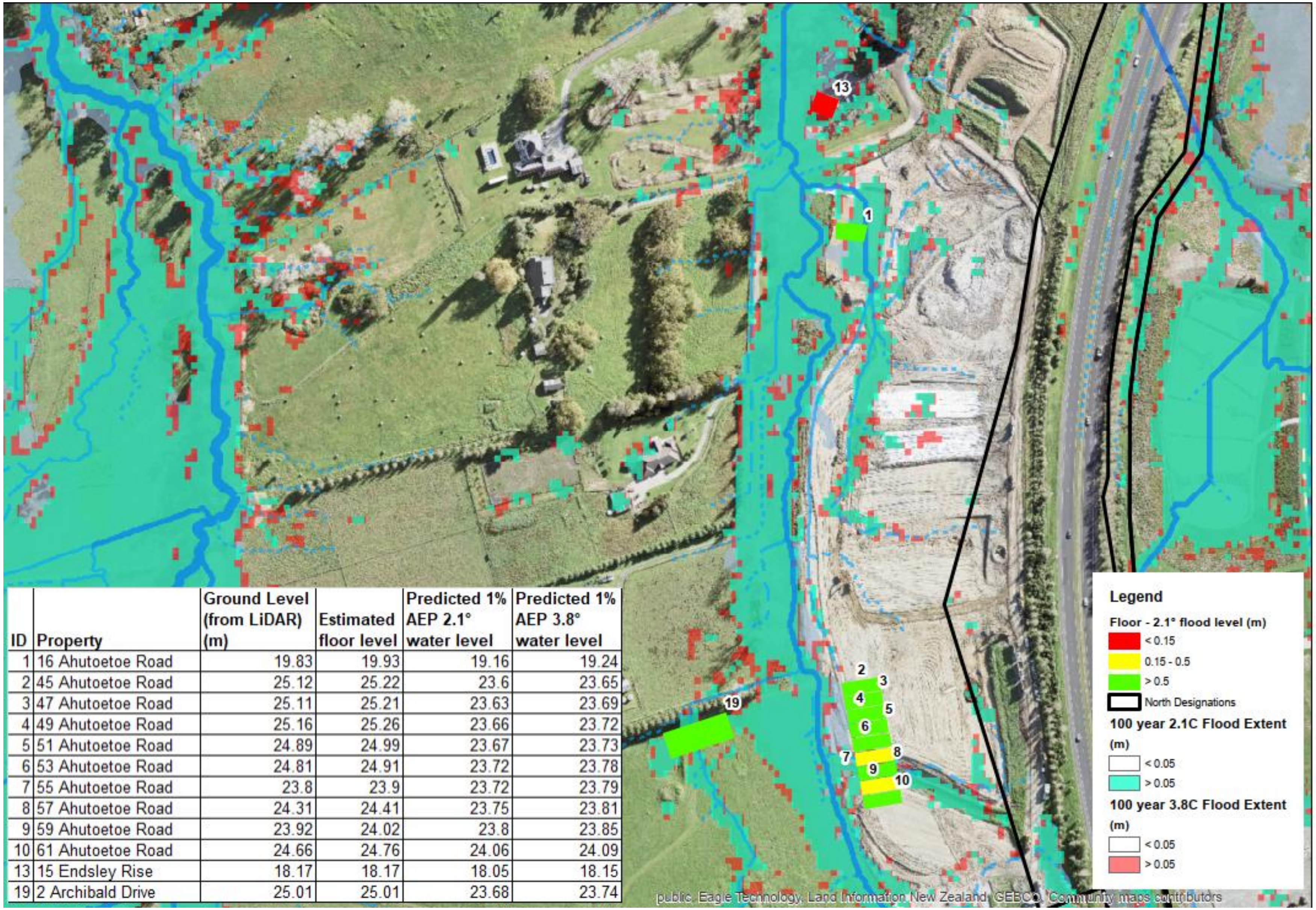
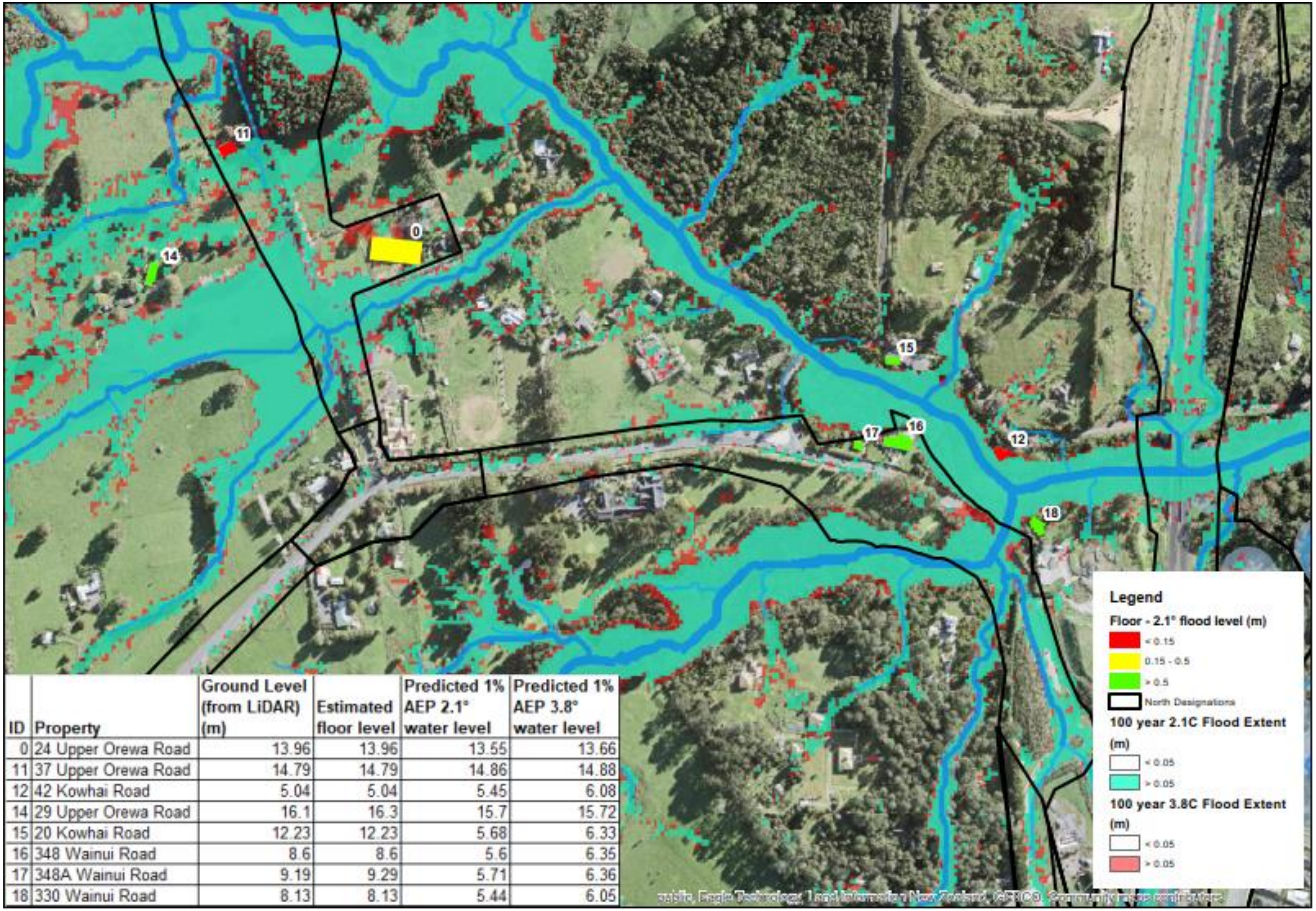


ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
1	16 Ahutoetoe Road	19.83	19.93	19.16	19.24
2	45 Ahutoetoe Road	25.12	25.22	23.6	23.65
3	47 Ahutoetoe Road	25.11	25.21	23.63	23.69
4	49 Ahutoetoe Road	25.16	25.26	23.66	23.72
5	51 Ahutoetoe Road	24.89	24.99	23.67	23.73
6	53 Ahutoetoe Road	24.81	24.91	23.72	23.78
7	55 Ahutoetoe Road	23.8	23.9	23.72	23.79
8	57 Ahutoetoe Road	24.31	24.41	23.75	23.81
9	59 Ahutoetoe Road	23.92	24.02	23.8	23.85
10	61 Ahutoetoe Road	24.66	24.76	24.06	24.09
13	15 Endsley Rise	18.17	18.17	18.05	18.15
19	2 Archibald Drive	25.01	25.01	23.68	23.74



ID	Property	Ground Level (from LiDAR) (m)	Estimated floor level	Predicted 1% AEP 2.1° water level	Predicted 1% AEP 3.8° water level
0	24 Upper Orewa Road	13.96	13.96	13.55	13.66
11	37 Upper Orewa Road	14.79	14.79	14.86	14.88
12	42 Kowhai Road	5.04	5.04	5.45	6.08
14	29 Upper Orewa Road	16.1	16.3	15.7	15.72
15	20 Kowhai Road	12.23	12.23	5.68	6.33
16	348 Wainui Road	8.6	8.6	5.6	6.35
17	348A Wainui Road	9.19	9.29	5.71	6.36
18	330 Wainui Road	8.13	8.13	5.44	6.05

Appendix 2 Pine Valley Design Flood modelling – updated 18 January 2024

Technical Note

Date Prepared: 19/01/2024

Prepared by: Tom Newman

Silverdale South - Pine Valley Culvert Design Flood Modelling

Purpose

This technical note has been prepared to provide details of additional design scenario flood modelling carried out using the Silverdale South – Pine Valley flood model detailed in the technical note dated 31/08/2023[1].

The post Project scenario detailed in this memo assessed the concept of adding culverts through the road formation to reduce flooding impacts back to the pre-Project predicted 1% AEP 2.1°climate change increase scenario.

[1] Silverdale South - Pine Valley Design Flood Modelling, 31/08/2023

Document Status

Responsibility	Name
Author	Tom Newman
Reviewer	Mike Summerhays, Roger Seyb
Approver	Kathleen Bunting

Revision Status

Version	Date	Reason for Issue
1.0	19/01/2024	

Table of Contents

Figures

1. Introduction

This technical note provides details of the flood modelling undertaken post lodgement of the North Projects NoRs to assess culverts through the post Project concept design for NoR 7 – Upgrade to Pine Valley Road.

1.1 Flood Model Setup

The Silverdale South – Pine Valley post Project Rev B flood model was used to assess the impact of additional culverts through the Pine Valley Road design.

Figure 1 shows the Post-Project – Pre-Project water level without the addition of culverts. The areas circled in blue identify areas where the water level increased.

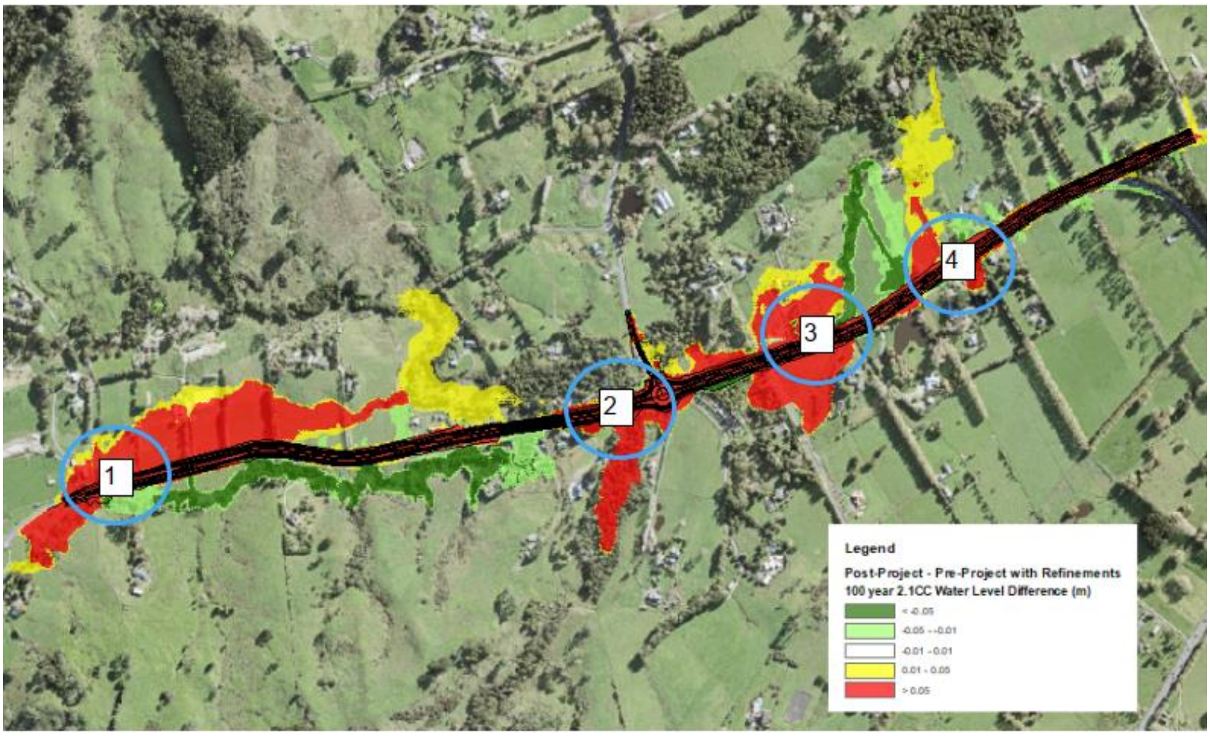


Figure 1. Predicted post Pine Valley Road upgrade future 100yr 2.1° climate change water level difference and location plan of culvert amendments.

Plan area 1 on the western end of Pine Valley Road was modelled with terrain openings through the road design to represent culverts and allow overland flow to follow closer to its Pre-Project flow path.

Culvert Master was used to estimate the required pipe diameters to maintain the Pre-Project water levels in plan areas 2-4.

Plan area 2 was previously modelled with a 1200mm culvert in the Pre-Project model. This 1200mm culvert was increased to a 2100mm culvert in the post Project with culverts model.

An existing 375mm culvert at plan area 3 was not modelled in the Pre-Project model due to the small size. In the Post-Project with culverts model, a 2100mm culvert was added.

An existing 600mm culvert at plan area 4 was not modelled in the pre-Project model due to its samlet diameter.

Culvert Master identified that the 600mm culvert would be sufficient to maintain the Pre-Project water levels. Two 600mm culverts were modelled as this would reduce risk of pipe blockages occurring.

2. Results

Figure 2 shows the location plan and overview of results with the addition of the culverts.

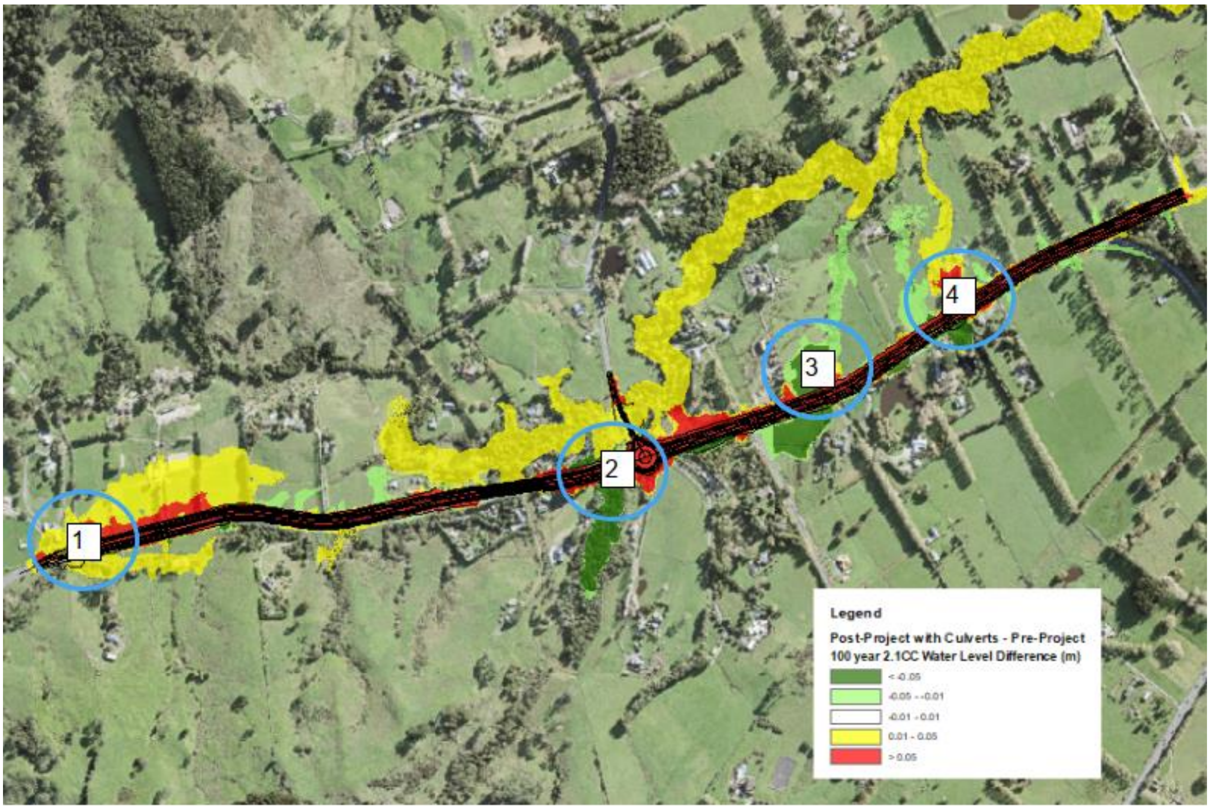


Figure 2. Predicted post Pine Valley Road with amended culverts 100yr 2.1° climate change water level difference and location plan of areas discussed in detail.

2.1 Location Plan Area 1

Figure 3 shows location plan area 1 where the increase in water level post Project has decreased from 160mm in some areas without the terrain openings down to 60mm with the terrain openings. With further refinements, the existing overland flow paths can be accommodated within the culverts to maintain existing water levels.

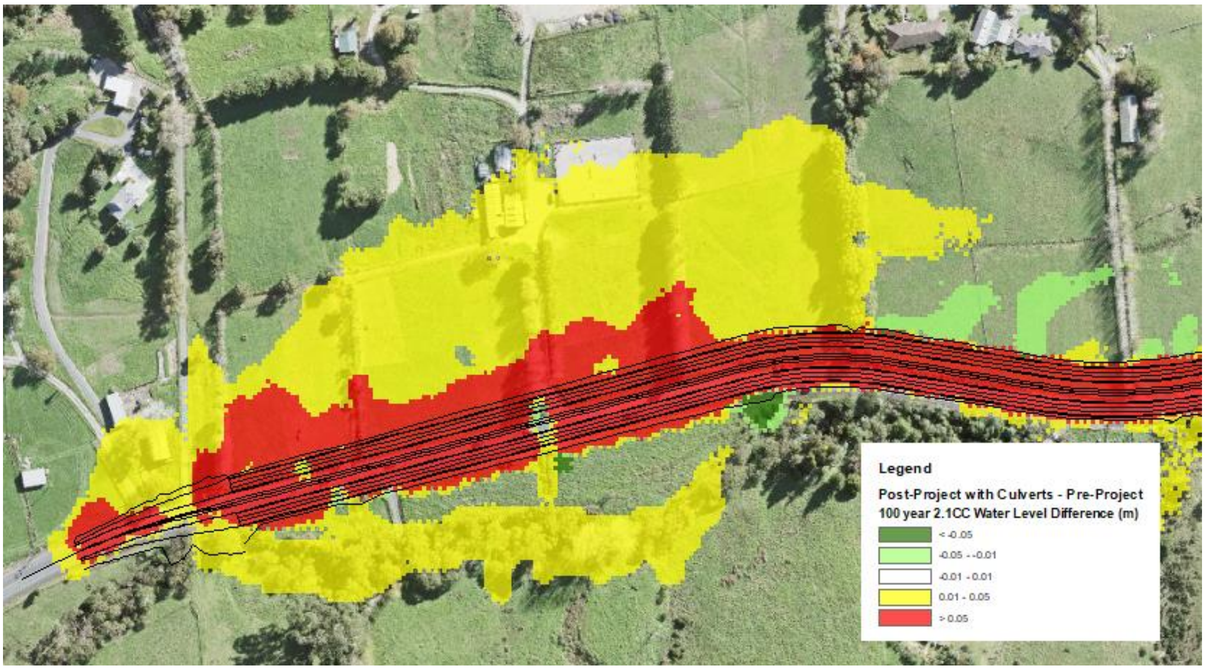


Figure 3. Area 1 location showing results with terrain openings to represent culverts.

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SUPPORTING GROWTH

2.2 Location Plan Area 2

Figure 5. Location Plan Area 2 showing the post Project flood results with the addition of a 2100mm culvert.

Error! Reference source not found. shows the results with the existing 1200mm culvert size increased to 2100mm. This shows that the water level upstream has decreased compared to Pre-Project levels and as such the culvert could be reduced in size to prevent a higher peak flow to the downstream side of Pine Valley Road.

Figure 5. Location Plan Area 2 showing the post Project flood results with the addition of a 2100mm culvert.

2.3 Location Plan Area 3

A 2100mm culvert was added at location plan area 3 shown in Figure 6. This shows that the water level is lower in the post Project scenario both upstream and downstream of the culvert. Road drainage is not modelled, and as such flow within the road design remains on the road and flows to the west of the culvert location and into the stream.

With the addition of the road drainage network and diameter optimisation of the proposed 2100mm culvert, the pre-Project water levels can be maintained.

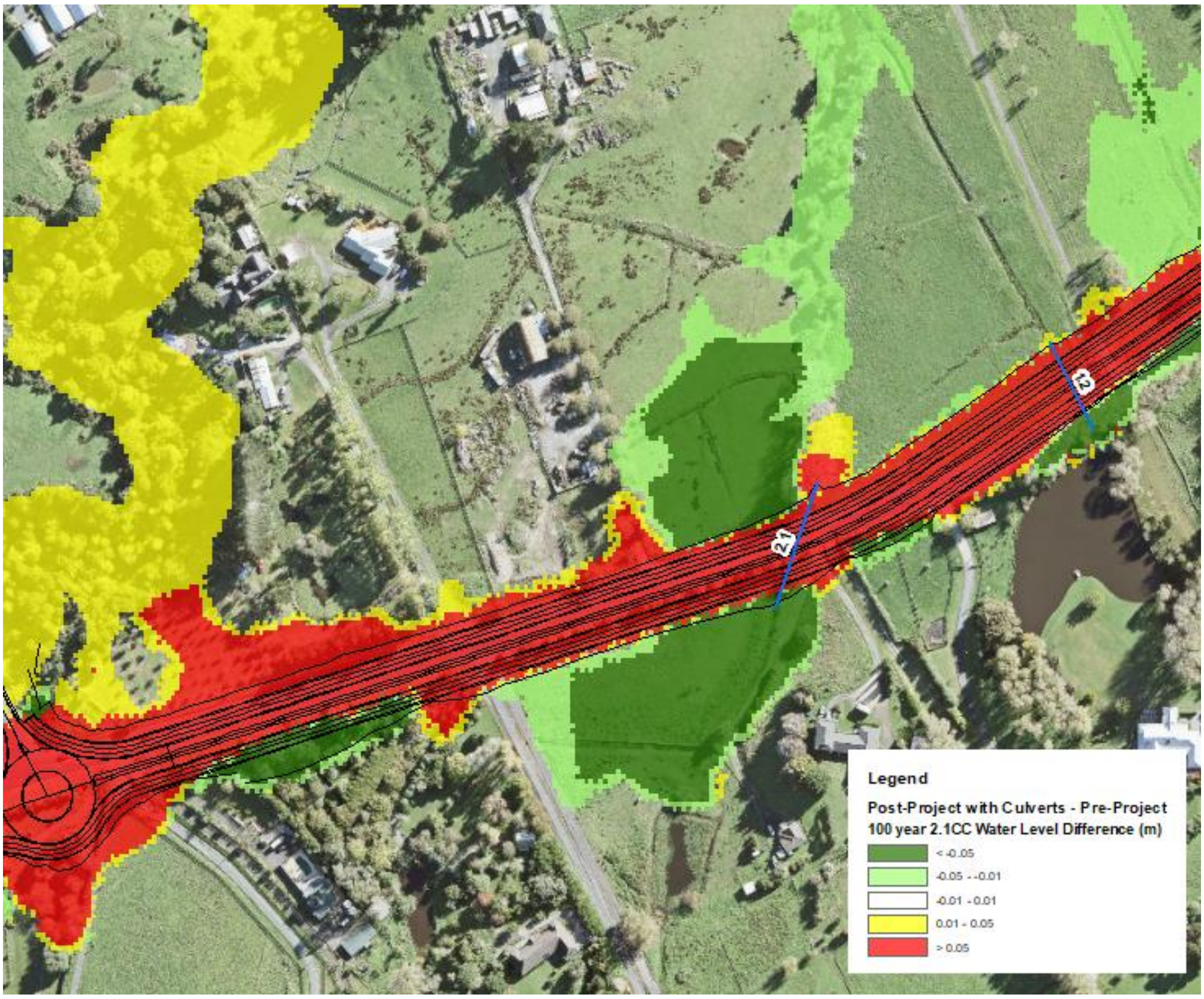

Figure 6. Location Plan Area 3 showing the flood results with the addition of a 2100mm culvert.

2.4 Location Plan Area 4

Figure 7 shows location plan 4 with two 600mm culverts modelled. The results show a decrease in water level upstream of the culverts resulting in an increase in water level downstream of the culverts. This suggests that retaining the existing single 600mm culvert may be sufficient to maintain the pre-Project water levels but further optimisation in the later design and flood modelling stages will confirm this.

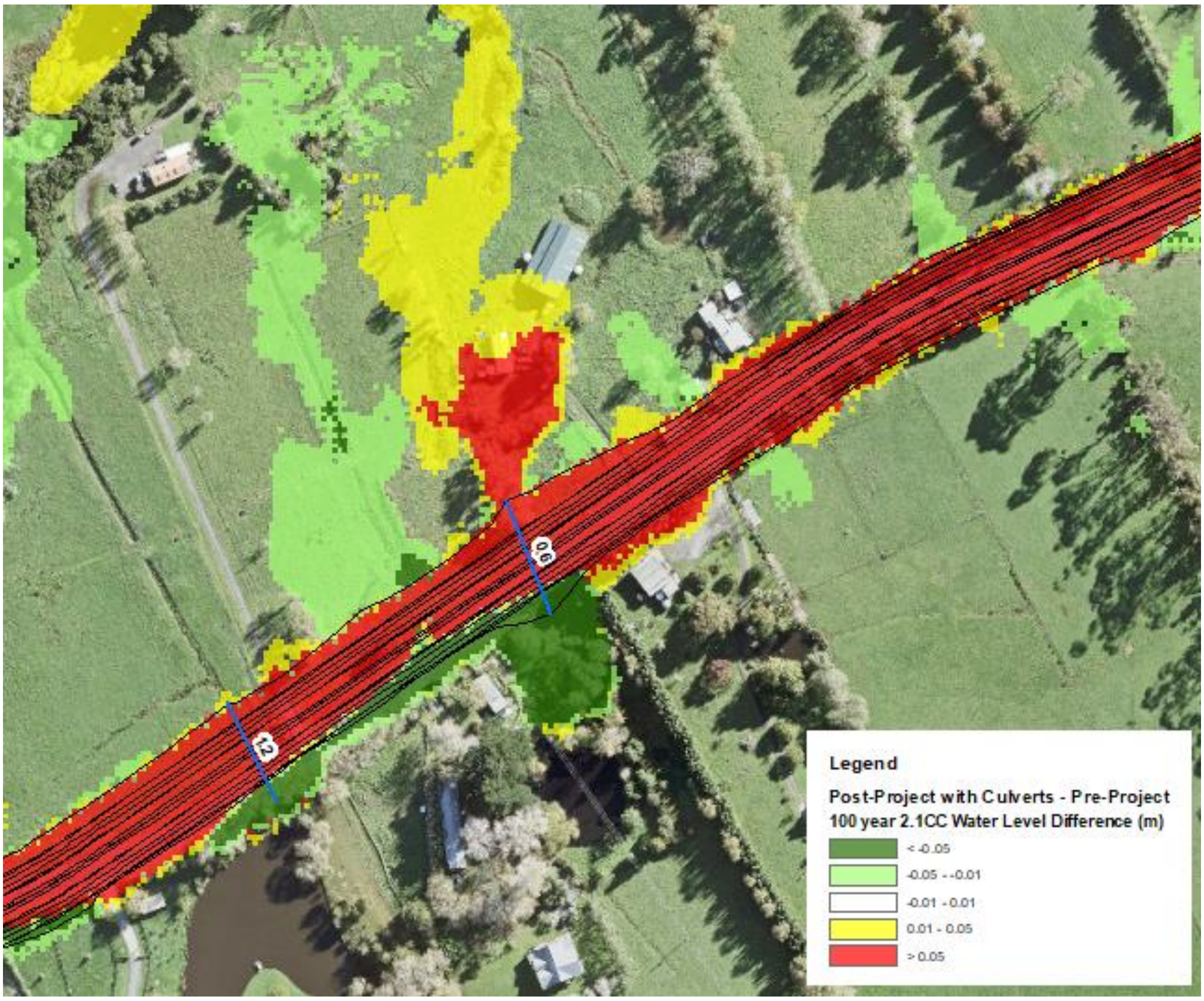

Figure 7. Location plan area 4 showing the Post-Project flood results with two 600mm culverts.

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3. Conclusions

The post Project flood model identified four locations where overland flow was impacted by the proposed Pine Valley Road formation raising to provide flood resilience.

Modelling undertaken to provide culvert capacity of the pre-Project overland flow paths was undertaken.

This modelling showed that, with some culvert design amendments, the pre-Project water levels can be maintained.