

Delmore Fast Track Application

Appendix 8: A21 (Auckland Transport - Stormwater) to Response to Comments letter

From: Lachlan Van der Meij – McKenzie & Co (MKC)

Date: 5 June 2026

Re: Auckland Transport Stormwater Memorandum

1.1 Introduction

This memorandum responds to the Technical Specialist Memo prepared by Auckland Transport (stormwater) in relation to the above fast-track application (as lodged). This response addresses:

- Further information requests / technical queries; and
- Recommended amendments to consent conditions.

The following attachments are included to this memorandum:

- **Attachment A: Dam Break Assessment**
- **Attachment B: PIC Assessment**
- **Attachment C: OLFP Assessment**

Comments that are now considered resolved are identified in green in the table below. Comments where further information has been provided are identified in blue.

1.2 Response to Further Information Requests / Technical Comments

Information Request from Council on the lodged material	Applicant Response	Information Request / Technical Comment from Council under section 53 FTAA	Applicant Response under Section 55 FTAA
Section 10.3 of the Flood Assessment Report (Appendix 35) states that “An adaptive time step based on a maximum Courant of 4 and a minimum Courant number of 1 was adapted”. Please clarify if this approach was agreed with Healthy Waters.	The raw model has been provided to Healthy Waters and they are still reviewing.	Noted, this can be closed.	Resolved.
It appears that only the NZTA culvert was blocked in the culvert block scenarios. Can the applicant please clarify the culverts proposed in this development were assessed for blockage scenarios? We note that this is a requirement in the Stormwater Code of Practice.	A culvert blockage scenario in line with the SWCoP requirements has been modelled and included in the documentation. Please see drawing 3725-0-4540 attached. This demonstrates that all lots are free of flooding and freeboard requirements of the SWCoP are achieved.	Please provide an assessment of the depth-velocity in the road. It is noted that several roads have the “very high hazard” classification in drawing 3725-0-4537.	On request from Healthy Waters, an inlet riser is now proposed at the NZTA Culvert. This is included in Appendix 6 (Civil Drawings) to the Response to Comments letter (refer Drawing 3725-1-4815). Healthy Waters are satisfied that this will provide adequate safeguard against this scenario from occurring (100% blockage). Based on this approach, it is our opinion that no assessment is necessary for these “very high hazard” classifications shown in this scenario on drawing 3725-0-4537 as the scenario has been

			mitigated against and is very unlikely to occur.
It is not clear where the inflow nodes for the model are located; are catchments PRE12-1, PRE29-2, and PRE33-1 the only ones that have inflow nodes at the bottom of the subcatchment? 1. Section 7 states “Inflow nodes have been applied at the top of sub-catchment boundaries”. 2. Section 10.5 states that “The hydrological inflow is configured to account for actual sub-catchment slope based on equal area terrain method., and each node is positioned at the highest point of its corresponding sub-catchment to ensure the full time of concentration is accurately represented in the model”. 3. Section 10.5 also states that “For catchments PRE12-1, PRE29-2, and PRE33-1, the time of concentration has been calculated using the equal area method based on the potential flow length and slope. The inflow nodes	1. Yes the PRE-XX catchments are applied at the bottom of the catchment as this is external inflow conditions and applied at the bottom with the tc calculated. 2. The inflow BC for the internal catchments has been updated to account for the time of concentration after a review and discussion with Healthy Waters. Please see drawing 3725-0-4500 with nodes showing this information. 3. Correct as per point 1.	It is noted that the annotations for the catchments appears to block the inflow nodes. Please clearly demonstrate where the inflow nodes for the subcatchments are located.	McKenzie and Co drawing 3725-0-4500 has been updated to ensure inflow node locations are clearly demonstrated. This is included in Appendix 6 (Civil Drawings) to the Response to Comments letter.

have been applied at the bottom of the respective sub-catchments.”			
While the Flood Assessment Report (Appendix 35) refers to drawing 3725-0-4500 for a Catchment Plan, it is not clear which document this is located in. Can the applicant please clarify which document this drawing is located in. Additionally, can the applicant please ensure that this drawing shows the inflow nodes? The intent for this comment is to verify that flows within roads are correctly represented.	Drawing 3725-0-4500 has been included for reference. The Hydrological inflow configurations were added to this drawing to address the above query.	Noted, this can be closed.	Resolved.
1. It is not clear what the Culvert Plans (Appendix 33) are intended to demonstrate: 1.1. The longsections have a ground profile through them; is this intended to be the ground embedment? 1.2. The elevation views often do not show culverts at the lowest point of the channel. In particular: 1.2.1. Culverts 4 and 11 are not located in the lowest point in the channel. 1.2.2. Culverts 5, 8, and 9 appear to be located underground (or completely embedded) i.e., with no area to allow flow.	1.1 - No, the ground profile has been shown to show the grade of the existing channel for freshwater ecology reasons (fish passage, maintaining similar grades across existing wetland, etc.). 1.2 - The cross section is taken through the middle of the proposed culverts, the ground will be locally re-shaped around the inlet and outlets, as part of the culvert, headwall, and rip rap install. Plans have been updated to reflect this. 1.2.1 – Inlet and outlets are located at the base of the channels. As above, the ground will be locally re-shaped around	Noted, this can be closed.	Resolved.

1.2.3. It is not clear how flow is proposed to enter Culvert 9 as it appears to be completely embedded. 1.2.4. Culvert 10 is missing from the elevation view.	the inlet and outlets, as part of the culvert, headwall, and rip rap installation. 1.2.2 - As above the ground will be locally re-shaped around the inlet and outlets, as part of the culvert, headwall and rip rap installation. 1.2.3 - Culvert 9 has been extended slightly to remove this concern. 1.2.4 - Noted and updated.		
3. It is not clear what the culvert dimensions are for Culvert 10. The Flood Assessment Report states it to be a 1,900 mm circular culvert, however the calculations in Appendix B of the Stormwater Report state it to have a span of 2,100 mm and a rise of 2,100 mm and the culvert plans state it to have a 2,100 mm diameter. Can the applicant please clarify what dimensions the culvert is to have, and what was used in the model?	Reporting, modelling / calculations and plans have been updated to ensure consistency across all culverts. To answer this particular question, the culvert is circular with a diameter of 2100Ø.	Noted, this can be closed.	Resolved.
4. Section 10 (Culvert Crossings) in the applicant's Stormwater Report (Appendix 32) states that "All culverts have been designed to comply with the SWCOP v4", however this is not demonstrated. Can the applicant	A damming assessment of all culverts has been undertaken by Flow State Consulting (FS). We understand discussions are currently being undertaken between FS and Auckland Transport's stormwater	AT's stormwater comments on the Delmore Fast Track identified that while the Stormwater Report stated the culverts were designed to comply with the Stormwater Code of Practice, the calculations	A Dam Break Assessment is included within Attachment A to this memo. A supporting PIC Assessment is included as Attachment B.

please provide an assessment of all proposed culverts demonstrating compliance with all the requirements of section 4.3.9.8? We note that section 6.6 of the SMP (Appendix 34) states that “Attenuation of the 1% AEP event is proposed through the throttling of flows that will occur behind the proposed culverts”. Considering this, demonstration of compliance to the SW CoP is critically important. 1. We note that culvert calculations are provided in Appendix B of this document, however they are not complete. They also demonstrate that the headwater depth for culverts 3, 4, 5, 8, 9, 10, 11, and 12 appears to exceed the 3.0 m permitted in the SwCOP.	specialist. A memo will be provide on this separately.	provided in Appendix B indicated otherwise. As a result, AT have requested further information on the culverts to ensure that they are designed to be compliant with the requirements of the Stormwater Code of Practice. Flowstate Consulting have since confirmed that many of the culverts will be classified as Dams under the Building Act 2004 or the Building (Dam Safety) Regulations 2022. To provide direction on what information is necessary for this Fast Track Application, this has been raised with AT’s Principal Stormwater Engineer who has confirmed that the culverts cannot be conditioned, and full assessments of the culverts demonstrating compliance with the Stormwater Code of Practice, and therefore compliance with the Building Act 2004 and Building (Dam Safety) Regulations 2022 is required.	
5. It appears that many of the culverts may be a classifiable dam according to	See above.		A Dam Break Assessment is included within Attachment A to

the Building (Dam Safety) Regulations 2022, as the headwater above embedment (Appendix B of the Stormwater Report) exceeds 4 m. However, it is not clear what the volume of water impounded by the culverts is. Can the applicant please clarify which culverts will be classifiable dams under the Building Act 2004 or the Building (Dam Safety) Regulations 2022? Can the applicant then also please demonstrate that these classifiable dams meet the requirements of the Stormwater Code of Practice, the Building Act 2004, and the Building (Dam Safety) Regulations 2022? Note that if there is overlap of requirements, as per section 4.3.9.8.a of the Stormwater Code of Practice, the more stringent requirement will take precedence over the Stormwater Code of Practice requirements.			this memo. A supporting PIC Assessment is included as Attachment B.
6. It is not clear why the embedment depths have been selected. We note that the culvert calculations in Appendix B of the Stormwater Report (Appendix 32) reports that culvert 8, which has a rise of 1,000 mm has an embedment of 600 mm.	Except for Culvert 9, all box culverts have an embedment of at least 350mm, and circular culverts are embedded at least 25% to ensure fish passage is provided. Culvert 9 is located along wetland and is required to match the existing topography and upstream invert level to	Noted, this can be closed.	Resolved.

We also note that section 10 of this report states that “All culverts are proposed to be embedded 25% into the existing stream bed”. However, section 11.6 of the Flood Assessment Report (Appendix 35) states that “All proposed culverts within the Delmore development are embedded a minimum of 35% of their total height. It is unclear which requirement should be met; however, many culverts do not meet this requirement. For example, Culvert 3 has a rise of 4,000 mm but an embedment of 350 mm, which is 9%. Can the applicant please clarify what embedment depths are provided, and why these values were selected?	ensure the existing wetland is not impacted. In some cases, additional embedment has been provided to attenuate flows during storm events. Wording and inconsistencies within the reporting have been updated to suit the above.		
7. It is not clear if fish passage is required. Can the applicant please clarify if fish passage is required for the proposed culverts?	Comment from the ecologist (Viridis) from a response to the freshwater ecology queries is below: Yes, appropriate fish passage is required for the species present, which include (based on trapping and eDNA); redfin bully, longfin and shortfin eel, banded kōkopu, and giant bully. The proposal improves overall fish passage by removing 17 existing farm culverts that currently restrict connectivity and replacing them with 12	Noted, please demonstrate compliance with fish passage requirements.	Fish passage requirements are identified within the culvert drawings at Appendix 6 to the Response to Comments Letter (Civil Drawings).

	new culverts designed to maintain natural stream conditions. Most new culverts are short (<30 m), sized at ~1.3× stream width, and embedded (25% for pipes or ~350 mm for box culverts), supporting natural bed continuity and fish movement. Culverts 7, 9, and 10 are exceptions due to site constraints (e.g., wetland levels and wide, flat terrain). These are located high in the catchment where fish communities are dominated by strong climbers (eels and banded kōkopu). While passage may be reduced during high flows, conditions during normal/low flows, and the short culvert lengths, are expected to provide adequate passage. Overall, removal of existing barriers and improved culvert design is expected to enhance fish passage across the site.		
8. It appears that not all culverts extend beyond the road reserve. Can the applicant please revisit the Culvert Plans (Appendix 33) and revise the culvert locations.	All culverts have been amended to ensure they extend past the road reserve. Plans have been updated to reflect this.	Noted, item can be closed.	Resolved.
9. It is not clear how many culverts can be accessed on both sides for maintenance. Can the applicant please clarify how the culverts can be	Access to both sides of culverts has been provided. Plans have been updated to reflect this.	Please provide access longsections, of the access and clarify what the width of the access tracks is.	McKenzie & Co drawings 3725-1-4800 to 4812 and 3725-1-4820 to 4824 have been updated to clearly show the proposed culvert access

accessed on both sides and update their Culvert Plans (Appendix 33) to demonstrate this?			tracks. This is included in Appendix 6 (Civil Drawings) to the Response to Comments letter. Culvert access tracks are proposed to be 3m wide and a maximum gradient of 1:4 as shown on the longsections.
10. OLFP: 1. Can the applicant please clarify what the red polygon in the legend represents. It appears to indicate where the depth-velocity product exceeds 0.4 m²/s, however this is not stated.	Updated drawings (series 4610) have been attached that clearly indicate all layers in the legend.	Please clarify if the TUFLOW model has been reviewed by Healthy Waters. It is noted that the previous OLFP assessment had sections of roads with depth-velocity products exceeding 0.4 m²/s, however the new drawings and assessment do not report this. Please clarify why this has changed.	Healthy Waters has confirmed that they do not need to review the TUFLOW model. The TUFLOW model has since been provided to Auckland Transport for review. It is worth noting that the model parameters have been adopted from the RAS models that have been checked & approved by Health Waters and nothing has changed. The initial model was a 1D model created in 12d and some inaccuracies were identified in the results of the model such as that highlighted in this query. As a result of this a more accurate 2D TUFLOW model has been produced to correctly represent the OLFP's within the road network.

			The results of this model are discussed in the OLFP memo provided in the previous response. This is included as Attachment C to this memo.
2. The OLFP section (section 9.8) of the Stormwater Report (Appendix 32), and in the Stormwater Management Plan (section 6.7 of Appendix 34) does not discuss OLFP's within the road. While some OLFP analyses are provided in the drawings, there appears to be locations of obvious danger to pedestrians (e.g., around corners) that have depth-velocity products exceeding 0.4 m²/s. Notably, section 12 within the Stage 2 OLFP drawings (Appendix 33) reports a depth velocity product of 0.43 m²/s, and this section is close to a corner between Road 20 and 18 – an area of obvious danger to pedestrians. Can the applicant please provide a discussion of the OLFP analysis provided in their drawings, and demonstrate that the requirements of Table 3 of the Road Drainage chapter of AT's TDM are met?	A memo addressing the OLFP's across the site and focusing on these concerns has been prepared and amended to this response.	Please clarify if the TUFLOW model has been reviewed by Healthy Waters. It is noted that the previous OLFP assessment had sections of roads with depth-velocity	Same as above.

3. In the OLFP drawings it is not clear where pedestrian crossings are proposed. Considering that pedestrian crossings will be places of obvious danger to pedestrians, can the applicant please clearly identify these in their drawings?	See 2 above.	Please clarify if the TUFLOW model has been reviewed by Healthy Waters.	Same as above.
4. There is currently no assessment of the depth-velocity, and therefore flood hazard for locations where OLFP's overtop the roads. Can the applicant please provide this, ensuring that the requirements of Table 3 of the Road Drainage chapter of AT's TDM are met?	See 2 above.	Please clarify if the TUFLOW model has been reviewed by Healthy Waters.	Same as above.

Attachment A: Dam Break Assessment

Memorandum

To: Vineway Ltd.
Attn: Andrew Allsopp-Smith, Myland Partners

From: Shakti Singh, Senior Engineer, Flowstate Consulting

Reviewer: Pranil Wadan, Managing Director, Flowstate Consulting

Date: 04/06/2026

Subject: Delmore Development (Upper Orewa): Dam Classification & Dam Breach Flood Hazard Assessment

Reference: FS26-132

Revision: A

1. Introduction

Flowstate Consulting LP (Flowstate Consulting) has been engaged by Vineway Ltd. to undertake a dam classification assessment and a subsequent dam breach flood hazard assessment for the proposed Delmore Development at 53A, 53B & 55 Russell Road and 88, 130 & 132 Upper Ōrewa Road, Ōrewa. Both assessments have been prepared in support of the Fast-track application lodged under the Fast-track Approvals Act 2024 and respond to the following query raised by Auckland Transport (AT):

“It appears that many of the culverts may be a inadvertent dam according to the Building (Dam Safety) Regulations 2022, as the headwater above embedment (Appendix B of the Stormwater Report) exceeds 4 m. However, it is not clear what the volume of water impounded by the culverts is. Can the applicant please clarify which culverts will be inadvertent dams under the Building Act 2004 or the Building (Dam Safety) Regulations 2022?”

“Can the applicant then also please demonstrate that these inadvertent dams meet the requirements of the Stormwater Code of Practice, the Building Act 2004, and the building (Dam Safety) Regulations 2022? Note that if there is overlap of requirements, as per section 4.3.9.8.a of the Stormwater Code of Practice, the more stringent requirement will take precedence over the Stormwater Code of Practice requirements.”

A meeting was held with AT on 21 April 2026 to agree on the scope of works in response to the above query. The associated email correspondence between Flowstate Consulting and Auckland Transport is provided in Appendix A.

1.1 Scope

In summary, the scope of assessment includes:

- A dam classification assessment will be completed in line with the New Zealand Society of Large Dams 2024 (NZSOLD), Building Act 2004 and NZ Building Dam Safety Regulation 2022 requirements.
- Undertake a dam break assessment for the culverts identified as 'inadvertent dams' as per NZSOLD 2024 and Auckland Transport discussions. This includes
 - o Simulation of a Post-development model scenario to establish a base-case scenario.
 - o Simulation of a scenario which allows for a 'rainy-day' and 'cascade' failure scenario:
 - o A 100-year ARI (+3.8°C) storm event, assuming culverts to be fully operational (or 0% blockage).
 - o A 1000-year ARI (+3.8°C) storm event, assuming culverts are partially or completely in operational.
- Evaluate the risk to the lots/roads under the above-mentioned scenarios and recommend likely mitigation measures (if required). Details of the mitigation measures to be finalised during detailed design stage.
- Identify safety-egress routes for all areas in the development.
- Provide a technical memorandum providing parameters, assumptions, findings and recommendations for the assessment.
- A detailed potential impact classification (PIC) reports meeting the requirements of NZSOLD 2024 by Riley Consultants. Referred to as *Potential Impact Classification Assessment – Russell Road, Orewa (Riley ref: 240065-U)*, prepared by Riley Consultants Limited, for Vineway Ltd.

Collectively, these scenarios allow for a conservative assessment under extreme conditions. The assessment provides a comprehensive overview of the potential flood hazard associated with the breach of identified inadvertent dams and is considered appropriate for the current stage of design, with any further stress-testing or sensitivity analysis able to be undertaken during future detailed design stages, if required.

2. Dam Classification

2.1 Methodology

The dam classification assessment was carried out in accordance with the criteria set out in the Building Act 2004 and NZSOLD 2024. The assessment considered each proposed culvert structure individually and evaluated whether both the height and volume thresholds are simultaneously exceeded using the bathymetry information included in the development design surface.

2.2 Height calculation

The NZSOLD 2024 guidelines state that “*The Act (2004) defines the height of the dam as the vertical distance from the crest of the dam and must be measured: (a) in the case of a dam across a stream, from the natural bed of the stream at the lowest downstream outside limit of the dam*”.

The crest of the dam for the purposes of measuring height is also defined in the Act (2004) as *the uppermost surface of a dam, not taking into account any camber allowed for settlement, or any curbs, parapets, guard rails, or other structures that are not part of the water-retaining structure; and for the avoidance of doubt, any freeboard is part of the water- retaining structure for the purposes of this definition*.

For the purposes of the assessment, the height was measured between the highest elevation of the road across the culvert crossing (including the road embankment or the road crest level), and stream invert level immediately downstream of the road the embankment.

2.3 Volume calculation

The impoundment volume was calculated as the volume of water retained upstream of the culvert structure up to the controlling water surface level i.e. to the highest elevation of the road crossing, derived from the post-development design surface. The calculation does not assume runoff conveyance through the culverts, i.e. fully blocked scenario. The classification was based on the full impoundment volume.

Additionally, for the flood hazard assessment, volume stored upstream of the embankments during 100-year ARI and 1000-year ARI was also calculated with the use of flood model and stage-storage relationships derived from the design terrain model (12d model).

2.4 Results

Of the twelve culverts assessed, Culverts 3, 4, 6, 8, 9, and 11 are identified as *inadvertent dam*. The remaining six culverts (Culverts 1, 2, 5, 7, 10, and 12) do not meet both criteria and are not identified as *inadvertent dam* (refer to Table 1 for results). Figure 1 shows the location of all the culvert embankments included in the classification assessment.

Appendix B contains the cross sections and a table for each dam showing heights, stored reservoir, and flood levels at various ARI's.

Table 1: Dam classification results

Culvert ID	Structure Height (m)	Impounded Volume (m³)	Height ≥ 4 m	Volume ≥ 20,000 m³	Result
Culvert 1	8.8	6,088	Yes	No	Criterion not met
Culvert 2	4.6	563	Yes	No	Criterion not met
Culvert 3	10.3	31,322	Yes	Yes	Inadvertent dam
Culvert 4	9.6	124,844	Yes	Yes	Inadvertent dam

Culvert 5	8.8	18,687	Yes	No	Criterion not met
Culvert 6	16	110,766	Yes	Yes	Inadvertent dam
Culvert 7	11.1	15,684	Yes	No	Criterion not met
Culvert 8	12.8	20,196	Yes	Yes	Inadvertent dam
Culvert 9	12.2	89,443	Yes	Yes	Inadvertent dam
Culvert 10	6.6	6,438	Yes	No	Criterion not met
Culvert 11	18.2	212,504	Yes	Yes	Inadvertent dam
Culvert 12	2.4	N/A	No	N/A	Criterion not met

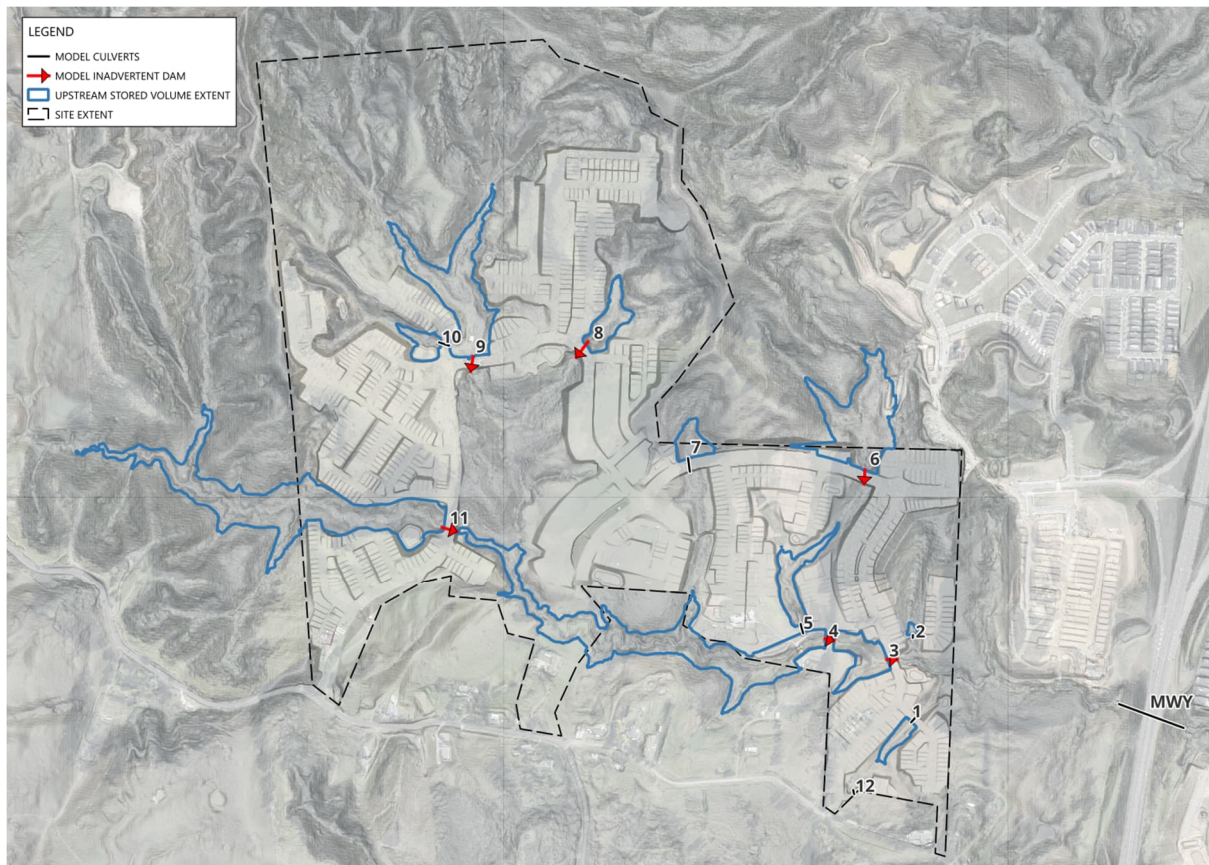


Figure 1: Location of culverts and inadvertent dams

3. Dam Breach Assessment

3.1 Model Update

The dam-breach assessment was undertaken in TUFLOW (build 2026 iSP w64) using the post-development hydraulic model previously developed for the Delmore site by McKenzie and Co. It is noted that originally a HEC-RAS model was developed by McKenzie and Co. for the site which has been peer reviewed by Healthy Waters. The model was later converted to a TUFLOW model where the parameters and assumptions regarding the model build were kept consistent with the reviewed HEC-RAS model. McKenzie and Co. have informed Flowstate Consulting that the checks have been carried out where the comparison of peak flows between the TUFLOW model and HEC-RAS model were determined to be within an acceptable range.

The model was updated to include a 1D representation of each inadvertent dam embankment with both piping (internal erosion) and overtopping failure mechanisms. The 1D dam-break structure routes flow through a time-varying breach opening that develops over the breach formation time, with peak outflow controlled by the selected breach parameters.

Breach triggers were set on water-level basis depending on the storm event. Piping failure was initiated when the upstream water level reached either the road embankment level or the maximum water level (for culvert embankments which do not overtop), while the overtopping failure was initiated immediately following the piping failure.

The 1000-year ARI 24-hour rainfall depth were extrapolated using a Gumbel distribution using the TP108 24-hour rainfall depths adjusted for future climate change of +3.8°C (Note: the climate change factors have remained consistent with the factors recommended for 100-year ARI storm event). Appendix C contains the extrapolation derivation used for the assessment.

3.2 Model Scenarios

Five model scenarios were simulated as noted below and further summarised in Table 2 below.

- Scenario 1: This scenario was modelled to estimate the volume stored upstream of each inadvertent dam for respective ARI which was used to set the breach parameters.
- Scenario 2: This model scenario forms the basis of baseline to carry out breach assessment. The scenario considers all culverts to be fully operational (i.e. no blockage).
- Scenario 3: This model scenario forms the primary basis for carrying out dam breach assessment and contains representation of the 1D dam-breach structures in the model scenario.
- Scenario 4: This model scenario tests sensitivity of the culvert present under SH01 and assumes 50% blockage.
- Scenario 5: This scenario tests the sensitivity of the Culvert 11 embankment to early breach timing. Given its relatively large storage volume, additional simulations were run to assess the effects of breach coinciding with the storm peak and upstream inadvertent dams. A 50% blockage of the culvert under SH01 is assumed.

Table 2: Model scenarios simulated for the dam-breach assessment

#	Scenario	Storm Event	Culvert Blockage Assumption	Purpose
1	Post-development (pre-breach baseline)	100-year +3.8°C; 1000-year +3.8°C	100% blockage at inadvertent dams; all other culverts fully operational.	Establish peak water level behind each inadvertent dam under the worst-credible blockage condition. Outputs used to set dam-breach trigger water levels in Scenarios 3–5.
2	Post-development (Base scenario)	100-year +3.8°C; 1000-year +3.8°C	All culverts fully operational (no blockage).	Provide baseline flood-extent and depth mapping for comparison with the post-breach scenarios. Inputs to the geotechnical PIC.
3	Post-development: Dam breach	100-year +3.8°C; 1000-year +3.8°C	Inadvertent dams breached; motorway culvert at 0% blockage; remaining culverts unblocked.	Primary dam-breach hazard scenario. Breach trigger water levels and stored volumes adopted from Scenario 1.
4	Post-development: Dam breach - Motorway sensitivity	100-year +3.8°C; 1000-year +3.8°C	Inadvertent dams breached; motorway culvert at 50% blockage; remaining culverts unblocked.	Sensitivity test on the NZTA motorway culvert blockage assumption.
5	Post-development: Dam breach - Embankment 11 early-breach sensitivity	100-year +3.8°C; 1000-year +3.8°C	As Scenario 4; PF11 breached early. Early breach scenario for embankment 11.	Cascade-failure sensitivity test which examines whether an early breach of PF11 breach materially changes the downstream hazard.

3.3 Breach Parameter Formulations

Empirical regression-based method (Froehlich, 2016) was used to estimate breach geometry and formation time which is listed as an accepted regression-based approach in NZSOLD (2024). Breach parameter formulation spreadsheet has been included in Appendix D. The peak water levels, reservoir heights and stored volumes derived from the baseline scenarios (Scenario 1 for trigger derivation) are also included in Appendix D. Inputs are tabulated separately for the piping and overtopping failure modes and for each of the 100-year and 1000-year ARI events.

In all modelled scenarios the peak reservoir water level at Culvert embankment 06 and 11 remained below the embankment crest elevation and doesn't overtop. The model nonetheless develops the breach to the full embankment cross-section post piping failure to assume a full-breach scenario.

3.4 Model results discussion

Flood hazard mapping was generated from the TUFLOW outputs for each of the five scenarios at both the 100-year and 1000-year ARI rainfall events as requested by Auckland Transport.

Out of all the modelled scenarios, Scenario 5 was noted to be the “worst-case” scenario. Figure 2 shows the maximum modelled flood depth Scenario 5 during a 1000-year CC ARI storm event. For comparison of the incremental hazard attributable to the dam breach, Figure 3 shows the difference

in maximum modelled flood depth between Scenario 5 and Scenario 2 during a 1000-year CC ARI storm event.

Flood depth maps for all model scenarios are included as Appendix E.

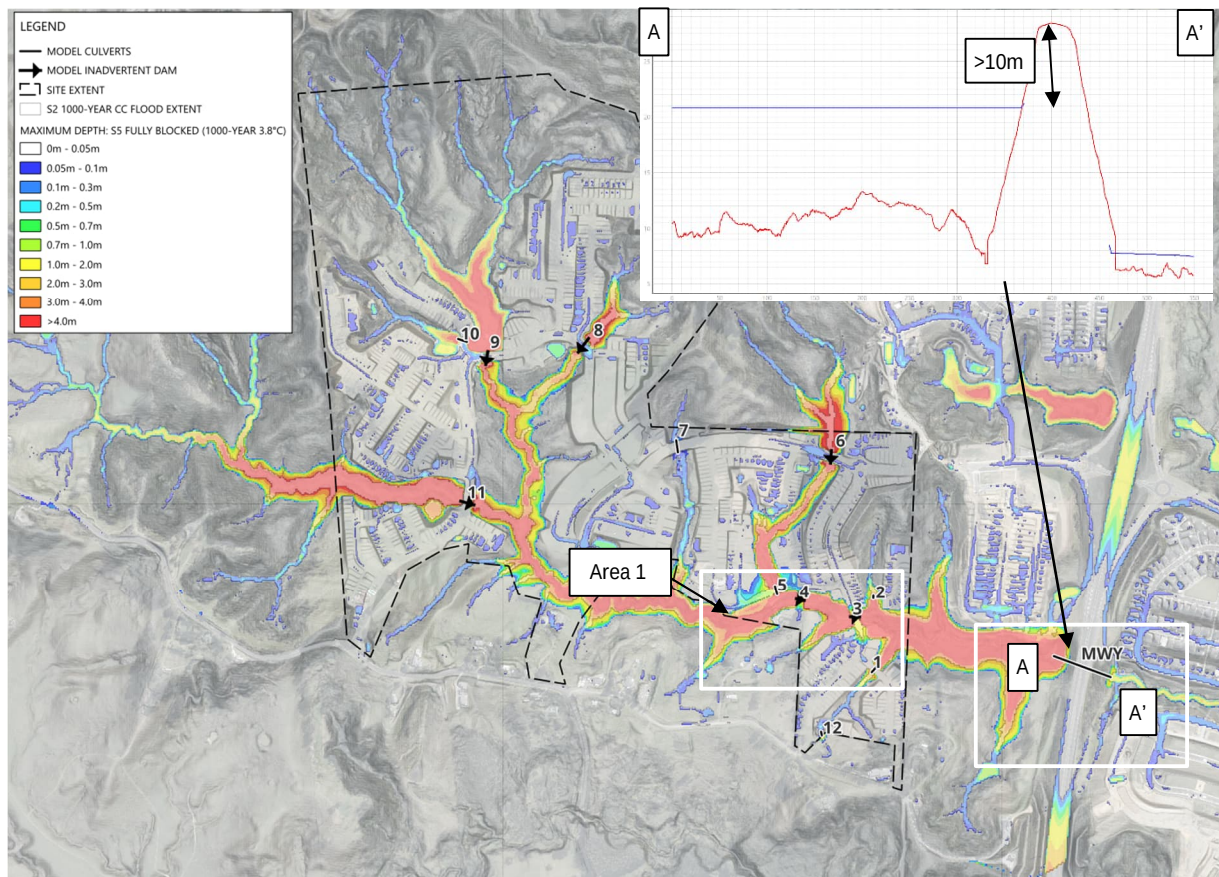


Figure 2: Maximum modelled flood depth: S5 1000-year 3.8°C and S2 1000-year 3.8°C flood extent

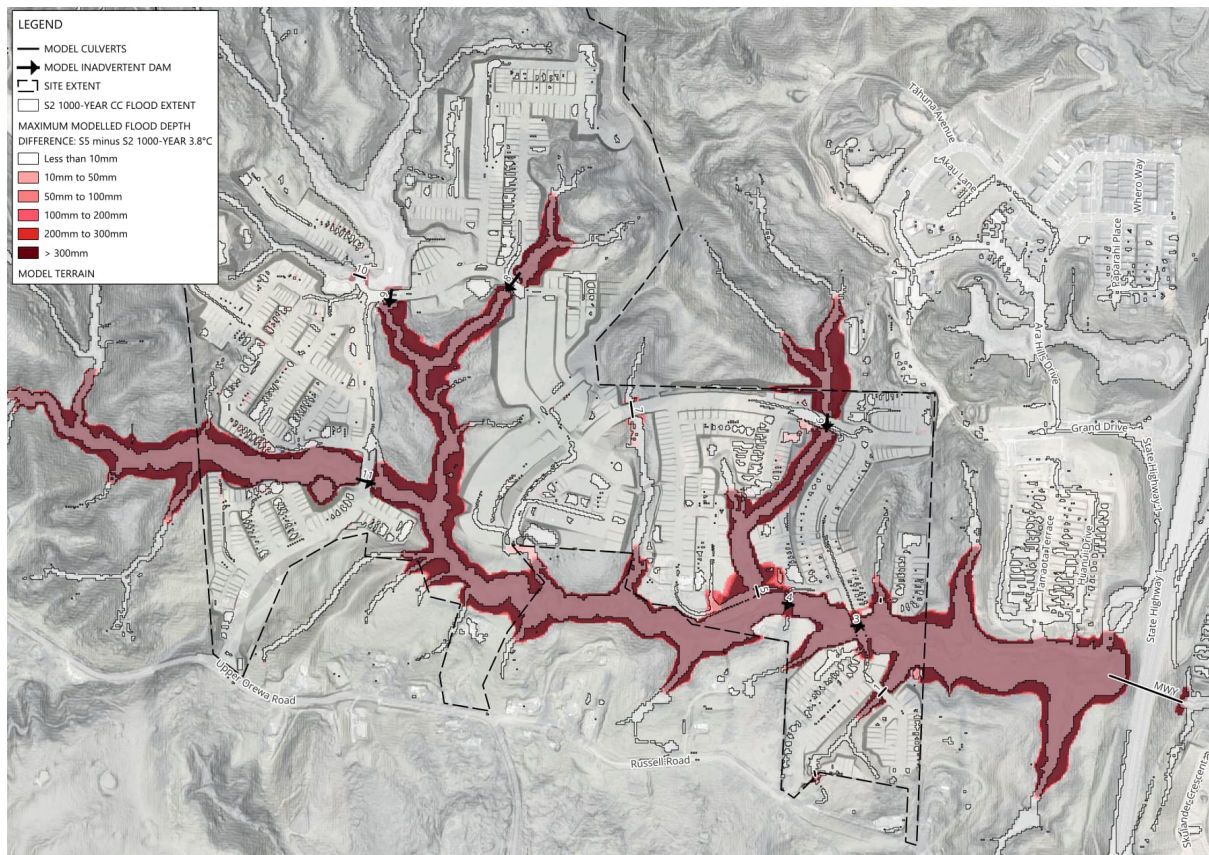


Figure 3: Maximum modelled flood depth difference: S5 minus S2 1000-year 3.8°C (and S2 1000-year 3.8°C flood extent)

The model results from Figure 2 and Figure 3 show that:

- Majority of the flooding within the development, particularly within lots and roads, occur in Scenario 2 (base scenario) as well as Scenario 5 (dam-breach scenario). This indicates that there is largely no additional flood hazard caused in the development due to dam-breach, except for Area 1 (as annotated in Figure 2) which has been further discussed in the following sections.
- There is increased flooding within the watercourses, however, this is largely limited to the stream flood conveyance section and does not extend to any existing habitable floors or dwellings.
- There is noted to be increased flooding on roads at the location of the culvert crossing (3 and 4), which is expected due to the dam overtopping trigger. The increased depth at these locations indicates collapse of the road embankment through which the stored volume is passed downstream.
 - It should be noted that the PIC assessment undertaken by Riley includes discussion of the flooding risk associated with overtopping.

3.4.1 SH1 culvert consideration

The model results indicate that runoff traversing downstream of the development is constrained by the culvert under SH1. Due to the high embankment height of SH1, the flows do not overtop the motorway (maximum water level = 18.21m RL, SH1 crest level = 28.41m RL, freeboard > 10m). Therefore, the impact of the dam breach to the downstream environment is considered negligible.

The consideration for the breach of SH1 culvert embankment was not included as part of this assessment because it was determined that this breach will allow for the ponded volume to be passed downstream and therefore, reducing flood hazard for the areas upstream of the embankment including the proposed Delmore development.

The flood hazard that may result from the breach of SH1 culvert lies outside the scope of this assessment and the fast-track application. The ponding upstream of the SH1 culvert is an existing matter and the flood hazard associated with the breach of SH1 culvert will need to separately assessed.

3.4.2 Auckland Council Flood Hazard

Auckland Council Flood Hazard methodology has been adopted to evaluate the flood hazard associated with the dam-breach simulations. In summary, the following four levels of hazard categories and their criterion basis is noted:

- Very High Hazard: Depth equal or greater than 1200mm or depth * velocity product greater than or equal to $0.8\text{m}^2/\text{s}$.
- High Hazard: Depth between 500mm and 1200mm or depth * velocity product between $0.4\text{m}^2/\text{s}$ and $0.8\text{m}^2/\text{s}$.
- Medium Hazard: Depth between 300mm and 500mm or depth * velocity product between $0.24\text{m}^2/\text{s}$ and $0.4\text{m}^2/\text{s}$.
- Low Hazard: Depth equal to or less than 300mm or depth * velocity product less than or equal to $0.24\text{m}^2/\text{s}$.

3.4.3 Area 1 discussion

For the purposes of discussion, the model results for all breach scenarios were evaluated at this location, with the “worst-case” scenario (Scenario 5) been shown in Figure 4. Additionally, for a comprehensive evaluation of flood hazard at Area 1, Table 2 shows the maximum flood depth, maximum velocity, maximum product of depth x velocity, and the associated flood hazard for all dam-breach scenario during a 1000-year ARI storm event.

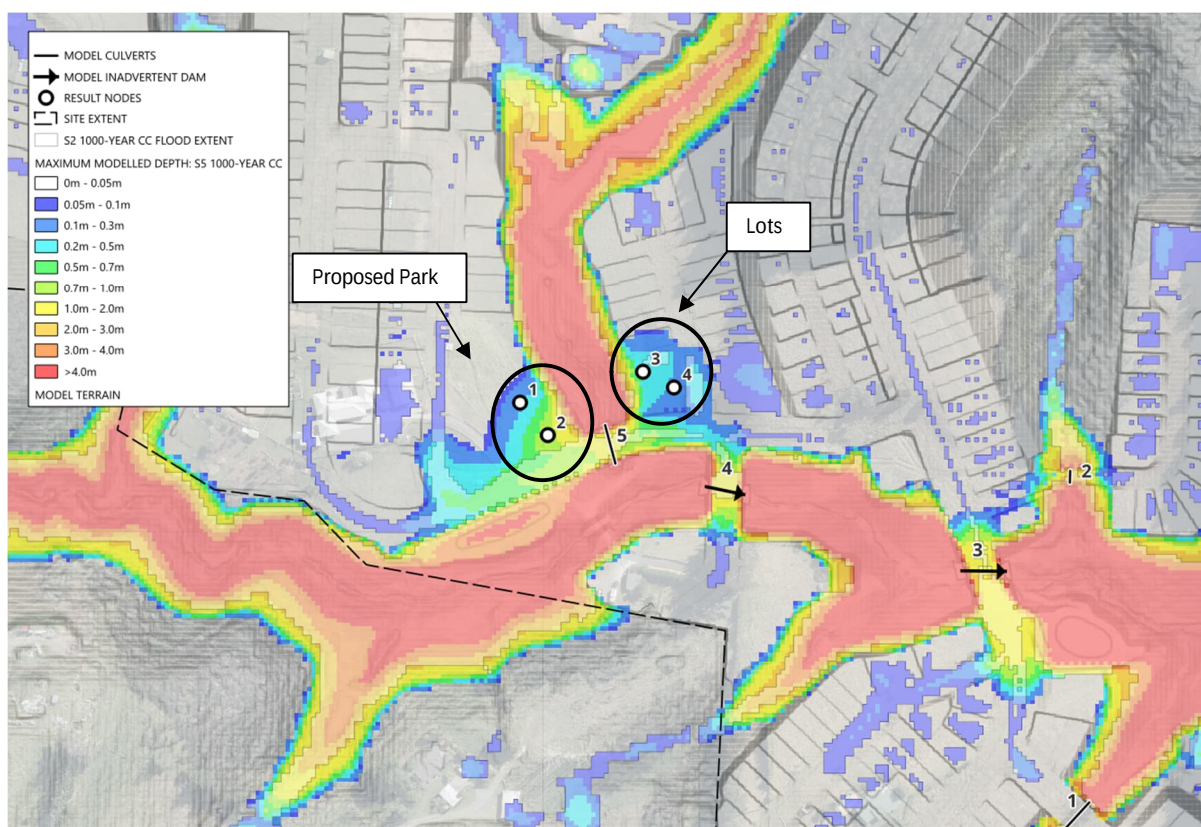


Figure 4: Scenario 5 (1000-year ARI 3.8°C storm event)

Table 3: Summary of results for points

Points	Scenario	Storm event	Maximum flood depth (m)		Maximum velocity (m/s)	Maximum depth x velocity (m ² /s)*	Auckland Council Flood Hazard Category
P1	S3	1000-year 3.8°C	No flooding – N/A				Low hazard
	S4		0.11		0.353	0.04	
	S5		0.25		0.64	0.16	
P2	S3		0.57		1.49	0.86	Very high hazard
	S4		0.70		1.72	1.20	
	S5		0.84		1.96	1.65	
P3	S3		0.08		0.19	0.02	Low hazard to medium hazard
	S4		0.25		0.52	0.13	
	S5		0.44		0.67	0.29	
P4	S3		No flooding – N/A				Low hazard
	S4		0.11		0.44	0.05	
	S5		0.24		0.78	0.19	

*The values stated here have been calculated as maximum depth x maximum velocity which is considered to be conservative. Computational maximum depth x velocity will be lower.

The simulated model results as included in Figure 4 and Table 2 show that:

- There is low hazard present within the lot boundaries in the “worst-case” scenario. This demonstrates that the habitable areas susceptible to flood hazard is subjected to low and lower bounds of medium hazard in all the simulated model scenarios.

- Point 2 which is located within the proposed park location and near to the stream, is subjected to very high hazard. It is unlikely that people will be present around this location during a significant storm (1000-year ARI storm event), however, the risk around this area is further covered in detail in the PIC assessment.

4. Safety-egress assessment

A high-level assessment of the available safety-egress routes have been undertaken for the habitants residing within the development. The safety-egresses have been determined for the dam-breach scenario where available routes may be cut-off during collapse of the identified inadvertent dams. The assessment categorises different areas into habitable zones and provides alternate safety-egress routes available to each zone.

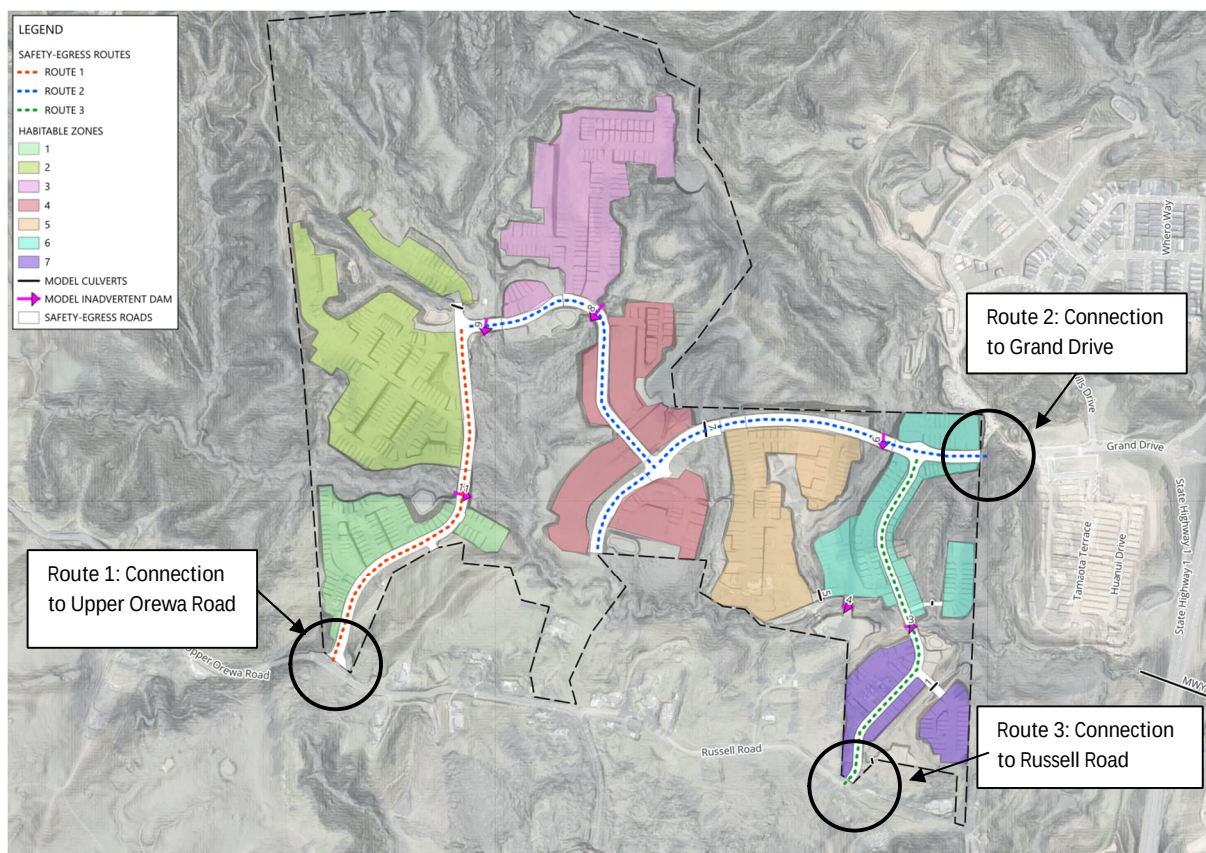


Figure 5: Safety-egress routes

As shown in Figure 5, there are three route connections identified for the development:

- Route 1: Connection to upper Orewa Road
- Route 2: Connection to Grand Drive (proposed to be constructed as part of Stage 1 of construction)
- Route 3: Connection to Russel Road

Based on the above, Table 4 has been prepared which identifies safety-egress routes available for each habitable zone and the number of inadvertent dams present for each route.

Table 4: Safety-egress routes for habitable zones

Habitable zone	Safety Routes Available	Inadvertent dam present	Best route available
1	Route 1	0	Route 1
	Route 2	4	
	Route 3	5	
2	Route 1	1	Route 1
	Route 2	3	
	Route 3	4	
3	Route 1	2	Route 1 or Route 2
	Route 2	2	
	Route 3	3	
4	Route 1	3	Route 2
	Route 2	1	
	Route 3	2	
5	Route 1	3	Route 2
	Route 2	1	
	Route 3	2	
6	Route 1	4	Route 3
	Route 2	0	
	Route 3	1	
7	Route 1	5	Route 3
	Route 2	1	
	Route 3	0	

Based on the presented information, majority of the habitable zones have safety-egress routes available with only one inadvertent dam present. For Habitable Zone 3, Route 1 and Route 2 have two inadvertent dams present, however, these are different embankments, and therefore the likelihood of these structures collapsing during the same event is very low. In conclusion, it is determined that there are adequate safety-egress routes available for all areas of the development during a dam-breach scenario.

5. Conclusion

A dam classification and dam breach flood hazard assessment has been undertaken for the twelve proposed culvert structures in the Delmore Development, in support of the Fast-track application and in response to the query raised by Auckland Transport. Both assessments were carried out in accordance with the scope agreed with AT at the meeting held on 21 April 2026 (refer Appendix A).

The dam classification assessment, carried out in accordance with the Building Act 2004, the Building (Dam Safety) Regulations 2022, and the NZSOLD 2024 Dam Safety Guidelines, identified six of the twelve assessed culverts (Culverts 3, 4, 6, 8, 9, and 11) as inadvertent dams. The remaining six culverts do not meet both the height and impounded-volume thresholds and are therefore not classified as inadvertent dams.

A dam-breach flood hazard assessment has been completed for the six inadvertent dams. The assessment was undertaken in TUFLOW using a 1D piping and overtopping breach formulation, with

breach geometry derived from the Froehlich (2016) regression method in accordance with NZSOLD 2024 guidance. Five scenarios were simulated, including 'rainy-day' and 'cascade' conditions for a 100-year ARI +3.8°C and 1000-year ARI +3.8°C storm event. Additional sensitivity testing on motorway-culvert blockage and largest embankment was also undertaken.

In summary, the results indicate that:

- The results indicate that the majority of flooding within the development is attributable to the base post-development scenario (Scenario 2), with dam breach contributing minimal incremental hazard across lots and internal roads.
- The exception is Area 1, where breach-driven flows are concentrated near the stream corridor. Within Area 1, habitable lot boundaries (P1, P3, P4) are subject to Low to Medium Hazard under the worst-case scenario (Scenario 5), with depth × velocity products not exceeding 0.29 m²/s. P2, located within the proposed park adjacent to the stream, is subject to Very High Hazard; however, this is consistent with its proximity to the watercourse and it is unlikely to be occupied during a 1000-year ARI event.
- Downstream of the development, the SH1 embankment provides a significant hydraulic barrier, with freeboard exceeding 10 m in all scenarios, confirming negligible impact to the downstream environment.

Safety-egresses have been determined for all areas in the development where available routes may be cut-off during collapse of the identified inadvertent dams. In conclusion, it is determined that there are adequate safety-egress routes available for all areas of the development during a dam-breach scenario.

The PIC assessment has not been included in the memorandum and separately undertaken by Riley Consultants. The objectives of the outcomes are consistent with the scope discussed with Auckland Transport and the outcomes of this assessment demonstrate that the Delmore Development can meet the requirements of the Building Act 2004, the Building (Dam Safety) Regulations 2022, and the NZSOLD 2024 Dam Safety Guidelines.



Appendix A

AT Correspondence Confirming Scope



Shakti Singh <shakti@fsconsulting.co.nz>

Delmore Fast Track Dam Meeting

13 messages

Sean Pearce <sean.pearce@awa.kiwi>

17 April 2026 at 10:42

To: "shakti@fsconsulting.co.nz" <shakti@fsconsulting.co.nz>, "pranilw@fsconsulting.co.nz" <pranilw@fsconsulting.co.nz>, "Mohammed Sahim (AT)" <mohammed.sahim@at.govt.nz>, "Nadine Perera (AT)" <nadine.perera@at.govt.nz>, Sean Pearce <sean.pearce@awa.kiwi>

Microsoft Teams meeting

Join: <https://teams.microsoft.com/meet/48740002234396?p=Nz6xoSuxxZ9kDx9KjH>

Meeting ID: 487 400 022 343 96

Passcode: kp34dj9t

[Need help?](#) | [System reference](#)

For organizers: [Meeting options](#)



Shakti Singh <shakti@fsconsulting.co.nz>

22 April 2026 at 16:02

To: "Mohammed Sahim (AT)" <mohammed.sahim@at.govt.nz>, Sean Pearce <sean.pearce@awa.kiwi>

Cc: "pranilw@fsconsulting.co.nz" <pranilw@fsconsulting.co.nz>, "Nadine Perera (AT)" <nadine.perera@at.govt.nz>, James Kitchen <james@mckenzieandco.co.nz>

Hi Mohammed and Sean,

Thank you for meeting with us on Tuesday. As discussed, I have developed the scope of work for the dam assessment required for the fast-track application. Could you please review the following and suggest any necessary changes?

- A dam classification assessment has been completed in line with the NZSOLD 2024 and Building Act 2003 requirements. The assessment identified 6 out of 12 culverts as 'classifiable dams.' Based on Tuesday's discussion, the memorandum will be updated to replace all reference of 'classifiable dams' with 'inadvertent dams'.

- I note that some identified 'inadvertent dams' have catchments too small for runoff to realistically approach the embankment crest level. We will address this in the report to provide a transparent view of the actual site constraints.

Dam-Break assessment

- Undertake a dam break assessment for the culverts identified as 'inadvertent dams' as per NZSOLD 2024 and AT discussions. This includes
 - Simulation of a Post-development model scenario to establish a base-case scenario.
 - Simulation of a scenario which allows for a 'rainy-day' and 'cascade' failure scenario:
 - A 100-year (+3.8°C) storm event, assuming culverts to be fully operational (or 0% blockage).
 - A 1000-year ARI storm event, assuming culverts are partially or completely inoperational.
- Undertake a PIC assessment (to be completed by Geotechnical engineer) and categorize the risk of 'dam break'.
- Evaluate the risk to the lots/roads under the above mentioned scenarios and recommend likely mitigation measures (if required) to reduce the likelihood and consequence of 'dam break'— this will be pursued during the EPA stage.
 - This will also include Geotechnical insights and commentary.
- Identify safety-egress routes for all areas in the development.
- Optional: Undertake additional scenarios to further include the existing NZTA culvert in the 'dam break' assessment.
- Provide a technical memorandum providing parameters, assumptions, findings and recommendations for the assessment.

As noted above, we will seek consent conditions to address any medium/high hazards identified through the assessment that will be pursued during the EPA stage. The report will include commentary on the likely measures available to reduce hazard severity.

Thanks and kind regards,



Shakti Singh - Senior Engineer

BEngTech, CPEng, CMEngNZ

+64 22 384 7197

www.fsconsulting.co.nz

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[Quoted text hidden]

Shakti Singh <shakti@fsconsulting.co.nz>

To: Charlotte MacDonald <CharlotteM@barker.co.nz>

Cc: Pranil Wadan <pranilw@fsconsulting.co.nz>

22 April 2026 at 16:23

Sorry Charlotte, forgot to tag you in the email chain. Will flick through the response to you once i receive it.

Thanks,



Shakti Singh - Senior Engineer

BEngTech, CPEng, CMEngNZ

+64 22 384 7197

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sender immediately and delete this email.

[Quoted text hidden]

Charlotte MacDonald <CharlotteM@barker.co.nz>

23 April 2026 at 11:30

To: Shakti Singh <shakti@fsconsulting.co.nz>

Cc: pranilw <pranilw@fsconsulting.co.nz>

Thanks Shakti. As a note – we haven't sent the dam assessment you prepared to AT yet as we thought it would be best to have the meeting with them first. Happy for you to send this on directly to Mohammed and Sean if you think useful, otherwise will leave for you to incorporate into the updated assessment.

Ngā mihi | Kind regards,

CHARLOTTE MACDONALD

Associate

027 296 5383

CharlotteM@barker.co.nz



barker.co.nz 

This email and any attachments are confidential. They may contain privileged information or copyright material. If you are not an intended recipient, please do not read, copy, use or disclose the contents without authorisation and we request you delete it and contact us at once by return email.

[Quoted text hidden]

[Quoted text hidden]

[Quoted text hidden]

[Quoted text hidden]

[Quoted text hidden]

○ This will also include Geotechnical insights and commentary.

- Identify safety-egress routes for all areas in the development.
- Optional: Undertake additional scenarios to further include the existing NZTA culvert in the 'dam break' assessment.
- Provide a technical memorandum providing parameters, assumptions, findings and recommendations for the assessment.

As noted above, we will seek consent conditions to address any medium/high hazards identified through the assessment that will be pursued during the EPA stage. The report will include commentary on the likely measures available to reduce hazard severity.

Thanks and kind regards,



Shakti Singh - Senior Engineer

BEngTech, CPEng, CMEngNZ

+64 22 384 7197

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[Quoted text hidden]

Mohammed Sahim (AT) <Mohammed.Sahim@at.govt.nz>

23 April 2026 at 12:52

To: Shakti Singh <shakti@fsconsulting.co.nz>, Sean Pearce <sean.pearce@awa.kiwi>

Cc: "pranilw@fsconsulting.co.nz" <pranilw@fsconsulting.co.nz>, "Nadine Perera (AT)" <Nadine.Perera@at.govt.nz>, James Kitchen <james@mckenzieandco.co.nz>

Hi Shakti,

Draft SoW for dam assessment refers. Please include comments as suggested on email below, is in blue colour and italics.

Please note, further technical details pertaining to inadvertent dams (road embankment) and culvert under new roads will be reviewed at EA.

Regards

Mohammed

From: Shakti Singh <shakti@fsconsulting.co.nz>

Sent: Wednesday, 22 April 2026 4:03 pm

To: Mohammed Sahim (AT) <Mohammed.Sahim@at.govt.nz>; Sean Pearce <sean.pearce@awa.kiwi>

Cc: pranilw@fsconsulting.co.nz; Nadine Perera (AT) <Nadine.Perera@at.govt.nz>; James Kitchen <james@mckenzieandco.co.nz>

Subject: Re: Delmore Fast Track Dam Meeting

Hi Mohammed and Sean,

Thank you for meeting with us on Tuesday. As discussed, I have developed the scope of work for the dam assessment required for the fast-track application. Could you please review the following and suggest any necessary changes?

- A dam classification *assessment will be completed* in line with the NZSOLD 2024, Building Act *2004 and NZ Building Dam Safety Regulation 2022* requirements. The brief assessment identified 6 out of 12 culverts as 'classifiable dams.' Based on Tuesday's discussion, the memorandum will be updated to replace all reference of 'classifiable dams' with 'inadvertent dams'.
- *Memorandum needs to be updated to include illustrated cross sections for each dam showing heights, stored reservoir, and flood levels at various ARI's (note, use culvert completely blocked scenario for volume calc).*
- *A detailed potential impact classification (PIC) reports meeting all the requirement of NZSOLD 2024 is required for the fast-track application.*
 - I note that some identified 'inadvertent dams' have catchments too small for runoff to realistically approach the embankment crest level. We will address this in the report to provide a transparent view of the actual site constraints.

Dam-Break assessment

- Undertake a dam break assessment for the culverts identified as 'inadvertent dams' as per NZSOLD 2024 and AT discussions. This includes
 - Simulation of a Post-development model scenario to establish a base-case scenario.
 - Simulation of a scenario which allows for a 'rainy-day' and 'cascade' failure scenario:
 - A 100-year (+3.8°C) storm event, assuming culverts to be fully operational (or 0% blockage).
 - A 1000-year ARI storm event, assuming culverts are partially or completely in operational.
 - *Simulation to include guidance (storm events to consider) in accordance with NZSOLD 2024 when assessing dam breach.*
- Undertake a PIC assessment (to be completed by *Chartered Geotechnical engineer, specialised in SW management dams*) and categorize the risk of 'dam break'.
- Evaluate the risk to the lots/roads under the above-mentioned scenarios and recommend likely mitigation measures (if required) to reduce the likelihood and consequence of 'dam break'— this will be pursued during the EPA stage. *Note, likely new lots affected by the potential flood inundation arising from dam breach will be need to be protected and will require "registering consent notices on titles".*

○ This will also include *Chartered Geotechnical/Dam Engineers* insights and commentary.

- Identify safety-egress routes for all areas in the development.
- Optional: Undertake additional scenarios to further include the existing NZTA culvert in the 'dam break' assessment.
- *Provide PIC providing parameters, assumptions, findings, dam locations, sections and flood level details and SW Flood modelling.*
- Provide a technical memorandum providing parameters, assumptions, findings and recommendations for the assessment.

As noted above, we will seek consent conditions to address any *low/medium/high risks dams* identified through the assessment that will be pursued during the EPA stage. The report will include commentary on the likely measures available to reduce hazard severity.

Thanks and kind regards,



Shakti Singh - Senior Engineer

BEngTech, CPEng, CMEngNZ

+64 22 384 7197

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On Fri, 17 Apr 2026 at 10:42, Sean Pearce <sean.pearce@awa.kiwi> wrote:

Microsoft Teams meeting

Join: <https://teams.microsoft.com/meet/48740002234396?p=Nz6xoSuxxZ9kDx9KjH>

Meeting ID: 487 400 022 343 96

Passcode: kp34dj9t

Appendix B

Illustrated Cross-Sections of Inadvertent Dams for 100-year and 1000-year ARI (+3.8°C) storm events

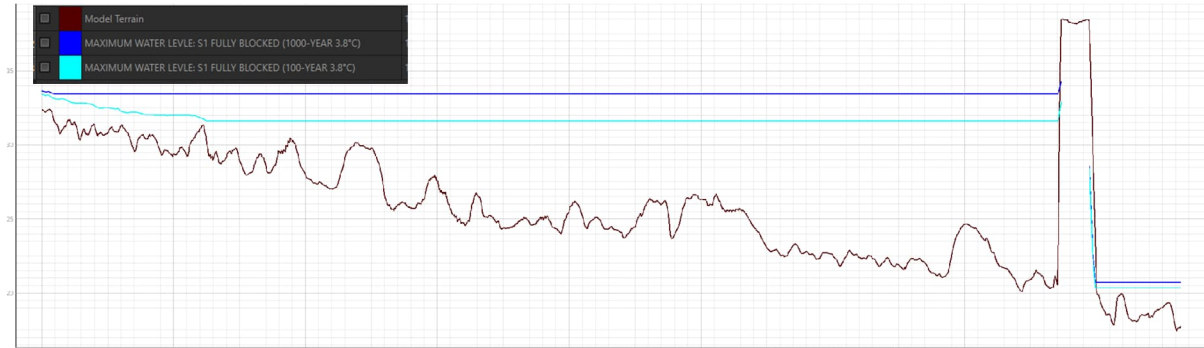


Figure: Embankment 11 cross-section



Figure: Embankment 9 cross-section

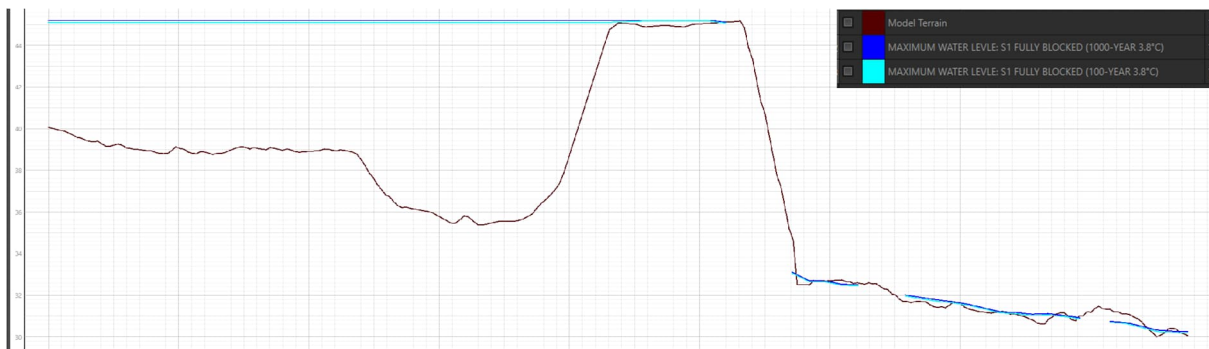


Figure: Embankment 8 cross-section

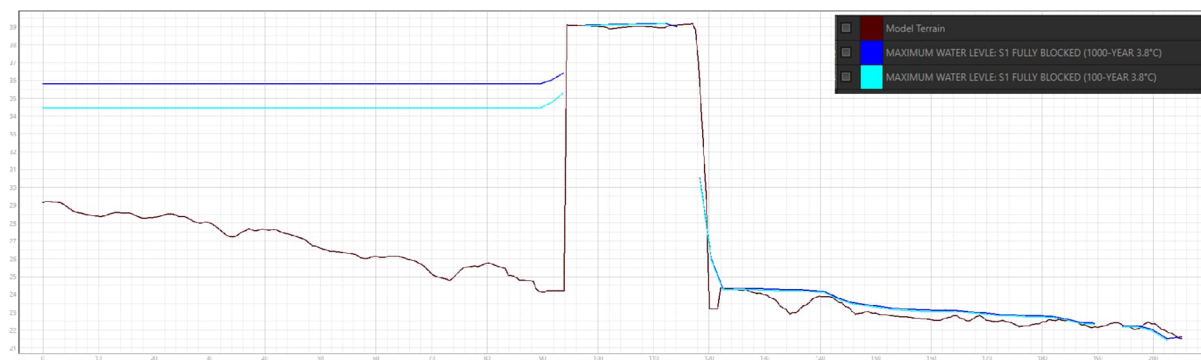


Figure: Embankment 6 cross-section

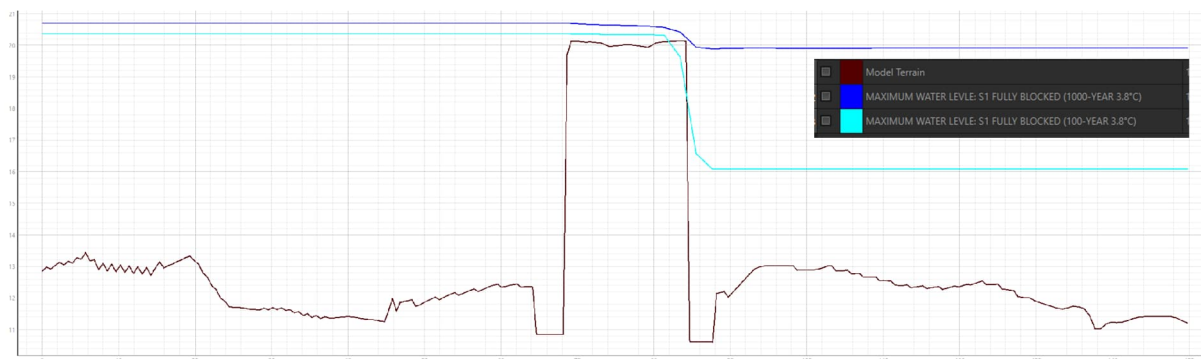


Figure: Embankment 4 cross-section

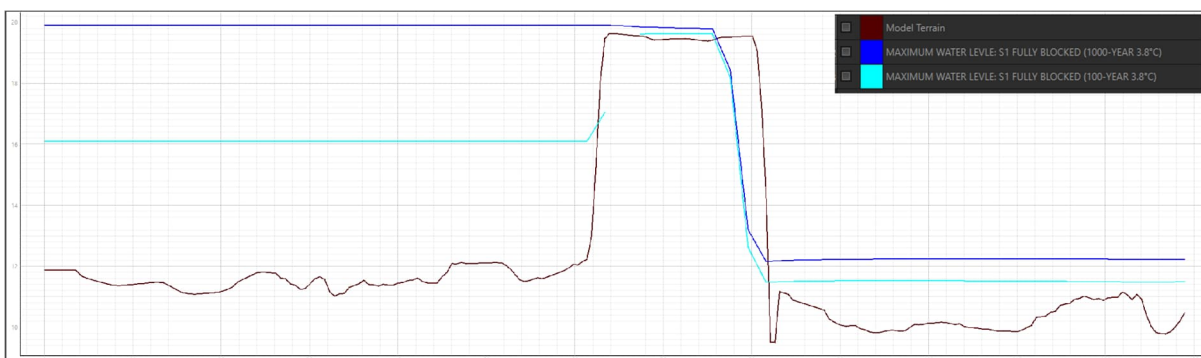


Figure: Embankment 3 cross-section

Table E1: Piping-failure input parameters — 100-year ARI (+3.8°C).

Parameter	PF03	PF04	PF06	PF08	PF09	PF11
U/S invert (m RL)	10.10	11.02	24.21	34.00	28.00	19.21
D/S invert (m RL)	9.51	10.85	23.21	32.50	25.30	17.64
Peak WL: Scenario 3 (m RL)	19.40	19.95	34.45	44.85	36.75	31.30
Peak WL: Scenario 4 and Scenario 5 (m RL)	19.40	19.95	34.45	44.85	36.75	30.67
Reservoir height: Scenario 3 (m)	9.30	8.93	10.24	10.85	8.75	12.09
Reservoir height: Scenario 4 and Scenario 5 (m)	9.30	8.93	10.24	10.85	8.75	11.46

Stored volume: Scenario 3 (m³)	31,322	124,844	33,888	20,196	89,443	214,284
Stored volume: Scenario 4 and Scenario 5 (m³)	31,322	124,844	33,888	20,196	89,443	160,887

Table E2: Piping-failure input parameters — 1000-year ARI (+3.8°C).

Parameter	PF03	PF04	PF06	PF08	PF09	PF11
U/S invert (m RL)	10.10	11.02	24.21	34.00	28.00	19.21
D/S invert (m RL)	9.51	10.85	23.21	32.50	25.30	17.64
Peak WL: Scenario 3 (m RL)	19.40	19.95	35.48	44.85	36.75	33.06
Peak WL: Scenario 4 and Scenario 5 (m RL)	19.40	19.95	35.48	44.85	36.75	31.42
Reservoir height: Scenario 3 (m)	9.30	8.93	11.27	10.85	8.75	13.85
Reservoir height: Scenario 4 and Scenario 5 (m)	9.30	8.93	11.27	10.85	8.75	12.21
Stored volume: Scenario 3 (m³)	31,322	124,844	45,668	20,196	89,443	265,905
Stored volume: Scenario 4 and Scenario 5 (m³)	31,322	124,844	45,668	20,196	89,443	188,873

Table E3: Overtopping-failure input parameters (geometry identical for all scenarios).

Parameter	DF03	DF04	DF06*	DF08	DF09	DF11*
Road / crest elevation (m RL)	19.45	20.00	38.85	44.90	36.80	35.30
Dam height to crest (m)	9.35	8.98	14.64	10.90	8.80	16.09
Stored volume at crest (m³)	31,322	124,844	103,153	20,196	89,443	405,892

*Overtopping doesn't occur, breach parameter set to simulate complete collapse of the embankment due to internal erosion

Appendix C

Gumbel Extrapolation of 1000-year ARI Rainfall

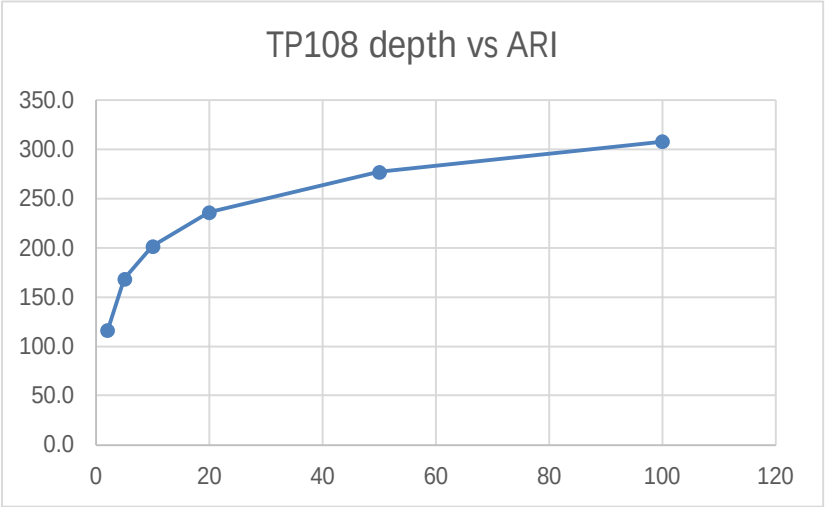
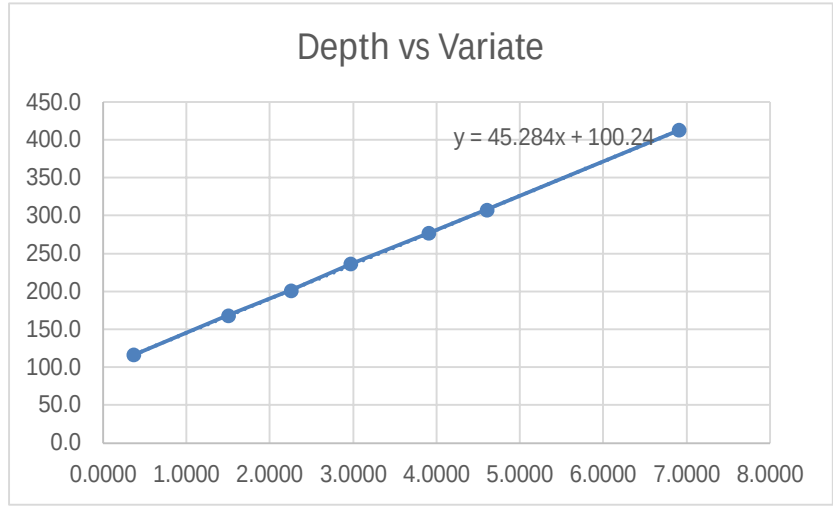
FLOWSTATE CONSULTING SPREADSHEET

HIRDS Rainfall ARI Extrapolation — Calculation

1. Site information		
Site / project	Delamore — Culvert-Dam 1	
Duration	24 h	
Source	TP108 v4 (NIWA)	
Date / analyst	5/20/2026	

2. HIRDS depths input (enter values in the yellow column; ARI list is fixed)						
ARI T (yr)	AEP = 1/T	Non-exc. F = 1 - 1/T	Gumbel reduced variate y = -ln(-ln F)	HIRDS depth P (mm)	Gumbel predicted (mm)	Squared error — Gumbel
2	0.5000	0.500000	0.3665	116.4	116.8	0.15
5	0.2000	0.800000	1.4999	168.5	168.2	0.10
10	0.1000	0.900000	2.2504	201.4	202.1	0.51
20	0.0500	0.950000	2.9702	236.2	234.7	2.01
50	0.0200	0.980000	3.9019	277.0	276.9	0.00
100	0.0100	0.990000	4.6001	307.9	308.6	0.47
1000	0.0010	0.999000	6.9073	413.03		

3. Gumbel (EV1) fit — linear regression of depth on the reduced variate	
Slope β (scale)	45.284
Intercept μ (location)	100.239
R ²	0.9999



Appendix D

Breach Parameter Formulation and input parameters

FLOWSTATE CONSULTING SPREADSHEET		
From	SS	
Date	5/6/2026	
Froehlich (2016) — Both Failure Modes (100-year CC Full Blockage CULV11)		

Equations: $t_f = 60 \cdot v(V_w / (g \cdot h_b^2))$ [s, mode-independent]; $\bar{B} = 0.23 \cdot k_0 \cdot V_w^{1/3}$ [m]; $Q_p = 0.0175 \cdot k_0 \cdot k_H \cdot v(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})$ [m³/s]. Coefficients used: k_0 for $\bar{B} = 1.3$ (OT) / 1.0 (P); k_0 for $Q_p = 1.85$ (OT) / 1.0 (P) per Froehlich (2016); $z = 1.0$ (OT) / 0.6 (P). k_H is a reservoir-shape correction — default 1.0; adjust per source paper if warranted.

Inputs (linked from Inputs tab)									
Parameter	Symbol	Unit	Dam 3	Dam 4	Dam 6	Dam 8	Dam 9	Dam 11	Notes
Piping volume	V_w	m³	31322	124844	33888	20196	89443	160887	Linked from Inputs
Volume to Road Crest	V_w Road Crest	m³	31322	124844	103153	20196	89443	405892	Linked from Inputs
Water depth above invert	h_w	m	9.30	8.93	10.24	10.85	8.75	11.46	Linked from Inputs
Breach height	h_b	m	9.94	9.15	15.64	12.40	11.50	17.66	Linked from Inputs
Dam structural height	h_d	m	9.35	8.98	14.64	10.90	8.80	16.09	Used by Xu & Zhang
Reservoir Shape Correction (User Input)									
Reservoir shape correction (Q_p)	k_H	—	1.00	1.00	1.00	1.00	1.00	1.00	USER INPUT — default 1.0. Same value applied to OT and P.

Common Result (mode-independent)									
Time to failure (seconds)	t_f	s	341	740	225	220	498	435	$60 \cdot \sqrt{(V_w / (g \cdot h_b^2))}$
Time to failure (hours)	t_f	hr	0.095	0.205	0.063	0.061	0.138	0.121	$t_f(s) / 3600$ — for comparison

Overtopping Failure (OT)									
Width coefficient (OT)	k_0 ($\bar{B}$)	—	1.50	1.50	1.50	1.50	1.50	1.50	1.3 for overtopping
Outflow coefficient (OT)	k_0 (Q_p)	—	1.85	1.85	1.85	1.85	1.85	1.85	1.85 for overtopping (Froehlich 2016)
Average breach width (OT)	$\bar{B}$	m	10.88	17.24	16.18	9.40	15.43	25.54	$0.23 \cdot k_0 \cdot V_w^{1/3}$. Volume to Road Crest used to avoid negative base widths which is also conservative.
Side slope ratio (OT)	z	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0 (h:v) for overtopping
Peak outflow (OT)	Q_p	m³/s	165.0	235.9	232.3	192.0	262.6	481.1	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})}$. Only Volume to the Max WL used for Peak Flow Check
Top Width	B_{top}	m	20.2	26.2	30.8	21.8	24.2	41.6	Top Width for TUFLOW input

Piping Failure (P)									
Width coefficient (P)	k_0 ($\bar{B}$)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping
Outflow coefficient (P)	k_0 (Q_p)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping (Froehlich 2016)
Average breach width (P)	$\bar{B}$	m	7.25	11.50	7.44	6.26	10.29	12.51	$0.23 \cdot k_0 \cdot V_w^{1/3}$
Side slope ratio (P)	z	—	0.6	0.6	0.6	0.6	0.6	0.6	0.6 (h:v) for piping
Average breach width (P)	$\bar{B}$	m	7.25	11.50	7.44	6.26	10.29	12.51	Average Width for Rectangular Orifice (TUFLOW)
Peak outflow (P)	Q_p	m³/s	109.2	156.2	185.1	127.1	173.9	371.6	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})}$

FLOWSTATE CONSULTING SPREADSHEET		
From	SS	
Date	5/6/2026	
Froehlich (2016) — Both Failure Modes (100-year CC Full Blockage)		

Equations: $t_f = 60 \cdot v(V_w / (g \cdot h_b^2))$ [s, mode-independent]; $\bar{B} = 0.23 \cdot k_0 \cdot V_w^{(1/3)}$ [m]; $Q_p = 0.0175 \cdot k_0 \cdot k_H \cdot v(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})$ [m³/s]. Coefficients used: k_0 for $\bar{B} = 1.3$ (OT) / 1.0 (P); k_0 for $Q_p = 1.85$ (OT) / 1.0 (P) per Froehlich (2016); $z = 1.0$ (OT) / 0.6 (P). k_H is a reservoir-shape correction — default 1.0; adjust per source paper if warranted.

Inputs (linked from Inputs tab)									
Parameter	Symbol	Unit	Dam 3	Dam 4	Dam 6	Dam 8	Dam 9	Dam 11	Notes
Piping volume	V_w	m³	31322	124844	33888	20196	89443	214284	Linked from Inputs
Volume to Road Crest	V_w Road Crest	m³	31322	124844	103153	20196	89443	405892	Linked from Inputs
Water depth above invert	h_w	m	9.30	8.93	10.24	10.85	8.75	12.09	Linked from Inputs
Breach height	h_b	m	9.94	9.15	15.64	12.40	11.50	17.66	Linked from Inputs
Dam structural height	h_d	m	9.35	8.98	14.64	10.90	8.80	16.09	Used by Xu & Zhang
Reservoir Shape Correction (User Input)									
Reservoir shape correction (Q_p)	k_H	—	1.00	1.00	1.00	1.00	1.00	1.00	USER INPUT — default 1.0. Same value applied to OT and P.

Common Result (mode-independent)									
Time to failure (seconds)	t_f	s	341	740	225	220	498	502	$60 \cdot \sqrt{(V_w / (g \cdot h_b^2))}$
Time to failure (hours)	t_f	hr	0.095	0.205	0.063	0.061	0.138	0.139	t_f(s) / 3600 — for comparison

Overtopping Failure (OT)									
Width coefficient (OT)	k_0 ($\bar{B}$)	—	1.50	1.50	1.50	1.50	1.50	1.50	1.3 for overtopping
Outflow coefficient (OT)	k_0 (Q_p)	—	1.85	1.85	1.85	1.85	1.85	1.85	1.85 for overtopping (Froehlich 2016)
Average breach width (OT)	$\bar{B}$	m	10.88	17.24	16.18	9.40	15.43	25.54	$0.23 \cdot k_0 \cdot V_w^{(1/3)}$. Volume to Road Crest used to avoid negative base widths which is also conservative.
Side slope ratio (OT)	z	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0 (h:v) for overtopping
Peak outflow (OT)	Q_p	m³/s	165.0	235.9	232.3	192.0	262.6	570.3	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})}$. Only Volume to the Max WL used for Peak Flow Check
Top Width	Btop	m	20.2	26.2	30.8	21.8	24.2	41.6	Top Width for TUFLOW input

Piping Failure (P)									
Width coefficient (P)	k_0 ($\bar{B}$)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping
Outflow coefficient (P)	k_0 (Q_p)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping (Froehlich 2016)
Average breach width (P)	$\bar{B}$	m	7.25	11.50	7.44	6.26	10.29	13.76	$0.23 \cdot k_0 \cdot V_w^{(1/3)}$
Side slope ratio (P)	z	—	0.6	0.6	0.6	0.6	0.6	0.6	0.6 (h:v) for piping
Average breach width (P)	$\bar{B}$	m	7.25	11.50	7.44	6.26	10.29	13.76	Average Width for Rectangular Orifice (TUFLOW)
Peak outflow (P)	Q_p	m³/s	109.2	156.2	185.1	127.1	173.9	420.0	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{(g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B})}$

FLOWSTATE CONSULTING SPREADSHEET		
From	SS	
Date	5/6/2026	
Froehlich (2016) — Both Failure Modes (1000-year CC Full Blockage CULV11)		

Equations: $t_f = 60 \cdot \sqrt{V_w / (g \cdot h_b^2)}$ [s, mode-independent]; $\bar{B} = 0.23 \cdot k_0 \cdot V_w^{1/3}$ [m]; $Q_p = 0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$ [m³/s]. Coefficients used: k_0 for $\bar{B} = 1.3$ (OT) / 1.0 (P); k_0 for $Q_p = 1.85$ (OT) / 1.0 (P) per Froehlich (2016); $z = 1.0$ (OT) / 0.6 (P). k_H is a reservoir-shape correction — default 1.0; adjust per source paper if warranted.

Inputs (linked from Inputs tab)									
Parameter	Symbol	Unit	Dam 3	Dam 4	Dam 6	Dam 8	Dam 9	Dam 11	Notes
Piping volume	V_w	m³	31322	124844	45668	20196	89443	188873	Linked from Inputs
Volume to Road Crest	V_w Road Crest	m³	31322	124844	103152	20196	89443	405892	Linked from Inputs
Water depth above invert	h_w	m	9.30	8.93	11.27	10.85	8.75	12.21	Linked from Inputs
Breach height	h_b	m	9.94	9.15	15.64	12.40	11.50	17.66	Linked from Inputs
Dam structural height	h_d	m	9.35	8.98	14.64	10.90	8.80	16.09	Used by Xu & Zhang
Reservoir Shape Correction (User Input)									
Reservoir shape correction (Q_p)	k_H	—	1.00	1.00	1.00	1.00	1.00	1.00	USER INPUT — default 1.0. Same value applied to OT and P.

Common Result (mode-independent)									
Time to failure (seconds)	t_f	s	341	740	262	220	498	471	$60 \cdot \sqrt{V_w / (g \cdot h_b^2)}$
Time to failure (hours)	t_f	hr	0.095	0.205	0.073	0.061	0.138	0.131	$t_f(s) / 3600$ — for comparison

Overtopping Failure (OT)									
Width coefficient (OT)	k_0 ($\bar{B}$)	—	1.50	1.50	1.50	1.50	1.50	1.50	1.5 for overtopping
Outflow coefficient (OT)	k_0 (Q_p)	—	1.85	1.85	1.85	1.85	1.85	1.85	1.85 for overtopping (Froehlich 2016)
Average breach width (OT)	$\bar{B}$	m	10.88	17.24	16.18	9.40	15.43	25.54	$0.23 \cdot k_0 \cdot V_w^{1/3}$. Volume to Road Crest used to avoid negative base widths which is also conservative.
Side slope ratio (OT)	z	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0 (h:v) for overtopping
Peak outflow (OT)	Q_p	m³/s	165.0	235.9	282.9	192.0	262.6	538.1	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$. Only Volume to the Max WL used for Peak Flow Check
Top Width	B_{top}	m	20.2	26.2	30.8	21.8	24.2	41.6	Top Width for TUFLOW input

Piping Failure (P)									
Width coefficient (P)	k_0 ($\bar{B}$)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping
Outflow coefficient (P)	k_0 (Q_p)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping (Froehlich 2016)
Average breach width (P)	$\bar{B}$	m	7.25	11.50	8.22	6.26	10.29	13.20	$0.23 \cdot k_0 \cdot V_w^{1/3}$
Side slope ratio (P)	z	—	0.6	0.6	0.6	0.6	0.6	0.6	0.6 (h:v) for piping
Average breach width (P)	$\bar{B}$	m	7.25	11.50	8.22	6.26	10.29	13.20	Average Width for Rectangular Orifice (TUFLOW)
Peak outflow (P)	Q_p	m³/s	109.2	156.2	214.5	127.1	173.9	404.7	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$

FLOWSTATE CONSULTING SPREADSHEET		
From	SS	
Date	5/6/2026	
Frøehlich (2016) — Both Failure Modes 1000-year CC Full Blockage		

Equations: $t_f = 60 \cdot \sqrt{V_w / (g \cdot h_b^2)}$ [s, mode-independent]; $\bar{B} = 0.23 \cdot k_0 \cdot V_w^{1/3}$ [m]; $Q_p = 0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$ [m³/s]. Coefficients used: k_0 for $\bar{B} = 1.3$ (OT) / 1.0 (P); k_0 for $Q_p = 1.85$ (OT) / 1.0 (P) per Frøehlich (2016); $z = 1.0$ (OT) / 0.6 (P). k_H is a reservoir-shape correction — default 1.0; adjust per source paper if warranted.

Inputs (linked from Inputs tab)									
Parameter	Symbol	Unit	Dam 3	Dam 4	Dam 6	Dam 8	Dam 9	Dam 11	Notes
Piping volume	V_w	m³	31322	124844	45668	20196	89443	265905	Linked from Inputs
Volume to Road Crest	V_w Road Crest	m³	31322	124844	103152	20196	89443	405892	Linked from Inputs
Water depth above invert	h_w	m	9.30	8.93	11.27	10.85	8.75	13.85	Linked from Inputs
Breach height	h_b	m	9.94	9.15	15.64	12.40	11.50	17.66	Linked from Inputs
Dam structural height	h_d	m	9.35	8.98	14.64	10.90	8.80	16.09	Used by Xu & Zhang
Reservoir Shape Correction (User Input)									
Reservoir shape correction (Q_p)	k_H	—	1.00	1.00	1.00	1.00	1.00	1.00	USER INPUT — default 1.0. Same value applied to OT and P.

Common Result (mode-independent)									
Time to failure (seconds)	t_f	s	341	740	262	220	498	559	$60 \cdot \sqrt{V_w / (g \cdot h_b^2)}$
Time to failure (hours)	t_f	hr	0.095	0.205	0.073	0.061	0.138	0.155	$t_f(s) / 3600$ — for comparison

Overtopping Failure (OT)									
Width coefficient (OT)	k_0 ($\bar{B}$)	—	1.50	1.50	1.50	1.50	1.50	1.50	1.5 for overtopping
Outflow coefficient (OT)	k_0 (Q_p)	—	1.85	1.85	1.85	1.85	1.85	1.85	1.85 for overtopping (Frøehlich 2016)
Average breach width (OT)	$\bar{B}$	m	10.88	17.24	16.18	9.40	15.43	25.54	$0.23 \cdot k_0 \cdot V_w^{1/3}$. Volume to Road Crest used to avoid negative base widths which is also conservative.
Side slope ratio (OT)	z	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0 (h:v) for overtopping
Peak outflow (OT)	Q_p	m³/s	165.0	235.9	282.9	192.0	262.6	680.0	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$. Only Volume to the Max WL used for Peak Flow Check
Top Width	B_{top}	m	20.2	26.2	30.8	21.8	24.2	41.6	Top Width for TUFLOW input

Piping Failure (P)									
Width coefficient (P)	k_0 ($\bar{B}$)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping
Outflow coefficient (P)	k_0 (Q_p)	—	1.00	1.00	1.00	1.00	1.00	1.00	1.0 for piping (Frøehlich 2016)
Average breach width (P)	$\bar{B}$	m	7.25	11.50	8.22	6.26	10.29	14.79	$0.23 \cdot k_0 \cdot V_w^{1/3}$
Side slope ratio (P)	z	—	0.6	0.6	0.6	0.6	0.6	0.6	0.6 (h:v) for piping
Average breach width (P)	$\bar{B}$	m	7.25	11.50	8.22	6.26	10.29	14.79	Average Width for Rectangular Orifice (TUFLOW)
Peak outflow (P)	Q_p	m³/s	109.2	156.2	214.5	127.1	173.9	483.1	$0.0175 \cdot k_0 \cdot k_H \cdot \sqrt{g \cdot V_w \cdot h_w \cdot h_b^2 / \bar{B}}$

Appendix E

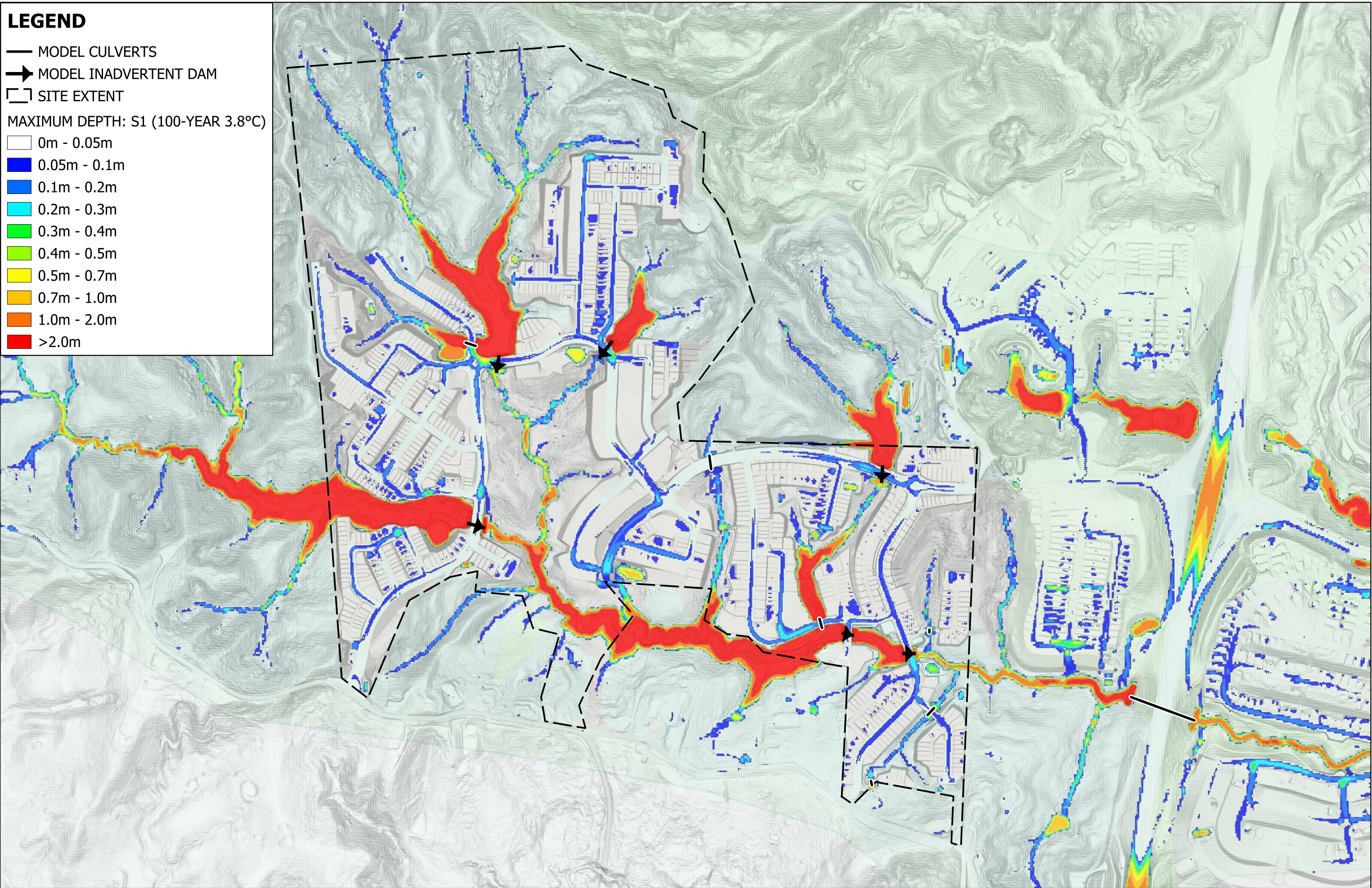
Maximum modelled flood depth maps

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S1 (100-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S1: 100-YEAR ARI 3.8°C



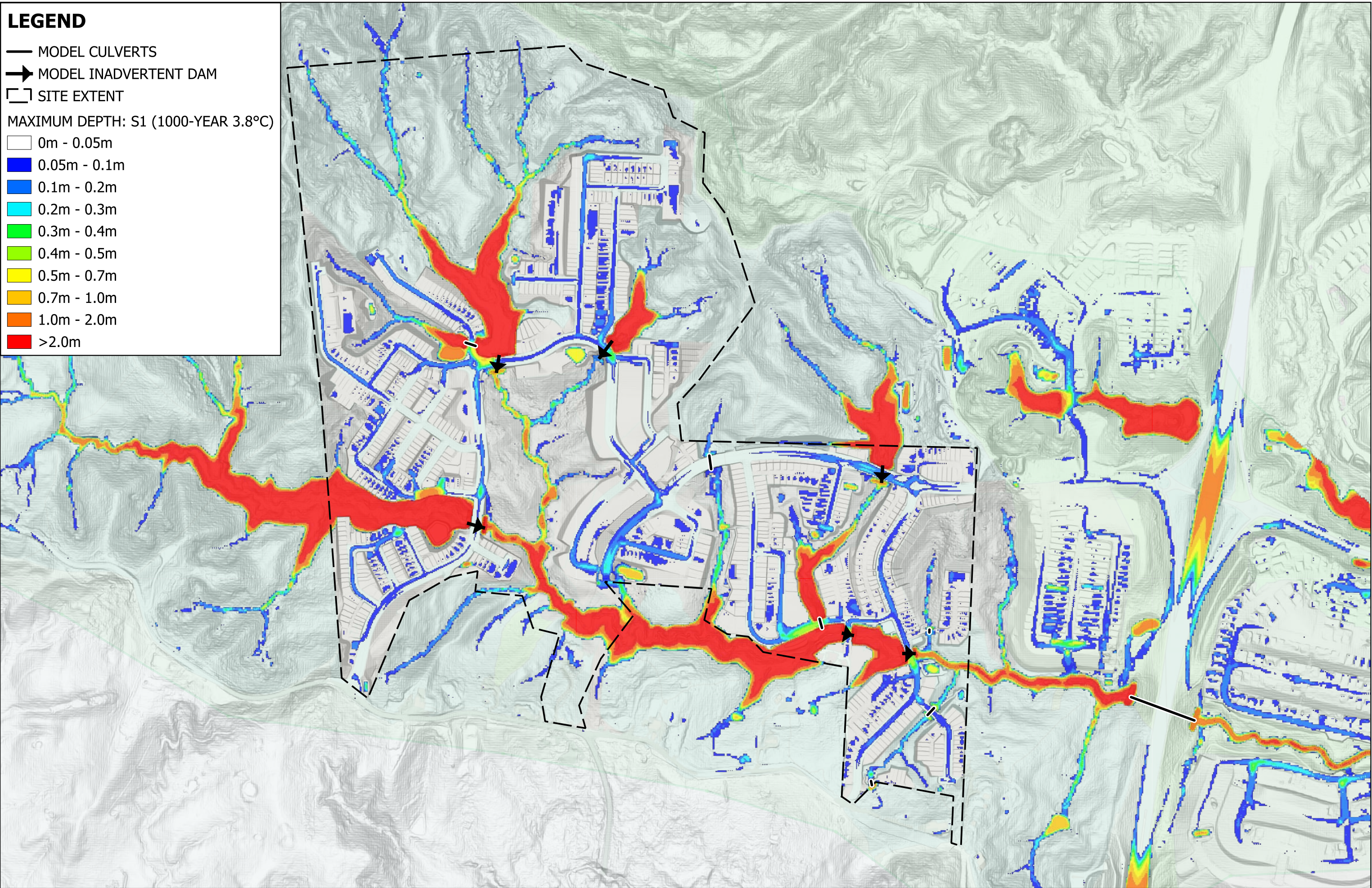
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 1 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S1 (1000-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S1: 1000-YEAR ARI 3.8°C

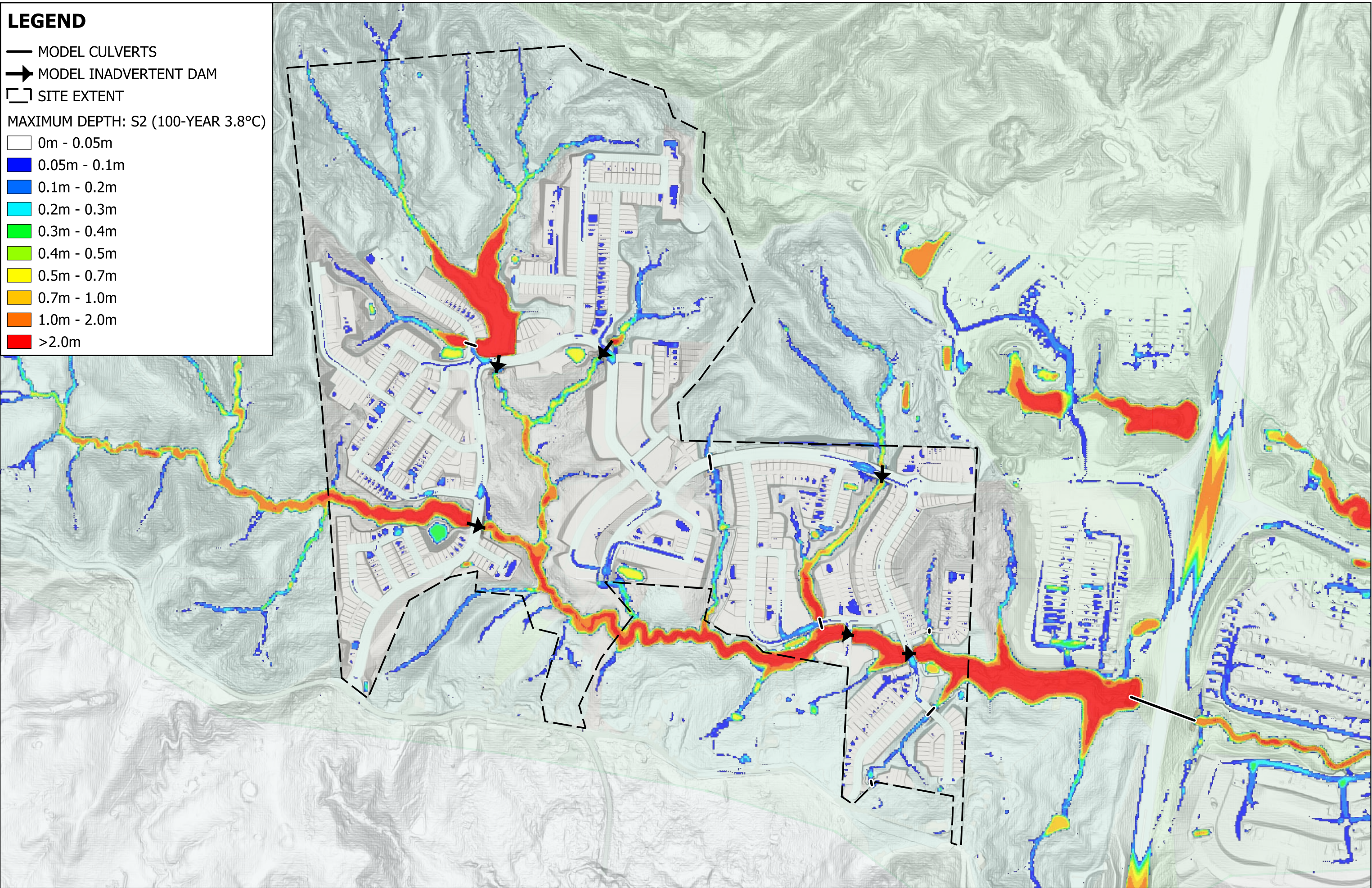
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 2 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S2 (100-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S2: 100-YEAR ARI 3.8°C



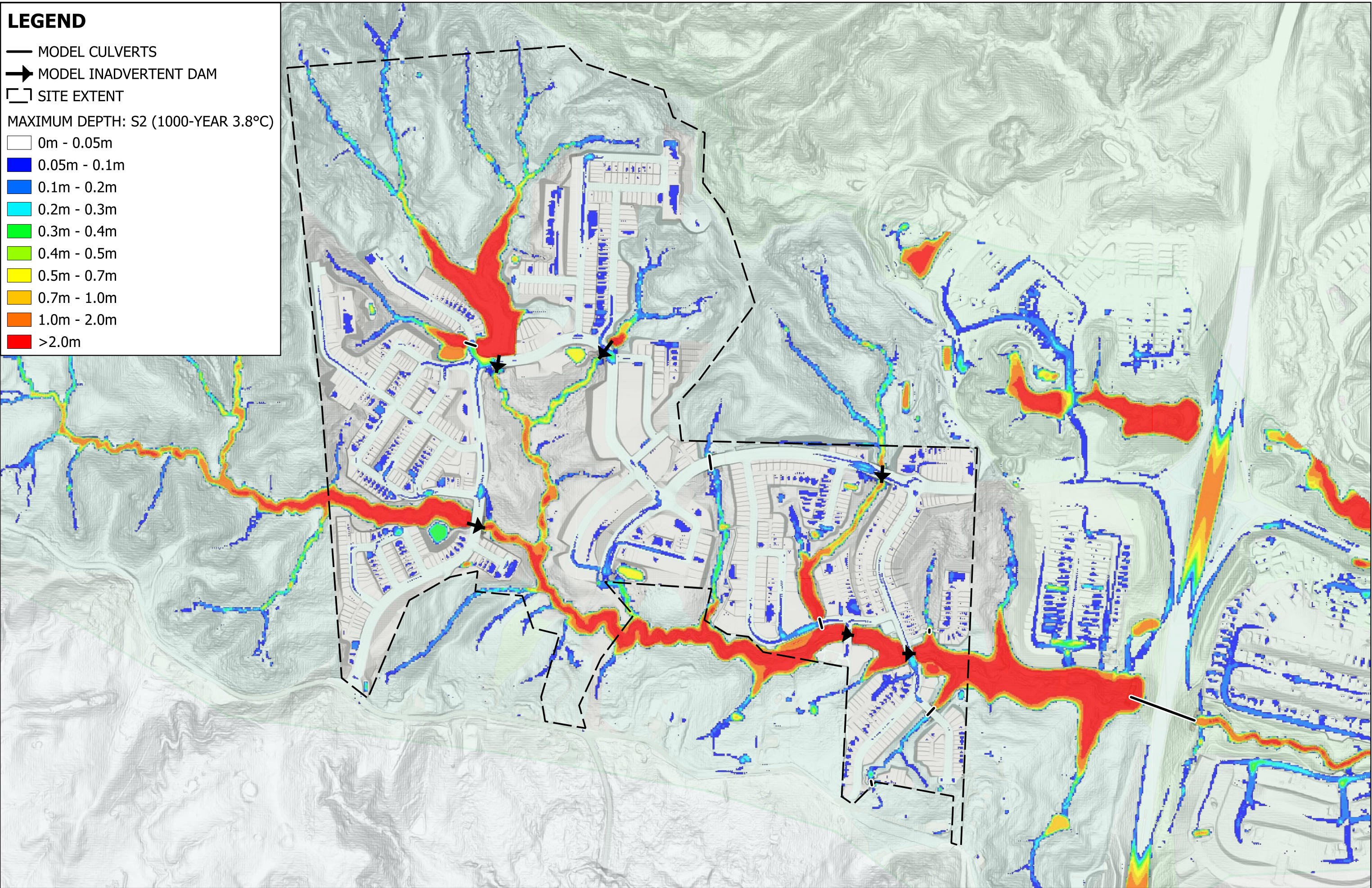
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 3 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S2 (1000-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S2: 1000-YEAR ARI 3.8°C



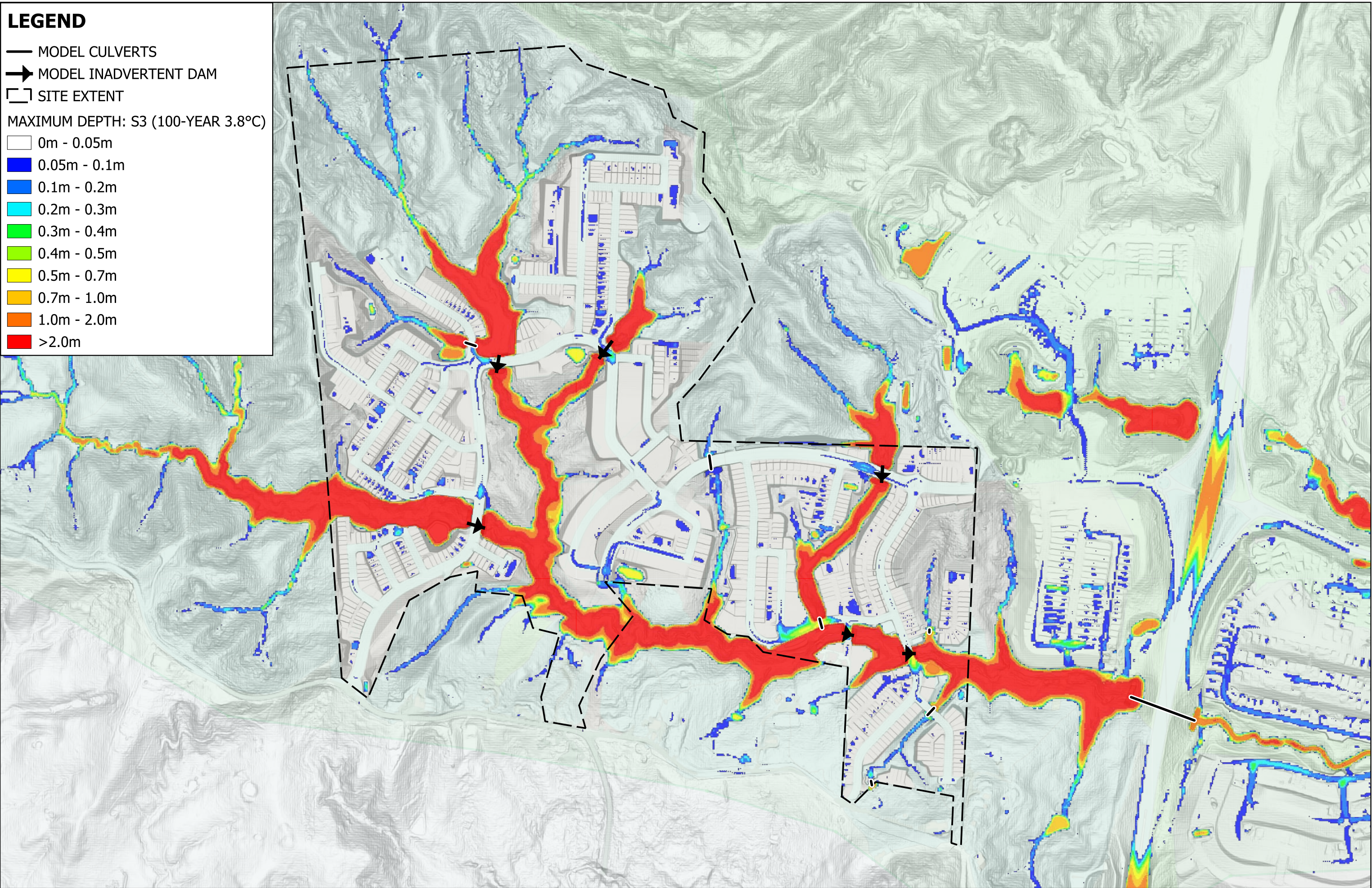
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 4 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S3 (100-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S3: 100-YEAR ARI 3.8°C

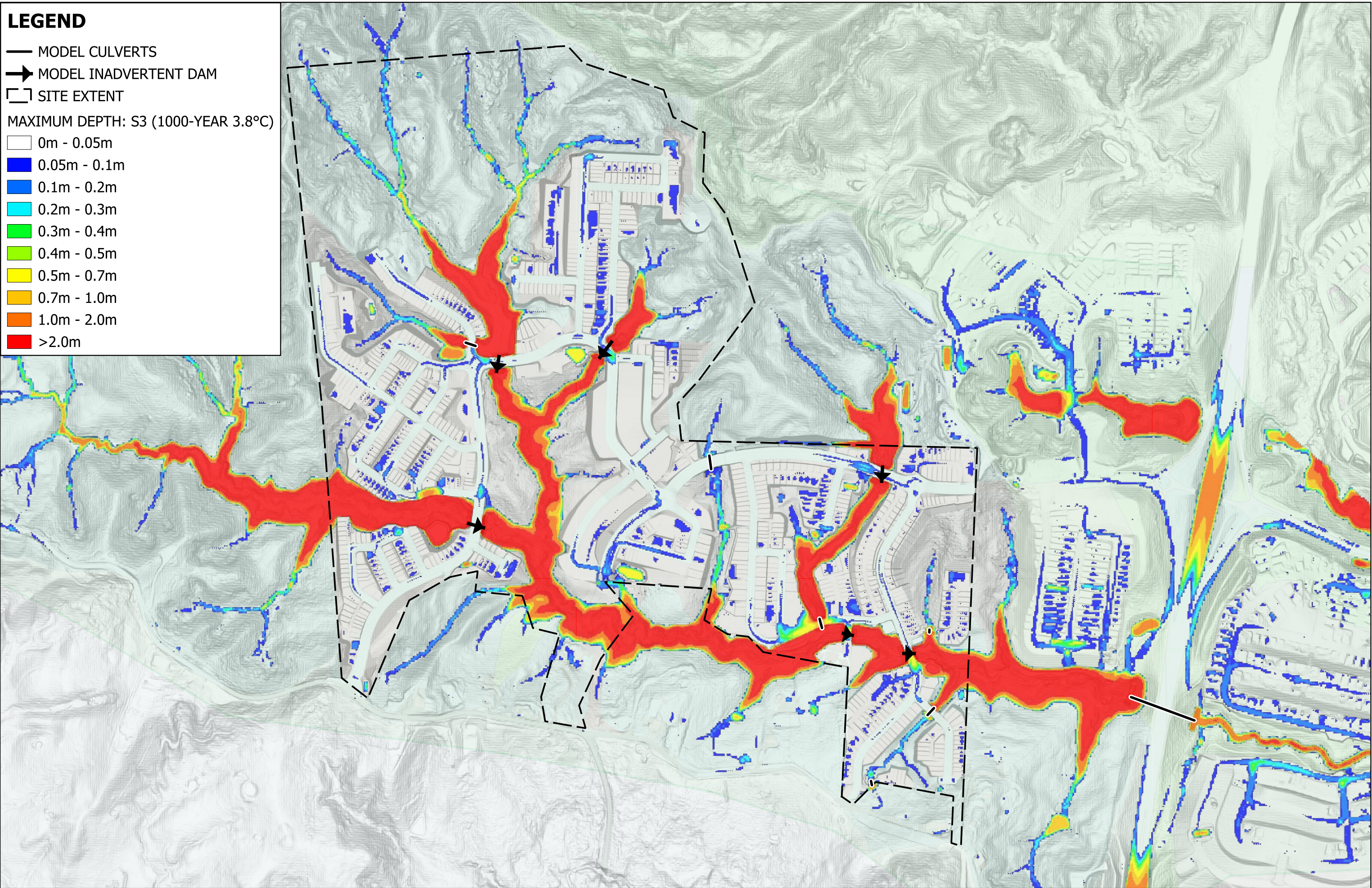
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 5 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S3 (1000-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S3: 1000-YEAR ARI 3.8°C

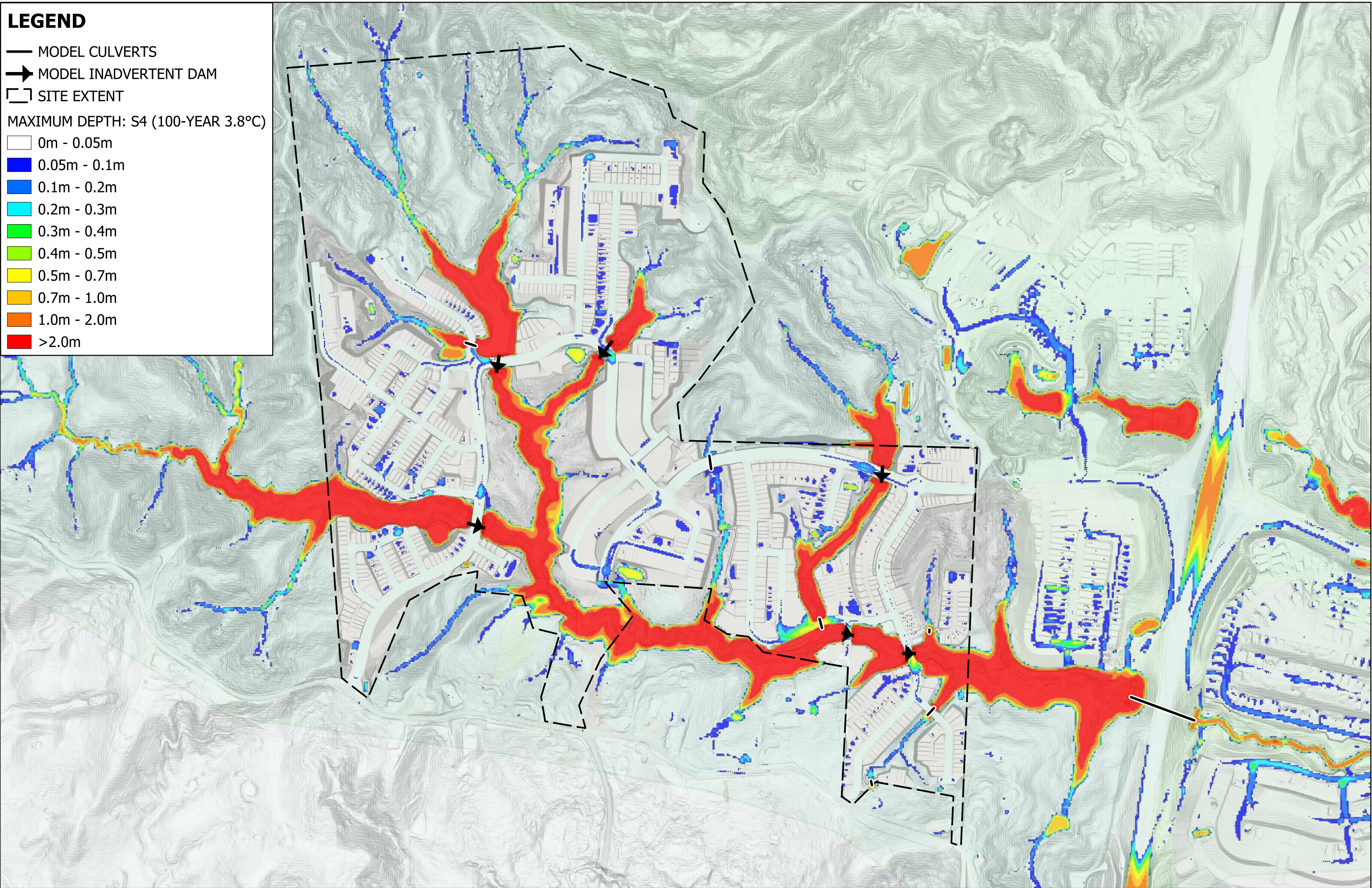
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 6 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S4 (100-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S4: 100-YEAR ARI 3.8°C



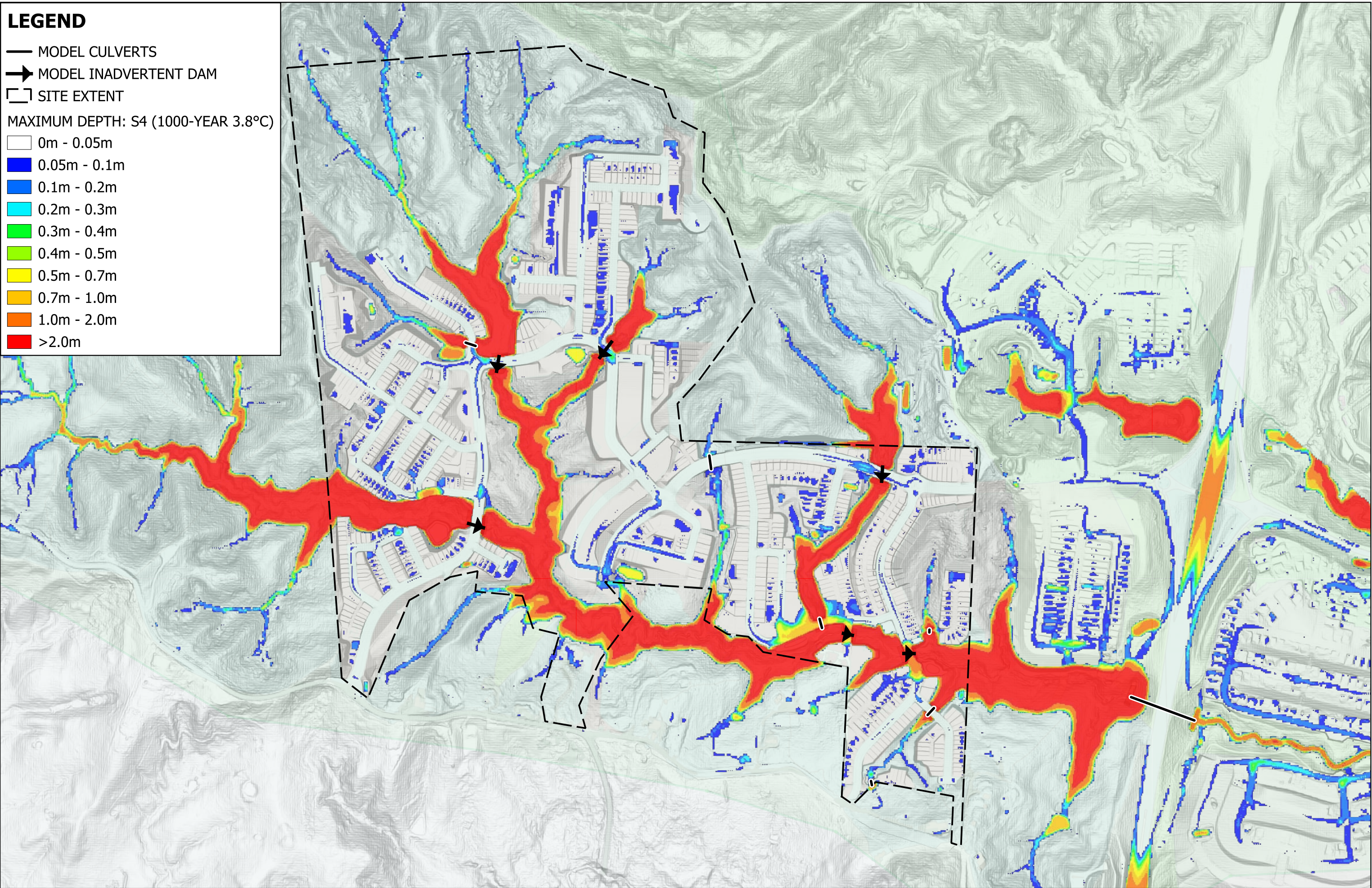
STATUS	ISSUED FOR INFORMATION	REV
SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 7 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S4 (1000-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S4: 1000-YEAR ARI 3.8°C



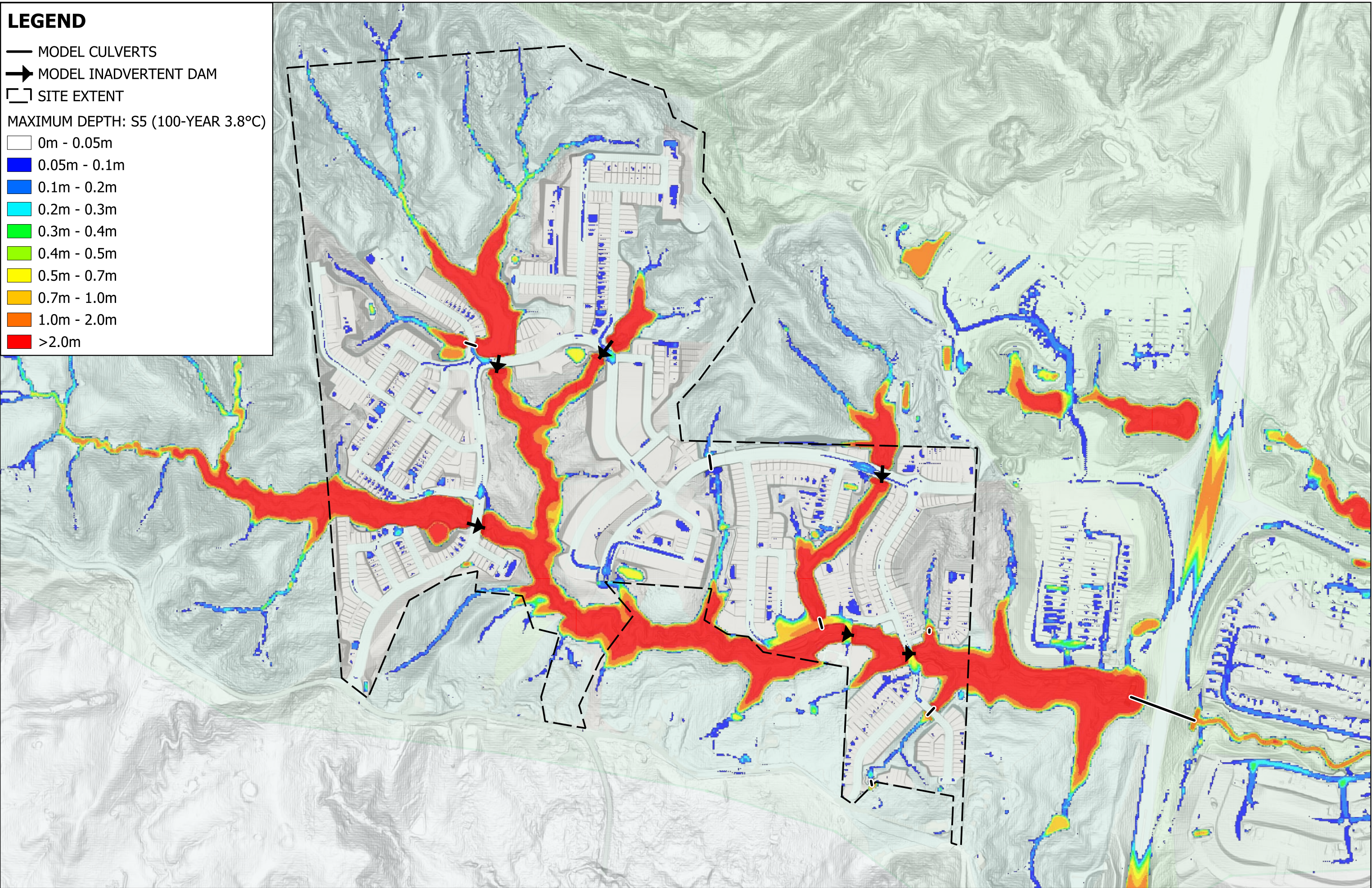
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SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 8 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S5 (100-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
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				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S5: 100-YEAR ARI 3.8°C

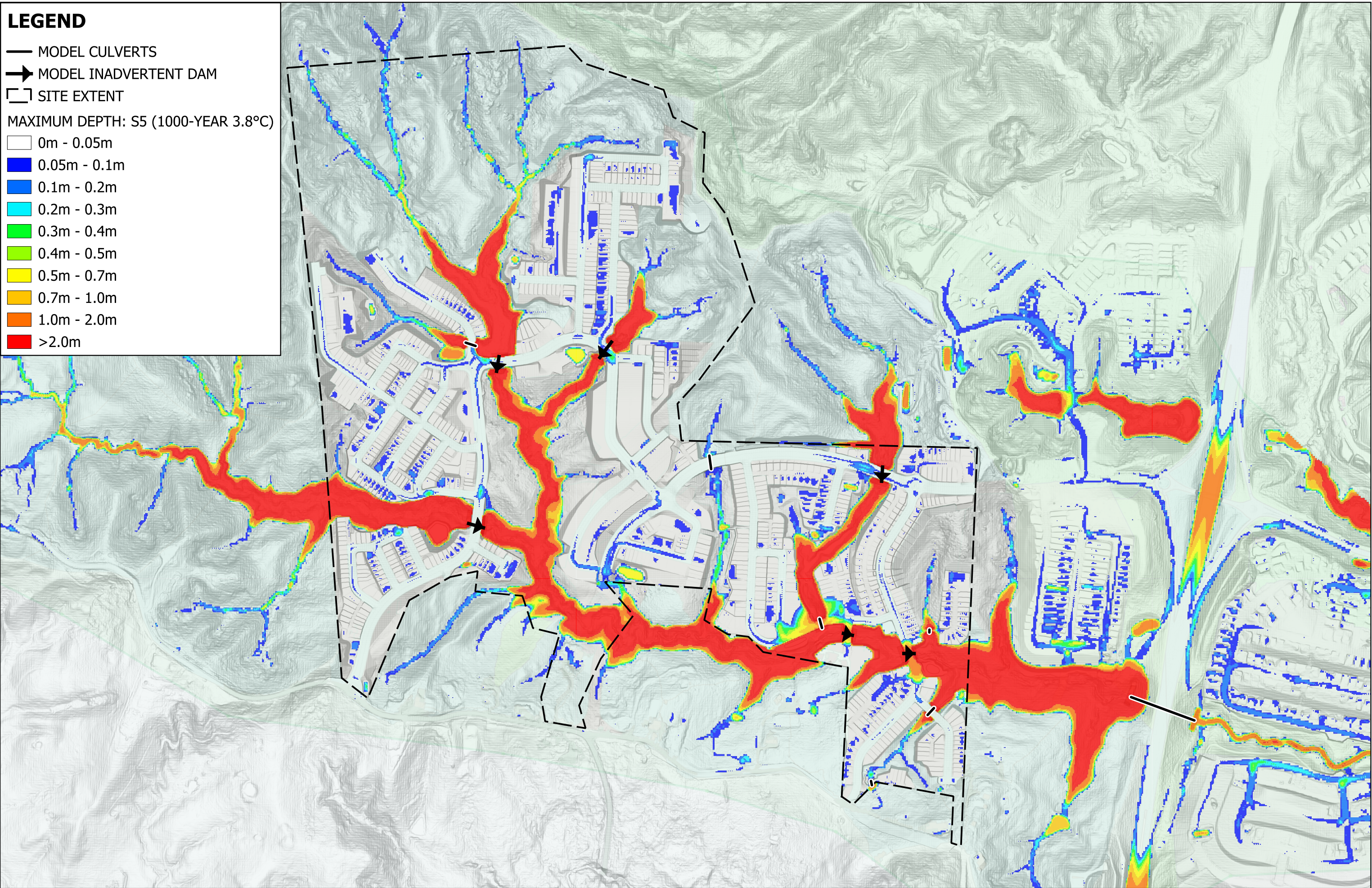
STATUS	ISSUED FOR INFORMATION	REV
SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 9 OF 10	

LEGEND

- MODEL CULVERTS
- MODEL INADVERTENT DAM
- SITE EXTENT

MAXIMUM DEPTH: S5 (1000-YEAR 3.8°C)

- 0m - 0.05m
- 0.05m - 0.1m
- 0.1m - 0.2m
- 0.2m - 0.3m
- 0.3m - 0.4m
- 0.4m - 0.5m
- 0.5m - 0.7m
- 0.7m - 1.0m
- 1.0m - 2.0m
- >2.0m



REVISION DETAILS		INT	DATE	SURVEYED	-	LEVEL 9, 4 WILLIAMSON AVENUE, PONSONBY, AUCKLAND, 1021 fsconsulting.co.nz
1.0	FOR INFORMATION	-	05/06/2026	DESIGNED	SS	
-	-	-	-	DRAWN	AL	
-	-	-	-	CHECKED	PW	
				APPROVED	PW	



FS26-132 DELMORE DAM ASSESSMENT
MAXIMUM MODELLED FLOOD DEPTH
S5: 1000-YEAR ARI 3.8°C

STATUS	ISSUED FOR INFORMATION	REV
SCALE	NTS	1.0
COUNCIL	AUCKLAND COUNCIL	
SHEET	SHEET 10 OF 10	

Attachment B: Geotechnical Assessment



Potential Impact Classification Assessment

Russell Road, Orewa

Potential Impact Classification Assessment

Russell Road, Orewa

Report prepared for: Vineway Ltd

Report prepared by: Steve Singh, Water Resources Engineer


Report prepared and reviewed by: Oscar Barrett-Garnier, Water Resources Engineer


Report approved for issue by: Don Tate, Project Director, CPEng


Report reference: 240065-U

Date: 5 June 2026

Copies to: Vineway Ltd Electronic copy

Riley Consultants Ltd Electronic copy

Issue	Details	Date
1.0	Final	5 June 2026

Executive Summary

Riley Consultants Ltd has assessed the Potential Impact Classification (PIC) for six proposed road embankments, at the request of Vineway Ltd. The Potential Impact Classification has been assessed in accordance with the Building Regulations, while following recommendations from the New Zealand Dam Safety Guidelines.

The PIC assessment was informed by estimates of the flood hazard, which could eventuate during a hypothetical worst-case cascading dam breach of the embankments, as modelled by Flow State Consultants.

For all six road embankments, the Potential Impact Classification has been assessed to be Low (Table A). As a result of:

- **Damage Level – Minimal.** Noting that damage is expected to be limited to the embankments themselves and the watercourses between the embankments and State Highway 1. Attenuation from the State Highway 1 embankment is expected to mitigate potential impacts downstream of State Highway 1. Peak flows downstream of State Highway 1 were similar to those expected during large natural floods.
- **Population at Risk – 1 to 10 persons.** Comprising road users on the embankments themselves, and downstream roads. It seems unlikely that there would be recreational users on tracks/paths downstream during such an extreme rainfall event.
- **Potential for Loss of Life – no persons.** While there will always be potential for loss of life, it appears unlikely that a life would be lost as a result of a dam breach. Any potential for loss of life seems most likely to be associated with a vehicle driving or being swept off a road embankment. However, given the expected number of vehicle movements, speed environment and available sight lines, it seems that in all probability, a vehicle would identify and avoid this hazard.

Table A: Dam Potential Impact Classification (PIC) – NZSOLD (2024) and the Building Regulations (2022)

Assessed Damage Level	Population at Risk				Potential Loss of Life
	0	1-10	11-100	> 100	
Catastrophic	High	High	High	High	No persons
	N/A	High	High	High	One person
	N/A	High	High	High	Two or more persons
Major	Medium	Medium	High	High	No persons
	N/A	Medium	High	High	One person
	N/A	High	High	High	Two or more persons
Moderate	Low	Low	Medium	Medium	No persons
	N/A	Medium	Medium	Medium	One person
	N/A	High	High	High	Two or more persons
Minimal	Low	Low	Low	Low	No persons
	N/A	Medium	Medium	Medium	One person
	N/A	High	High	High	Two or more persons

Note: The PIC could potentially increase in the future, if uses of the downstream floodplain are altered.

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Appendices

Appendix A:	Damage Level Assessment
Appendix B:	Road Users Assessment – Campbell Method
Appendix C:	Dam Breach Flood Hazard Maps (Riley Sketch: 240065-SK102)

Potential Impact Classification Assessment

Russell Road, Orewa

1.0 Introduction

Riley Consultants Ltd has assessed the Potential Impact Classification (PIC) for six proposed road embankments, at the request of Vineway Ltd. The PIC has been assessed in accordance with the Building (Dam Safety) Regulations (The Regulations, 2022), while following recommendations from the New Zealand Dam Safety Guidelines (2024).

2.0 Background

A number of road embankments designed within a development proposed at the above address, are proposed to serve a flood attenuation function, and inadvertently act as dams (if the culverts block and/or during extreme rainfall events). Flow State Consultants (FSC) have undertaken hypothetical dam breach modelling for six of the embankments, which may (or may not) meet the definition of a classifiable dam once they are constructed. Key characteristics of the embankments, and the roads they will support are summarised below.

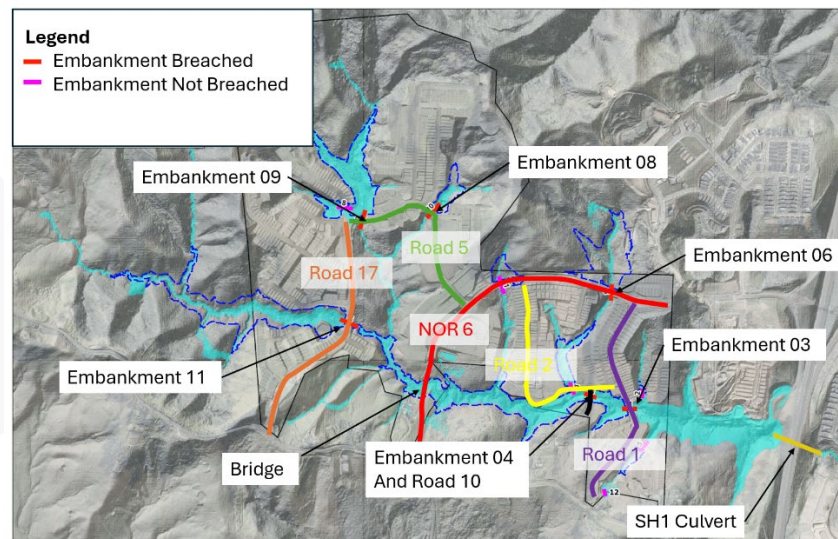


Figure 1 Embankments Breached – Locations

Table 1: Embankments Breached – Details

Embankment	Dam Toe (RL, m)	Spill Level (RL, m)	Dam height (m)	Volume to spill level (m ³)	Road Average Annual Daily Traffic (veh/day)
03	9.4	19.4	10.0	30,000	1,500 (Road 1)
04	10.8	20	9.2	130,000	1,000 (Road 10)
06	23.2	38.9	15.7	100,000	15,000 (NOR 6)
08	32.5	45.0	12.5	20,000	2,600 (Road 5)
09	25.2	37.1	11.9	100,000	2,600 (Road 5)
11	17.5	35.4	17.9	400,000	2,600 (Road 17)

3.0 Scope

The scope is to assess the PIC of the six proposed road embankments, which may inadvertently act as dams during extreme rainfall events. This is intended to ensure that appropriate design standards can be selected, in support of a fast track resource consent application for the structures. It is intended for the scope to be suitable to also fulfil the PIC requirements of the Dam Safety Regulations (once the reservoir is constructed). The scope includes:

1. Presenting dam breach hydraulic modelling undertaken by FSC. This simulates hypothetical worst-case effects that could result from a dam breach.
2. Damage level assessment, to document potential effects to communities, infrastructure and the environment, in accordance with the New Zealand Dam Safety Guidelines (2024).
3. Assessment of the Population at Risk and Potential for Loss of Life.
4. Determination of the PIC for the proposed embankments.

4.0 Dam Breach

4.1 Model Scenarios

FSC have modelled 5 scenarios, including a 100-year and 1,000-year Average Recurrence Interval (ARI) rainfall coinciding with:

1. No-breach scenario, with total blockage of low-level outlet culverts.
2. No-breach scenario, with total blockage of all culverts (excluding SH1 culvert).
3. Dam-breach scenario
4. Dam-breach scenario, with 50% blockage of the motorway culvert
5. Dam-breach scenario, with 50% blockage of the motorway culvert, and earlier Dam 11 breach.

Dam breach scenarios modelled include failure of each of the 6 embankments, either:

- Through an overtopping mechanism, when water levels reach the spillover level.
- Through a piping mechanism (dams 06 and 11) at a specified time

We have considered the dam breach results from the 1,000-year ARI rainfall coinciding with Scenarios 4 and 5 (Table 2). From reviewing the modelling, we note that:

- Dam breach floodwaters take less than 10 minutes to progress from the most upstream dam to the SH1 culvert/embankment.
- Embankments 03 and 04 are downstream of embankments 06, 08, 09 and 11. As such, the failure of embankments 03 and 04 is largely controlled by the timing of the failure of the upstream dams.

- If embankments 03 and 04 were to withstand overtopping flows, floodwaters upstream of these embankments would be higher, and may inundate nearby proposed buildings. A broad crested weir equation, using the peak flow through embankment 04, suggests that headwater levels upstream of embankment 04 might approach RL 22m (2m higher). Given the upstream/downstream slopes of the proposed embankments, it is assumed that this would be an unrealistic scenario.
- Flood levels upstream of embankments 06 and 11 do not reach the spillover level. A rainfall with a more extreme ARI, or of longer duration could potentially result in these embankments storing approximately two times as much volume. We consider that assessment of such a scenario would be overconservative, noting that the embankments have very large culverts, and the assumption of total blockage is already very conservative.

Table 2: Dam Breach Details

Embankment	Scenario 4				Scenario 5			
	Peak HWL (RL, m)	Peak Storage (m³)	Peak Outflow (m³/s)	Breach Timing	Peak HWL (RL, m)	Peak Storage (m³)	Peak Outflow (m³/s)	Breach Timing
03	19.4	31,322	-	12:40	19.4	31,322	-	12:40
04	19.95	124,844	-	12:35	19.95	124,844	-	12:35
06	35.48	45,668	100	20:45	35.48	45,668	115	20:45
08	44.85	20,196	125	12:45	44.85	20,196	125	12:45
09	36.75	89,443	260	12:25	36.75	89,443	260	12:25
11	33.06	265,905	525	20:40	31.42	188,873	250	13:10

4.2 Verification

Froelich (2016a) presents estimates of peak discharges from 42 dams that have failed. The dams in the catalogue tended to be water storage reservoirs, with much greater storage-to-height ratios:

- Dams with similar storage tended to have lower heights and lower peak discharge.
- Dams of similar height tended to have much greater storage and higher peak discharge.

We consider that peak discharges (breach outflows) from Flow State Consultants modelling fall within the expected range. We note that the peak outflows from dams 3 and 4 are somewhat controlled by the magnitude of breach flows from the upstream dams and the presence of the downstream State Highway 1 embankment.

4.3 State Highway 1 (SH1)

The SH1 embankment crosses the dam breach floodplain (Figure 2). Flows are passed under the embankment through a culvert. The inlet to the culvert is of large diameter (several meters). The hydraulic modelling considers 50% blockage of the culvert inlet, which is considered to be quite a conservative blockage scenario.

Regardless of the blockage assumed at the SH1 culvert inlet, flows downstream of the SH1 embankment are heavily attenuated. In all modelled scenarios, the flood extent remains very similar to the flood extent in the baseline (no dam breach) flood scenario. We have therefore limited the assessment of effects to areas upstream of the SH1 embankment. We note that there are a number of cultural sites and bridges downstream of the SH1 embankment.



Figure 2: State Highway 1 Culvert (Reproduced from MCKENZIE & CO. Flood Assessment Report)

Even if dams 06 and 11 were to breach while storing water to their crest, it seems unlikely that the SH1 embankment would overtop.

- 250,000m³ – Approximate additional water able to be stored within dams 06 and 11.
- Approximately 900,000m³ of storage upstream of the SH1 embankment.
- RL 27m – Peak flood level upstream of the SH1 embankment (all modelled scenarios).
- 340,000m³ – Storage to peak water level (from 2.).
- 560,000m³ – Storage remaining above peak water level (from 2.)

4.4 Flood Hazard Mapping

We have extracted the modelled peak flood depths and velocities from the 1,000-year ARI dam breach scenarios (4 and 5). We have used these to create dam breach flood hazard maps (Appendix C), using the six flood hazard categories derived by Smith et al. (2014):

H1 – Generally safe for vehicles, people and buildings

H2 – Unsafe for small vehicles

H3 – Unsafe for vehicles, children and the elderly.

H4 – Unsafe for vehicles and people. Some less robust buildings subject to failure.

H5 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

5.0 Potential Impact Classification

5.1 Damage Level Assessment

The Regulations require assessment of a damage level for the dam, considering potential for downstream damage across four specified categories. Details of the damage level assessment are provided within Appendix A. We consider that the damage level for the dam is Minimal (Table 3), taking into account:

- No buildings were identified to be in floodwaters other than those expected to generally be safe for buildings (H1 – Smith et al. 2014).
- No cultural sites were identified upstream of the SH1 embankment.
- No more than minor effects identified for Critical or Major Infrastructure. The road embankments (including NOR 6) are not considered to be Critical or Major Infrastructure, as they are not State Highways, and alternate access is possible. The NOR 6 bridge, and SH1 road embankment is expected to incur minimal damage (if any).
- Minor rehabilitation/restoration is required for the downstream environment to recover.

Table 3: Damage Level (Reproduced from Table 2.2 – NZSOLD, 2024)

Damage Level	Community Buildings	Cultural Sites	Specified Categories		Natural Environment
			Damage	Time to restore operation ¹	
Catastrophic	One or more of the following apply: 50 or more households rendered uninhabitable. 20 or more commercial or industrial facilities rendered inoperable. 2 or more community facilities rendered inoperable.	Irreparable loss to 2 or more historical or cultural sites.	Two or more critical or major infrastructure facilities rendered inoperable.	One year or more.	Extensive and widespread damage, with permanent, irreparable effects on the natural environment.
Major	One or more of the following apply: 4 or more but less than 50 household units rendered uninhabitable. 5 or more but less than 20 commercial or industrial facilities rendered inoperable. 1 community facility rendered inoperable.	One or both of the following apply: irreparable loss to 1 historical or cultural site. loss to 1 or more where is impracticable, to fully restore the site.	One critical or major infrastructure facility is rendered inoperable.	Three months or more but less than 1 year.	Extensive and widespread damage where it is possible, but impracticable, to fully restore or repair the damage.
Moderate	One or more of the following apply: 1 or more but less than 4 household units rendered uninhabitable. 1 or more but less than 5 commercial or industrial facilities rendered inoperable. loss of some functionality of one or more community facilities.	Significant loss to 1 or more historical or cultural sites where it is practicable to restore the site.	One or more critical or major infrastructure facilities are affected by the loss of some functionality.	Less than 3 months.	Significant damage that is practicable to restore or repair.
Minimal	Minor damage that does not materially affect the functionality of any household unit, commercial or industrial facility, or community facility (or no damage).	Loss to 1 or more historical or cultural sites that will require minor restoration only (or no loss to any historical or cultural site)	Minor damage to 1 or more critical or major infrastructure facilities (or no damage).	One week or less.	Only minor rehabilitation or restoration may be required or recovery is possible without intervention (or no damage)

5.2 Population at Risk

The Regulations define Population at Risk (PAR) as the number of people likely to be affected by a dam breach scenario (assuming that no person takes any action to evacuate). The Regulations require the PAR to be categorised as either:

- 0
- 1 to 10
- 11 to 100
- greater than 100

The Guidelines clarify that the term 'likely to be affected' limits populations to those where dam break flood inundation would have potential life safety impacts. They highlight that the PAR will vary through time and recommend that the PAR be derived from the period of greatest consequence.

PAR identified downstream of the dam is limited to temporary populations associated with road, cycleway and footpath users on the dam embankment(s) themselves, and proposed Road 2:

- No buildings were modelled to be inundated by floodwaters unsafe for people (exceeding HI). We therefore consider that it is unlikely to be PAR associated with permanent populations.
- We have assumed that there is no PAR associated with temporary users on footpaths, cycleways or within the downstream watercourses. It seems unlikely that anyone would be present in these areas during an extreme rainfall event.

The New Zealand Dam Safety Guidelines state that temporary populations on roads should be estimated by methods which consider the annual average daily traffic count (AADT) and the length of the route exposed. This seems to imply that the period of greatest consequence should be based on average traffic (the AADT), as opposed to a shorter peak period (say when a bus full of passengers is crossing the embankment). The New Zealand Dam Safety Guidelines reference Appendix 11 of DNRME (2018), which contains examples of such methods.

Of the methods summarised within Appendix 11 of DNRME (2018), the Campbell Method has been selected for use within this assessment, following recommendations from Rhoades (2019), which provides an in-depth discussion around potential flood hazard effects for vehicle traffic. For instantaneous flooding scenarios, where vehicle occupants may be impacted in a timeframe which allows for no practical evasive response, Rhoades (2019) recommends that the Campbell Method be used.

The Campbell et al. (2013) methodology also considers probabilities of vehicle occupancy and of vehicles being present on the embankments. It also considers how these would differentiate between business-hour and after-hour scenarios.

When assessing the PAR, we have applied an average vehicle occupancy of 1.5 persons. We have assumed that potential life safety impacts are limited to the average occupants of:

- The time weighted probability of a vehicle being on an embankment at the time of a breach occurring.
- One additional vehicle, which chooses to drive across the embankment/floodwater, before the hazard is properly realized and the road is closed. We have assumed that the road will be closed by subsequent vehicles, limiting further potential life safety impacts.

When assessing the time weighted PAR, the Campbell et al. (2013) methodology also considers the probability of vehicles choosing to avoid the floodwaters, and the probability of vehicles which choose to enter the floodwaters having an accident. We have conservatively ignored these probabilities.

The exact PAR estimates derived by the Campbell et al. (2013) methodology are presented within Appendix B. The PAR for each individual dam embankment comprises:

1. The PAR associated with the road crossing the embankment itself.
2. The PAR associated with any downstream road embankments.
3. For dam embankment 06, the PAR associated with flows overtopping (and potentially breaching) Road 2.

Some embankments may be overtopped in the baseline scenario, which could potentially necessitate closure of the road. We have conservatively ignored the potential for this to occur, when assessing the incremental effects in a dam breach scenario.

While there is no guarantee that there would be any PAR, the PAR has been estimated to most likely be in the range of 1 to 10 for all of the dam embankments considered (Table 4). Of course, a scenario could also be conceived where the number of occupants, or vehicles on the embankment, is greater. Say where there is a queue of traffic on the embankment, or a bus loaded with occupants.

Table 4: Population at Risk (Road Users)

Road No.	Embankment	Estimate of PAR associated with a Dam Breach of Embankment					
		03	04	06	08	09	11
2	-			2			
1	03	2	2	2	2	2	2
10	04		2	2	2	2	2
NoR6	06			3			
5	08				2*		
5	09					2*	
17	11						2
Population at Risk		2	4	9	6	6	6

* Similar to the value derived for dam embankment 11.

5.3 Potential for Loss of Life

The Regulations define the Potential Loss of Life as the number of people expected to lose their life in a dam breach scenario. The Guidelines clarify that the Potential for Loss of Life is a subset of the PAR. The Regulations require the Potential for loss of life to be categorised as either no persons, one person or two or more persons. The New Zealand Dam Safety Guidelines provide guidance to assess the potential loss of life. The guidelines state that:

- No allowances for evacuation, early warning systems, or other emergency actions should be considered in estimating the potential loss of life, and
- Potential Loss of Life estimates are inherently difficult to develop.

The Potential for Loss of Life is a subset of the PAR defined by Campbell et al. (2013). PAR identified downstream of the dam was associated with temporary populations on roads.

When deriving the Potential for Loss of Life using Campbell et al. (2013), a time weighted approach, accounting for the probability of exposure/fatality and length of time populations are in the floodplain. We have assumed:

Probability a vehicle takes no action to avoid the dam-break hazard as 100% after-hours (or for vehicles already on the embankment when the breach occurs), and 10% for vehicles with time to choose whether to cross the embankment. We have then reduced the probabilities by an order of magnitude (as recommended by Campbell et al., 2013), to reflect heightened awareness of drivers in a rainy-day scenario.

- Probability of an accident for vehicles that do not take action to avoid the dam break hazard at 80%. This value is recommended for vehicles within and/or driving into an inundation zone during/after an event, with significant washout of a culvert.
- Vulnerability of vehicle passengers set at 90% (vehicle passengers would be unlikely to survive).

In reality, either no lives will be lost, or one (or more) life will be lost. When estimating the Potential for Loss of Life, NZSOLD recommends that fractional estimates be rounded to the nearest whole number. The Potential for Loss of Life (Table 5) was estimated to range from 0.08 to 0.43. In all cases the Potential for Loss of Life, therefore, gets rounded to 0. While it is possible that a breach of the dam embankments could result in loss of life, it does not appear likely.

Table 5: Potential for Loss of Life (Road Users)

Road No.	Road Embankment	Estimate of Potential for Loss of Life associated with a Dam Breach of Embankment					
		03	04	06	08	09	11
2	Road 2			0.08			
1	03	0.08	0.08	0.08	0.08	0.08	0.08
10	04		0.11	0.11	0.11	0.11	0.11
NoR6	06			0.16			
5	08				0.08*		
5	09					0.08*	
17	11						0.08
Potential for Loss of Life		0.08	0.19	0.43	0.27	0.27	0.27

* Similar to the value derived for dam embankment 11.

5.4 Dam Classification

The Potential Impact Classification for all 6 road embankments has been assessed to be Low (Table 6). This is a result of:

- Damage Level of Minimal
- Population at Risk of 1 to 10 persons
- Potential for Loss of Life of No Persons.

All considered breach scenarios result in the same classification. The outcome of the assessment would be insensitive to selection of:

- The Population at Risk.
- A Moderate damage level.

Table 6: Dam Potential Impact Classification (PIC)

Assessed Damage Level	Population at Risk				Potential Loss of Life
	0	1-10	11-100	> 100	
Catastrophic	High	High	High	High	No persons
	N/A	High	High	High	One person
	N/A	High	High	High	Two or more persons
Major	Medium	Medium	High	High	No persons
	N/A	Medium	High	High	One person
	N/A	High	High	High	Two or more persons
Moderate	Low	Low	Medium	Medium	No persons
	N/A	Medium	Medium	Medium	One person
	N/A	High	High	High	Two or more persons
Minimal	Low	Low	Low	Low	No persons
	N/A	Medium	Medium	Medium	One person
	N/A	High	High	High	Two or more persons

Note: *The PIC could potentially increase in the future if uses of the downstream floodplain alter in the future.

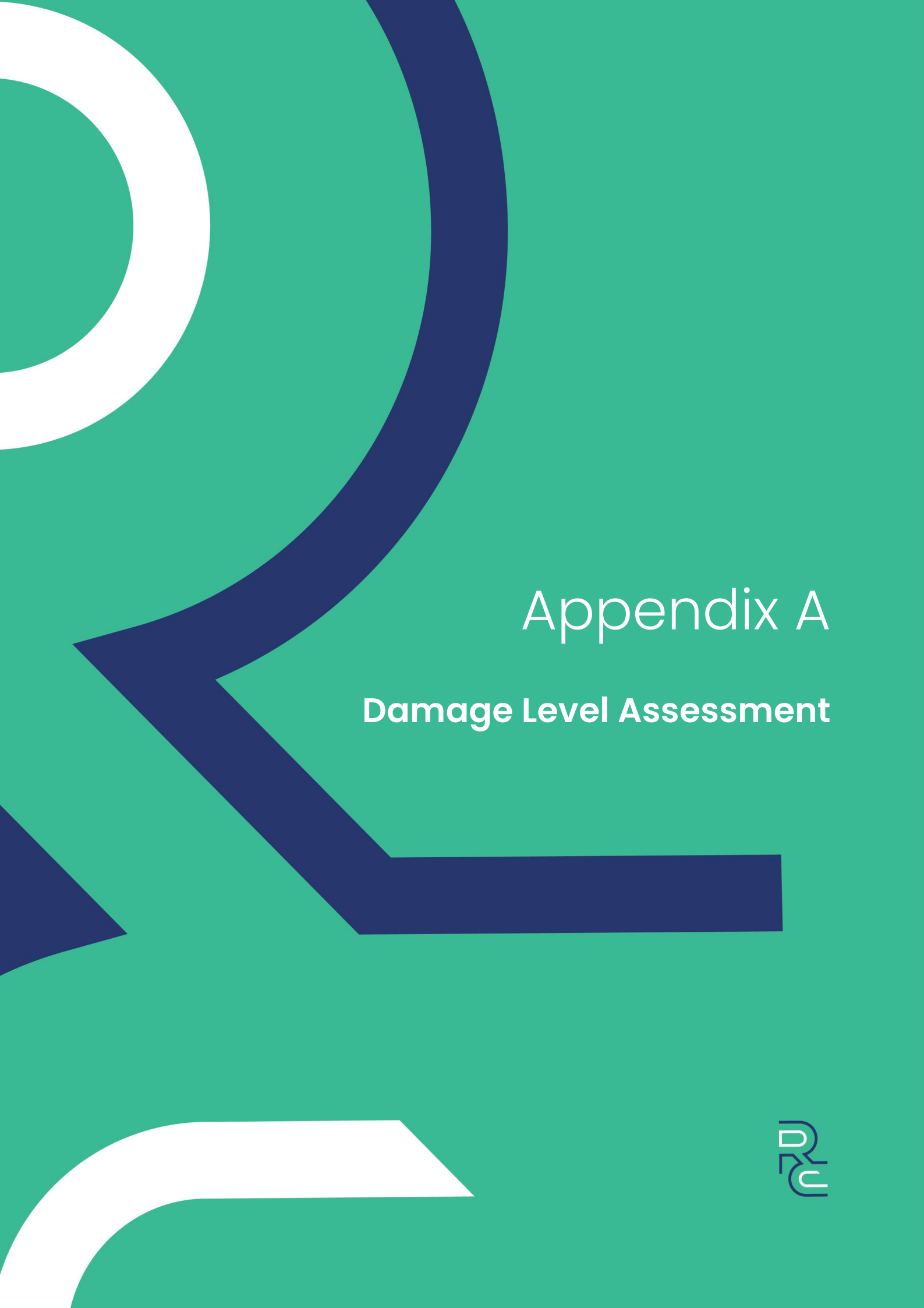
6.0 Limitation

This report has been prepared solely for the benefit of Vineway Ltd as our client with respect to the brief and Auckland Council in processing the consent(s). The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

The analyses and recommendations contained in this report are based on our understanding and interpretation of the available information. The recommendations are therefore subject to the accuracy and completeness of the information available at the time of the study. Should any further information become available, the analyses and findings of this report should be reviewed accordingly.

References

- Wahl, T. L. (1998). *Prediction of embankment dam breach parameters: A literature review and needs assessment*. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation. Dam Safety Research Report, Water Resources Research Laboratory. DSO-98-004.
- Campbell, J., Barker, G., Southcott, P., & Wallis, M. (2013). *Flooded cars: Estimating the consequences to itinerants exposed to dam break floods on roads*. IPENZ Proceedings of Technical Groups 39 (LD), New Zealand Society on Large Dams & ANCOLD Conference 2013
- Froehlich, D. C. (2016a). Predicting peak discharge from gradually breached embankment dam. *Journal of Hydrologic Engineering*, 21(10), 04016041. [https://doi.org/10.1061/\(ASCE\)HE.1943-5584.0001424](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001424)
- Froehlich, D. C. (2016b). *Empirical model of embankment dam breaching*. In Proceedings of the 3rd IAHR Europe Congress. <https://doi.org/10.1201/9781315644479-285>
- New Zealand Society on Large Dams. (NZSOLD, 2024). *Dam safety guidelines* (4th ed.). Wellington, NZ: NZSOLD.



Appendix A

Damage Level Assessment



Damage Level

1.0 Introduction

The Regulations require determination of a damage level for four categories:

- Community Buildings
- Cultural Sites
- Natural Environment
- Critical or Major Infrastructure

For each of the four categories, the damage level is to be assessed as either:

- Catastrophic
- Major
- Moderate
- Minimal

The dam breach scenario being considered within this assessment is a rainy-day scenario. In a rainy-day scenario, the damage level is limited to incremental damage. Where incremental damage is defined as the additional damage resulting from a dam-breach occurring, relative to the damage which would occur had the dam operated as intended (without breaching). By way of an example:

- Say a dam breach had potential to damage four areas.
- But three of those areas had potential to be damaged, even if the dam operated as intended (without breaching).
- The damage level would be based on potential for incremental damage to one additional area. As three of those areas would be damaged, regardless of whether the dam breached (or not).

The following sections assess the damage level for each of the four categories. The damage level for the dam(s) is selected as the highest of damage levels across the four specified categories.

1.2 Damage to Community Buildings

The damage level for community buildings (i.e. household units, commercial and industrial facilities and community facilities), is selected based on the number of individual buildings, which a dam breach could render uninhabitable or inoperable.

Neither the Regulations nor the Guide to complying with the Dam Safety Regulations state exactly how to determine whether a building would be rendered uninhabitable or inoperable. However, the New Zealand Dam Safety Guidelines recommend use of a method developed by Smith et al. (2014). This method (Figure 1) suggests that buildings:

- are likely to be rendered uninhabitable/inoperable if they are in floodwaters meeting a H6 flood hazard category.
- may be rendered uninhabitable/inoperable, if they are in floodwaters meeting a H5 flood hazard category, depending on the construction type.

It is noted that flood depth used in the method is intended to be measured relative to the building floor level. In this instance, floor level information is not available. We have assumed that floor levels are equal to the highest surrounding ground levels. It seems likely that this assumption will be conservative, as floor levels are expected to be slightly above surrounding ground levels.

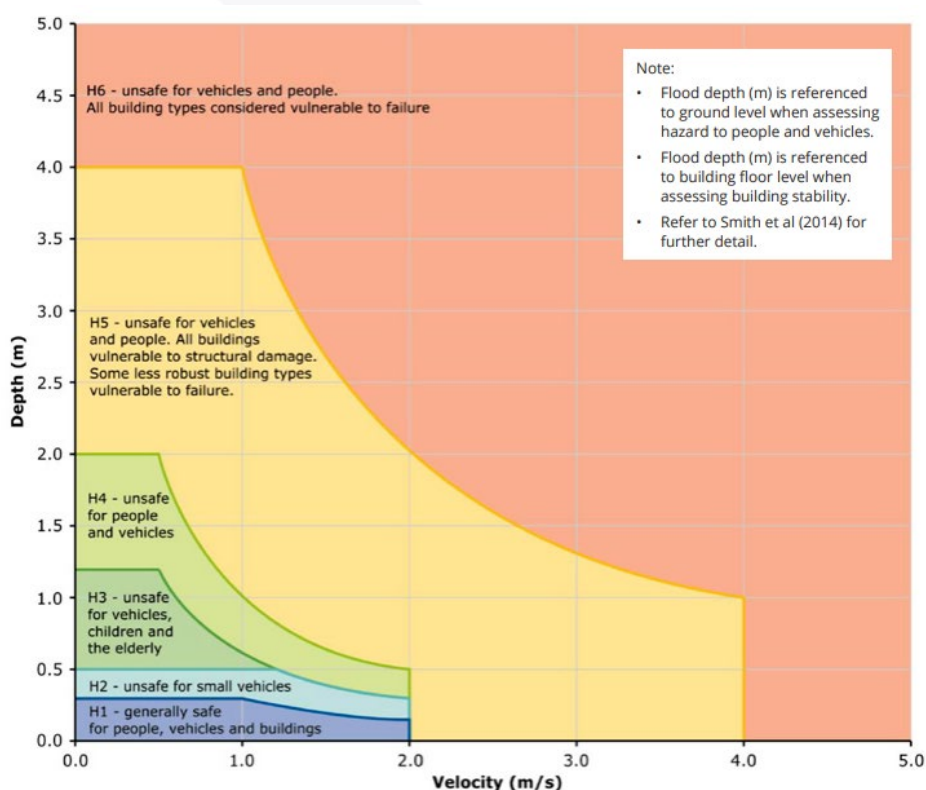


Figure 1: Flood Hazard Categories

Table 1 summarises the most relevant information in Figure 1 in tabular form. We have assumed that community buildings are rendered uninhabitable/inoperable (without consideration of construction type) where affected by floodwaters meeting a H5 flood hazard category. i.e. where:

- water depth is greater than 2.0m; or
- velocity is greater than 2.0m/s; or
- the VD product is greater than 1.0m²/s.

Table 1: Flood Hazard Categories

Flood Hazard Category	Lower VD Product Limit (m ² /s)	Lower Velocity Limit (m/s)	Lower Depth Limit (m)
H4	0.6	2.0	1.2
H5	1.0	2.0	2.0

The model results indicate that no buildings are proposed to be located in areas where floodwaters exceed the H1 category. Table 2 presents the corresponding minimal damage level for the community.

Table 2: Community Damage Level

Damage Level	Description
Catastrophic	One or more of the following apply: 50 or more household units rendered uninhabitable: 20 or more commercial or industrial facilities rendered inoperable: 2 or more community facilities rendered inoperable or uninhabitable
Major	One or more of the following apply: 4 or more but less than 50 household units rendered uninhabitable: 5 or more but less than 20 commercial or industrial facilities rendered inoperable: 1 community facility rendered inoperable or uninhabitable
Moderate	One or more of the following apply: 1 or more but less than 4 household units rendered uninhabitable: 1 or more but less than 5 commercial or industrial facilities rendered inoperable: loss of some functionality of 1 or more community facilities
Minimal	Minor damage that does not materially affect the functionality of any household unit, commercial or industrial facility, or community facility (or no damage)

1.3 Damage to Cultural Sites

The damage level for Cultural Sites is selected based on the number of individual sites expected to experience:

- Irreparable loss
- Loss where it is possible but impracticable, to fully restore the site
- Significant loss where it is practicable to restore the site
- Minor loss that will require minor restoration only
- No loss

The Guide to complying with the Dam Safety Regulations states that the intent is that only historical or cultural sites that have already been identified or designated as heritage sites are considered, rather than seeking out or introducing new ones.

We have reviewed the following sources to identify cultural sites:

1. New Zealand Archaeological Association: Archaeological Site Recording Scheme
2. Heritage New Zealand Pouhere Taonga: New Zealand Heritage List
3. The Auckland Unitary Plan, including the cultural heritage inventory, and also overlays for:
 - Natural Heritage
 - Historic Heritage and Special Character
 - Mana Whenua
4. The Department of Conservation: National Register of heritage sites managed by DOC.

No cultural sites were identified between the proposed dam embankments and State Highway 1.

A number of cultural sites have been identified downstream of State Highway 1. The attenuation provided by the State Highway 1 embankment, means that peak flows under State Highway 1 in a dam breach scenario, were of similar magnitude to those resulting from the same flood without a dam breach occurring. We therefore consider that a dam breach is unlikely to result in incremental damage to cultural sites in this area, beyond what can be expected from the baseline (no breach) scenario.

We consider the most appropriate cultural damage level is Minimal (Table 3) as we have not identified any historical or cultural sites expected to be incrementally damaged in a dam breach scenario.

Table 3: Cultural Damage Level

Damage Level	Description
Catastrophic	Irreparable loss to 2 or more historical or cultural sites
Major	One or both of the following apply: - irreparable loss to 1 historical or cultural site: - loss to 1 or more historical or cultural sites where it is possible, but impracticable, to fully restore the site
Moderate	Significant loss to 1 or more historical or cultural sites where it is practicable to restore the site
Minimal	Loss to 1 or more historical or cultural sites that will require minor restoration only (or no loss to any historical or cultural site)

1.4 Natural Environment

The damage level for the natural environment needs to be established as either:

- Extensive and widespread damage, with permanent, irreparable effects.
- Extensive and widespread damage where it is possible, but impracticable, to fully restore or repair the damage.
- Significant damage that is practicable to restore or repair.
- Minor rehabilitation or restoration may be required, or recovery is possible without intervention.

Neither the Regulations nor the Guide to complying with the Dam Safety Regulations define the natural environment. The New Zealand Dam Safety Guidelines suggest that environmental information should be sourced from topographic maps, internet searches, discussion with local agencies and organisations, District Planning maps, and searches of Department of Conservation databases. It also suggests that damage to the following environmental aspects should be considered:

- Waterways and wetlands
- Flora and fauna
- Rare or endangered species
- Deposition or erosion of sediment
- Reduction of visual amenity
- Contamination (particularly for tailings or wastewater treatment dams).

The natural environment between the dam embankments and State Highway 1 is heavily modified. There are several areas with proposed ecological covenants. Damage from a dam breach would likely result in damage to the waterway, flora and fauna, and the species present in these areas.

Within the modelled dam breach flood extent, the Auckland Unitary Plan includes:

1. Rural and exotic macroinvertebrate community indexes
2. A marine significant ecological area, downstream of State Highway 1.

The incremental damage resulting from a dam breach would be most extreme immediately downstream of the dam embankments. Incremental sedimentation may be most extreme immediately upstream of the State Highway 1 embankment. We consider that in most of the dam breach floodplain, the level of damage would be similar to the baseline (no breach) scenario. We therefore consider that recovery is likely to be possible with at most minor rehabilitation or restoration, and the damage level for the natural environment category should be Minimal (Table 4).

Table 4: Natural Environment Damage Level

Damage Level	Description
Catastrophic	Extensive and widespread damage, with permanent, irreparable effects on the natural environment
Major	Extensive and widespread damage where it is possible, but impracticable, to fully restore or repair the damage
Moderate	Significant damage that is practicable to restore or repair
Minimal	Only minor rehabilitation or restoration may be required, or recovery is possible without intervention (or no damage)

1.5 Critical or Major Infrastructure

The damage level for critical or major infrastructure depends on both the severity of the damage which may occur, and how long it may take to restore full functionality. The Regulations define the critical or major infrastructure as:

- a) a building or other infrastructure operated or used by a lifeline utility within the meaning of Section 4 of the Civil Defence Emergency Management Act 2002:
- b) hospital building that is likely to be needed in an emergency (within the meaning of Section 4 of the Civil Defence Emergency Management Act 2002) to provide—
 - emergency medical services; or
 - ancillary services that are essential for the provision of emergency medical services:
- c) a building that is used to provide emergency response services (for example, policing, fire, ambulance, or rescue services):
- d) buildings or infrastructure that are essential to the containment of a hazardous substance (as defined by section 2 of the Hazardous Substances and New Organisms Act 1996):
- e) the dam, another dam, or flood protection works if the service that the dam, other dam, or flood protection works provide is critical to the community and that service cannot be reasonably provided by alternative means.

We consider that the State Highway 1 embankment is critical or major infrastructure, but is unlikely to experience more than minor damage in a dam breach scenario. Water reaching the embankment is expected to generally be low velocity.

We consider that the proposed NOR 6 bridge could potentially meet the definition of critical or major infrastructure. However, any more than minor damage to the bridge appears unlikely. Peak dam breach flood levels do not exceed RL 25m in this area, and the proposed road carriageway is above RL 29m. No doubt the piers will already be designed for extreme flood flows and debris loading.

We have identified a wastewater pump station (Lot 1605) from the Scheme Layout Appendix 10a (refer to 240065-Sk102 for location). We consider the station to fall under the definition of a critical infrastructure containing a hazardous substance. The pump station appears to be outside the dam breach flood inundation extent and therefore, is not affected by flood waters. To ensure that future design changes do not alter this, we recommend that constructing the structure outside the dam breach flood inundation extent should be added as a design criteria for the structure (during detailed design).

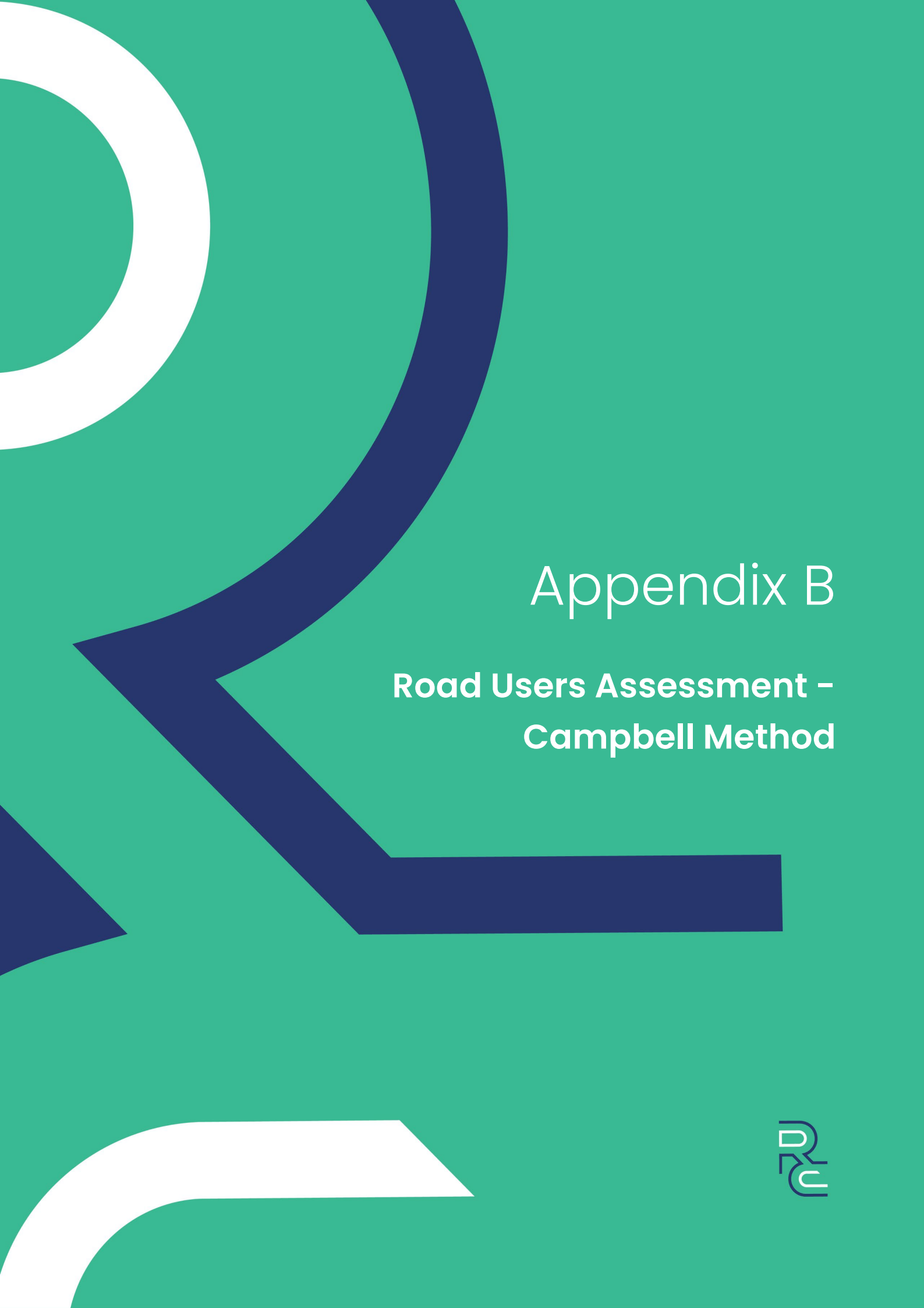
No other critical or major infrastructure was identified within the dam breach floodplain. We consider that the road embankments (including those supporting NOR 6) don't meet the definition of critical or major infrastructure. Noting that:

- The road embankments are not state highways, and are not critical for connecting communities.
- Alternate access routes are possible (along different roads) to either side of the embankments.
- While the dams do serve a flood attenuation function. That service is not critical for the downstream community (and could potentially be provided temporarily by alternate means).

The damage level for critical or major infrastructure is considered to be Minimal (Table 5).

Table 5: Infrastructure Damage Level

Damage Level	Damage to infrastructure	Time to restore operation
Catastrophic	Two or more critical or major infrastructure facilities rendered inoperable	One year or more
Major	One critical or major infrastructure facility is rendered inoperable	Three months or more but less than 1 year
Moderate	One or more critical or major infrastructure facilities are affected by the loss of some functionality	Less than 3 months
Minimal	Minor damage to 1 or more critical or major infrastructure facilities (or no damage)	One week or less



Appendix B

Road Users Assessment – Campbell Method

Road Users Assessment – Campbell Method

Proposed AADT for roads within the development (Table 2) were sourced from Commute Transportation. We consider that the use of AADT estimates in the assessed rainy-day scenario are likely to be conservative, as some drivers may choose to avoid travelling in adverse weather conditions.

Table 1: AADT Estimates

Road	AADT
Road 1	1,500
Roads 2 & 10	1,000
Roads 5 & 17	2,600
NOR 6	15,000+

NoR6 crosses the Dam 06 embankment. It appears to have a high AADT, comparable to that of State Highway 1. The road branches from the Upper Orewa Road, which is classified as a 'primary collector' under the One Network Road Classification by the New Zealand Transport Agency.

The Campbell Method suggests that the hazard posed to road users arises from three potential scenarios:

- Scenario A: The vehicle is caught within the floodwaters, with no ability to avoid the floodwater.
- Scenario B: The vehicle travels into floodwaters, with some ability to avoid floodwaters.
- Scenario C: The vehicle travels into the floodplain after the flood has passed.

For many of the embankments, the hazard is not associated with breach flows overtopping the road embankment and washing vehicles off. Instead, the hazard is associated with the breach, significantly damaging the embankment, and vehicles driving into the breach (then being washed away).

The inundated/damaged roads have low to high traffic volumes; the Campbell Method suggests that Scenario C will have a negligible contribution. We have therefore only assessed Scenarios A and B. For Scenario B, we have limited assessment to traffic from a single direction, due to:

1. The clear sight lines across the road embankment.
2. The short distance from either side of the damaged embankment/floodwaters.

Scenario A

We consider that the Scenario A assessment (Table 3) is conservative, as vehicles may have some ability to avoid the floodwaters (which has not been allowed for). The assessments consider:

- Vehicles travelling up to 50 km/hr.
- AADT (vehicles/day) as per Table 2, with 80% occurring during daytime hours (10 hours from 8am – 6pm) and 20% after hours (14 hours from 6pm – 8am).
- Length of road within the dam breach inundation zone.
- An average vehicle occupancy rate of 1.5 people per vehicle.
- Exposure factors vary between daytime and after-hour periods.

Table 2: Scenario A – Number of Vehicles

Period	Route	Traffic Volume	Vehicles in Period (cars/hour)	Approx. Length of inundated road (m)
Business hours (8am to 6pm)	NoR6	High	1,200	70
	Road 10	Moderate	80	90
	Road 1	Moderate	120	140
	Road 2	Moderate	80	160
	Roads 5 and 17	Moderate	208	70
After hours (6pm to 8am)	NoR6	Moderate	215	70
	Road 10	Low	15	90
	Road 1	Low	22	140
	Road 2	Low	15	160
	Road 17	Moderate	38	70

Scenario B

Under Scenario B, further vehicles may enter the floodplain either because the driver:

- Does not see or realise the significance of the flood hazard.
- Realises the significance of the flood hazard but does not have time to stop prior to hitting the floodwaters.

The Campbell Method considers that one additional vehicle will enter the floodwaters at each road. Subsequent vehicle movements are assumed to stop, either a result of the first vehicle:

- Choosing not to enter the floodwaters (and blocking the road). Or,
- Crashing, leading to subsequent vehicles closing the road.

Summary

Time weighted PAR estimates are derived from the Campbell Method (Table 4). It is noted that the time weighting means that these are not necessarily from a period of peak consequence. These consider time weighted exposure to the hazard, without any allowance for evasive actions.

Table 3: PAR Assessment

Road	Scenario	Time of Day	Proportion of Day	P _{T.S}	Weighted PAR
NoR6	A	Business hours (8am – 6pm)	0.42	1.68	1.05
	B		0.42	1.00	0.63
	A	After hours (6pm – 8am)	0.58	0.22	0.19
	B		0.58	1.00	0.88
	Total				2.75
Roads 5 & 17	A	Business hours (8am – 6pm)	0.42	0.29	0.18
	B		0.42	1.00	0.63
	A	After hours (6pm – 8am)	0.58	0.04	0.03
	B		0.58	1.00	0.86
	Total				1.72
Road 10	A	Business hours (8am – 6pm)	0.42	0.14	0.09
	B		0.42	1.00	0.63
	A	After hours (6pm – 8am)	0.58	0.03	0
	B		0.58	1.00	0.88
	Total				1.6
Road 1	A	Business hours (8am – 6pm)	0.42	0.34	0.21
	B		0.42	1.00	0.63
	A	After hours (6pm – 8am)	0.58	0.00	0
	B		0.58	1.00	0.88
	Total				1.72
Road 2	A	Business hours (8am – 6pm)	0.42	0.26	0.16
	B		0.42	1.00	0.63
	A	After hours (6pm – 8am)	0.58	0.00	0
	B		0.58	1.00	0.86
	Total				1.66

Notes:

1. P_{T.S}: Probability of a vehicle being exposed to the dam-break hazard. This is a product of the exposure time of a vehicle and the traffic volume.
2. P_{T.S} multiplied by proportion of day, multiplied by the number of occupants in a vehicle, which is assumed to be 1.5.

Potential for Loss of Life estimates from the Campbell Method (Table 5) take into account probabilities of evasive actions, and also fatalities (if an incident occurs).

Table 4: PLL Assessment

Road	Scenario	Time of Day	P _{T:S} ¹	P _{NE:T} ²	P _{A:NE} ³	Exposure ⁴	V _{D:A} ⁵	Weighted Potential for Loss of Life ⁶ .
NoR6	A	Business hours (8am – 6pm)	1.68	0.1	0.8	0.06	0.9	0.076
	B		1.00	0.01	0.8	0.00	0.9	0.005
	A	After hours (6pm – 8am)	0.22	0.1	0.8	0.01	0.9	0.014
	B		1.00	0.1	0.8	0.05	0.9	0.062
	Total							
Roads 5 & 17	A	Business hours (8am – 6pm)	0.29	0.1	0.8	0.01	0.9	0.013
	B		1.00	0.01	0.8	0.00	0.9	0.005
	A	After hours (6pm – 8am)	0.04	0.1	0.8	0.00	0.9	0.002
	B		1.00	0.1	0.8	0.05	0.9	0.062
	Total							
Road 10	A	Business hours (8am – 6pm)	0.14	0.1	0.8	0.00	0.9	0.006
	B		1.00	0.1	0.8	0.03	0.9	0.045
	A	After hours (6pm – 8am)	0.03	0.1	0.8	0.00	0.9	0
	B		1.00	0.1	0.8	0.05	0.9	0.062
	Total							
Road 1	A	Business hours (8am – 6pm)	0.34	0.1	0.8	0.01	0.9	0.015
	B		1.00	0.01	0.8	0.00	0.9	0.005
	A	After hours (6pm – 8am)	0.00	0.1	0.8	0.00	0.9	0
	B		1.00	0.1	0.8	0.05	0.9	0.062
	Total							
Road 2	A	Business hours (8am – 6pm)	0.26	0.1	0.8	0.01	0.9	0.012
	B		1.00	0.01	0.8	0.00	0.9	0.005
	A	After hours (6pm – 8am)	0.00	0.1	0.8	0.00	0.9	0
	B		1.00	0.1	0.8	0.05	0.9	0.062
	Total							

Notes:

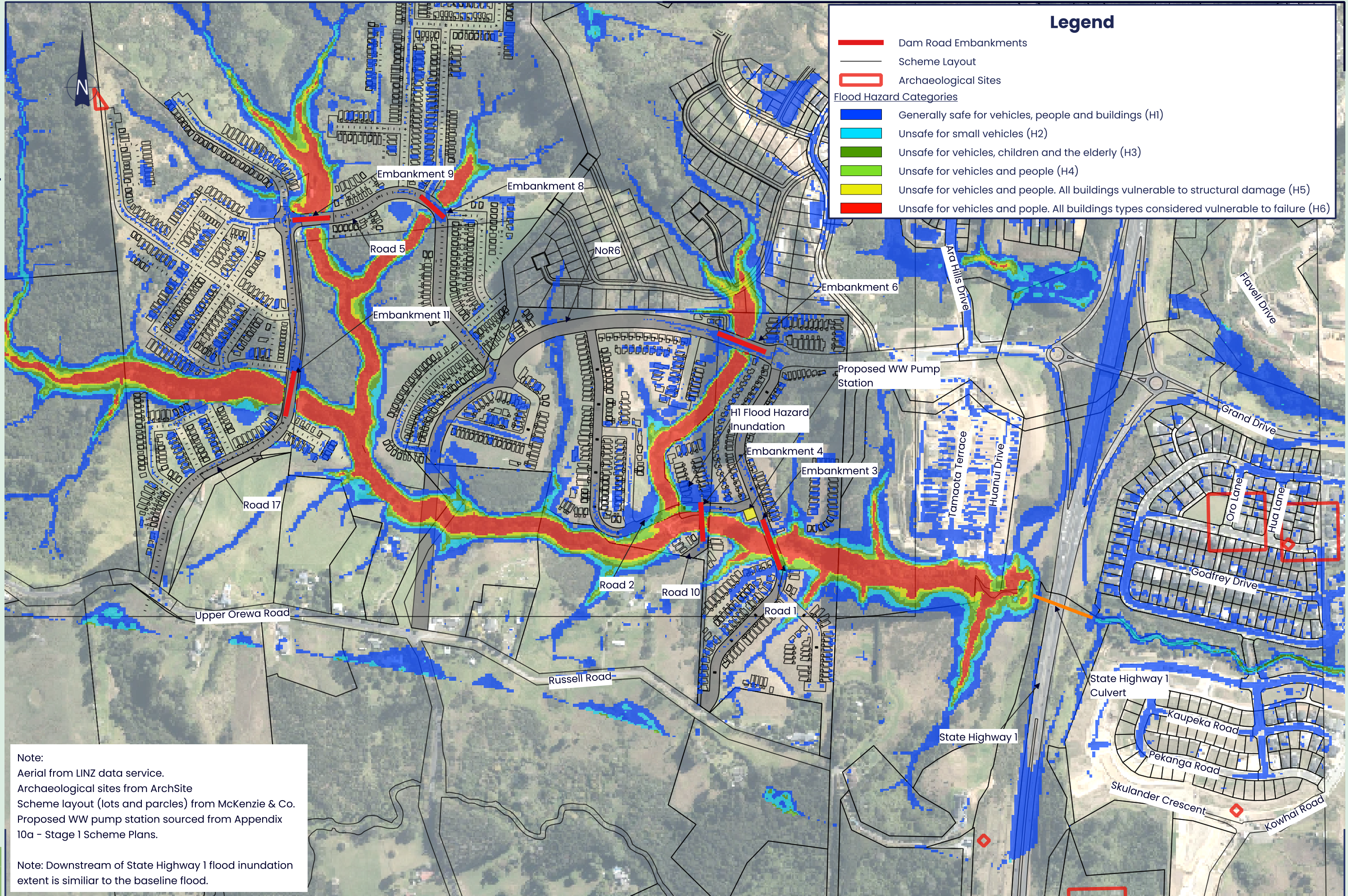
1. PT:S: Probability of a vehicle being exposed to the dam-break hazard. This is a product of the exposure time of a vehicle and the traffic volume.
2. PNE:T: Probability of a driver taking no action to avoid the dam-break hazard. During business hours, with satisfactory sightlines on all of the inundation zones on the road, and stopping distances less than said sightlines, it is considered unlikely that someone would drive into the inundated road while water is still flowing (0.1). After hours and during periods of darkness, it is considered highly unlikely that any action will be taken to avoid the hazard (0.99). This value is generally reduced by a factor of 10 in a rainy day scenario.
3. PA:NE: Probability of an accident given that the driver of the vehicle has taken no action to avoid the dam-break hazard. Given an assumed vehicle speed of 50km/hr, and the expected damage to the embankment, the probability of an accident is PA:NE = 0.8.
4. Exposure is calculated to be the product of PT:S, PNE:T, PA:NE, and the probability of the breach occurring during business hours (10/24), or after hours (14/24).
5. Factor to represent vulnerability of vehicle occupants. Assumed to be 90%.
6. This is the probability of exposure multiplied by the VD:A and the number of occupants in a vehicle, which is assumed to be 1.5.



Appendix C

Dam Breach Flood Hazard Maps
Riley Sketch: 240065-102





AUCKLAND

4 Fred Thomas Drive, Takapuna
riley@riley.co.nz

CHRISTCHURCH

22 Moorhouse Avenue, Addington
rileychch@riley.co.nz

riley.co.nz



Attachment C: OLFP Assessment

Technical Memo – Internal Development

Overland Flow Path Analysis

To:	Vineway Limited		
From:	McKenzie & Co – Haka Subagio (MCCL)		
Cc:	Project Team		
Date:	Thursday, 16 April 2026		
Job:	Delmore 53A, 53B & 55 Russell Road, Orewa	Ref:	3725
Location:	53A, 53B & 55 Russell Road, Orewa, Delmore		

Re: Civil Engineering – Infrastructure – 100% Detailed Design

1. Purpose

This memorandum presents the overland flow path analysis for the proposed road reserve within the Delmore Development. The assessment evaluates flood depth, velocity, and depth-velocity (DxV) hazard along the proposed road network under the 1% AEP Design rainfall.

The external overland flow path assessment is addressed separately in the flood assessment report and is excluded from this memorandum

2. Overview

The analysis was undertaken using TUFLOW with a rain-on-grid rainfall methodology. Hydrological data, boundary conditions, and topographic inputs were ported from the HEC-RAS model used for the Delmore flood assessment, which has been provided to Healthy Waters for council review.

Tuflow was adopted to allow 2m x 2m grid resolution within the road reserve with 250mm sub-grid sampling, providing increased model resolution to understand the hydraulic performance. Outside of Road reserve, a grid size of 4x4m was adopted.

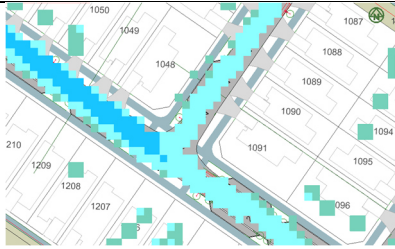
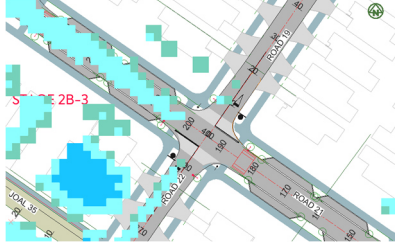
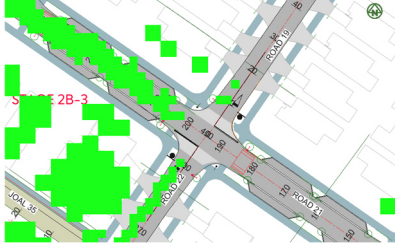
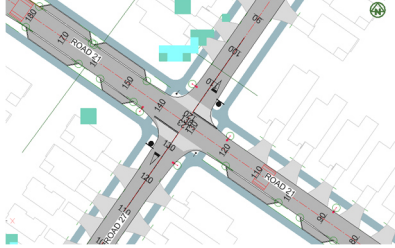
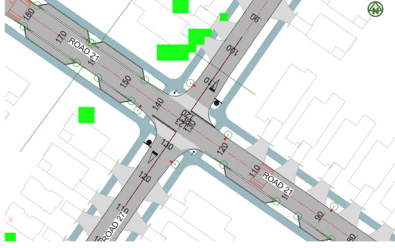
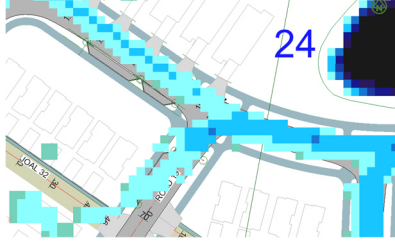
3. Assessment Criteria

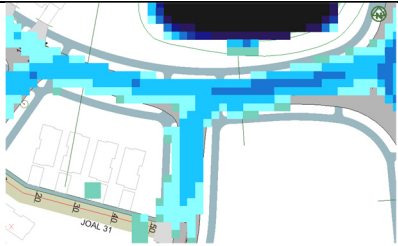
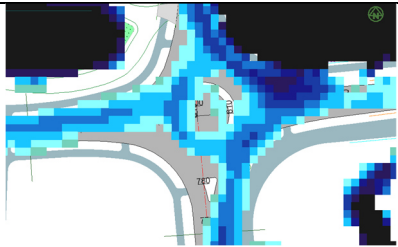
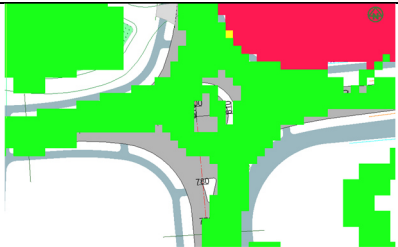
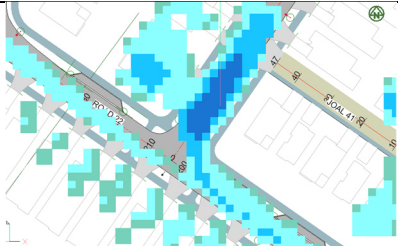
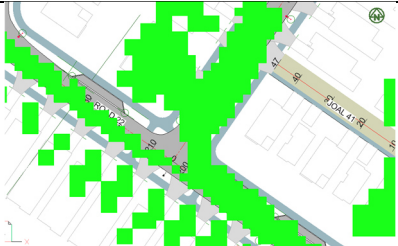
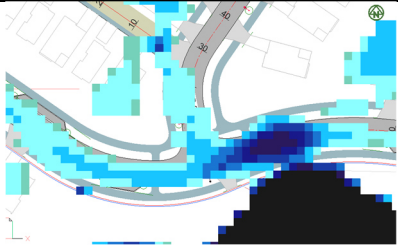
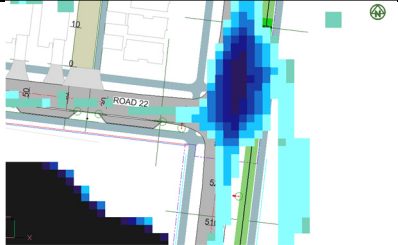
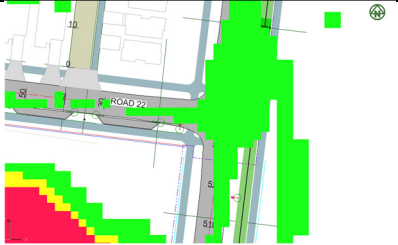
The hydraulic performance criteria have been assessed against Auckland Transport Design Manual (ATTDM) Road Drainage Chapter particularly under table 3:

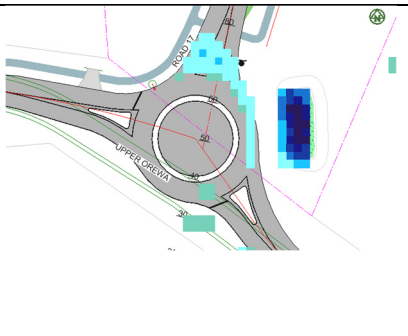
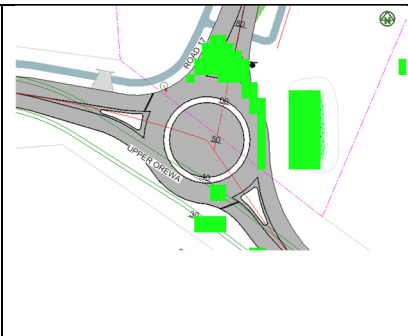
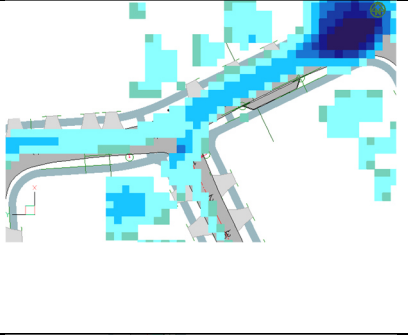
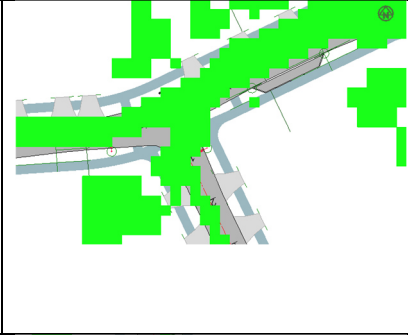
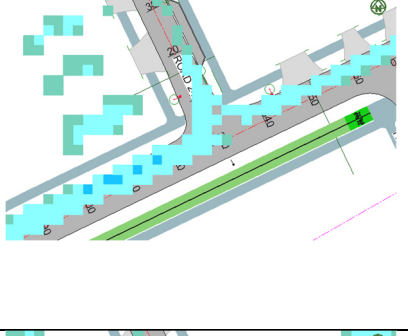
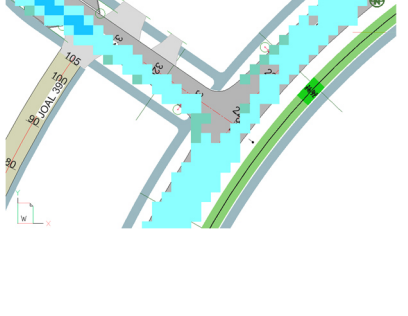
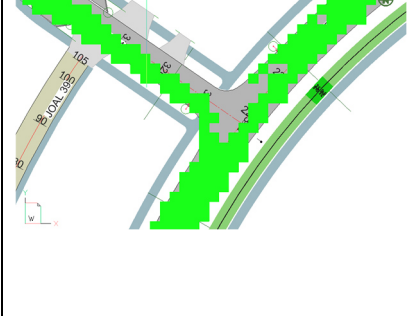
- Pedestrian Safety to be less than $0.4\text{m}^2/\text{s}$ where the location is classified as obvious danger (pram crossings, intersections), and less than $0.6\text{m}^2/\text{s}$ for everywhere else
- Maximum water levels of 300mm above roadways surface for areas subject to transverse flow.

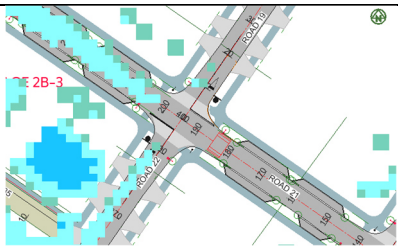
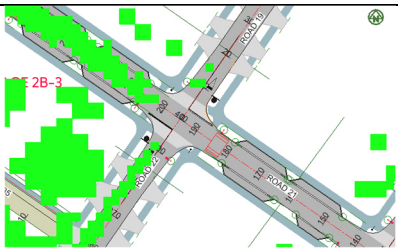
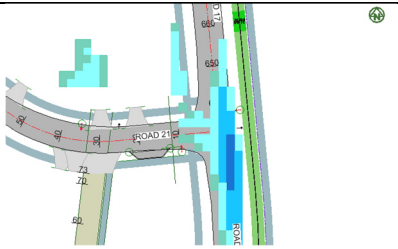
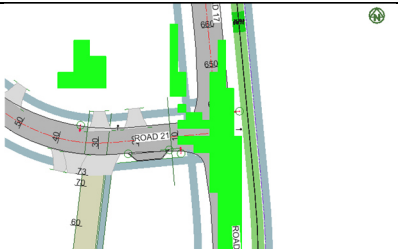
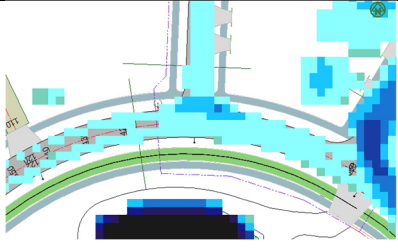
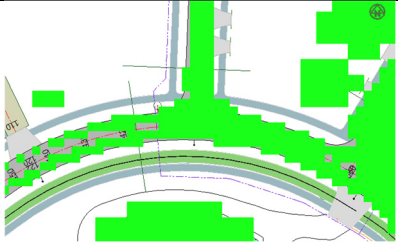
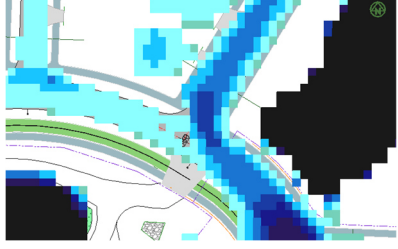
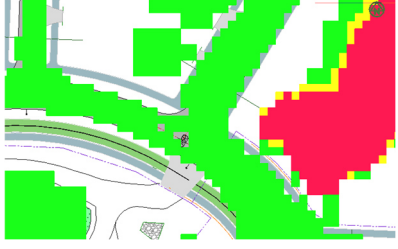
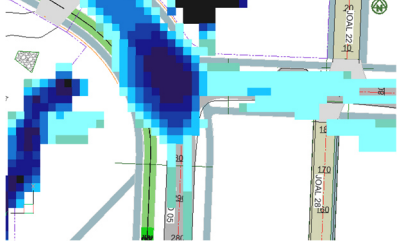
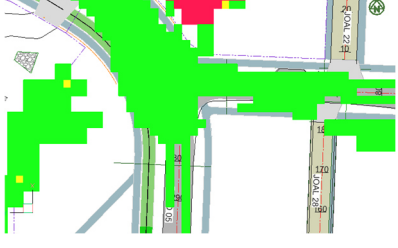
4. Results

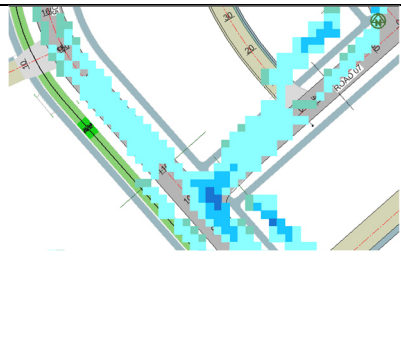
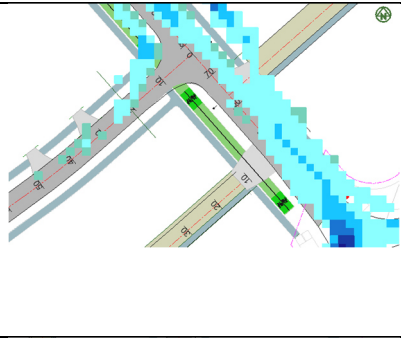
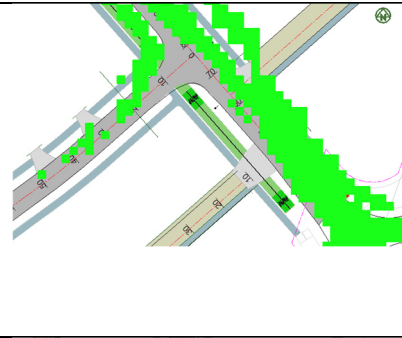
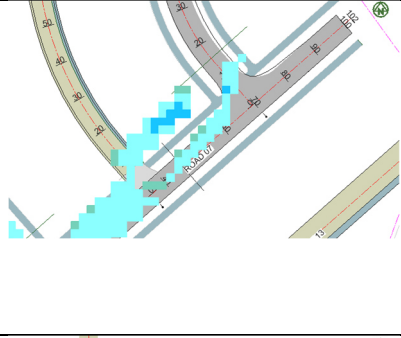
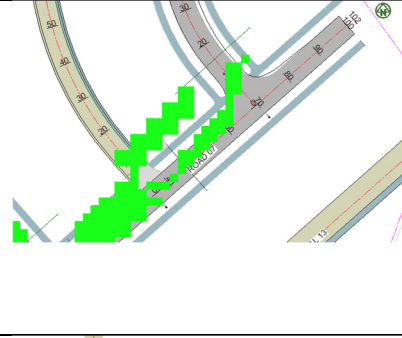
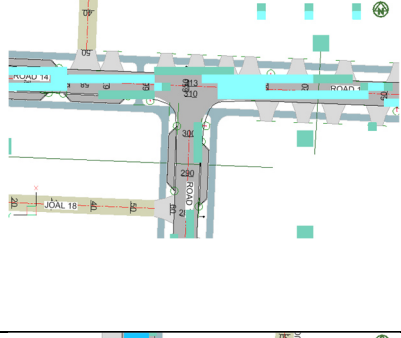
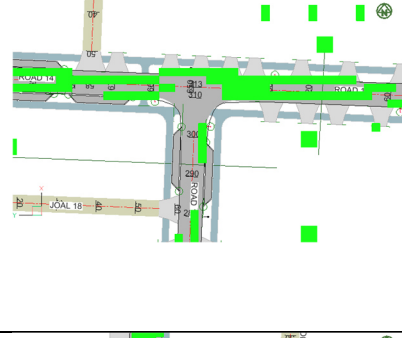
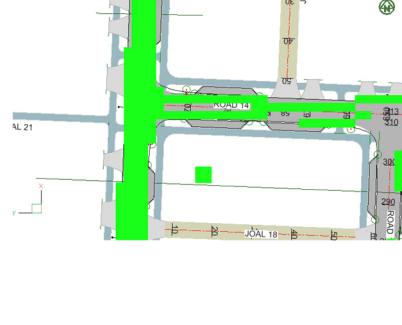
The site is located on the property of 53A, 53B & 55 Russell Road, Orewa with legal description (LOT 1 DP 497022, LOT 2 DP 497022, LOT 1 DP 336616.) as shown on Figure 1 below. The property is located in Auckland Council (AC).

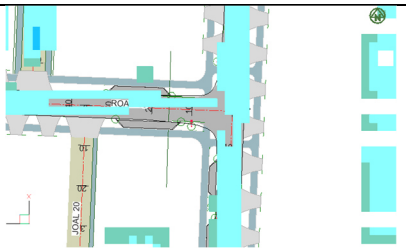
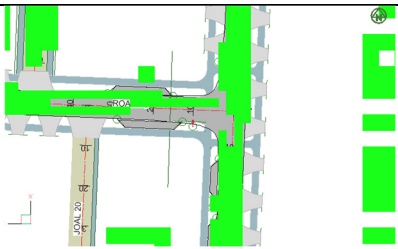
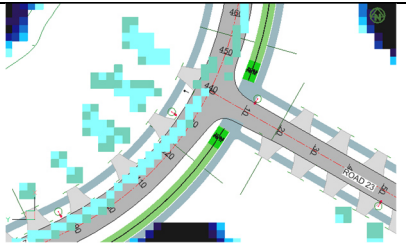
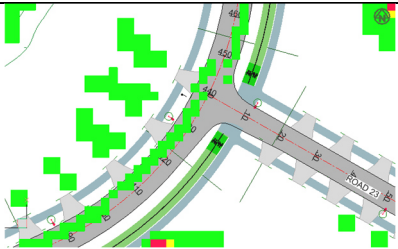
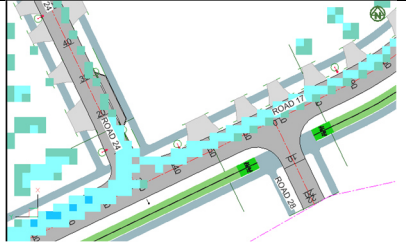
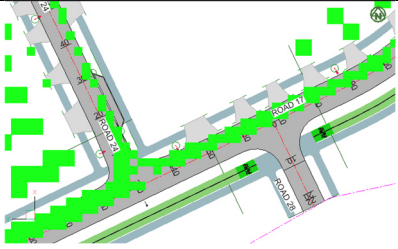
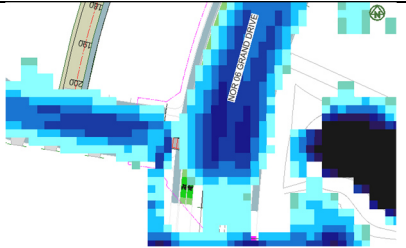
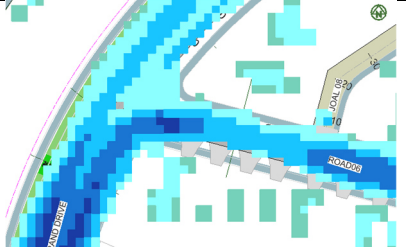
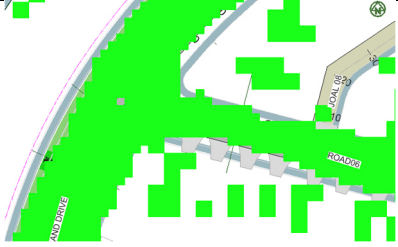
Location		Depth Map	Hazard Map	Comments
Stage 2				
1	Road 21 / Road 18			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m ² /s
2	Road 21 / Road 19 / Road 22			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m ² /s
3	Road 21 / Road 27			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m ² /s
4	Road 19 / Road 18			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m ² /s

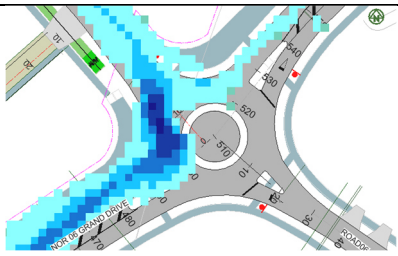
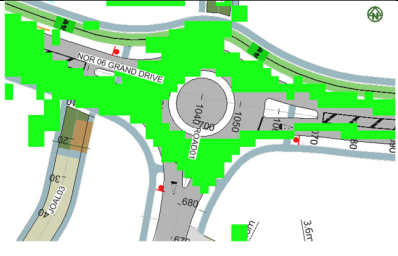
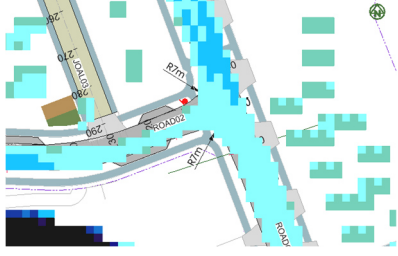
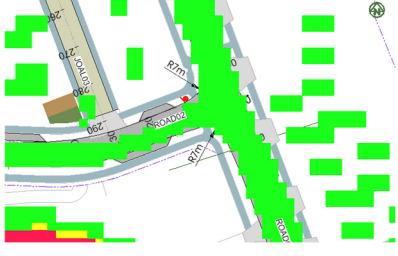
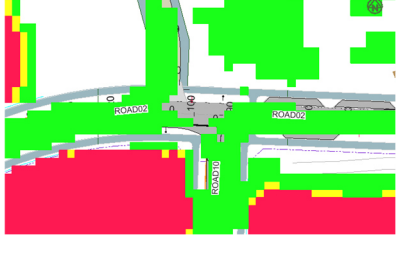
5	Road 18 / Road 20			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m²/s
6	Road 05 / Road 17 / Road 18			Flood Depth within the carriageway area ranges within 0mm to 300mm. DxV are less than 0.4m²/s
7	Road 22 / Road 27			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m²/s
8	Road 22 / Road 26			Flood Depth within this area ranges within 0mm to 400mm. DxV are less than 0.4m²/s
9	Road 22 / Road 17			Flood Depth within this area ranges within 0mm to 350mm. DxV are less than 0.4m²/s

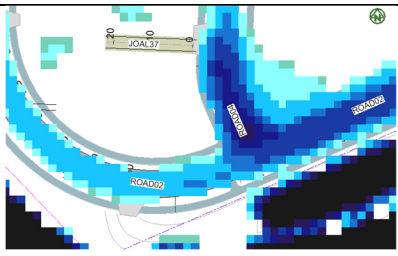
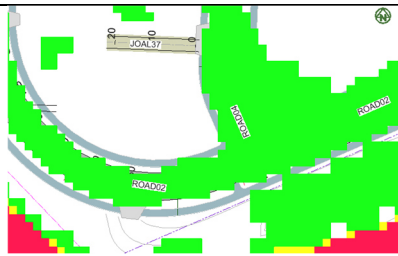
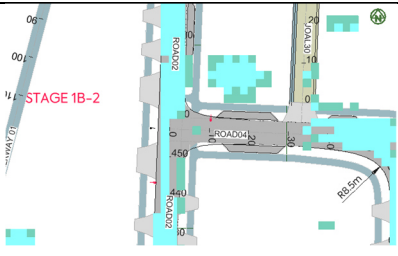
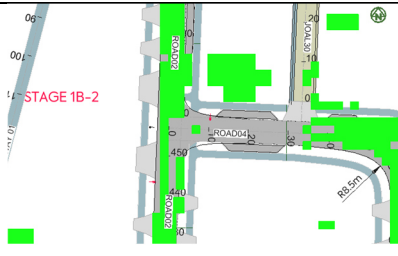
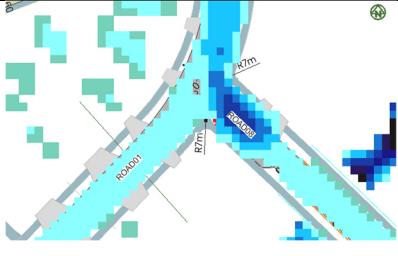
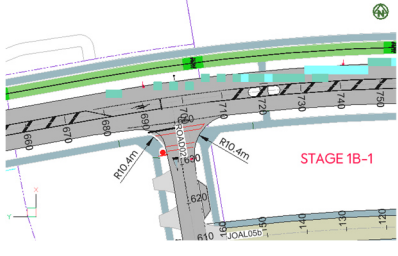
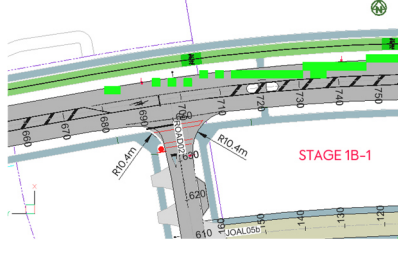
10	Road 17 / Upper Orewa			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s
11	Road 24 / Road 25			Flood Depth within this area ranges within 0mm to 400mm. DxV are less than 0.4m²/s
12	Road 24 / 17			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s
13	Road 25 / Road 17			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
14	Road 24 / Road 17			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s

15	Road 21 / Road 19			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
16	Road 21 / Road 17			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m²/s
17	Road 05 / Road 14			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m²/s
18	Road 05 / Road 13			Flood Depth within this area ranges within 0mm to 400mm. DxV are less than 0.4m²/s
19	Road 05 / Road 15			Flood Depth within this area ranges within 0mm to 400mm. DxV are less than 0.4m²/s

20	Road 05 / Road 07			Flood Depth within this area ranges within 0mm to 200mm. DxV are less than 0.4m²/s
21	Road 05 / Road 12			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s
22	Road 07 / Road 15			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s
23	Road 13 / Road 14			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
24	Road 14 / Road 14			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s

25	Road 14 / Road 16			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
26	Road 23 / Road 17			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
27	Road 17 / Road 28			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m²/s
Stage 1				
28	Road 12 / Nor 06 Grand Drive			Flood Depth within this area ranges within 0mm to 300mm. DxV are less than 0.4m²/s
29	Road 06 / Nor 06 Grand Drive			Flood Depth within this area ranges within 0mm to 250mm. DxV are less than 0.4m²/s

30	Road 06 / Nor 06 Grand Drive / Road 05			Flood Depth within this area ranges within 0mm to 300mm. DxV are less than 0.4m²/s
31	Road 03 / Nor 6 Grand Drive			Flood Depth within this area ranges within 0mm to 250mm. DxV are less than 0.4m²/s
32	Road 01 / Nor 6 Grand Drive			Flood Depth within this area ranges within 0mm to 250mm. DxV are less than 0.4m²/s
33	Road 02 / Road 01			Flood Depth within this area ranges within 0mm to 150mm. DxV are less than 0.4m²/s
34	Road 02 / Road 10			Flood Depth within this area ranges within 0mm to 350mm. DxV are less than 0.4m²/s

35	Road 04 / Road 02			Flood Depth within this area ranges within 0mm to 350mm. DxV are less than 0.4m ² /s
36	Road 04 / Road 02			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m ² /s
37	Road 01 / Road 08			Flood Depth within this area ranges within 0mm to 250mm. DxV are less than 0.4m ² /s
38	Road 02 / Nor 6 Grand Drive			Flood Depth within this area ranges within 0mm to 100mm. DxV are less than 0.4m ² /s

The analysis of the above critical intersections has shown that all intersections comply with the Auckland Transport Technical Design Manual (AT TDM).

The predicted flood hazard at the identified discharge points 6, 8, 9, 11, 18, 19, 28, 30, 34 and 35 are characterised by depths between 300 mm and 400 mm, with D*V values remaining below 0.4. While the resulting depths exceed Auckland Transport's preferred general thresholds for nuisance flooding, the associated hazard rating indicates that the flow conditions are low risk in terms of pedestrian and vehicle stability.

It's noted that the maximum flood depth between 300–400mm are confined to overland flow path discharge points and the roadway design has been optimised to reduce the extent of these isolated

flood areas. As per the Stormwater Code of Practice, the primary network is considered to be 100% blocked.

The exceedance is expected to be temporary in nature, with durations limited to between 5 and 23.5 minutes (refer to Attachment A), with rapid recession of floodwater following peak flows. The frequency and duration of inundation are therefore limited, reducing the overall level of risk to users.

It is also noted that alternative access routes remain available during such events, ensuring network connectivity is maintained and that users are not solely reliant on the affected locations.

Given the constraints of the existing topography and downstream network, further mitigation to fully eliminate ponding at these points is not practicable without disproportionate intervention. As such, a risk management approach is adopted. This will include the provision of appropriate signage to warn users of potential flood hazards during storm events, the inclusion of high flow catch pits allowing informed decision-making and reinforcing safe use of the network. As the risk hazard is considered low, and the DxV values are compliant with the AT TDM, the details of the mitigation measures will be confirmed during the Engineering Plan Approval process, once the construction level design detail has been completed.

On this basis, the residual flooding effects are considered acceptable within the context of the wider system performance.

5. Conclusion

The overland flow path assessment demonstrates that the proposed road network achieves compliance with the Auckland Transport Technical Design Manual (AT TDM) in terms of hydraulic hazard, with all modelled D*V values remaining below $0.4 \text{ m}^2/\text{s}$ across the assessed network. This confirms that flood conditions do not pose a stability risk to pedestrians or vehicles.

While localised exceedances of the 300 mm depth guideline are predicted at key overland flow path discharge points, these are confined, shallow ponding areas associated with the conveyance of exceedance flows under a 1% AEP event with a fully blocked primary system. The road layout has been optimised to minimise both the extent and depth of flooding where practicable.

These flood conditions are temporary in nature, occurring only during short duration storm events with rapid recession of water levels. The limited duration and frequency of inundation reduces the overall risk to users. In addition, alternative access routes are available throughout the network, ensuring that connectivity is maintained during such events.

Given the constraints of the existing topography and downstream receiving environment, further mitigation to eliminate these localised effects is not practicable without disproportionate intervention. A risk-based approach is therefore adopted, including the provision of appropriate signage to warn users of potential flood hazards during storm events, with final details to be confirmed at Engineering Plan Approval stage.

On this basis, the residual flooding effects are considered acceptable, and the proposed road network is deemed to achieve an appropriate level of service and safety under the design storm event.

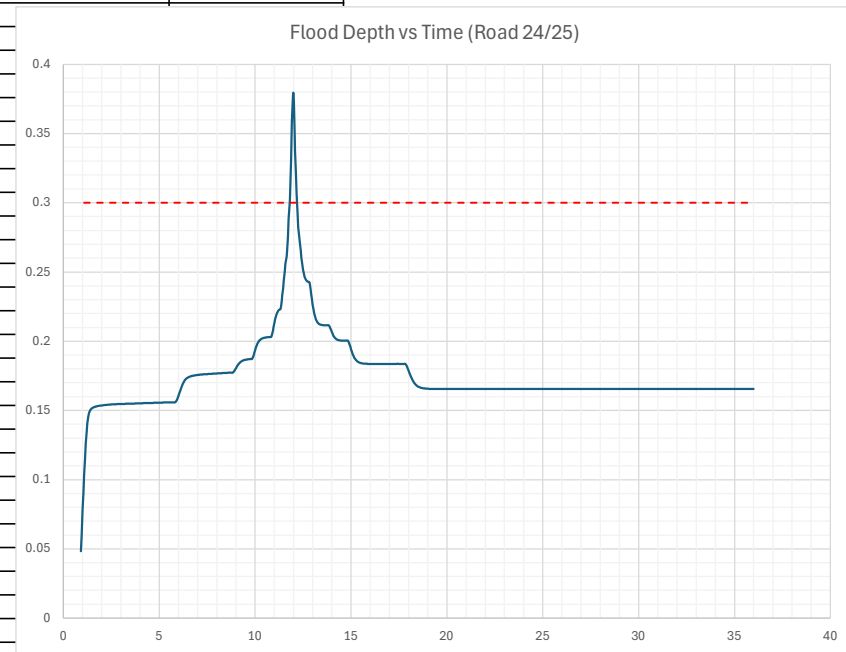
Attachment A – Depth Exceedance Analysis

Road 24 & 25 - Depth vs Time

Time (hr)	Depth (m)	Threshold (m)	Rising Cross X (hr)	Falling Cross X (hr)
0.00				
0.08				
0.17				
0.25				
0.33333				
0.42				
0.50				
0.58				
0.67				
0.75				
0.83				
0.92	0.04829			
1.00	0.0774			
1.08	0.10357	0.3		
1.17	0.12567	0.3		
1.25	0.14092	0.3		
1.33	0.14793	0.3		
1.42	0.15054	0.3		
1.50	0.15172	0.3		
1.58	0.15229	0.3		
1.67	0.15272	0.3		
1.75	0.15302	0.3		
1.83	0.15328	0.3		
1.92	0.1535	0.3		
2.00	0.15363	0.3		
2.08	0.15378	0.3		
2.17	0.15392	0.3		
2.25	0.15403	0.3		
2.33	0.15416	0.3		
2.42	0.15423	0.3		
2.50	0.15434	0.3		
2.58	0.15442	0.3		
2.67	0.15447	0.3		
2.75	0.15454	0.3		
2.83	0.15458	0.3		
2.92	0.15464	0.3		
3.00	0.15464	0.3		
3.08	0.15471	0.3		
3.17	0.15475	0.3		
3.25	0.15479	0.3		
3.33	0.15487	0.3		
3.42	0.15489	0.3		
3.50	0.15491	0.3		
3.58	0.15493	0.3		
3.67	0.15496	0.3		
3.75	0.15503	0.3		
3.83	0.15505	0.3		
3.92	0.15511	0.3		
4.00	0.15517	0.3		
4.08	0.15519	0.3		
4.17	0.15526	0.3		
4.25	0.15528	0.3		
4.33	0.15533	0.3		
4.42	0.15534	0.3		
4.50	0.15538	0.3		
4.58	0.15543	0.3		
4.67	0.15548	0.3		
4.75	0.15551	0.3		
4.83	0.15555	0.3		
4.92	0.1556	0.3		
5.00	0.15562	0.3		

Summary

Rising X intercept (hr): 11.7970
Falling X intercept (hr): 12.1887
Duration above 0.3m (hr): 0.3916
Duration in Minutes 23.5

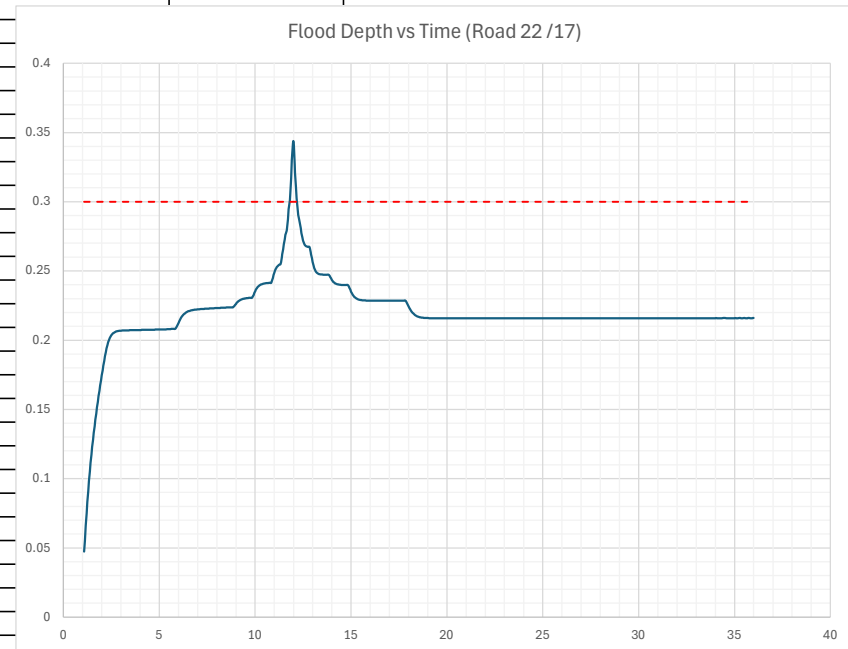


Road 22 & 27- Depth vs Time

Time (hr)	Depth (m)	Threshold (m)	Rising Cross X (hr)	Falling Cross X (hr)
0				
0.08333				
0.16667				
0.25				
0.33333				
0.41667				
0.5				
0.58333				
0.66667				
0.75				
0.83333				
0.91667				
1				
1.08333	0.04732	0.3		
1.16667	0.06605	0.3		
1.25	0.08315	0.3		
1.33333	0.09826	0.3		
1.41667	0.11137	0.3		
1.5	0.12283	0.3		
1.58333	0.13306	0.3		
1.66667	0.14244	0.3		
1.75	0.1513	0.3		
1.83333	0.15957	0.3		
1.91667	0.16736	0.3		
2	0.17466	0.3		
2.08333	0.18166	0.3		
2.16667	0.18837	0.3		
2.25	0.1941	0.3		
2.33333	0.1985	0.3		
2.41667	0.20159	0.3		
2.5	0.20362	0.3		
2.58333	0.2049	0.3		
2.66667	0.20575	0.3		
2.75	0.20624	0.3		
2.83333	0.20655	0.3		
2.91667	0.20677	0.3		
3	0.20689	0.3		
3.08333	0.20694	0.3		
3.16667	0.20705	0.3		
3.25	0.20709	0.3		
3.33333	0.20712	0.3		
3.41667	0.20714	0.3		
3.5	0.20719	0.3		
3.58333	0.20723	0.3		
3.66667	0.20723	0.3		
3.75	0.20726	0.3		
3.83333	0.2073	0.3		
3.91667	0.20734	0.3		
4	0.20735	0.3		
4.08333	0.20738	0.3		
4.16667	0.2074	0.3		
4.25	0.20745	0.3		
4.33333	0.20746	0.3		
4.41667	0.20751	0.3		
4.5	0.20753	0.3		
4.58333	0.20755	0.3		
4.66667	0.20757	0.3		
4.75	0.20761	0.3		
4.83333	0.20764	0.3		
4.91667	0.20768	0.3		
5	0.20774	0.3		

Summary

Rising X intercept (hr): 11.7954
Falling X intercept (hr): 12.1832
Duration above 0.3m (hr): 0.3878
Duration in Minutes 23.3

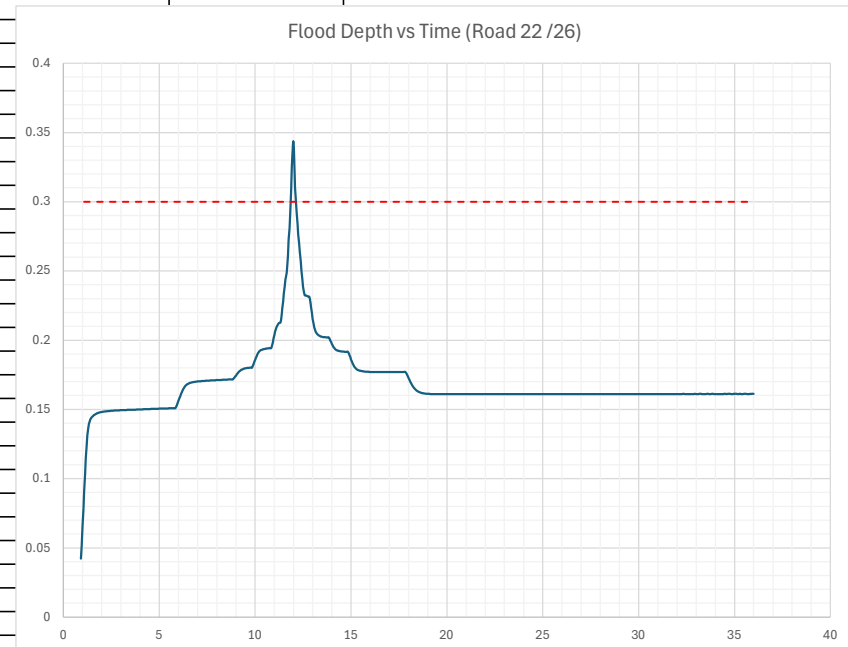


Road 22 & 26- Depth vs Time

Time (hr)	Depth (m)	Threshold (m)	Rising Cross X (hr)	Falling Cross X (hr)
0				
0.08333				
0.16667				
0.25				
0.33333				
0.41667				
0.5				
0.58333				
0.66667				
0.75				
0.83333				
0.91667	0.04215			
1	0.06557			
1.08333	0.09063	0.3		
1.16667	0.11401	0.3		
1.25	0.1313	0.3		
1.33333	0.1395	0.3		
1.41667	0.14298	0.3		
1.5	0.14462	0.3		
1.58333	0.14567	0.3		
1.66667	0.14648	0.3		
1.75	0.14709	0.3		
1.83333	0.14756	0.3		
1.91667	0.14791	0.3		
2	0.14814	0.3		
2.08333	0.14838	0.3		
2.16667	0.14851	0.3		
2.25	0.14867	0.3		
2.33333	0.14876	0.3		
2.41667	0.14887	0.3		
2.5	0.14899	0.3		
2.58333	0.14908	0.3		
2.66667	0.14919	0.3		
2.75	0.14923	0.3		
2.83333	0.14929	0.3		
2.91667	0.14937	0.3		
3	0.1494	0.3		
3.08333	0.14948	0.3		
3.16667	0.14953	0.3		
3.25	0.14955	0.3		
3.33333	0.14961	0.3		
3.41667	0.14964	0.3		
3.5	0.14966	0.3		
3.58333	0.14969	0.3		
3.66667	0.14976	0.3		
3.75	0.14982	0.3		
3.83333	0.14984	0.3		
3.91667	0.14991	0.3		
4	0.14996	0.3		
4.08333	0.15001	0.3		
4.16667	0.15006	0.3		
4.25	0.15009	0.3		
4.33333	0.15015	0.3		
4.41667	0.1502	0.3		
4.5	0.15026	0.3		
4.58333	0.15033	0.3		
4.66667	0.15034	0.3		
4.75	0.15037	0.3		
4.83333	0.15042	0.3		
4.91667	0.15048	0.3		
5	0.15053	0.3		

Summary

Rising X intercept (hr): 11.8549
 Falling X intercept (hr): 12.1320
 Duration above 0.3m (hr): 0.2771
 Duration in Minutes: 16.6

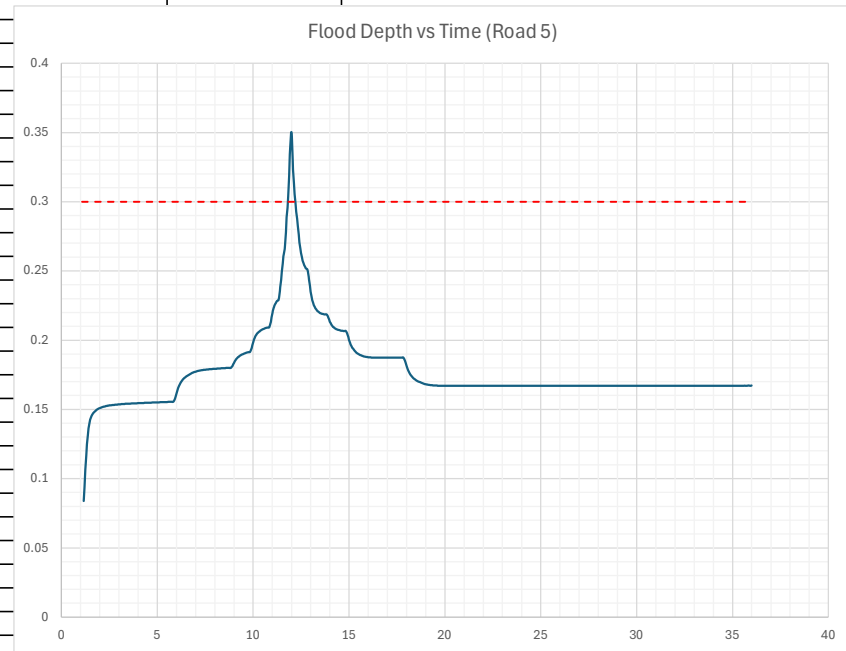


Road 5 Depth vs Time

Time (hr)	Depth (m)	Threshold (m)	Rising Cross X (hr)	Falling Cross X (hr)
0				
0.08333				
0.16667				
0.25				
0.33333				
0.41667				
0.5				
0.58333				
0.66667				
0.75				
0.83333				
0.91667				
1				
1.08333		0.3		
1.16667	0.08394	0.3		
1.25	0.10655	0.3		
1.33333	0.12469	0.3		
1.41667	0.13626	0.3		
1.5	0.14248	0.3		
1.58333	0.14565	0.3		
1.66667	0.14746	0.3		
1.75	0.14866	0.3		
1.83333	0.14963	0.3		
1.91667	0.15037	0.3		
2	0.15094	0.3		
2.08333	0.1514	0.3		
2.16667	0.15181	0.3		
2.25	0.15213	0.3		
2.33333	0.1524	0.3		
2.41667	0.15263	0.3		
2.5	0.15285	0.3		
2.58333	0.153	0.3		
2.66667	0.15316	0.3		
2.75	0.15329	0.3		
2.83333	0.15341	0.3		
2.91667	0.15353	0.3		
3	0.15366	0.3		
3.08333	0.15373	0.3		
3.16667	0.15385	0.3		
3.25	0.15391	0.3		
3.33333	0.15399	0.3		
3.41667	0.15411	0.3		
3.5	0.15412	0.3		
3.58333	0.15416	0.3		
3.66667	0.15425	0.3		
3.75	0.15432	0.3		
3.83333	0.15436	0.3		
3.91667	0.15442	0.3		
4	0.15448	0.3		
4.08333	0.15454	0.3		
4.16667	0.15459	0.3		
4.25	0.15464	0.3		
4.33333	0.15468	0.3		
4.41667	0.15474	0.3		
4.5	0.15478	0.3		
4.58333	0.15483	0.3		
4.66667	0.1549	0.3		
4.75	0.15492	0.3		
4.83333	0.15498	0.3		
4.91667	0.15505	0.3		
5	0.15507	0.3		

Summary

Rising X intercept (hr):	11.8119
Falling X intercept (hr):	12.2027
Duration above 0.3m (hr):	0.3908
Duration in Minutes	23.4



Time (hr)	Depth (m)	Threshold (m)	Rising Cross X (hr)	Falling Cross X (hr)
0				
0.08333				
0.16667				
0.25				
0.33333				
0.41667				
0.5				
0.58333				
0.66667				
0.75				
0.83333				
0.91667				
1				
1.08333		0.3		
1.16667		0.3		
1.25	0.04154	0.3		
1.33333	0.04467	0.3		
1.41667	0.04673	0.3		
1.5	0.04876	0.3		
1.58333	0.05024	0.3		
1.66667	0.05118	0.3		
1.75	0.05181	0.3		
1.83333	0.05236	0.3		
1.91667	0.05273	0.3		
2	0.05306	0.3		
2.08333	0.0534	0.3		
2.16667	0.0536	0.3		
2.25	0.05379	0.3		
2.33333	0.05396	0.3		
2.41667	0.0541	0.3		
2.5	0.05421	0.3		
2.58333	0.05435	0.3		
2.66667	0.05446	0.3		
2.75	0.05459	0.3		
2.83333	0.05468	0.3		
2.91667	0.05477	0.3		
3	0.05486	0.3		
3.08333	0.05493	0.3		
3.16667	0.05499	0.3		
3.25	0.05508	0.3		
3.33333	0.05517	0.3		
3.41667	0.05524	0.3		
3.5	0.05534	0.3		
3.58333	0.0554	0.3		
3.66667	0.05548	0.3		
3.75	0.05552	0.3		
3.83333	0.05558	0.3		
3.91667	0.05565	0.3		
4	0.0557	0.3		
4.08333	0.05576	0.3		
4.16667	0.05584	0.3		
4.25	0.05593	0.3		
4.33333	0.056	0.3		
4.41667	0.05603	0.3		
4.5	0.0561	0.3		
4.58333	0.05615	0.3		
4.66667	0.05621	0.3		
4.75	0.05627	0.3		
4.83333	0.05635	0.3		
4.91667	0.05642	0.3		
5	0.05647	0.3		

Summary

Rising X intercept (hr):	11.9649
Falling X intercept (hr):	12.0445
Duration above 0.3m (hr):	0.0797
Duration in Minutes	4.8

