REPORT

Tonkin+Taylor

Dannevirke Raw Water Reservoir

Comprehensive Potential Impact Classification (PIC) Assessment

Prepared for
Tararua District Council
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1 Introduction

Tonkin & Taylor Ltd (T+T) has undertaken a Potential Impact Classification (PIC) assessment of the existing Dannevirke No 1 Water Supply Reservoir ("Dannevirke Dam") on behalf of our client Tararua District Council (TDC). The findings are presented in this report.

A PIC represents the consequences of a hypothetical dam failure or uncontrolled release of reservoir contents. A dam's PIC has no correlation with the probability of the dam failing or experiencing a dam safety incident. The New Zealand Dam Safety Guidelines (NZSOLD DSG 2023) [1] describe a dam's PIC as "*the parameter on which recommended criteria for dam design, construction and operational safety assurance are based*".

1.1 Legislation and methodology

The Building (Dam Safety) Regulations 2022 (the "regulations") commenced on 13 May 2024. The Ministry for Business, Innovation and Employment (MBIE) released a "Guide to complying with the regulations" (MBIE 2024[2]).

The regulations, supported by MBIE 2024, set out minimum requirements for PIC assessment. In addition, the NZSOLD DSG 2023 provide detailed guidance on recommended practice, including aspects not covered by the regulations.

The current assessment has been undertaken in accordance with the method for a PIC in the regulations, MBIE 2024, and NZSOLD DSG 2023 (listed in order of decreasing precedence). The steps completed to determine the PIC are summarised in Figure 1.1 below.

Figure 1.1: Overview of the Dam Classification Process (reproduced from NZSOLD DSG 2023).

[1] New Zealand Society on Large Dams (NZSOLD). 2023. *New Zealand Dam Safety Guidelines.*
[2] MBIE 2024. *Guide to complying with the Dam Safety Regulations*. Version 3. https://www.building.govt.nz/assets/Uploads/managing-buildings/building-safety/guide-to-complying-with-the-dam-safety-regulations.pdf .

Step 1, the dam break flood hazard assessment, has involved modelling the breach development and estimating the characteristics of breach flows downstream of the dam based on relevant breach scenarios. Step 1 is presented in Section 2 of this report.

Step 2, the consequence assessment, has considered the incremental impacts of the hypothetical breach flows on people, property, infrastructure, and the natural environment. The *incremental* consequences of a failure are those consequences above and beyond a base “no failure” condition i.e., the consequences that are directly attributable to dam failure. Step 2 is presented in Section 3 of this report.

Step 3, assigning the PIC, is based on inputting the incremental consequences identified in Step 2 into the tables from Schedule 2 of the regulations. Step 3 is presented in Section 4 of this report.

1.2 Level of assessment

A PIC assessment can be undertaken at an Initial, Intermediate, or Comprehensive level. The recommended practice for the different levels is set out in NZSOLD DSG 2023. In summary:

- An Initial PIC is based on existing knowledge, or a qualitative estimate of the magnitude of a dam break flood and a visual inspection of the flood path and its potential consequences.
- An Intermediate PIC involves the next level of detail and a quantitative assessment of the dam break flood and consequences.
- A Comprehensive PIC considers potential failure modes and includes quantitative hydrological and hydraulic modelling of the flood path, detailed consequence assessment, and detailed outputs.

The level of assessment should be commensurate with the consequences of failure i.e., a more detailed assessment and outputs are appropriate where the consequences of failure are higher. More detailed assessment may also be necessary to provide confidence in the assigned PIC due to site-specific or dam-specific considerations, for instance, where:

- The dam is close to the threshold between Low and Medium, or Medium and High,
- There are open flat areas where the flood path is unclear without modelling, or
- Greater accuracy is needed because houses or infrastructure is close to the edge of the dam break flood path.

The assessment in this report is in general accordance with a Comprehensive level of assessment. This level of assessment was necessary to define the dam break flood path across relatively flat areas downstream of the dam. The Comprehensive level of assessment is also considered appropriate for the Medium PIC identified.

2 Dam break flood hazard assessment

As already noted, this section presents the dam break flood hazard assessment, which comprises the first step in Figure 1.1. The following is covered:

- The dam characteristics, which inform the items below,
- Relevant breach scenarios, including the most critical and credible hydrological conditions,
- The potential failure modes, breach locations, breach parameters and dam breach outflow, and
- Hydraulic modelling.

2.1 Dam characteristics

2.1.1 Ownership and critical function for water supply

Dannevirke Dam is owned and operated by TDC. Appendix A shows the location of the dam and downstream area relevant to the dam break flood hazard assessment.

Raw water is abstracted from the Tamaki River and piped to fill the reservoir by siphon action. The raw water is then temporarily stored in the reservoir, before being treated at the plant at the southern end of the reservoir and distributed to the community.

The full supply depth is 12.7 to 12.9 m to reservoir floor (14.5 m to base of the concrete outlet structure). The full supply volume is 135,300 m^3. At dam crest level[3], the reservoir stores in the order of 160,800 m^3.

The reservoir provides continuity of supply when direct supply from the Tamaki River is limited due to naturally low or turbid stream flows, or when demand exceeds consented take from the river in summer. TDC confirmed via email on 20 December 2022 that there is only one source of water taken from the Tamaki River and that the consented flow rate is not enough to service the town in summer without the additional storage provided from the dam. Thus, the Dannevirke Dam meets the definition of "*critical or major infrastructure*" in Clause 3(1) of the regulations because:

- The dam represents infrastructure used by a lifeline utility (i.e., drinking water); and
- The service the dam provides is critical to the community and cannot be reasonably provided by alternative means.

2.1.2 Topography

The reservoir is located on a 25 m high natural terrace, comprising up to 5 m of clayey SILT (Loess), overlying silty, gravelly CLAY on the eastern side of the terrace (Makirikiri Alluvium), and GRAVEL on the western side of the terrace (Tamaki Alluvium), in turn overlying slightly to highly weathered SILTSTONE / SANDSTONE (Mangaheia Group). The reservoir is mostly formed by excavation into these natural materials, with the excavation just intersecting the top of the Mangaheia Group SILTSTONE / SANDSTONE close to reservoir floor level. Sections of the reservoir rim are formed by homogeneous earthfill bunds comprising GRAVEL (inferred source Tamaki Alluvium). The largest earthfill bund is the eastern fill embankment. The earthfill bund on the western side is much smaller but is positioned at the top of a natural slope.

For the purposes of the current assessment, the eastern fill embankment has been considered as a "dam", as has the combination of the smaller fill bund, natural slope, and excavated reservoir slope on the western side. The combined structures on the western side have been interpreted as "a natural feature that has been significantly modified to function as a dam" in line with the Building Act 2004 definition of a "dam". The combined structures on the western side are referred to as the "western reservoir rim" for simplicity in this report.

2.1.3 Lining and drainage systems

The reservoir is covered by a floating reinforced polypropylene (RPP) cover. The inside faces and floor of the reservoir are lined with high density polyethylene (HDPE), in turn overlying 300 mm of compacted Low Permeability Fill (inferred source Loess). Below this, a network of subsoil drains was installed with the original intent of preventing uplift pressures on the liner from natural groundwater seepage. The outlet pipe from the subsoil drainage network is located in a trench cut through the natural ground below the eastern fill embankment.

[3] The volume at dam crest level is relevant for definitions and requirements under the Building Act 2004.

2.1.4 Local catchment

The reservoir is filled by abstraction from the Tamaki River and has a very small natural catchment. A conservative estimate of the maximum plausible catchment is shown in Figure 2.1, comprising up to 28,000 m^2. The catchment will likely be less than this because:

- Runoff from the slope to the north will be diverted along the slightly raised (100 to 300 mm high) northern edge of the reservoir, and then run down the eastern slope in most events. It would require a very large storm to overtop the slightly raised edge of the reservoir.
- Runoff cannot enter the reservoir without passing through holes and air vents in the floating cover, which effectively throttle inflows. Moreover, pumps on the cover remove water from the top of the cover to a separate discharge system.

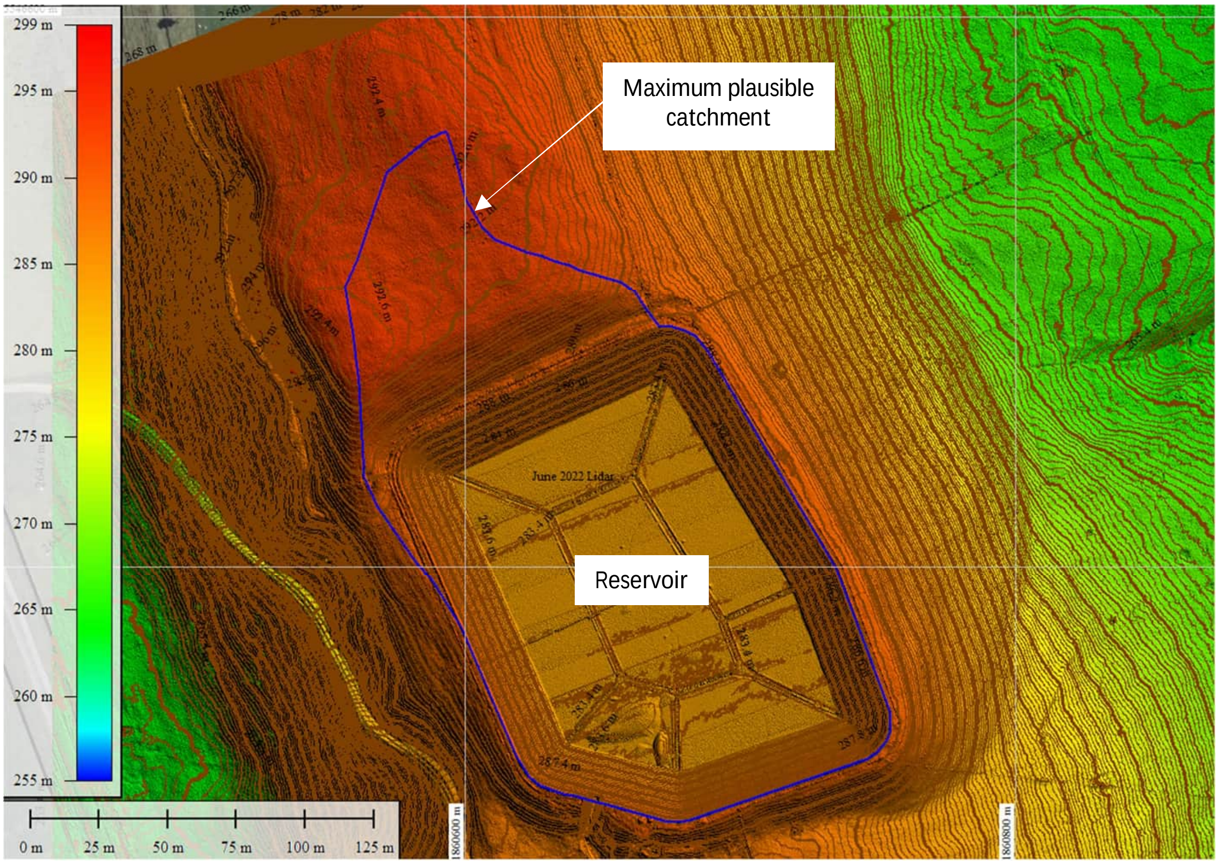

Figure 2.1: Maximum plausible local catchment for Dannevirke Dam (indicated in blue) (Note conservative, actual catchment likely smaller as described above).

2.1.5 Summary table of characteristics

Key characteristics of the dam are summarised in Table 2.1 below.

Table 2.1: Dannevirke Dam characteristics

Parameter	Value/description	Source
Name	Dannevirke No 1 Water Supply Reservoir.	
Date of construction	March 2011 to June 2013.	Construction Completion Report (TDC June 2013).
Spillway and full supply level raised	2016.	
Location	Laws Road, Dannevirke, 3.3 km north-west of the town centre.	
Purpose	Water supply to Dannevirke.	
Designer, construction monitoring, owner, and operator	TDC.	
PIC	Low PIC at the time of construction and spillway raising. Revised to Medium PIC by this report.	Building consent application and this report.
Dam type	Predominantly an excavated pond, with homogeneous earthfill embankments along parts of the reservoir rim.	
Dam crest level	Top of concrete ring beam (and top of extent of HDPE lining) is at 272.8 mRL (TDC 2023 survey). The earthfill portion of the crest ranges from 272.45 to 272.75 mRL (NZVD 2016) based on Kumeti 2022 LiDAR (lower on the eastern side).	As-built drawings, Kumeti 2022 LiDAR, TDC 2022 and 2023 survey, and clarifications from engineer on site during construction.
Full supply level (FSL)	271.536 m RL (NZVD 2016) based on TDC survey in 2022 and 2023.	
Reservoir floor level	258.8 mRL (NZVD 2016) at toe of internal batter slope, grading to 258.6 mRL at operational outlet sump box.	
Freeboard above spillway crest	1.264 m approximately from spillway crest to top of concrete ring beam; 0.855 m from top of spillway gate to top of concrete ring beam.	Estimated from TDC 2022 survey and Kumeti 2022 LiDAR.
Full supply depth	12.736 to 12.936 m from FSL to reservoir floor. 14.536 m from FSL to floor inside operational outlet structure.	
Storage volume at full supply level	135,300 m^3	Based on Kumeti 2022 LiDAR, extrapolated below water level.
Storage volume at dam crest (per Building Act 2004 definition)	160,800 m^3	
Dam height (dam crest to dam toe, per Building Act 2004 definition)	21 m	

Parameter	Value/description	Source
Crest width	3 m	As-built drawings.
Crest length	550 m	As-built drawings (scaled).
Internal slopes	1V:3H	As-built drawings.
External slopes	1V:4H	
Leakage control	1.5 mm thick HDPE liner over 300mm thick Low Permeability Fill liner, in turn over a network of subsoil drains.	As-built drawings. Quality Control & Assurance Report (Viking July 2013).
Reservoir cover	1.14 mm thick RPP floating cover.	
Spillway	2 m wide concrete-lined open channel spillway with spillway crest / sill level at 271.536 mRL (NZVD 2016). A gate prevents wind getting under the reservoir cover and is designed to automatically open with rising reservoir levels. If not removed by the cover pumps or flow through the cover air vents, water on top of the floating cover would overtop the spillway gate, which would effectively act as a 5.19 m wide weir at 271.945 mRL.	As-built drawings and TDC 2022 survey.
Operational inlet	A 300 mm diameter inlet pipe supplies raw water from the Tamaki River at a maximum rate of 110 L/s. The abstracted flow is delivered to a 5 m by 2.5 m concrete box structure (with internal baffle) at the southern end of the reservoir. Flows are released from the inlet box structure, entering the reservoir between the HDPE liner and floating reservoir cover, controlled by a 4.5 m wide weir with sill at 270.5 m RL (NZVD 2016).	
Operational outlet	A 2.7 m square concrete box structure is recessed centrally into the reservoir floor. Twin 300 mm diameter outlet pipes take water from the outlet box structure, up the southern internal slope of the reservoir (in trenches just below the HDPE and Low Permeability Fill liner) before connecting to the treatment plant and the water supply pipe network beyond the reservoir.	

2.2 Rainy day breach scenario

2.2.1 Introduction

NZSOLD DSG 2023 notes that dam break is typically considered in two hydrologic conditions, namely “sunny day” and “rainy day”. The sunny day scenario is when the dam failure occurs when the reservoir is full and under normal inflow conditions; the rainy day scenario is when the dam failure occurs under flood inflow conditions. The rainy day scenario was eliminated early based on the assessment presented in this section.

Section 2.2.2 discusses the general influence on incremental consequences of assuming a rainy day rather than sunny day scenario. Section 2.2.3 presents a check on whether there are any specific incremental consequences that could be sensitive to assuming a rainy day scenario. Section 2.2.4 presents our conclusion regarding scenario to take forward for the remainder of the assessment.

2.2.2 General influence on incremental consequences

Section 3.4 of the "Dannevirke Raw Water Reservoir Remediation – Design Report" (T+T September 2023) presents analyses of storms ranging from 1 in 1,000 AEP to 1 in 10,000 AEP, storm durations from 2-hour to 12-hour, climate change adjustment from RCP 4.5 2120 to RCP 8.5 2120, and all scenarios with raw water piped into the reservoir from the Tamaki River at a constant rate[4] of 0.11m^3/s. The analyses indicated a peak water level of 271.75 mRL for the critical scenario considered (1 in 10,000 AEP, 6-hour storm, RCP 4.5 2120, plus 0.11 m^3/s pumped inflows). This represents 0.21 m flood rise above the FSL of 271.536 mRL.

Consideration was also given in Section 4.8.2 of the Design Report to water levels on top of the cover should the cover pumps fail. In this unlikely, adverse, sensitivity case, flood flows would exit over the top of the spillway gate, which is effectively a 5.19 m wide weir at 271.945 mRL. This was assessed to result in a water level of up to 272.15 m i.e., up to 0.61 m above FSL and 0.65 m below dam crest.

The rainy day scenario is generally expected to have smaller incremental dam break consequences than the sunny day scenario (and thus be less critical for PIC) based on the following:

- Because the extra flood rise in the rainy day scenario is very small (likely less than 0.21 m as described above, up to 0.61 m in the unlikely sensitivity case for cover pumps failing), both sunny day and rainy day scenarios have similar upstream water levels at the time of breach.
- Because the upstream water levels are similar, both scenarios also produce similar breach outflows and a similar dam break flood in the downstream area.
- In contrast, the base "no failure" condition in the downstream area, used to identify the incremental consequences of a dam break, will be less severe for the sunny day scenario (normal base flow) than for the rainy day scenario (concurrent flood).
- Because the dam break flood is similar for both scenarios but the base "no failure" condition is smaller for the sunny day scenario, the incremental consequences are effectively larger for the sunny day scenario, potentially resulting in a higher PIC.

2.2.3 Sensitivity of specific incremental consequences

The sunny day scenario is generally expected to result in larger incremental consequences than a rainy day scenario as discussed above. That said, the dam break flood depths, velocities, and extents are expected to be larger in absolute (rather than incremental terms) if they are concurrent with a large flood in a rainy day scenario. This introduces the possibility that the larger dam break flood could exceed a threshold that triggers a step up in category of hazard / consequences.

A large flood on the Tamaki River at the same time as a dam break is not expected to trigger such a step up in category of hazard / consequence for the PIC because:

- Critical features for the PIC assessment, such as buildings and Laws Road, are set well back and above the level of the Tamaki River.
- At the rail and SH2 crossings of the Tamaki River, the dam break flow in the river is minor compared with the waterway capacity.

A large flood on the Makirikiri Stream at the same time as a dam break is similarly not expected to trigger a step up in category of hazard / consequence for the PIC because:

- The "bank-full" capacity of the stream is approximately 10 m^3/s at the narrowest locations.
- The addition of a large flood in the stream in combination with a dam break is anticipated to increase out-of-bank flows only marginally. NIWA's New Zealand River Flood Statistics

[4] Inflow capacity advised by TDC, email J D Villiers to D Knappstein 7 February 2023.

webtool[5] indicates that the 1,000 year ARI flood at the Makirikiri Stream rail bridge is approximately 20 m^3/s, which is only 6% of the estimated dam break outflow of 360 m^3/s (refer Section 2.3.3).

- The estimated 6% increase in out-of-bank flows will be spread across a flood plain so the increase in depths and velocities will be even smaller. The key features of interest on the flood plain are buildings and Laws Road. The flood hazard at these features (other than two buildings and a section of Laws Road already counted in the sunny day scenario) is relatively low, such that a minor increase in depths and velocities is not expected to change a category of hazard / consequence for the PIC[6].
- The estimated 6% increase in out-of-bank flows will potentially be concentrated where a portion of the flood plain is intercepted by a 550 m section of cut along the railway line to the east of the Tamaki River. However, the small increase in depths and velocities in the railway cut is anticipated to involve an incremental increase in damage rather than a change in whole damage category.
- Flood levels at the Makirikiri Stream rail bridge are not expected to increase significantly because the added non-dam break flows for the rainy day scenario are expected to leave the channel upstream of the bridge.

2.2.4 Conclusion

Based on the considerations in Section 2.2.2 and 2.2.3, the rainy day scenario was eliminated as likely to be less critical for the determination of PIC, and the sunny day scenario was taken forward for the remainder of this Comprehensive PIC assessment.

2.3 Dam break modelling

2.3.1 Potential failure modes

A potential failure mode is defined in the regulations as “a mechanism or set of circumstances that could result in the uncontrolled release of all or part of the contents of a reservoir”. A Stage 1 Failure Modes and Effects Analysis (FMEA) was presented in a summary letter report (T+T, 7 March 2023[7]) and identified the potential failure modes considered most relevant for Dannevirke Dam.

The highest risk and most plausible potential failure modes identified by the FMEA involved:

- Internal erosion / piping failure through the embankment fill and / or foundation,
- Occurring in normal operating (“sunny day") conditions, or
- In some cases, exacerbated by an earthquake.

The breach scenario that has been assessed comprehensively in this report has been developed to represent these types of failures.

Potential failure modes, involving overtopping in a flood or continuing to siphon water into the reservoir when it is already full, were identified in the FMEA as having a very rare / negligible likelihood or not being credible, which is supported by the hydrological analyses referred to in Section 2.2. Based on the spillway capacity being much larger than inflows from the local catchment

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[5] https://niwa.maps.arcgis.com/apps/webappviewer/ under Creative Commons License CC BY-NC 4.0.

[6] Flood hazard at the buildings and sections of Laws Road (that are not already counted in the sunny day scenario) is H1 and H2, compared with a threshold of H3 for inclusion as population at risk and H4 for inclusion as houses rendered uninhabitable. (These flood hazard categories are explained later in Section 3.) At least two houses would need to change to H3 or above to increase the category of population at risk. At least two houses would need to change to H4 or above to change the category of damage to community buildings. This is considered unlikely with the small increase in depths and velocities from a large flood on the Makirikiri Stream distributed across the flood plain.

[7] T+T. 2023, 7 March. *Dannevirke Dam – Failure Modes and Effects Analysis; Workshop 1 Summary Letter Report*.

and Tamaki River and spillway blockage being improbable, a failure involving overtopping is considered much less plausible than a failure involving internal erosion. Moreover, as already noted in Section 2.2, a failure during rainy day conditions is generally expected to have lesser incremental impacts than a failure during sunny day conditions. Therefore, scenarios involving overtopping type failures have not been taken further.

Other potential failure modes that were identified in the FMEA included:

- Slope instability in normal operating conditions or in an earthquake, resulting in loss of freeboard and / or internal erosion through instability-induced cracks.
- Liquefaction, cyclic softening, or fault displacement in an earthquake, resulting in loss of freeboard.

The internal erosion type failure in the first bullet point is considered reasonably represented by the breach scenario that has been assessed comprehensively in this report.

Relevant to the loss of freeboard (overtopping) type mechanisms in the two failure modes, the “Stage 2 Geotechnical Interpretation Report” (Version 1, Draft, T+T July 2024) provides an estimate of how far the dam crest could plausibly drop below the reservoir water level in the Safety Evaluation Earthquake (SEE):

- Western reservoir rim: In the base design case and all sensitivity cases, displacements are estimated to be less than freeboard i.e., no overtopping flows are expected.
- Eastern dam embankment: In the base design case, displacements are estimated to be less than freeboard. However, in a sensitivity case considering the National Seismic Hazard Model (NSHM 2022), displacements are estimated to exceed freeboard (2.9 m displacement versus 1.3 m freeboard) resulting in an overtopping flow. The sensitivity case is considered possible but unconfirmed because industry guidance on application of NSHM 2022 for design and performance assessment is not yet available. The sensitivity case should be reviewed when this guidance is provided by an update to NZSOLD DSG 2023 scheduled later this year.

Even if overtopping flows are confirmed as per the sensitivity case for the eastern dam embankment, it is uncertain whether flows would continue following the initial movement and outflow since there would be limited inflows to keep overtopping and enlarging the breach.

Based on current information, it is considered reasonable to expect that the scenario that has been assessed comprehensively in this report is conservative (i.e., assumes larger breach flows) compared with loss of freeboard and overtopping type scenarios due to limited inflows to drive / enlarge an overtopping breach.

2.3.2 Breach locations

Two breach locations were assessed, including:

- “East”, meaning a breach through the eastern dam embankment, and
- “West”, meaning a breach through the western reservoir rim (natural ground and dam embankment combined).

The locations are indicated in Figure 2.2.

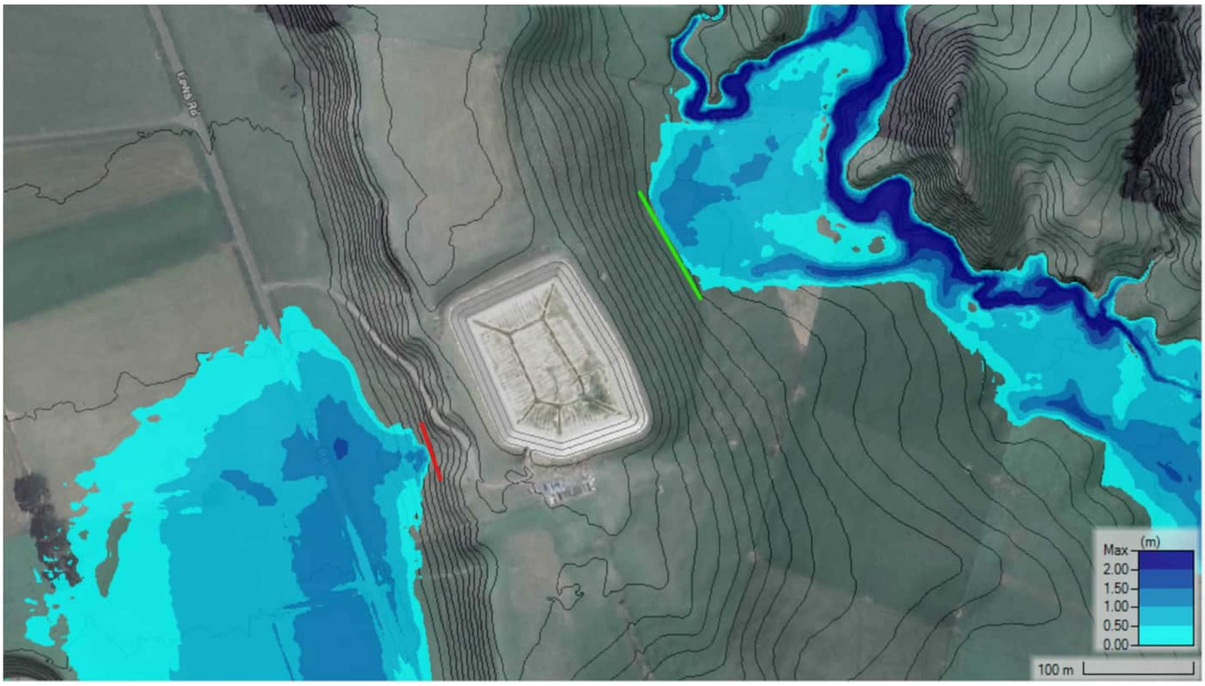


Figure 2.2: Breach locations for the dam (West in red, East in green).

2.3.3 Breach parameters and dam breach outflow

Breach parameters are used to model the development of a breach through a dam and to estimate the resulting outflows. The parameters include aspects such as the final breach shape and the time it takes for that final breach shape to be formed.

There are a variety of methods used to estimate parameters, usually relating to the depth and volume of water stored behind the dam. These are empirical methods, developed from back-analysis of historical dam failures. A range of breach widths and formation times for several methods is presented in Table 2.2 for the assumed sunny day internal erosion or piping type failure that has been considered for both the eastern embankment and western reservoir rim.

Table 2.2: Sunny day internal erosion dam breach parameters for several empirical methods

Methodology	Average Breach Width, B (m)	Formation Time, tf (hr)
Johnson & Illes (1976)	24.6	N/A
Singh & Snorrason (1982, 1984)	49.2	0.625
MacDonald & Langridge-Monopolis (1984)	N/A	0.266
FERC (1987)	42.2	0.550
USBR (1988)	38.6	0.424
Froehlich (2016) - Adopted	11.8	0.140
Average	26.3	0.485

The Froehlich (2016)[8] method was adopted to estimate breach parameters for the Dannevirke PIC assessment because this is the most recent method and builds on the other earlier studies. However, Table 2.2 is included above to demonstrate the range of possible values for parameters, which highlights the uncertainty inherent in a dam break model and estimated dam break flows.

[8] Froehlich. 2016. *Empirical Model of Embankment Dam Breaching.*

HEC-HMS version 4.10 was used to model the adopted breach scenario, using the parameters from Froehlich (2016). Table 2.3 summarises the key inputs and outputs and Figure 2.3 presents the resulting breach outflow hydrograph. The peak outflows have also been cross checked and correlate well with case studies of recorded embankment dam failures, as presented in Appendix B.

Table 2.3: Adopted dam breach parameters for both East and West breaches

Parameter	Adopted value
Failure mode	Internal erosion/piping
Initial depth of water (m)	12.85
Initial volume of water (m^3)	136,500
Bottom breach width (m)	3.4 (note, differs from “B” in Table 2.2 which is at mid height)
Breach formation time (hrs)	0.140
Breach side slope (1V:xH)	0.6
Peak outflow (m^3/s)	359

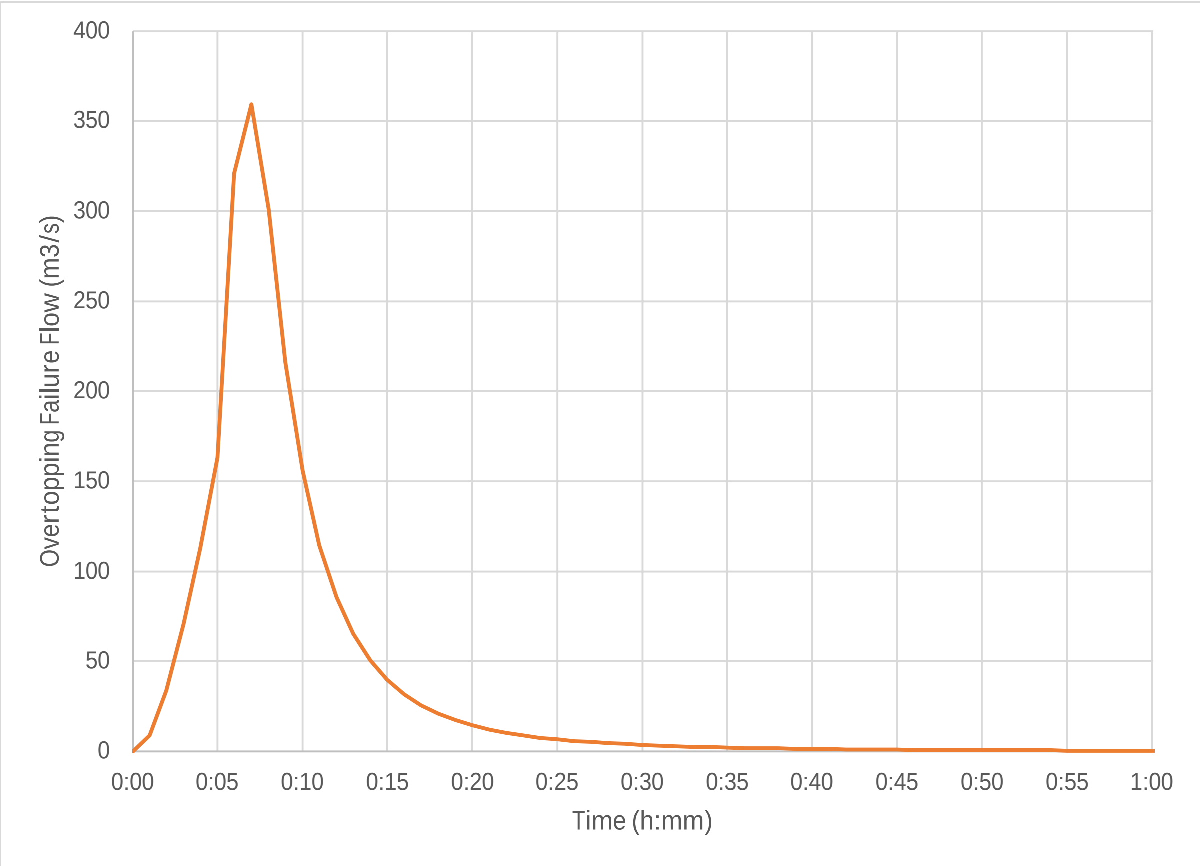


Figure 2.3: Sunny day internal erosion dam break hydrograph (for both East and West breaches).

2.4 Hydraulic modelling

Hydraulic modelling was completed using HEC-RAS version 6.5. HEC-RAS is a widely accepted one-dimensional and two-dimensional hydraulic modelling software developed by the United States Army Corps of Engineers Hydrologic Engineering Centre (USACE HEC).

2.4.1 Terrain, projection and datum

The terrain used in the model was derived from the 2022 Kumeti LiDAR. The horizontal projection is New Zealand Transverse Mercator 2000 (NZTM 2000), and the vertical datum is the New Zealand Vertical Datum 2016 (NZVD 2016).

2.4.2 Model geometry and hydrological inputs

The model geometry comprised a 2D flow area, supplemented by breaklines and 1D features. Two geometries were developed corresponding to the two breach locations respectively:

- East: The geometry extended from the eastern dam embankment, along Makirikiri Stream, along Mangatera Stream, and downstream to the confluence with the Manawatū River.
- West: The geometry extended from the western side of the reservoir, across Laws Road and along the Tamaki River, and then to the Manawatū River.

The 2D flow areas were based on a 10 m × 10 m grid.

Breaklines were used to delineate and adequately represent hydraulic behaviour at roads, bridges, the railway, waterways, and other linear topographic features. The breaklines ensured water had to build up and overtop the crest of these linear features before flowing to the other side.

A finer resolution than the 10 m grid was adopted for some breaklines, typically specified to fit cells to the half width of the feature. State Highway 2 (SH2) and the Palmerston North - Gisborne Railway Line (railway) were modelled with a 5 m spacing, and the Makirikiri Stream with 2 m spacing.

The railway bridge, SH2 bridge and SH2 stock underpass were modelled as 1D bridge elements, based on dimensions in as-built drawings. The SH2 stock underpass is located east of the Tamaki River and near 77848 SH2. This was modelled based on the original construction drawing from 1996 (refer Appendix D). Refer to Section 3.2.1.3.1 for further details on the railway bridge, and Section 3.2.1.3.2 for further details on the SH2 bridge.

During the site visit of 1 and 2 May 2023, bridges along the Tamaki River were visually assessed as having sufficient capacity to pass dam break flows without touching the underside of the bridge. Therefore, these bridges have not been included in the hydraulic model.

The Land Cover Database (LCDB) version 5 was used to create a spatially varying roughness across the model domains. Specific roughness values were developed for certain features based on observations from the site visit on 1 to 2 May 2023 and guidance from Open Channel Hydraulics (Chow, 1959)[9].

The adopted roughness values for specific features are summarised in Table 2.4. The boundary conditions adopted for the two geometries are summarised in Table 2.5.

The model geometries are presented in Appendix E.

[9] Chow, V.T. 1959. *Open Channel Hydraulics.* McGraw-Hill, New York.

Table 2.4: Adopted Manning's n for specific features

Feature	Manning's n	Waterway category in Chow 1959
Makirikiri Stream – upper	0.04	Natural main channel – clean and winding.
Makirikiri Stream – middle	0.03	Natural main channel – clean and straight.
Makirikiri Stream – lower	0.045	Natural main channel – clean and winding but with weeds and stones.
Railway bridge	0.045 inside structure and on approaches	Natural main channel – clean and winding but with weeds and stones.
SH2 bridge	0.015 inside structure 0.045 on approaches	Inside: concrete float finish. Outside: natural main channel – clean, winding, with weeds and stones.
SH2 stock underpass	0.013 inside structure 0.025 on approaches	Inside: concrete trowel finish. Outside: excavated channel in gravel, clean and uniform.

Table 2.5: Adopted boundary conditions

Boundary	East	West
Upstream	The Figure 2.3 breach hydrograph was applied with an Energy Grade (EG) slope of 0.08 at the downstream toe of the eastern dam embankment.	The Figure 2.3 breach hydrograph was applied with an EG slope of 0.3 at the downstream toe of the natural slope to the west of the reservoir.
Downstream	A "normal" flow depth based on a friction slope of 0.004 was applied at the confluence of the Makirikiri Stream and Manawatū River.	A "normal" flow depth based on a friction slope of 0.004 was applied at the confluence of the Tamaki River and Manawatū River.

2.4.3 Simulation parameters

Dam break modelling is generally more computationally intensive than conventional flood modelling due to the quick transition from dry to wet and back to dry as the dam break flood wave passes through. The full momentum version of the Navier-Stokes hydraulic equations is necessary to represent the momentum of a deep and fast moving dam break flood wave, as well as a small computational time step for numerical stability.

For the model of the eastern breach for Dannevirke Dam, a fixed time step of 1 second was adequate for numerical stability.

However, for the model of the western breach, a Courant[10]-controlled variable time-step was necessary. For this approach, the maximum allowable Courant number was set at 2.1 which was considered appropriate for full momentum equations to remain stable. Where the Courant number exceeded this maximum value for any cell at any time step, then the time step was halved until stability criteria were met. Conversely, where the Courant number was below 1, then the time step was doubled to reduce the calculation time.

2.4.4 Results – flood hazard for an eastern breach

Dam break flood hazard for the eastern breach is presented as maps of depth (D), velocity (V), flood hazard, and flood arrival time in Appendix C.

[10] The Courant number is a non-dimensional number that can be used to evaluate the time step (Δt) requirements of a transient simulation for a given mesh size (Δx) and flow velocity (v) and is linked to numerical stability.

The eastern breach is expected to involve:

- The breach outflow is released from the eastern side of the reservoir, then follows the Makirikiri Stream, with inundation beyond both stream banks.
- The breach outflow remains within a defined valley formed by the Makirikiri Stream for approximately 2 km, after which the valley opens out, and flood waters spread out into:
  - A western flow path that enters the Tamaki River upstream of the railway, and then continues along the Tamaki River to the Manawatū River.
  - An eastern flow path that continues to follow the Makirikiri Stream, which joins the Mangatera Stream, and then the Manawatū River.
  - A central flow path that travels across the flood plain and local channels before also reaching the Manawatū River.
- Approximately 2,117 m of Laws Road is partially / intermittently inundated. Only 62 m of this 2,117 m section is fully inundated across the road crown. Flood depths of up to 0.1 m and velocities of up to 1.0 m/s are observed across the road crown.
- Approximately 160 m of SH2 is inundated, with a flood depth of up to 0.2 m, velocity of up to 0.4 m/s, and depth x velocity (DV) values of up to approximately 0.07 m^2/s.
- Approximately 815 m of the railway is inundated, with a flood depth of up to 0.7 m, velocity of up to 1.9 m/s, and DV values of up to approximately 1 m^2/s.
- Floodwaters are not expected to overtop nor even reach the underside of the SH2 bridges and railway bridges over the Tamaki River and Makirikiri Stream.
- The ground around 23 residential and 12 commercial buildings is estimated to be inundated by the breach outflow (refer Table 3.2).

2.4.5 Results – flood hazard for a western breach

Dam break flood hazard for the western breach is presented as maps of depth (D), velocity (V), flood hazard, and flood arrival time in Appendix C.

The western breach is expected to involve:

- The breach outflow is released from western side of the reservoir, then immediately crosses and spreads out across a lower terrace between Laws Road and the Tamaki River.
- Some of the breach outflow (approximately 3,280 m^3 at a peak flow of 3 m^3/s) immediately enters the Tamaki River but a substantial portion (approximately 135,210 m^3 at a peak flow of 193 m^3/s) continues further south as a wide shallow flow path, some of which enters the Tamaki River upstream of the railway, and a smaller portion that instead enters the Makirikiri Stream.
- Approximately 3,830 m of Laws Road is partially / intermittently inundated. 1,454 m of this 3,830 m section is fully inundated across the road crown. Flood depths of up to 1.1 m and velocities of up to 2.8 m/s are observed across the road crown.
- Approximately 40 m of SH2 is partially inundated at the intersection with Laws Road, with a flood depth of up to 0.1 m, velocity of up to 0.05 m/s, and DV of up to approximately 0.05m^2/s.
- Approximately 724 m of the railway is inundated, with a flood depth of up to 0.7 m, velocity of up to 1.8 m/s, and DV values of up to approximately 1 m^2/s.
- Floodwaters are not expected to overtop nor even reach the underside of the SH2 bridges and railway bridges over the Tamaki River and Makirikiri Stream.

- The ground around 23 residential and 12 commercial buildings is estimated to be inundated by the breach outflow (refer Table 3.6).

3 Consequence assessment

Section 3 presents the consequence assessment for Dannevirke Dam, which comprises the second step in Figure 1.1. In accordance with the regulations, three types of impacts / consequences have been assessed and considered in combination to determine PIC:

- Damage level,
- Population at Risk (PAR), and
- Potential loss of life.

Section 3.2 covers the assessment for the eastern breach location, and Section 3.3 covers the assessment for the western breach. These assessments are based on the current downstream area and do not account for future development or land use changes.

3.1 Downstream area

The features in the downstream area that are considered in the consequence assessment include, but are not limited to:

- Residential buildings,
- Commercial buildings,
- Farmland,
- Roads,
- Railway, and
- Road and rail bridges.

Buildings in the downstream area have been identified based on the New Zealand Buildings Outline shapefile obtained from Land Information New Zealand (LINZ).

3.2 Consequence assessment for eastern breach location

3.2.1 Damage level

In accordance with the regulations, the damage level has been assessed across categories of Community, Cultural, Critical or Major Infrastructure, and the Natural Environment. The overall damage level taken forward to determine PIC is the highest damage level across the four categories.

Table 3.1 is based on a table from Schedule 2 of the regulations, which has been shaded and outlined in red to represent the assessment for Dannevirke Dam. Further information on the assessment for each category is provided following the table.

Table 3.1: Damage level assessment for eastern breach location (from Table 1 of Schedule 2 of the regulations)

Damage Level	Specified Categories				
	Community	Cultural[1]	Critical or Major Infrastructure[2]		Natural Environment
			Damage	Time to Restore to Operation[3]	
Catastrophic	One or more of the following apply: • Fifty or more household units rendered uninhabitable, • Twenty or more commercial or industrial facilities rendered inoperable, • Two or more community facilities rendered inoperable or uninhabitable.	Irreparable loss to two 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: • Four or more but less than 50 household units rendered uninhabitable, • Five or more but less than 20 commercial or industrial facilities rendered inoperable, • One community facility rendered inoperable or uninhabitable.	One or more of the following apply: • Irreparable loss to one historical or cultural site, • Loss to one or more historical or cultural sites where it is possible, but impracticable, to fully restore the site.	One critical or major infrastructure facility is rendered inoperable.	Three months or more but less than one 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: • One or more but less than four household units rendered uninhabitable, • One or more but less than five commercial or industrial facilities rendered inoperable, • Loss of some functionality of one or more community facilities.	Significant loss to one or more sites of historical or cultural significance 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 three 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 one or more historical or cultural sites that will require minor restoration only (or no loss to any historical or cultural site).	Minor damage to one 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).

Note:

[1] Sites of historical or cultural significance means:

- Any of the following that forms a part of the historic or cultural heritage of Aotearoa New Zealand, which is listed on the New Zealand Heritage List / Rārangi Kōrero or identified by other, independent means, and that lies within the territorial limits of Aotearoa New Zealand:
  - land, including an archaeological site, a cemetery, or urupā (or part of an archaeological site, cemetery, or urupā)
  - a building or structure (or part of a building or structure)
  - any combination of land, buildings, structures, or associated buildings or structures (or parts of buildings, structures, or associated buildings or structures); and
  - Includes anything that is in or fixed to land described in the bullet points above.

[2] Critical or major infrastructure includes:

- Lifelines (power supply, water supply, gas supply, transportations systems, wastewater treatment, telecommunications (network mains and nodes rather than local connections)).
- Emergency facilities e.g., hospitals, police, fire services.
- Large industrial, commercial, or community facilities, the loss of which would have a significant impact on the community.
- The dam, if the service the dam provides is critical to the community and that service cannot be provided by alternative means.

[3] The estimated time required to repair the damage sufficiently to return the critical or major infrastructure to the normal operation that the infrastructure had immediately before the failure of the dam.

3.2.1.1 Community

The Combined Hazard Curves published in the University of New South Wales Water Research Laboratory Technical Report 2014/07 (Smith et al., 2014)[11] have been used to assess damage level for the Community category (refer Figure 3.8 and Table 3.4 in Section 3.2.2.1). As per Table 2.5 of Module 2 of the NZSOLD DSG 2023, we have considered:

- Buildings in Hazard category H1 as subject to "*minor damage that does not materially affect the functionality*".
- Buildings in Hazard categories H2 and H3 as subject to "*loss of functionality*".
- Buildings in Hazard category H4 as subject to either "*loss of functionality*" or "*rendered uninhabitable or inoperable*" depending on the building type.
- Buildings in Hazard categories H5 and H6 as "*rendered uninhabitable or inoperable*".

For the Community category, the maximum estimated flood depth above ground level[12] and maximum estimated flood velocity around the building perimeter were used to assign the Hazard category. The D, V, DV, and assigned Hazard categories for these buildings are summarised in Table 3.2 below.

Table 3.2: Eastern embankment dam break affected buildings from upstream to downstream

Address	Building Type	Maximum depth (D)	Maximum velocity (V)	Maximum DV	Hazard Category
202 Laws Road	Residential	0.25	0.66	0.17	H1
198 Laws Road	Residential	0.17	0.50	0.09	H1
185 Laws Road	Residential	0.15	0.33	0.05	H1
5 Rifle Range Road	Residential	0.25	0.60	0.15	H1
9 Rifle Range Road	Residential	0.12	0.31	0.04	H1
102 Laws Road	Residential	0.18	0.30	0.05	H1
71 Laws Road	Residential	0.11	0.36	0.05	H1
49 Laws Road	Residential	0.06	0.36	0.02	H1
47 Laws Road	Residential	0.08	0.15	0.01	H1
Tararua Self Storage, 42 Laws Road	Commercial x6	0.42 m in a few isolated spots but predominantly < 0.3 m	0.44	0.09	H1 (a few isolated spots 0.3 to 0.42 m deep are strictly H2 but overall H1 is considered more representative)
39 Laws Road	Residential	0.23	0.30	0.07	H1
4 Beckett Lane	Residential	0.23	0.32	0.07	H1
12 Beckett Lane	Residential	0.10	0.18	0.02	H1
20 Beckett Lane	Residential	0.19	0.15	0.02	H1
37 Beckett Lane	Residential	0.09	0.24	0.02	H1

[11] Smith, G. P., Davey, E. K., & Cox, R. J. (2014). Flood Hazard Water Research Laboratory Technical Report 2014/07. *Water Research Laboratory. Sydney, NSW.*

[12] Version 1 of this report considered depth above building floor level rather than ground. However, following concerns raised during peer review about uncertainty of building floor levels, the assessment has been revised to refer more conservatively to depths above ground level. Key conclusions for the community damage category have not changed based on the update.

Address	Building Type	Maximum depth (D)	Maximum velocity (V)	Maximum DV	Hazard Category
40 Beckett Lane	Residential	0.20	0.35	0.07	H1
41 Beckett Lane	Residential	0.15	0.45	0.07	H1
43 Beckett Lane	Residential	0.13	0.24	0.03	H1
35 Laws Road	Residential	0.13	0.41	0.05	H1
31 Laws Road	Residential	0.20	0.51	0.10	H1
16 Laws Road	Commercial x1	0.18	0.22	0.02	H1
6 Tapuata Place	Commercial x1	0.06	0.20	0.01	H1
Goldpine, 4 Tapuata Place	Commercial x4	0.14	0.15	0.01	H1
3 Laws Road	Residential	0.22	0.29	0.06	H1
40 Hamoa Road	Residential	0.05	0.03	0.00	H1
42 Hamoa Road	Residential	0.07	0.12	0.01	H1
176 Totaramahonga Road	Residential	0.06	0.10	0.01	H1

All buildings are in the H1 category which corresponds to "*minor damage that does not materially affect the functionality*".

Therefore, the damage level for the Community category is Minimal for the eastern breach location.

3.2.1.2 Cultural

In line with definitions in MBIE 2024, we have searched Rārangi Kōrero (Heritage New Zealand) and the National register of heritage sites managed by DOC (Department of Conservation) for previously designated historical and cultural sites. These databases indicate no cultural or historic sites within the modelled dam break flood path. The damage level is therefore Minimal for the Cultural category.

The assessment has been completed by an engineer rather than a cultural / heritage specialist. The assessment is for the purpose of determining PIC and does not comprise a cultural impact assessment as might often be undertaken to support a resource consent application.

3.2.1.3 Critical or Major Infrastructure

The railway, SH2 and the dam itself, are considered Critical or Major Infrastructure since they fulfil the definition of a lifeline utility within the meaning of the Civil Defence Emergency Management Act 2002. The railway is discussed in Section 3.2.1.3.1, the SH2 in Section 3.2.1.3.2, and the dam itself in Section 3.2.1.3.3. The resulting overall damage level for Critical or Major Infrastructure is presented in Section 3.2.1.3.4.

3.2.1.3.1 Railway

The dam break flows from the flood plain to the north of the railway drop down the railway cut batter and are then conveyed along the railway line to the Tamaki River. As noted in Section 2.4.4, approximately 815 m of the railway is inundated, with a flood depth of up to 0.7 m, velocity of up to 1.9 m/s, and DV values of up to approximately 1 m^2/s. The higher hazard occurs where the railway is in cut over a 550 m long section to the east of the Tamaki River, which gradually increases from a cut depth of 0 m to 8.5 m at the Tamaki River.

KiwiRail was approached to obtain information on the rail bridge over the Tamaki River. Photos of this rail bridge (KiwiRail reference 140 PNGL) and the approach cut section are shown in Figure 3.1, Figure 3.2, and Figure 3.3. The rail side drains close to the Tamaki River are concrete-lined and likely able to convey relatively fast flows without scour. As flow approaches the Tamaki River, it is conveyed from the drain on the northern side of the rail bridge to the concrete lined chute on the southern side, before entering the Tamaki River. The rail bridge appears to be piled.

Ballast typically comprises a coarse gravel. Etcheverry (1915) indicates that a coarse gravel can withstand mean velocities of 1.5 to 1.8 m/s. Fortier and Scobey (1926) indicates that a non-colloidal coarse gravel channel can withstand mean velocities of 1.2 m/s (clear water) to 2.0 m/s (water conveying non-colloidal silts, sands, gravels, or rock fragments). The hydraulic modelling indicates that 375 m of the railway line is subject to velocities greater than 1.2 m/s for approximately 1 hour 20 minutes.

Based on the above, damage to the railway is anticipated to comprise:

- Shallow to medium-sized landslides across the track related to the flows down the northern cut batter and undermining the toe of the batter.
- Ballast loss, track subsidence, some track misalignment, and scour of side drains over a section of up to approximately 375 m.
- Significant damage to the Tamaki River rail bridge is not anticipated due to:
  - The bridge being piled.
  - Side drains being concrete-lined drains close to the bridge.
  - Dam break flood flows are not expected to reach the underside of the bridge based on observations during the site visit of 1 and 2 May 2023.
- The track damage above is assumed able to be restored to normal operation in less than 3 months.

Following extensive flood damage to the railway in Hawke’s Bay in Cyclone Gabrielle in February 2023, a recovery team developed a triage tool for classifying damage to nearly 600 sites into five categories[13]:

i “No obvious railway damage” despite adjacent land being damaged – in case of rail damage later became apparent;

ii “Minor damage” – localised damage readily cleared e.g., short track misalignment, ballast loss;

iii “Moderate damage” – shallow landslides covering the track with surface soils and vegetation, track subsidence, repairable damage to bridges, more serious track misalignment;

iv “Major damage” – track and formation are buried, pushed out of alignment, or lost. Culverts collapsed, and bridge foundations were undermined. A full formation rebuild is needed. Bridge repairs up to six months; and

v “Extreme damage” – track and formation damaged over more than 500 metres, track deformed and displaced, damage to tunnel portals, life safety threats for access. Bridge repairs in excess of six months. There were 15 such sites in Hawkes Bay, 14 of them north of Napier.

The triage tool above provides a framework for categorising the level of flood damage to railway. The dam break flood damage to the railway is considered mostly likely represented by the “moderate damage” category above.

[13] https://cilt.co.nz/magazine/impact-of-cyclone-gabrielle-and-other-severe-weather-events-on-the-rail-system/

For the purposes of PIC, this assessment of damage also needs to be translated to the damage level descriptions in Table 3.1:

- Rendered inoperable.
- Affected by the loss of some functionality.
- Minor damage.
- No damage.

In terms of the descriptions above, the dam break flood damage to the up to 375 m of railway is considered most likely represented as "*affected by the loss of some functionality"* and able to be repaired in *"less than 3 months"*.

Strictly the railway will not be operating while damage is being repaired, which could be deemed "rendered inoperable". However, this is not considered to be the intent of the wording as explained further in this paragraph. The regulations introduced the terms "rendered inoperable" and "loss of some functionality", which correspond respectively to Major and Moderate damage to Critical or Major Infrastructure per Table 3.1. NZSOLD DSG 2023 was updated to match the terminology in the regulations. The terms in the previous 2015 version of NZSOLD DSG were "extensive destruction of and damage" and "significant damage" for Major and Moderate damage to Critical or Major Infrastructure respectively. During development of the regulations, MBIE indicated that the intent of the regulations is not to change the PIC of dams. Therefore, the term "rendered inoperable" in the regulations is understood as intended to still represent "extensive destruction" rather than being out of operation during repairs that take less than 3 months. Therefore, "rendered inoperable" is not considered the appropriate category for the damage to the railway.

Figure 3.1: Photograph of drain north of rail bridge over Tamaki River

Figure 3.2: Photograph of concrete lined chute south of rail bridge over Tamaki River

Figure 3.3: Photograph of rail bridge over Tamaki River from true right

We have also considered the potential for dam break flood damage to the Makirikiri Stream railway bridge. KiwiRail has provided the photo and dimensioned sketch of the rail bridge (KiwiRail reference PNGL 142) from an inspection in 2017 in Figure 3.4 and Figure 3.5. They have advised that they have no drawings on file.

Based on the structure dimensions in Figure 3.5, the hydraulic model indicates that the dam break flood level does not reach the underside of the Makirikiri Stream railway bridge. Therefore, the Makirikiri Stream railway bridge is expected to remain operational following a dam break flood. The damage to the bridge is considered most likely to be *"minor"* or *"no damage"* with respect to the descriptions in Table 3.1.

Figure 3.4: Photograph of rail bridge over Makirikiri Stream

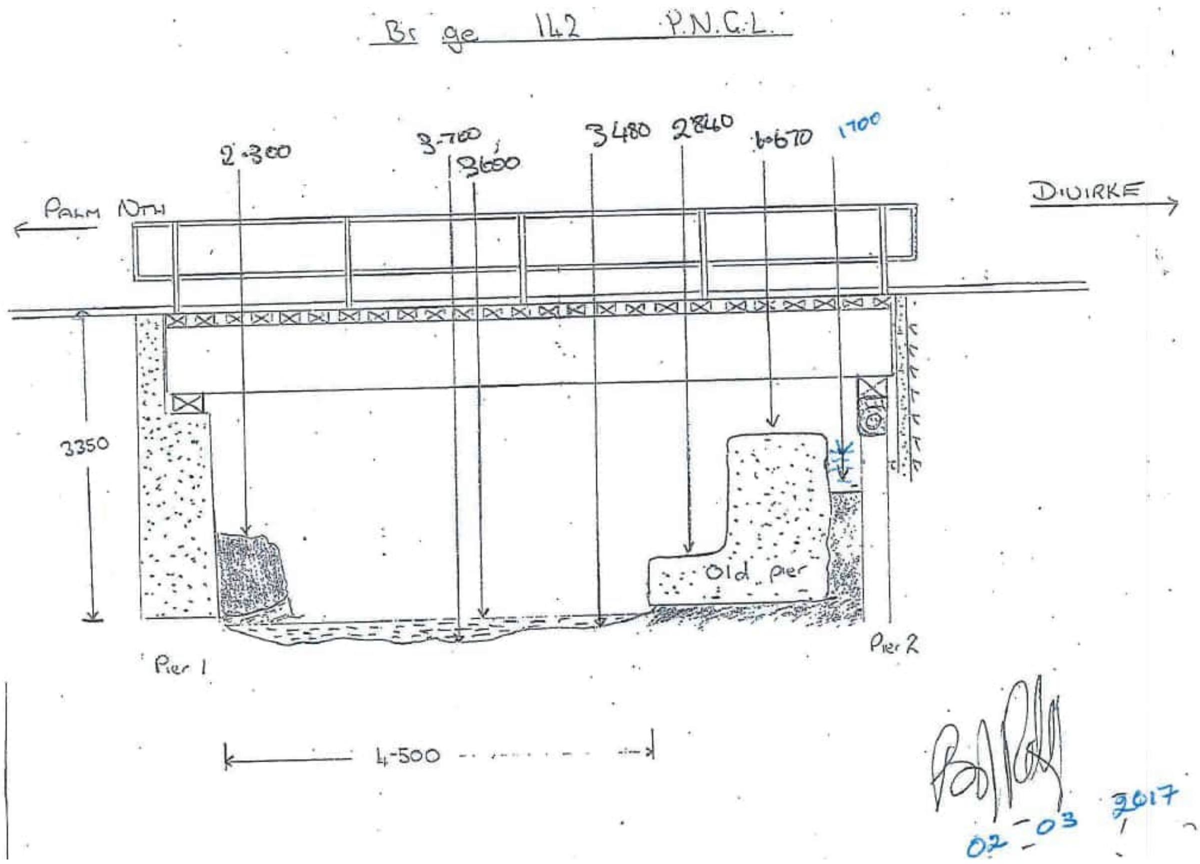


Figure 3.5: Sketch of rail bridge over Makirikiri Stream from 2017 inspection

3.2.1.3.2 SH2

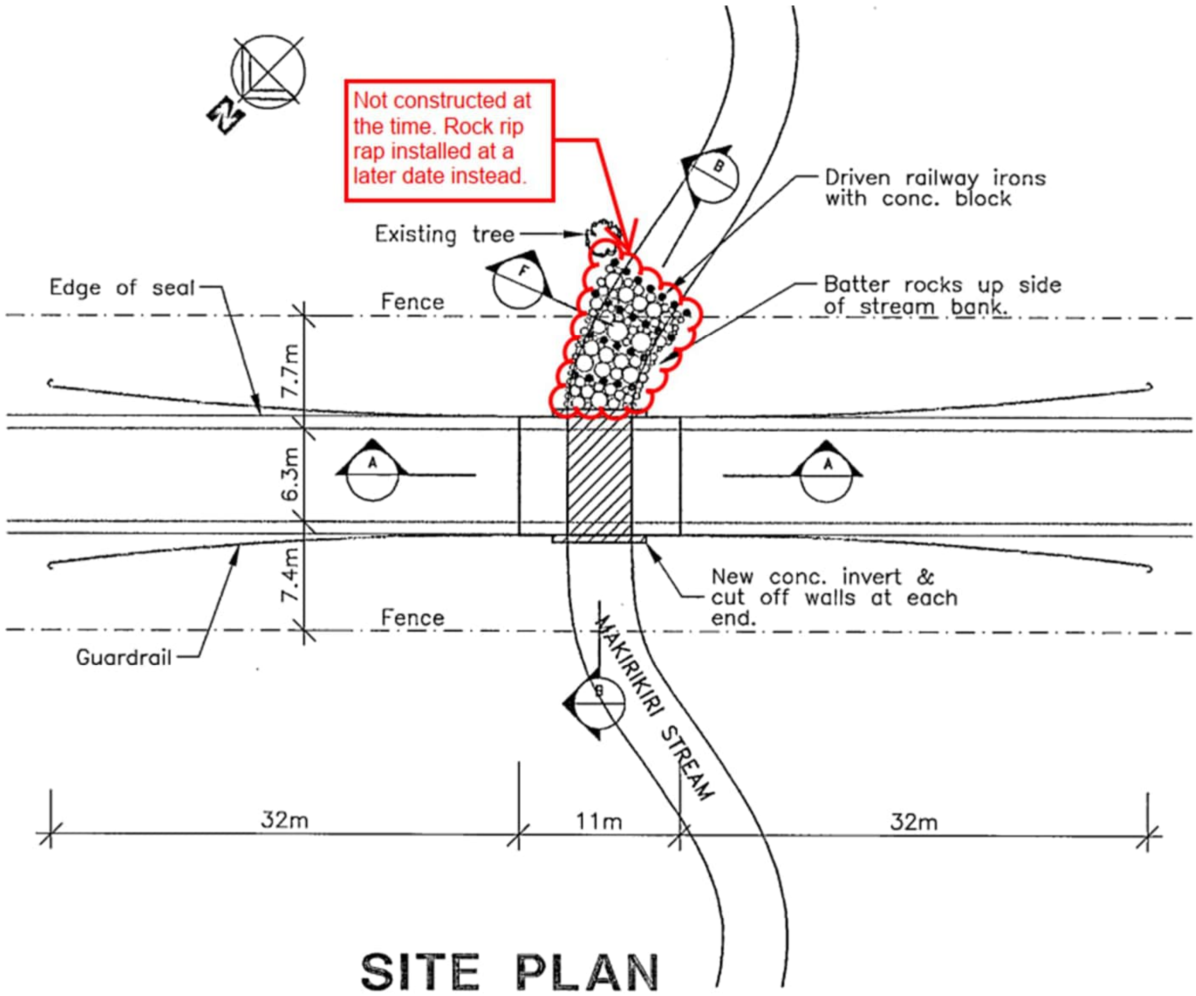
As noted in Section 2.4.4, approximately 160 m of SH2 is inundated, with a flood depth of up to 0.2m, velocity of up to 0.4 m/s, and DV values of up to approximately 0.07 m^2/s. This corresponds to flood hazard category H1 "Generally safe for people, vehicles, and buildings" (refer Figure 3.8 and Table 3.4 in Section 3.2.2.1). Based on the low flood hazard, damage to the SH1 roadway is expected to comprise *"no damage"* or *"minor damage*" with respect to the descriptions in Table 3.1.

We have also considered potential for dam break flood damage to the SH2 bridge over the Makirikiri Stream. A photo of the SH2 bridge from Google Earth is shown in Figure 3.6. WK NZTA has no as-built drawings nor hydraulic studies but has provided a drawing of scour repair works completed in the 1990s. Extracts from this drawing are included Figure 3.7. The repair works were undertaken because the stream channel was degrading below the bridge foundations. The works comprised construction of a reinforced concrete invert below the bridge. The downstream rock protection shown in the drawing was not constructed at the time to the best of WK NZTA's knowledge, but other rock protection was installed later.

Based on the structure dimensions in Figure 3.7 and the hydraulic modelling, the dam break flood level does not reach the underside of the bridge. Therefore, the Makirikiri Stream SH2 bridge is expected to remain operational following a dam break flood. The damage level is considered likely to comprise "*minor"* or *"no damage"* per the descriptions in Table 3.1.

Regarding the potential for dam break flood damage to the SH2 bridge over the Tamaki River, this is similarly assumed to be *"minor"* or *"no damage"* because the dam break flood flows are not expected to reach the underside of the bridge based on observations during the site visit of 1 and 2 May 2023.

Figure 3.6: Photo of SH2 road bridge from Google Street View dated November 2022



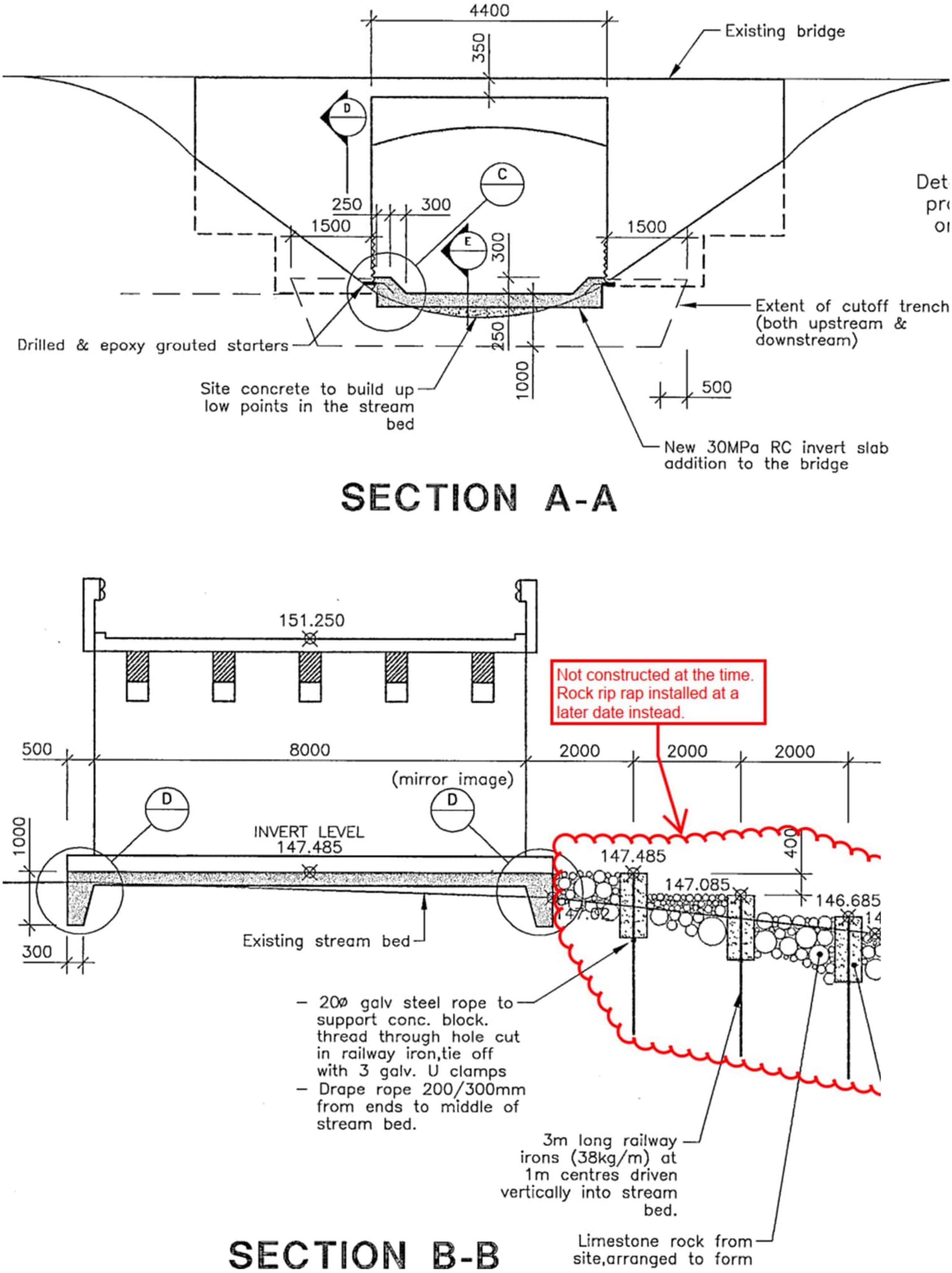


Figure 3.7: Extracts from Drawing 6881715X29-01-Rev A showing scour repair works to the SH2 bridge in the 1990s

3.2.1.3.3 Dannevirke Dam

As described in Section 2.1.1, the Dannevirke Dam is interpreted as meeting the definition of "*critical or major infrastructure*" in Clause 3(1) of the regulations.

The damage to the dam in a dam break is interpreted as being *"rendered inoperable"* per the descriptions in Table 3.1. It is expected that the dam would be dewatered and unavailable for water supply whilst the failure was investigated and repaired. The time to restore the dam to normal operation has been assumed to be *"Three months or more but less than one year"* per the descriptions in Table 3.1. Although it is possible for restoration works to take longer than 1 year, the timeframe assumed in this PIC assessment is based on the repair works being prioritised and fast-tracked.

3.2.1.3.4 Resulting damage level for Critical or Major Infrastructure

The damage to Critical or Major Infrastructure has been assessed as comprising:

- Up to 375 m section of railway *"affected by the loss of some functionality"* and able to be repaired in *"less than 3 months"*.
- *"Minor"* or *"no damage"* to the SH2 roadway.
- *"Minor"* or *"no damage"* to the Makirikiri Stream and Tamaki River railway bridges and SH2 bridges.
- Dannevirke Dam itself *"rendered inoperable"* and able to be repaired in *"Three months or more but less than one year"*.

Based on the above, the overall damage level for Critical or Major Infrastructure has been assessed as Major, which is governed by "*One critical or major infrastructure facilities rendered inoperable"*, being Dannevirke Dam itself.

3.2.1.4 Natural Environment

We have assumed that damage to the natural environment could comprise:

- Scour of stream banks and riparian vegetation, local roads, pastural fields, farm fences and farm bridges; and
- Deposition of silt and debris in the stream, roads, railway, fields and adjacent to houses.

Based on the above and the large volume of embankment likely to be eroded and deposited across a wide area, we have assumed *"Significant damage that is practicable to restore or repair".* This corresponds to a Moderate damage level for the Natural Environment category.

The brief assessment has been completed by an engineer not specifically trained in environmental impact assessments. The assessment is for the purpose of determining PIC and does not comprise an environmental impact assessment as might often be undertaken to support a resource consent application.

3.2.1.5 Overall damage level

The damage level adopted when assigning the PIC is the highest level (worst case) of the four categories presented in Sections 3.2.1.1 to 3.2.1.4.

Table 3.3: Overall damage level for the eastern dam break

Damage level	Rainy dam internal erosion type failure
Community	Minimal
Cultural and historical	Minimal
Critical or major infrastructure	Major
Natural environment	Moderate
Overall	Major

Overall, the assessed damage level is Major for the eastern breach location, which is governed by the damage to Critical or Major Infrastructure associated with loss of Dannevirke Dam itself.

3.2.2 PAR

3.2.2.1 Definitions and thresholds for inclusion

PAR is defined in the regulations and NZSOLD DSG 2023 as:

- *"the number of people likely to be affected by an uncontrolled release of all or part of the stored water or other fluid due to a failure of the dam (assuming that no person takes any action to evacuate)"*.

NZSOLD DSG 2023 indicates that people in buildings or places of occupation should be included in the PAR if the flood hazard is "H3 and above" and people in vehicles should be included if the flood hazard is "H2 and above". These flood hazard categories are shown in Figure 3.8 and Table 3.4.

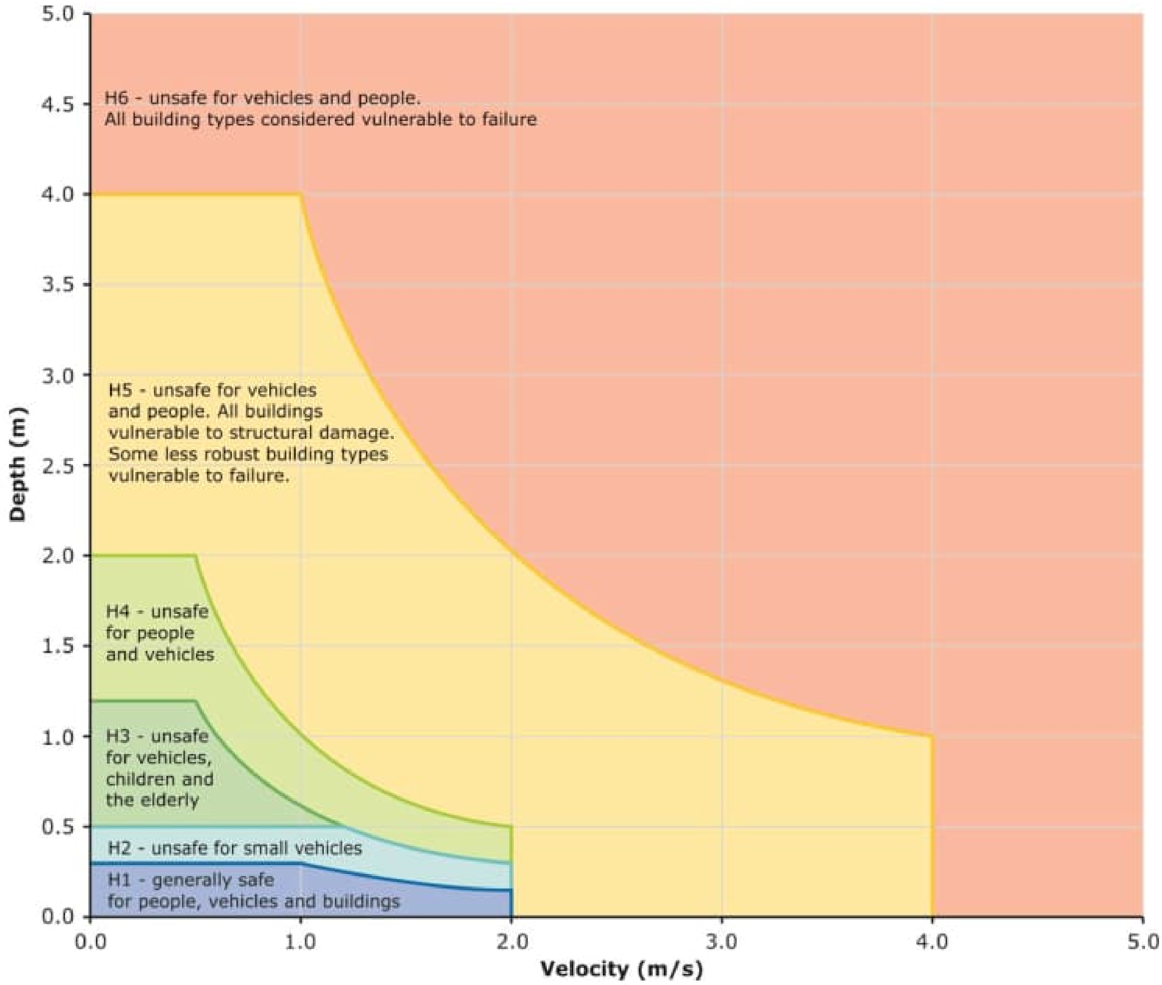


Figure 3.8: Combined flood hazard curves (Smith, Davey, & Cox. 2014).

Table 3.4: Combined hazard curves - vulnerability thresholds classification limits (Smith, Davey, & Cox. 2014)

Flood Hazard Category	Description	DV Limit (m^2/s)	Depth Limit (m)	Velocity Limit (m/s)
H1	Generally safe for people, vehicles, and buildings	0.3	0.3	2
H2	Unsafe for small vehicles	0.6	0.5	2
H3	Unsafe for vehicles, children, and the elderly	0.6	1.2	2
H4	Unsafe for people and vehicles	1	2	2
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure	4	4	4
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure	>4	>4	>4

3.2.2.2 Critical time of day

PAR includes "permanent" populations at fixed locations, such as residential, commercial, industrial and community buildings or facilities, and "temporary" populations, such as users of tracks, waterways, campers, agricultural or horticultural workers, passengers in vehicles on highways, railways, and bridges.

For both breach locations, the areas of flood hazard "H3 and above" are generally upstream of the railway line as indicated in the maps in Appendix C. This area of more severe flooding is dominated by residential buildings, farm buildings, local roads, pastural land, and farm tracks. As such, the critical time of day for permanent populations has been taken as nighttime, when people are at home inside their houses, rather than in commercial, industrial and community buildings or facilities.

In terms of temporary populations, the focus has been on the railway, SH2 and Laws Road, which has assumed a critical time for PAR of "business hours". Temporary populations using other local roads, farm buildings, pastural land, farm tracks and the railway are assumed to be too sparse to govern the determination of PIC.

3.2.2.3 PAR related to permanent populations

The addresses of the residential, commercial, industry and community buildings within the dam break flood extents are identified in Table 3.2. PAR was assessed using maximum estimated flood depth above ground level around the building perimeter and maximum estimated flood velocity at the building location. As already noted in Section 3.2.2.1, occupants of buildings within flood hazard "H3 and above" should be included in the PAR estimate.

For the eastern breach location, the permanent PAR within and around buildings is zero, because all buildings are in flood hazard category H1. There are six commercial buildings close to being categorised as H2 but this still below the "H3 and above" flood hazard threshold for inclusion as PAR.

3.2.2.4 PAR related to temporary populations

KiwiRail has advised there are approximately five train movements per day on this line with one person per train (no passengers). Campbell et al (2013)[14] provides a methodology for identifying PAR for people travelling on linear infrastructure such as rail and road. This method accounts for multiple factors, including the likelihood of a person using the relevant section of infrastructure at the time it is inundated. Based on previous experience using this method, we expect the PAR from 5 people per day using the railway would be negligible.

Hydraulic results show that SH2 and Laws Road is inundated in the eastern dam break. As already noted in Section 3.2.2.1, occupants of vehicles within flood hazard "H2 and above" are included in the PAR estimate. For the eastern breach location, the PAR in vehicles on Laws Road and SH2 is zero, because the inundated sections of SH2 and Laws Road are in flood hazard category H1.

For the eastern dam break, the highest flood hazard is confined to the defined Makirikiri Stream valley between the eastern side of the dam and where the valley opens out near 202 Laws Road. Few people are expected to be using this area, which comprises farm buildings, pastural land, and farm tracks.

3.2.2.5 PAR Summary

To determine PIC per Schedule 2 of the regulations, PAR is categorised as follows:

- 0 people,

[14] Campbell, J., Gregg, B., Southcott, P., & Wallis, M. 2013. *Flooded cars: estimating the consequences to itinerants exposed to dambreak floods on roads.*

- 1-10 people,
- 11-100 people, or
- More than 100 people.

For the eastern dam break, the PAR is assessed as "*0 people*" due to:

- The low dam break flood hazard at the location of houses, commercial buildings, Laws Road, and SH2, and
- The sparse population using the railway, farm buildings, pastural land and farm tracks.

Even if a few people using the railway, farm buildings, pastural land and farm tracks were counted as PAR this would be unlikely to increase the PAR above 10 people, which would not be enough of an increase to change the assigned PIC.

3.2.3 Potential loss of life

Potential loss of life is defined in the regulations and NZSOLD DSG 2023 as:

- *"the number of people expected to lose their life as a result of an uncontrolled release of all or part of the stored water or other fluid due to a failure of the dam"*.

Various factors influence life safety risk, including but not limited to:

- Dam break flood characteristics i.e., time to arrival, time to peak, depth of inundation, peak velocity, and duration of inundation.
- Time of breach i.e., day / night, weekday / weekend, and season.
- Available warning time.
- Effectiveness of evacuation.
- Human behaviour during the flood event.

Estimates of potential loss of life are unavoidably uncertain due to the complex interaction of the factors above.

To determine PIC per Schedule 2 of the regulations, potential loss of life is categorised as follows:

- No persons,
- One person, or
- Two or more persons.

For the eastern dam break, the potential loss of life is assessed as "*No persons*" due to the PAR being assessed as zero.

3.3 Consequence assessment for western breach location

3.3.1 Damage level

The damage level assessment for the western reservoir rim breach scenario is summarised in Table 3.5. The assessment for each category, Community, Cultural, Critical or Major Infrastructure, and Natural Environment, is described further in this section.

Table 3.5: Damage level assessment for western breach location (from Table 1 of Schedule 2 of the regulations)

Damage Level	Specified Categories				
	Community	Cultural[1]	Critical or Major Infrastructure[2]		Natural Environment
			Damage	Time to Restore to Operation[3]	
Catastrophic	One or more of the following apply: • Fifty or more household units rendered uninhabitable, • Twenty or more commercial or industrial facilities rendered inoperable, • Two or more community facilities rendered inoperable or uninhabitable.	Irreparable loss to two 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: • Four or more but less than 50 household units rendered uninhabitable, • Five or more but less than 20 commercial or industrial facilities rendered inoperable, • One community facility rendered inoperable or uninhabitable.	One or more of the following apply: • Irreparable loss to one historical or cultural site, • Loss to one or more historical or cultural sites where it is possible, but impracticable, to fully restore the site.	One critical or major infrastructure facility is rendered inoperable.	Three months or more but less than one 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: • One or more but less than four household units rendered uninhabitable, • One or more but less than five commercial or industrial facilities rendered inoperable, • Loss of some functionality of one or more community facilities.	Significant loss to one or more sites of historical or cultural significance 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 three 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 one or more historical or cultural sites that will require minor restoration only (or no loss to any historical or cultural site).	Minor damage to one 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).

Note:

[1] Sites of historical or cultural significance means:

- Any of the following that forms a part of the historic or cultural heritage of Aotearoa New Zealand, which is listed on the New Zealand Heritage List / Rārangi Kōrero or identified by other, independent means, and that lies within the territorial limits of Aotearoa New Zealand:
  - land, including an archaeological site, a cemetery, or urupā (or part of an archaeological site, cemetery, or urupā)
  - a building or structure (or part of a building or structure)
  - any combination of land, buildings, structures, or associated buildings or structures (or parts of buildings, structures, or associated buildings or structures); and
  - Includes anything that is in or fixed to land described in the bullet points above.

[2] Critical or major infrastructure includes:

- Lifelines (power supply, water supply, gas supply, transportations systems, wastewater treatment, telecommunications (network mains and nodes rather than local connections)).
- Emergency facilities e.g., hospitals, police, fire services.
- Large industrial, commercial, or community facilities, the loss of which would have a significant impact on the community.
- The dam, if the service the dam provides is critical to the community and that service cannot be provided by alternative means.

[3] The estimated time required to repair the damage sufficiently to return the critical or major infrastructure to the normal operation that the infrastructure had immediately before the failure of the dam.

3.3.1.1 Community

Refer to Section 3.2.1.1 for the methodology used to assess damage level to Community for the western dam break, which is the same as used for the eastern dam break. The D, V, DV, and hazard categories for the buildings in the western dam break flood extents are summarised in Table 3.6.

Table 3.6: Western reservoir rim dam break affected buildings from upstream to downstream

Address	Building Type	Maximum depth (D)	Maximum velocity (V)	Maximum DV	Hazard Category
373 Laws Road	Residential	0.89	1.77	1.58	H5
309 Laws Road	Residential	0.78	1.75	1.06	H5
278 Laws Road	Residential	0.34 m in one isolated spot but predominantly <0.3 m	0.53	0.18	H1 (one isolated spot 0.34 m deep is strictly H2 but overall H1 is more representative)
268 Laws Road	Residential	0.35	0.96	0.30	H2
268 Laws Road (behind above)	Residential	0.27	1.07	0.36	H2
266 Laws Road	Residential	0.35	0.96	0.22	H2
202 Laws Road[1]	Residential	0.52 m in one isolated spot but predominantly <0.5 m	1.20	0.63 in one isolated spot but predominantly < 0.6 m^2/s	H2[1] (one isolated spot is strictly H4 but overall H2 is more representative)
198 Laws Road	Residential	0.25	0.55	0.14	H1
185 Laws Road	Residential	0.27	0.57	0.15	H1
5 Rifle Range Road	Residential	0.28	0.58	0.16	H1
9 Rifle Range Road	Residential	0.10	0.24	0.02	H1
102 Laws Road	Residential	0.14	0.20	0.03	H1
71 Laws Road	Residential	0.10	0.32	0.03	H1
49 Laws Road	Residential	0.06	0.25	0.01	H1
47 Laws Road	Residential	0.06	0.14	0.01	H1
Tararua Self Storage, 42 Laws Road	Commercial x6	0.26	0.44	0.08	H1
39 Laws Road	Residential	0.13	0.24	0.02	H1
4 Beckett Lane	Residential	0.20	0.27	0.04	H1
20 Beckett Lane	Residential	0.14	0.12	0.01	H1
31 Laws Road	Residential	0.17	0.45	0.05	H1
16 Laws Road	Commercial x1	0.13	0.22	0.03	H1
6 Tapuata Place	Commercial x1	0.07	0.17	0.01	H1

Address	Building Type	Maximum depth (D)	Maximum velocity (V)	Maximum DV	Hazard Category
Goldpine, 4 Tapuata Place	Commercial x4	0.10	0.14	0.01	H1
3 Laws Road	Residential	0.12	0.11	0.00	H1
92 Totaramahonga Road	Residential	0.02	0.17	0.01	H1
40 Hamoa Road	Residential	0.02	0.02	0.00	H1
42 Hamoa Road	Residential	0.03	0.08	0.00	H1

1 The modelling for 202 Laws Road incorrectly indicates a sliver of H4 hazard zone encroaching into its building footprint as the DV is 0.63 m^2/s, greater than the 0.6 m^2/s threshold. However, this is considered an artifact of the LiDAR bare earth DEM where a building has been removed in the supplied DEM (refer Figure 3.9 below). H2 is considered the appropriate hazard category for this property.

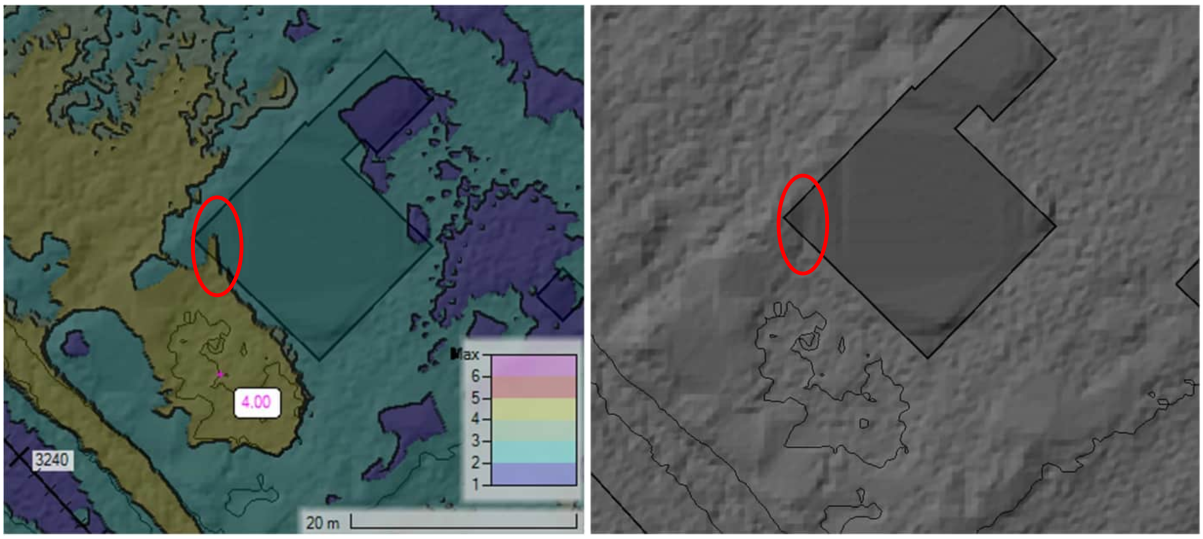


Figure 3.9: Hazard class (left image) and DEM (right image) at 202 Laws Road.

Based on the methodology described in Section 3.2.1.1, two residential houses (373 and 309 Laws Road, refer Table 3.6) are expected to be "*rendered uninhabitable*". A close view of the dam break flood depths around these houses is presented in Figure 3.10. The damage to these two houses results in a Moderate damage level for the Community category, corresponding to "*One or more but less than four household units rendered uninhabitable".*

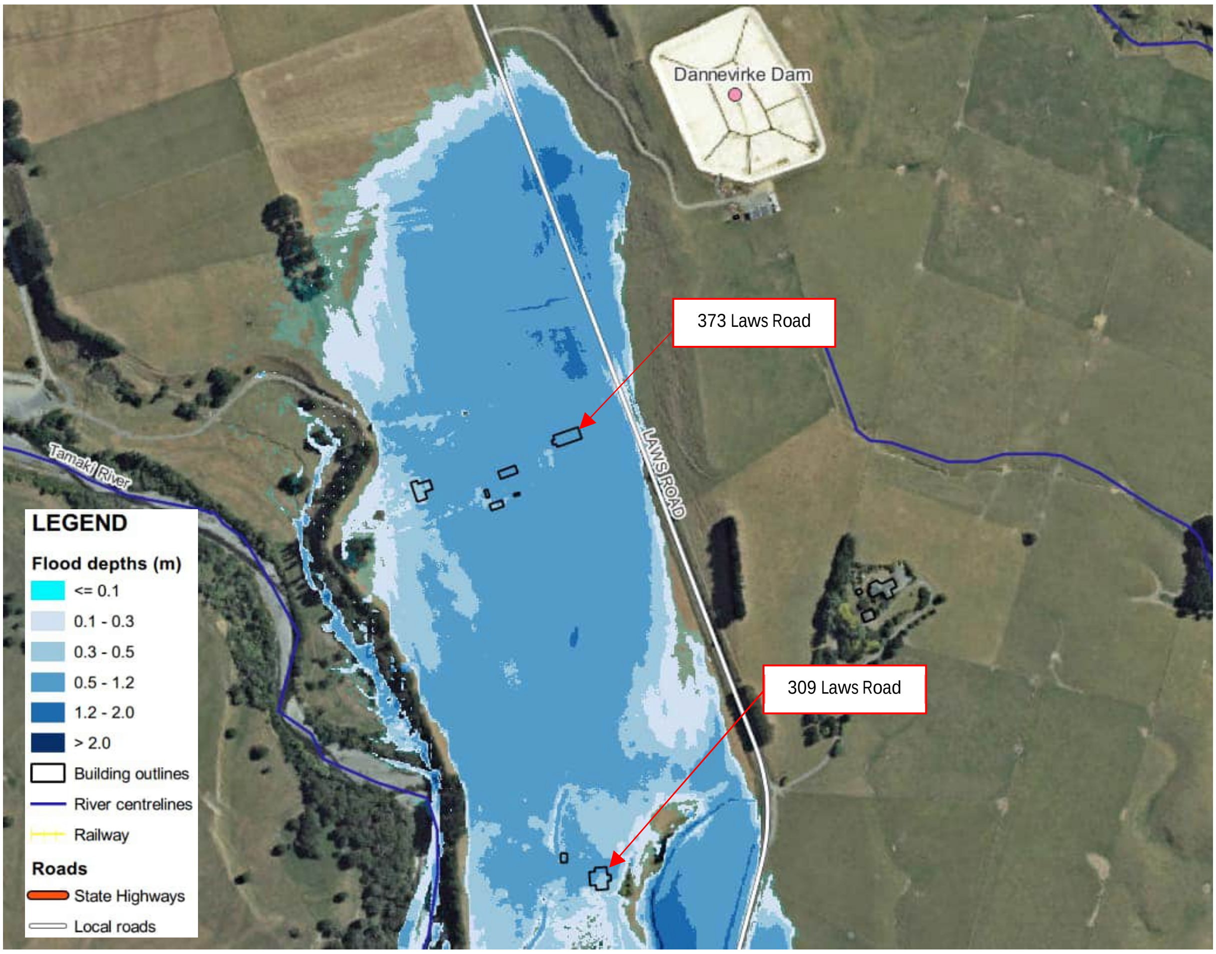


Figure 3.10: Houses assumed "rendered uninhabitable" for western breach location

3.3.1.2 Cultural

In line with guidance from MBIE 2024, we have searched Rārangi Kōrero (Heritage New Zealand) and the National register of heritage sites managed by DOC (Department of Conservation) for previously designated historical and cultural sites. These databases indicate no cultural or historic sites within the assessed dam break flood path. The damage level is therefore Minimal for the Cultural category.

The assessment has been completed by an engineer rather than a cultural / heritage specialist. The assessment is for the purpose of determining PIC and does not comprise a cultural impact assessment as might often be undertaken to support a resource consent application.

3.3.1.3 Critical or Major Infrastructure

As for the eastern dam break assessment, the impacts on the railway, SH2 and the dam itself, have been assessed in terms of impacts on Critical or Major infrastructure. The assessment is presented in Sections 3.3.1.3.1 to 3.3.1.3.4

3.3.1.3.1 Railway

The dam break flows from the flood plain to the north of the railway drop down the railway cut batter and are then conveyed along the railway line to the Tamaki River. As noted in Section 2.4.5, approximately 724 m of the railway is inundated, with a flood depth of up to 0.7 m, velocity of up to 1.8 m/s, and DV values of up to approximately 1 m^2/s. As for the eastern dam break, the higher hazard for the western dam break occurs where the railway is in cut over the 550 m long section on the eastern side of the Tamaki River. Refer to Section 3.2.1.3.1 for more information on the 550 m cut section of the railway and details of the Tamaki River rail bridge.

As per the references in Section 3.2.1.3.1, mobilisation of rail ballast is expected at a threshold velocity between 1.2 to 2.0 m/s (the threshold value varies depending on the specific reference and the sediment content of flows). The hydraulic modelling indicates that 360 m of the railway line is subject to velocities greater than 1.2 m/s for approximately 1 hour 30 minutes.

Based on the above, damage to the railway due to the western dam break is anticipated to be similar to the eastern dam break, comprising:

- Shallow to medium-sized landslides across the track related to the flows down the northern cut batter and undermining of the toe of the batter.
- Ballast loss, track subsidence, some track misalignment, and scour of side drains over a section of up to approximately 360 m.
- Significant damage to the Tamaki River rail bridge is not anticipated due to:
  - The bridge being piled.
  - Side drains being concrete-lined drains close to the bridge.
  - Dam break flood flows are not expected to reach the underside of the bridge based on observations during the site visit of 1 and 2 May 2023.
- The track damage above is assumed able to be restored to normal operation in less than 3 months.

In terms of the damage level descriptions described in Table 3.1, the dam break flood damage to up to 360 m of railway is considered most likely represented as "*affected by the loss of some functionality*" and able to be repaired in "*less than 3 months*".

Regarding the potential for dam break flood damage to the Makirikiri Stream railway bridge, this is expected to be even less for the western dam break, compared with the eastern dam break, based on the hydraulic modelling. Refer to Section 3.2.1.3.1 for more information on the bridge. The modelling and dimensions of the bridge indicate that the dam break flood remains below the underside of the bridge. Thus, the damage level to the Makirikiri Stream railway bridge for the western dam break is considered best described as "*minor*" or "*no damage*" per the descriptions in Table 3.1.

3.3.1.3.2 SH2

As noted in Section 2.4.5, approximately 40 m of SH2 is partially inundated at the intersection with Laws Road, with a flood depth of up to 0.1 m, velocity of up to 0.05 m/s, and DV values of up to approximately 0.05 m^2/s. This corresponds to flood hazard category H1 "Generally safe for people, vehicles, and buildings" (refer Figure 3.8 and Table 3.4 in Section 3.2.2.1). Based on the low flood hazard, damage to the roadway itself is expected to comprise *"no damage"* or *"minor damage*" with respect to the descriptions in Table 3.1.

We have also considered potential for dam break flood damage to the SH2 bridge over the Makirikiri Stream. This is expected to be even less for the western dam break, compared with the eastern dam break, based on the hydraulic modelling. Refer to Section 3.2.1.3.2 for more information on the bridge. The modelling and dimensions of the bridge indicate that the dam break flood remains below the underside of the bridge. Thus, the damage level to the Makirikiri Stream SH2 bridge for the western dam break is considered most likely to be "*minor*" or "*no damage*" per the descriptions in Table 3.1.

Regarding the potential for dam break flood damage to the SH2 bridge over the Tamaki River, this is similarly assumed to be "*minor*" or "*no damage*" because the dam break flood flows are not expected to reach the underside of the bridge based on observations during the site visit of 1 and 2 May 2023.

3.3.1.3.3 Dannevirke Dam

As described in Section 2.1.1, the Dannevirke Dam is interpreted as meeting the definition of "*critical or major infrastructure*" in Clause 3(1) of the regulations.

Similar to for the eastern dam break, the damage to the dam in the western dam break is interpreted as being *"rendered inoperable"* per the descriptions in Table 3.1. It is expected that the dam would be dewatered and unavailable for water supply whilst the failure was investigated and repaired. The time to restore the dam to normal operation has been assumed to be *"Three months or more but less than one year"* per the descriptions in Table 3.1. Although it is possible for restoration works to take longer than 1 year, the adopted timeframe for this PIC assessment assumes that the repair works are prioritised and fast-tracked.

3.3.1.3.4 Resulting damage level for Critical or Major Infrastructure

The damage to Critical or Major Infrastructure has been assessed as comprising:

- Up to 360 m section of railway *"affected by the loss of some functionality"* and able to be repaired in *"less than 3 months"*.
- *"Minor"* or *"no damage"* to the SH2 roadway.
- *"Minor"* or *"no damage"* to the Makirikiri Stream and Tamaki River railway bridges and SH2 bridges.
- Dannevirke Dam itself *"rendered inoperable"* and able to be repaired in *"Three months or more but less than one year"*.

Based on the above, the overall damage level for Critical or Major Infrastructure has been assessed as Major, which is governed by "*One critical or major infrastructure facilities rendered inoperable"*, being Dannevirke Dam itself.

3.3.1.4 Natural Environment

We have assumed that damage to the natural environment could comprise:

- Scour of stream banks and riparian vegetation, local roads, pastural fields, farm fences and farm bridges; and
- Deposition of silt and debris in the stream, roads, railway, fields and adjacent to houses.

Based on the above and the large volume of embankment likely to be eroded and spread across a wide area, we have assumed *"Significant damage that is practicable to restore or repair".* This corresponds to a Moderate damage level for the Natural Environment category.

The brief assessment has been completed by an engineer not specifically trained in environmental impact assessments. The assessment is for the purpose of determining PIC and does not comprise an environmental impact assessment as might often be undertaken to support a resource consent application.

3.3.1.5 Overall damage level

The damage level adopted when assigning the PIC is the highest level (worst case) of the four categories presented in Sections 3.3.1.1 to 3.3.1.4.

Table 3.7: Overall damage level for the western dam break

Damage level	Rainy dam internal erosion type failure
Community	Moderate
Cultural and historical	Minimal
Critical or major infrastructure	Major
Natural environment	Moderate
Overall	Major

Overall, the assessed damage level is Major for the western breach location, which is governed by the damage to Critical or Major Infrastructure associated with loss of Dannevirke Dam itself.

3.3.2 PAR

Refer to Section 3.2.2 for an introduction to the concept of PAR and the methodology used to identify PAR.

3.3.2.1 PAR related to permanent populations

The addresses of the residential, commercial, industry and community buildings within the dam break flood extents are identified in Table 3.6. As already noted in Section 3.2.2.1, occupants of buildings within flood hazard “H3 and above” should be included in the PAR estimate.

For the western dam break, Table 3.6 indicates that two houses are in flood hazard category “H3 and above” i.e., 373 Laws Road and 309 Laws Road, which modelling indicates are in H5 flood hazard.

The demographic breakdown of Dannevirke according to the 2018 New Zealand Census[15,16] (Statistics NZ 2021) indicates the following:

- The population is 5,508 people.
- There are 2,184 occupied private dwellings and 177 unoccupied private dwellings.
- 55 % of the population are in full or part-time employment; the other 45 % are unemployed or not in the labour force.

The average population per household in Dannevirke is 2.3 people per household, calculated by dividing 5,508 people over 2361 total dwellings (2,184 occupied dwellings plus 177 unoccupied dwellings).

For the western dam break, the permanent PAR has been estimated as 4.6 people, based on 2 houses x 2.3 people per house.

3.3.2.2 PAR related to temporary populations

As for the eastern dam break described in Section 3.2.2.4, the PAR from people using the railway is expected to be negligible due to there being only one person per train (no passengers) and only five train movements per day.

Hydraulic results show that SH2 and Laws Road is inundated in the western dam break. As already noted in Section 3.2.2.1, occupants of vehicles within flood hazard “H2 and above” should be included in the PAR estimate. For the western breach location, no PAR is included for vehicles on SH2 because the inundated section of SH2 is in flood hazard category H1.

[15] Stats NZ (accessed January 2023) https://www.stats.govt.nz/tools/2018-census-place-summaries/dannevirke-east
[16] Stats NZ (accessed January 2023) https://www.stats.govt.nz/tools/2018-census-place-summaries/dannevirke-west

As noted in Section 2.4.5, approximately 3,830 m of Laws Road is partially / intermittently inundated. Flood depths of up to 1.1 m and velocities of up to 2.8 m/s are observed across the road crown. The maximum flood hazard is category H5. There are four sections of Laws Road subject to flood hazard “H2 and above”, adding up to 1,120 m (= 320 m + 250 m + 85 m + 465 m).

The PAR for people in vehicles on Laws Road has been estimated using the methodology developed by Campbell et al (2013). The following risk scenarios are typically considered for road users:

- Scenario A: the vehicle is within the inundation zone as the flood wave hits.
- Scenario B: the vehicle drives into the inundation zone during the event.
- Scenario C: the vehicle drives into the inundation zone after the flood wave has passed.

The key inputs into the assessment for Laws Road are the following:

- Annual average daily traffic volume for Laws Road (AADT = 321[17]). This equates to one vehicle approximately every 4.5 minutes. This is considered a moderate traffic volume.
- A road vehicle occupancy rate of 1.19 people per vehicle[14] is used.
- Vehicle speed of 100 kph (according to TDC Speed Limit Bylaw 2013[18]).
- Laws Road inundation length of approximately 3,830 m. This is considered relatively conservative because only 1,120 m is “H2 and above”.
- Stopping sight distance of 184.2 m for road vehicles.
- Travel time from nearest major centre (6 minutes from Dannevirke township to Laws Road).

The PAR has been taken as the $P_{T:S}$ parameter (i.e. probability of a vehicle being exposed to the dam break hazard, which is a product of the exposure time of a vehicle and the traffic volume) outlined in the Campbell et al (2013) method multiplied by the number of occupants per vehicle.

Based on this method, the temporary PAR for vehicles on Laws Road has been estimated as 3.0 people, resulting in a total temporary PAR of 3.0 for the western breach location. The results are summarised in Table 3.8.

Table 3.8: Western dam break – Temporary PAR for vehicle users

Road	Total $P_{T:S}$ (1)	Road vehicle occupancy rate	Temporary PAR
Laws Road	2.5	1.19	3.0
Total			3.0

Note:

(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. The total $P_{T:S}$ value is the sum of $P_{T:S}$ values for scenarios A, B and C.

3.3.2.3 PAR Summary

The summation of permanent and temporary PAR for the western reservoir rim dam break is presented below in Table 3.9.

[17] Tararua District Council, 2022 AADT estimate. Accessed 8/07/2024 from https://mobileroad.org/desktop.html
[18] Tararua District Council. 2014. *The Tararua District Council Speed Limits Bylaw 2013.*

Table 3.9: Western dam break – total PAR

Dam Break Inundation Location / Population	Population at Risk
Permanent PAR	4.6
Temporary PAR	3.0
Total	7.6

For the western dam break, the PAR is assessed in the category of 1 to 10 people due to:

- Two houses (373 Laws Road and 309 Laws Road) being exposed to dam break flood hazard of H5.
- People using vehicles on 1,120 m section of Laws Road being exposed to dam break flood hazard "H2 and above", including one section where dam break flood hazard is H5.

3.3.3 Potential loss of life

Refer to Section 3.2.3 for an introduction to the concept of potential loss of life as defined in the regulations and NZSOLD DSG 2023.

As noted in this earlier section, estimates of potential loss of life are unavoidably uncertain due to depending on the complex interaction of several factors. However, a reasonable estimate of potential loss of life has been made for this PIC assessment based on the Reclamation Consequence Estimating Methodology (RCEM)[19] as recommended in the NZSOLD DSG 2023. A fatality rate of 0.01 has conservatively been adopted using the 'Suggested Limit' curve from Figure 1 ('Fatality Rate vs DV: Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning', refer Appendix F), as maximum DV values for the PAR are below 30 ft^2/s (2.8 m^2/s).

The summation of permanent and temporary potential loss of life for the western reservoir rim dam break has been estimated as 0.08 using RCEM as presented below in Table 3.10. Based on this total, it is not expected that a life will be lost in the western reservoir rim dam break i.e., the potential loss of life category has been taken as "*No persons*" per the categories in Schedule 2 of the regulations.

Table 3.10: Potential loss of life for western dam break using RCEM

Dam break inundation location / population	PAR	RCEM fatality rate	Potential loss of life
Permanent	4.6	0.01	0.05
Temporary	3.0	0.01	0.03
Total			0.08

[19] U.S. Department of the Interior Bureau of Reclamation. 2015. *RCEM – Reclamation Consequence Estimating Methodology. Interim Guidelines for Estimating Life Loss for Dam Safety Risk Analysis.*

4 Assigning PIC

Section 4 presents the process of assigning PIC for Dannevirke Dam, which is the third step in Figure 1.1. Table 4.1 and Table 4.2 cover the process for the eastern and western breach locations respectively. The tables are based on Schedule 2 of the regulations, which have been shaded and outlined in red to represent the assessment for Dannevirke Dam.

As per Table 4.1, the eastern dam embankment is assigned a Medium PIC based on:

- A damage level of Major, governed by impacts of a dam break on the dam itself.
- A PAR of 0.
- Potential loss of life of "*No persons*".

Table 4.1: PIC for the eastern breach location (from Table 2 of Schedule 2 of the regulations)

Assessed Damage Level	PAR				Potential loss of life
	0	1-10	11-100	More than 100	
Catastrophic	High	High	High	High	No persons
	N/A (See Note 1)	High	High	High	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Major	Medium	Medium	High	High	No persons
	N/A (See Note 1)	Medium	High	High	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Moderate	Low	Low	Medium	Medium	No persons
	N/A (See Note 1)	Medium	Medium	Medium	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Minimal	Low	Low	Low	Low	No persons
	N/A (See Note 1)	Medium	Medium	Medium	One person
	N/A (See Note 1)	High	High	High	Two or more persons

Note 1. Not applicable. PAR is zero therefore no potential loss of life.

As per Table 4.2, the western reservoir rim is assigned a Medium PIC based on:

- A damage level of Major, governed by impacts of a dam break on the dam itself.
- A PAR of 1 to 10.
- Potential loss of life of "*No persons*".

Table 4.2: PIC for the western breach location (from Table 2 of Schedule 2 of the regulations)

Assessed Damage Level	PAR				Potential loss of life
	0	1-10	11-100	More than 100	
Catastrophic	High	High	High	High	No persons
	N/A (See Note 1)	High	High	High	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Major	Medium	Medium	High	High	No persons
	N/A (See Note 1)	Medium	High	High	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Moderate	Low	Low	Medium	Medium	No persons
	N/A (See Note 1)	Medium	Medium	Medium	One person
	N/A (See Note 1)	High	High	High	Two or more persons
Minimal	Low	Low	Low	Low	No persons
	N/A (See Note 1)	Medium	Medium	Medium	One person
	N/A (See Note 1)	High	High	High	Two or more persons

Note 1. Not applicable. PAR is zero therefore no potential loss of life.

The key areas of judgement in this PIC assessment, where there is the most risk that alternative interpretations could change the PIC, comprise:

- The interpretation of Dannevirke Dam as critical infrastructure. If it was considered plausible that the critical service provided by the dam could reasonably be provided by alternative means, Dannevirke Dam would not comprise critical infrastructure. This could potentially reduce the overall damage level to Moderate, resulting in a Low PIC.
- The interpretation of the damage to the railway line as "*loss of some functionality*". If this was instead interpreted as "*rendered inoperable*", this could increase the assessed damage level to Catastrophic, resulting in a High PIC. Refer to further discussion in Section 3.2.1.3.1.
- The PAR estimated for the western dam break is getting close to the next category of 11 to 100 people. If additional people using the railway, farm buildings, pastural land and farm tracks are added as PAR, this could result in a High PIC for the western reservoir rim.
- If the Potential Loss of Life was assessed using a different method than RCEM, such as a qualitative approach, this could increase the estimate to "*Two of more persons*", resulting in a High PIC.

5 Conclusions

T+T has completed a Comprehensive PIC assessment for Dannevirke Dam for TDC as our client.

A "rainy day" breach scenario was eliminated early in the assessment as likely to be less critical than a "sunny day" breach scenario. A dam crest overtopping failure mode was considered and judged less plausible and less critical than an internal erosion / piping type failure due to limited inflows to develop an overtopping breach larger than an internal erosion breach. The full comprehensive level of assessment has been completed for an internal erosion / piping type failure mode in "sunny day" conditions.

Hydraulic models have been developed for two potential breach locations. This included a breach through the highest section of dam embankment on the eastern side of the reservoir. The second breach location was assumed through a smaller dam embankment bund, natural ground, and excavated side of the dam, which in combination have been interpreted as "a natural feature that has been significantly modified to function as a dam" in line with the Building Act 2004 definition of a "dam".

The consequence assessment has considered damage across categories of Community, Cultural, Critical or Major Infrastructure, and the Natural Environment. For both breach locations, the assessment indicates an overall damage level of Major, which is governed by the impact on the dam itself as critical infrastructure. The population at risk has been assessed as zero for the eastern breach and 1 to 10 for the western breach. The potential loss of life is estimated as "*No persons*" for both breach locations. Overall, this results in a PIC for Dannevirke Dam of Medium for both the eastern dam embankment and western reservoir rim.

This PIC has been identified as sensitive to the following areas of judgement:

- The interpretation of Dannevirke Dam as critical infrastructure where the service provided by the dam (water supply) cannot reasonably be provided by alternative means.
- The interpretation of the dam break damage to the railway line as "*loss of some functionality*" rather than being "*rendered inoperable*".
- The PAR estimated for the western dam break, which is close to the next PAR category of 11 to 100 people.
- The methodology adopted to estimate potential loss of life.

We consider that reasonable assumptions have been made in the areas listed above based on the information available. As such, the identified Medium PIC is recommended as appropriate for Dannevirke Dam.

6 Applicability

This report has been prepared for the exclusive use of our client Tararua District Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by Tararua District Council when applying for building and resource consents and in fulfilling its responsibilities under the Building (Dam Safety) Regulations 2022.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Reviewed by:

....

Dewi Knappstein
Dams Business Leader

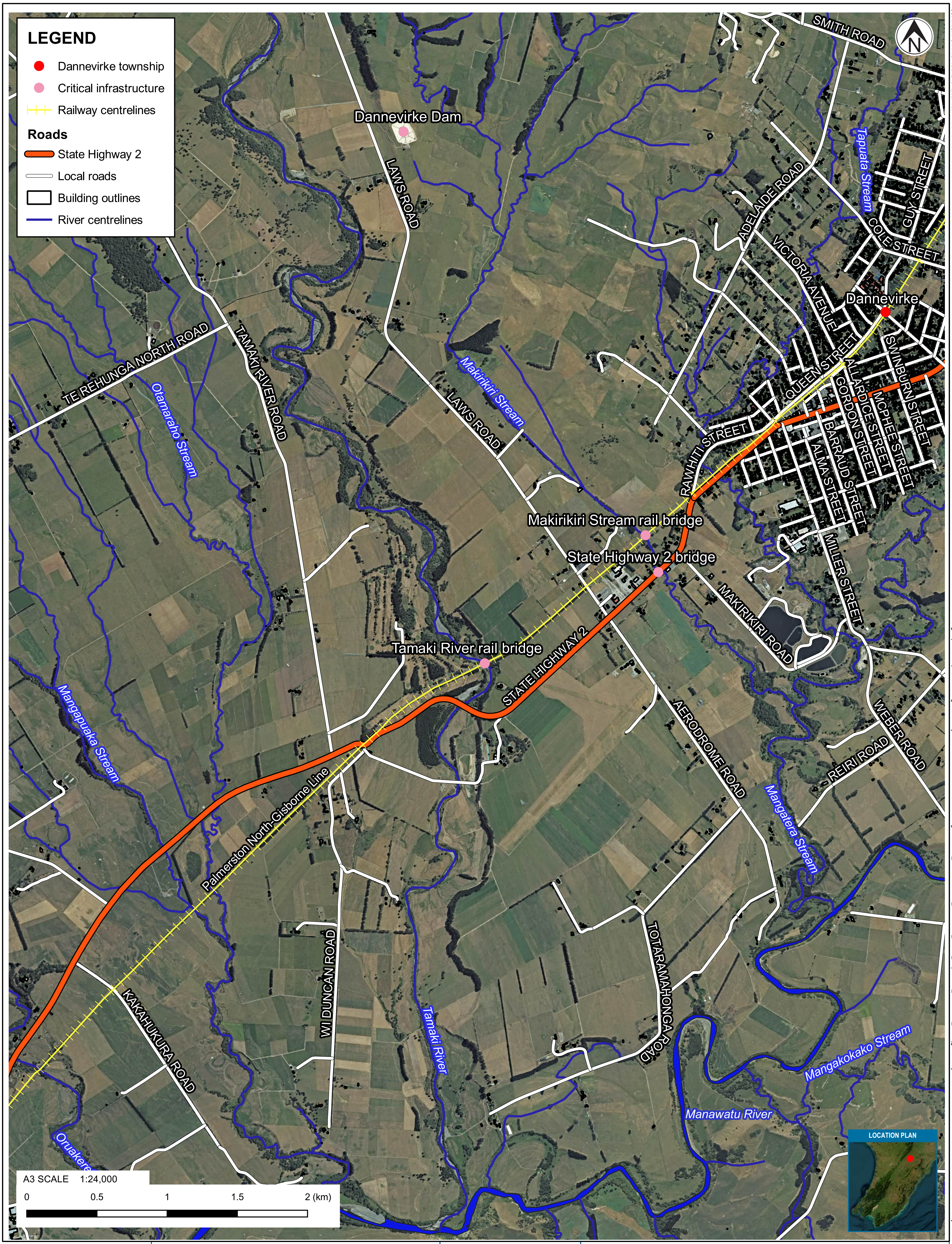
Authorised for Tonkin & Taylor Ltd by:

....

Hugh Cherrill
Project Director

NOHU
\\ttgroup.local\corporate\wellington\tt projects\1020688\1020688.2000\workingmaterial\02_reporting\20240805.dannevirke comprehensive pic rev 2.docx

Appendix A Dannevirke Dam location and downstream area



\\ttgroup.local\corporate\Wellington\TT Projects\1020688\1020688.2000\WorkingMaterial\03_GIS\QGIS\QGIS_Dannevirke_PIC\02_Maps\QGIS_Dannevirke_Dam.qgz

Layout: Dannevirke Dam and Downstream Area

Drawn by NOHU

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Exceptional thinking together

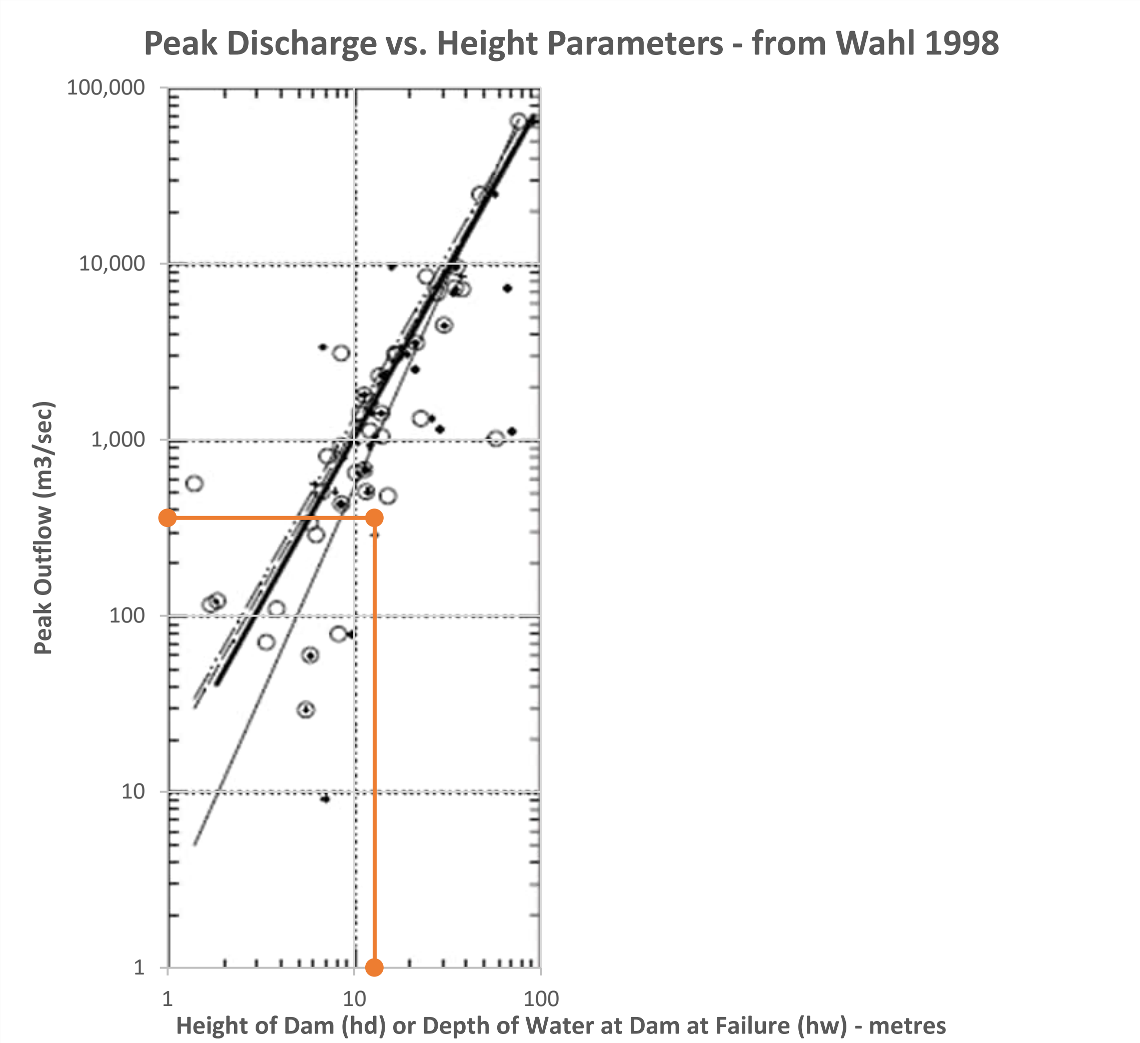
NOTES:
Aerial imagery, road centrelines and river centrelines from LINZ 2023

REV	DESCRIPTION	GIS	CHK	DATE	APPROVED	DATE
0	First version	NOHU	ACAM	29/06/23		

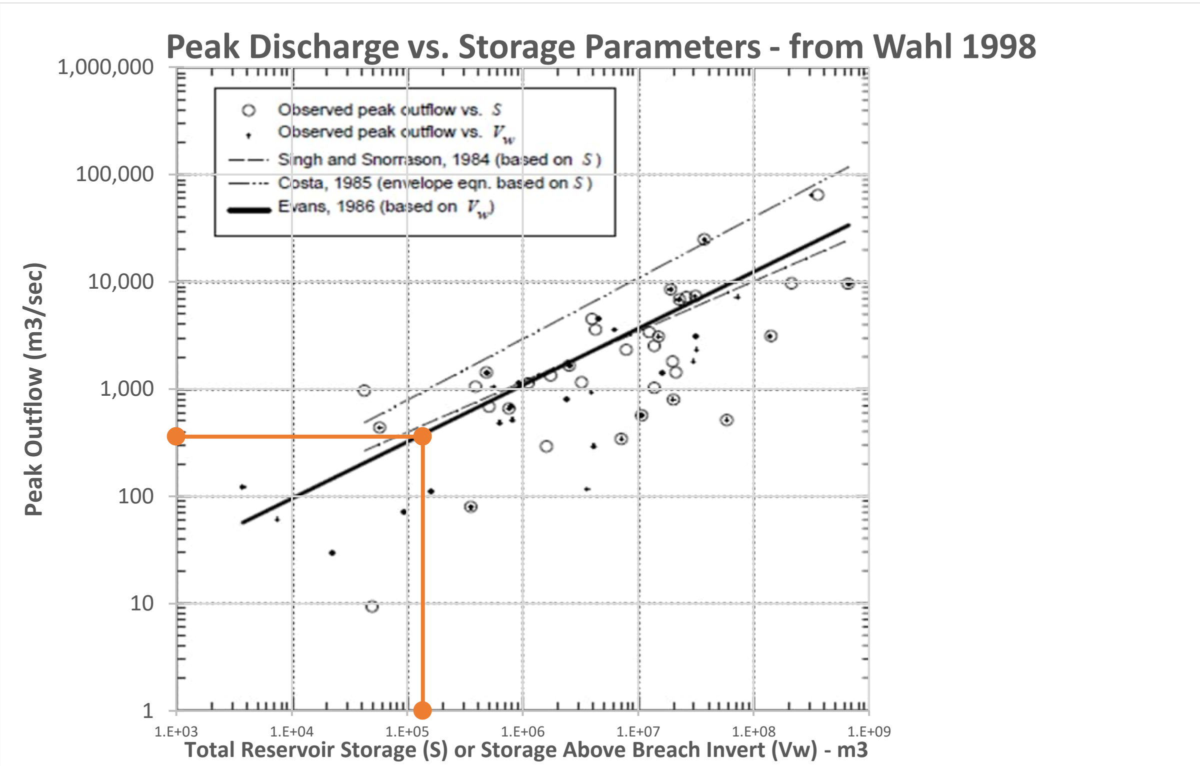
PROJECT No.	1020688.2000	
DESIGNED	NOHU	JUN.23
DRAWN	NOHU	JUN.23
CHECKED	ACAM	JUN.23

CLIENT	TARARUA DISTRICT COUNCIL
PROJECT	DANNEVIRKE WATER SUPPLY DAM PIC
TITLE	COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION DANNEVIRKE DAM AND DOWNSTREAM AREA
SCALE (A3)	1:24,000
FIG No.	FIGURE APPENDIX A.1
REV	0

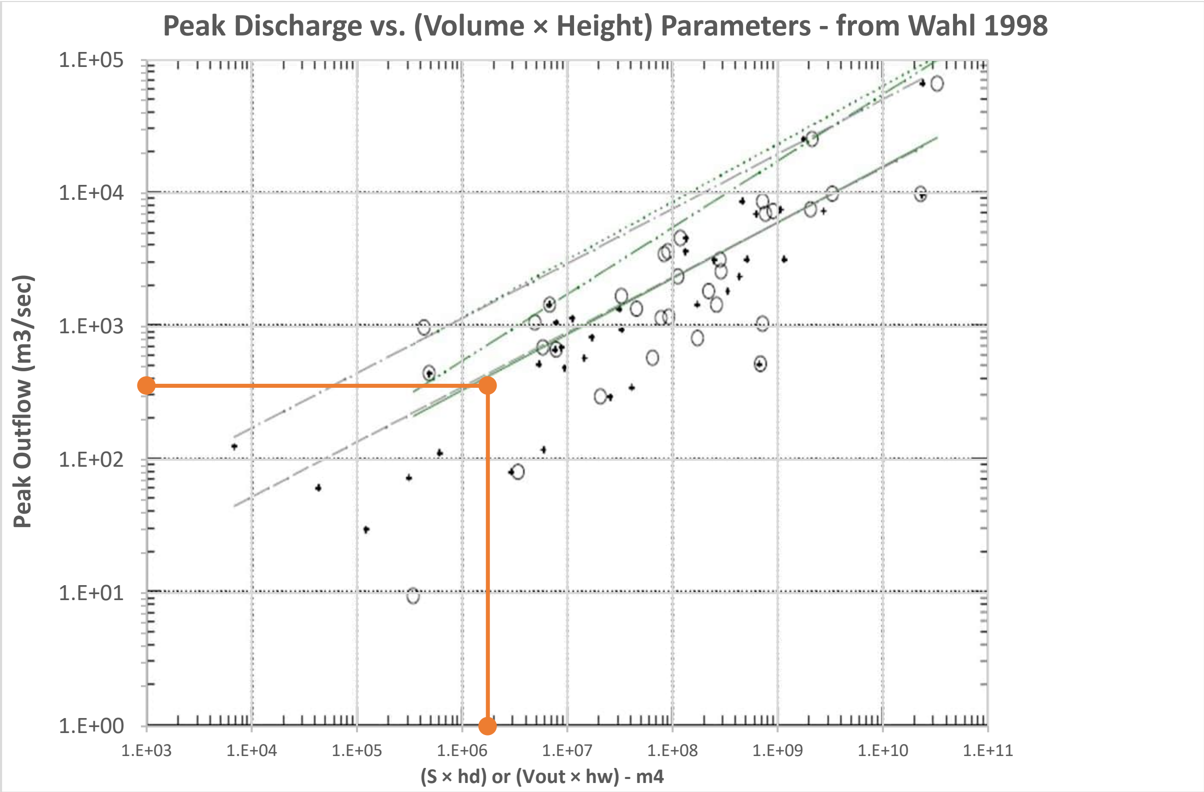
Appendix B Dam break peak flow comparisons



Peak Discharge vs. Height Parameters - from Wahl 1998
100,000
10,000
1,000
100
10
1
1
10
100
Peak Outflow (m3/sec)
Height of Dam (hd) or Depth of Water at Dam at Failure (hw) - metres

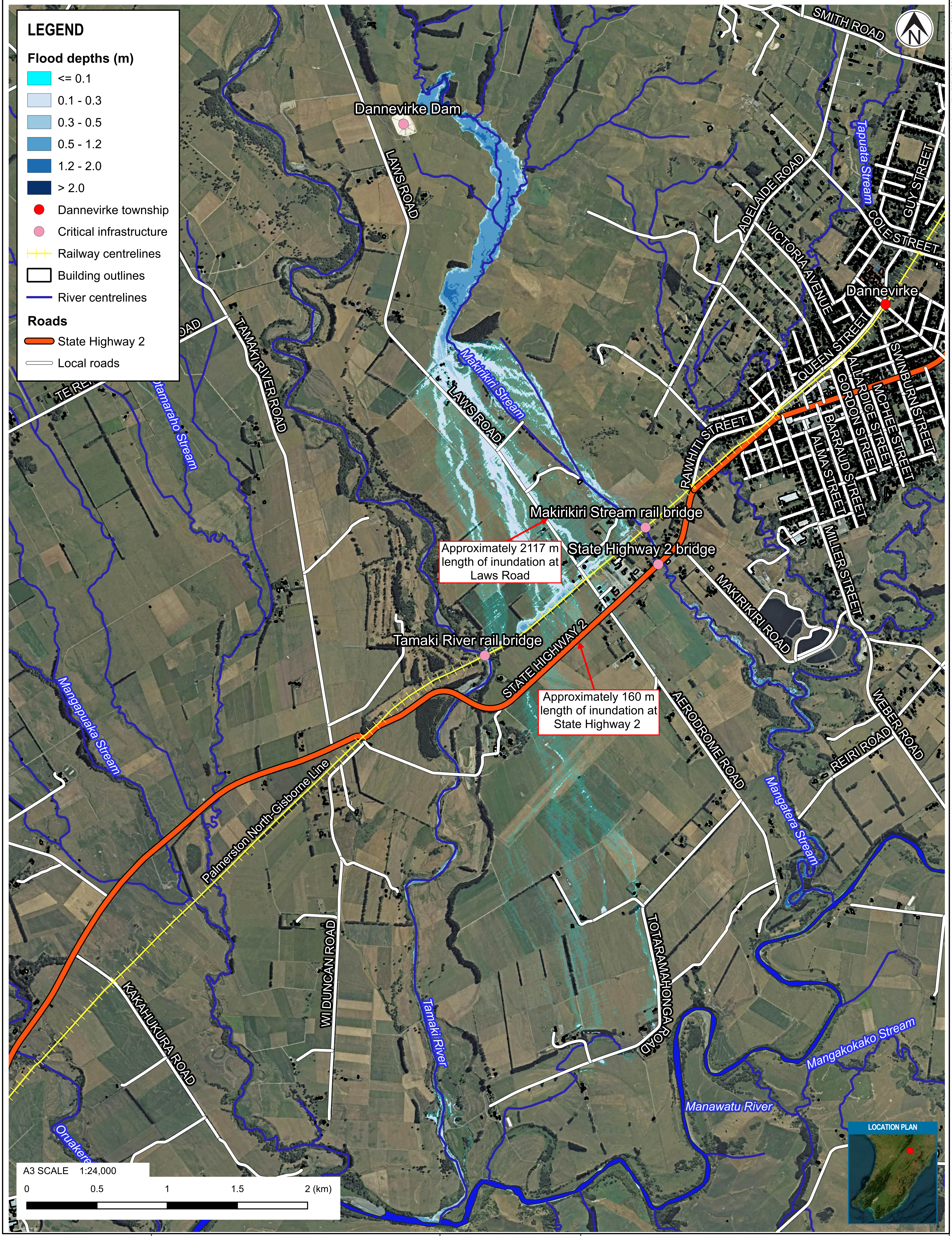


Peak Discharge vs. Storage Parameters - from Wahl 1998
Observed peak outflow vs. S
Observed peak outflow vs. Vw
Singh and Snorrason, 1984 (based on S)
Costa, 1985 (envelope eqn. based on S)
Evans, 1986 (based on Vw)
1,000,000
100,000
10,000
1,000
100
10
1
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
Peak Outflow (m3/sec)
Total Reservoir Storage (S) or Storage Above Breach Invert (Vw) - m3


Peak Discharge vs. (Volume × Height) Parameters - from Wahl 1998
Peak Outflow (m3/sec)
(S × hd) or (Vout × hw) - m4
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
1.E+10
1.E+11

Appendix C Dam break flood maps

- Eastern embankment dam break flood depth (D) map
- Eastern embankment dam break flood velocity (V) map
- Eastern embankment dam break flood hazard map
- Eastern embankment dam break flood arrival time
- Western reservoir rim dam break flood depth (D) map
- Western reservoir rim dam break flood velocity (V) map
- Western reservoir rim dam break flood hazard map
- Western reservoir rim dam break flood arrival time



DO NOT SCALE FROM THIS FIGURE

\\tgroup.local\corporate\Wellington\TT Projects\1020688\1020688.2000\WorkingMaterial\03_GIS\QGIS\QGIS_Dannevirke_PIC\02_Maps\QGIS_Dannevirke_Dam - updated.qgz

Layout:

Drawn by NOHU

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NOTES:
Aerial imagery, road centrelines and river centrelines from LINZ 2023

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1	Second version	NOHU	DMK	29/07/24		

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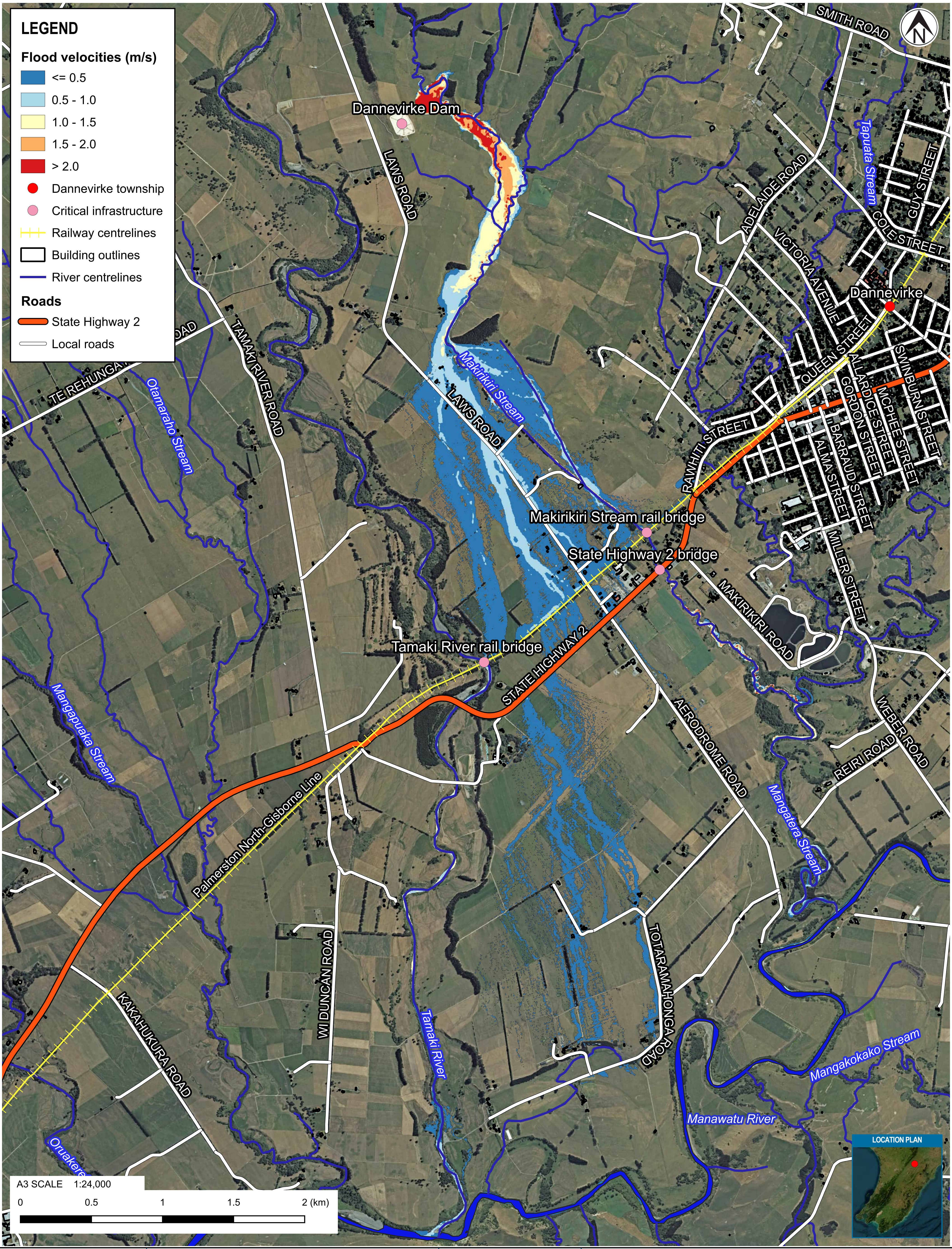
DRAWN	NOHU	JUN.23
CHECKED	ACAM	JUN.23

CLIENT	**TARARUA DISTRICT COUNCIL**
PROJECT	**DANNEVIRKE WATER SUPPLY DAM PIC**
TITLE	COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION EASTERN EMBANKMENT DAM BREAK FLOOD DEPTHS

SCALE (A3) 1:24,000 | FIG No. FIGURE APPENDIX C.1 | REV 1



\\ttgroup.local\corporate\Wellington\TT Projects\1020688\1020688.2000\WorkingMaterial\03_GIS\QGIS\QGIS_Dannevirke_PIC\02_Maps\QGIS_Dannevirke_Dam - updated.qgz

Layout:

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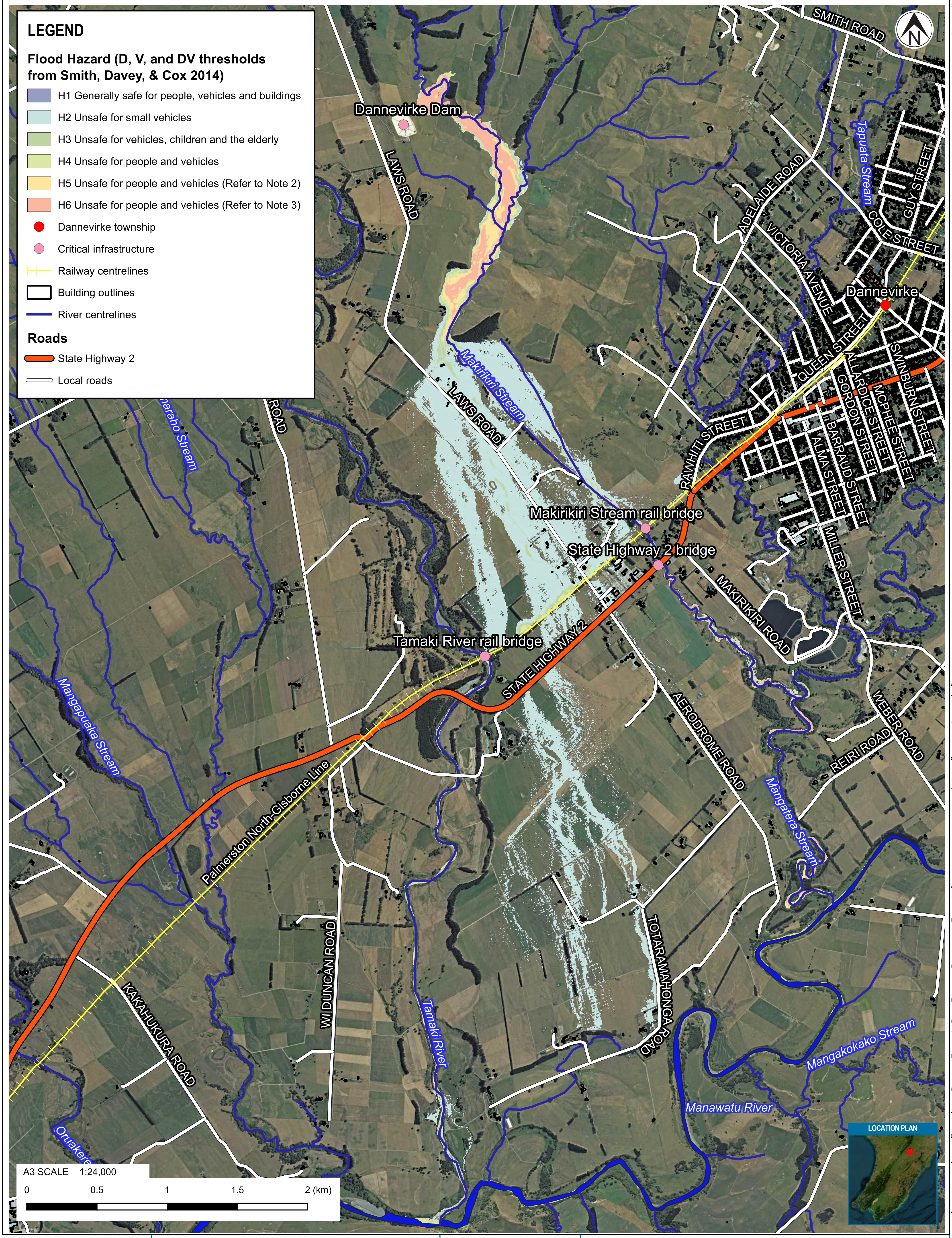
CHECKED	ACAM	JUN.23

CLIENT TARARUA DISTRICT COUNCIL

PROJECT DANNEVIRKE WATER SUPPLY DAM PIC

TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
EASTERN EMBANKMENT DAM BREAK VELOCITIES

SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.2 REV 1



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NOTES:
1. Aerial imagery, road centrelines and river centrelines from LINZ 2023
2. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
3. All buildings types considered vulnerable to failure

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PROJECT No. 1020688.2000

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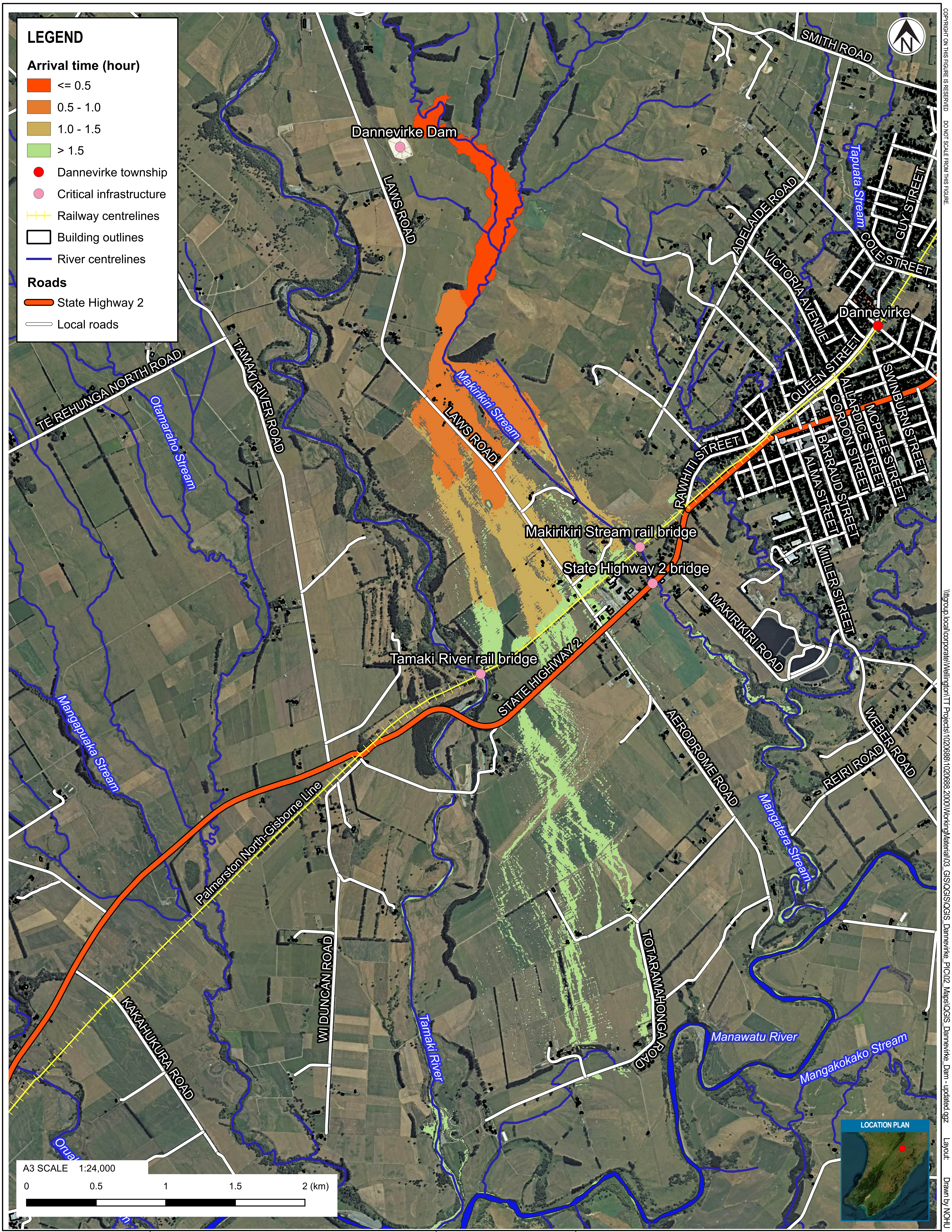
CLIENT **TARARUA DISTRICT COUNCIL**
PROJECT **DANNEVIRKE WATER SUPPLY DAM PIC**
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
EASTERN EMBANKMENT DAM BREAK FLOOD HAZARD
SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.3 REV 1

Drawn by NOHU



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NOTES:
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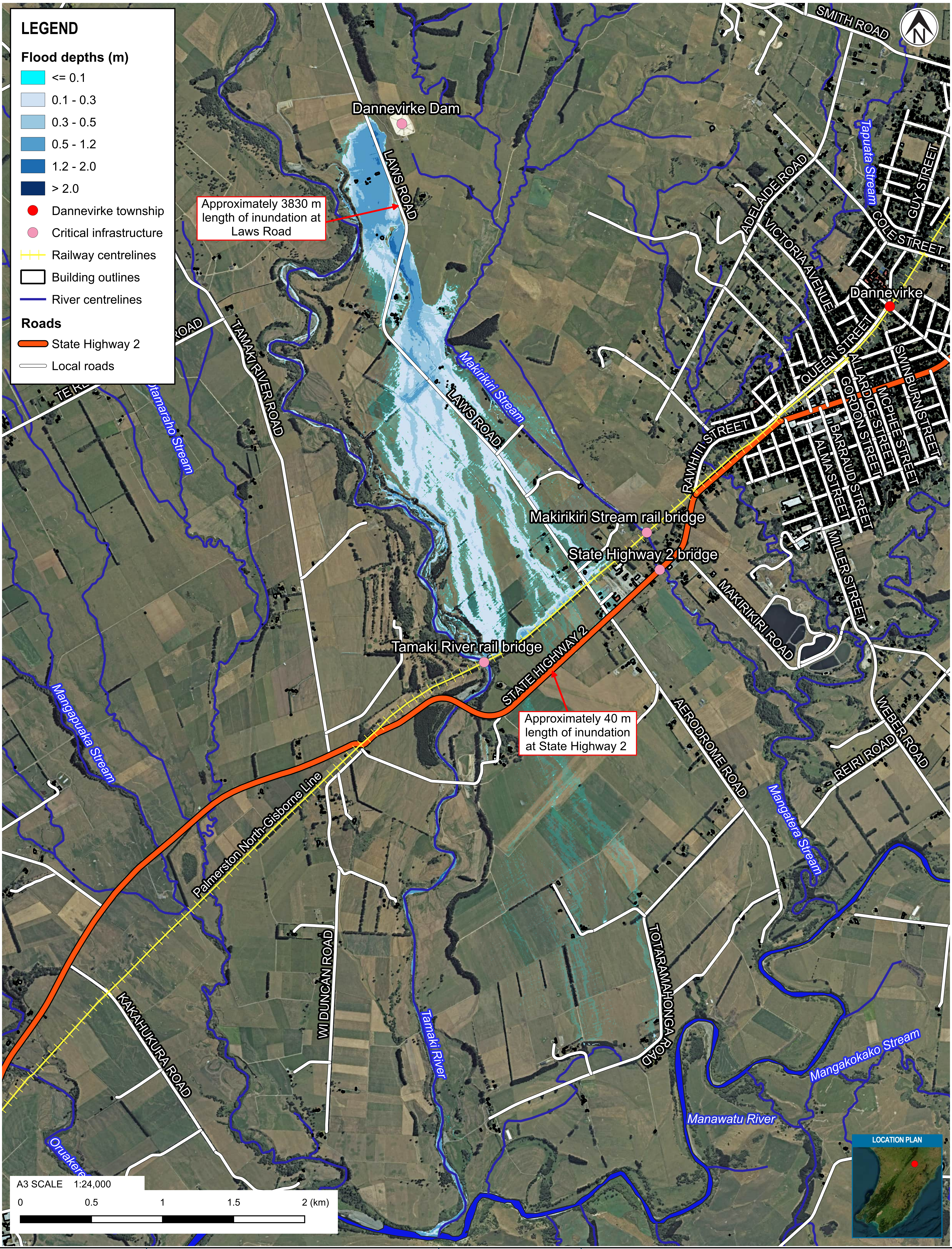
CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
EASTERN EMBANKMENT DAM BREAK ARRIVAL TIME

SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.4 REV 1

Layout: Drawn by NOHU



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NOTES:
Aerial imagery, road centrelines and river centrelines from LINZ 2023

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1	Second version	NOHU	DMK	29/07/24

PROJECT No. 1020688.2000

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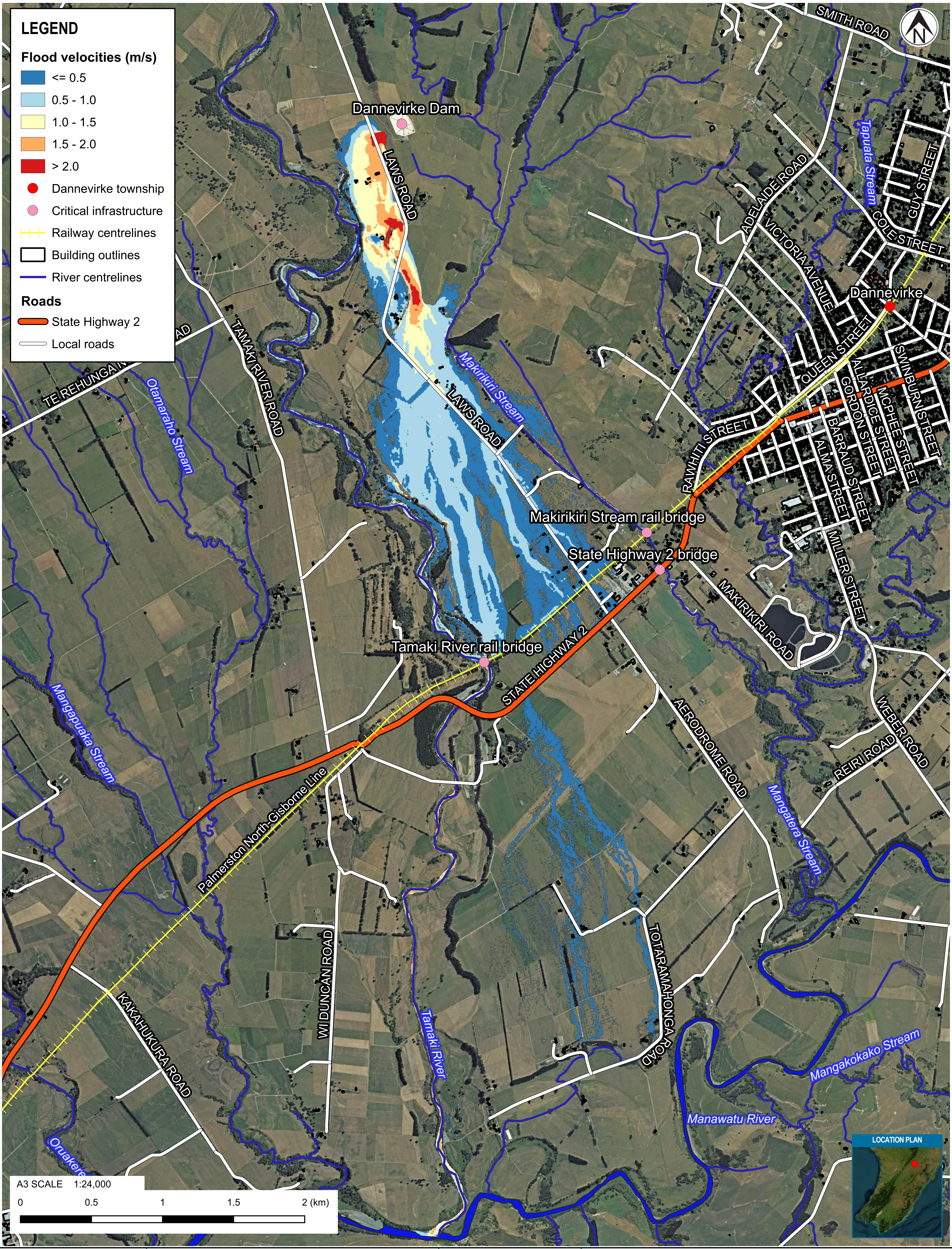
CHECKED	ACAM	JUN.23

APPROVED DATE

CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
WESTERN EMBANKMENT DAM BREAK FLOOD DEPTHS

SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.5 REV 1



DO NOT SCALE FROM THIS FIGURE

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NOTES:
Aerial imagery, road centrelines and river centrelines from LINZ 2023

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APPROVED DATE

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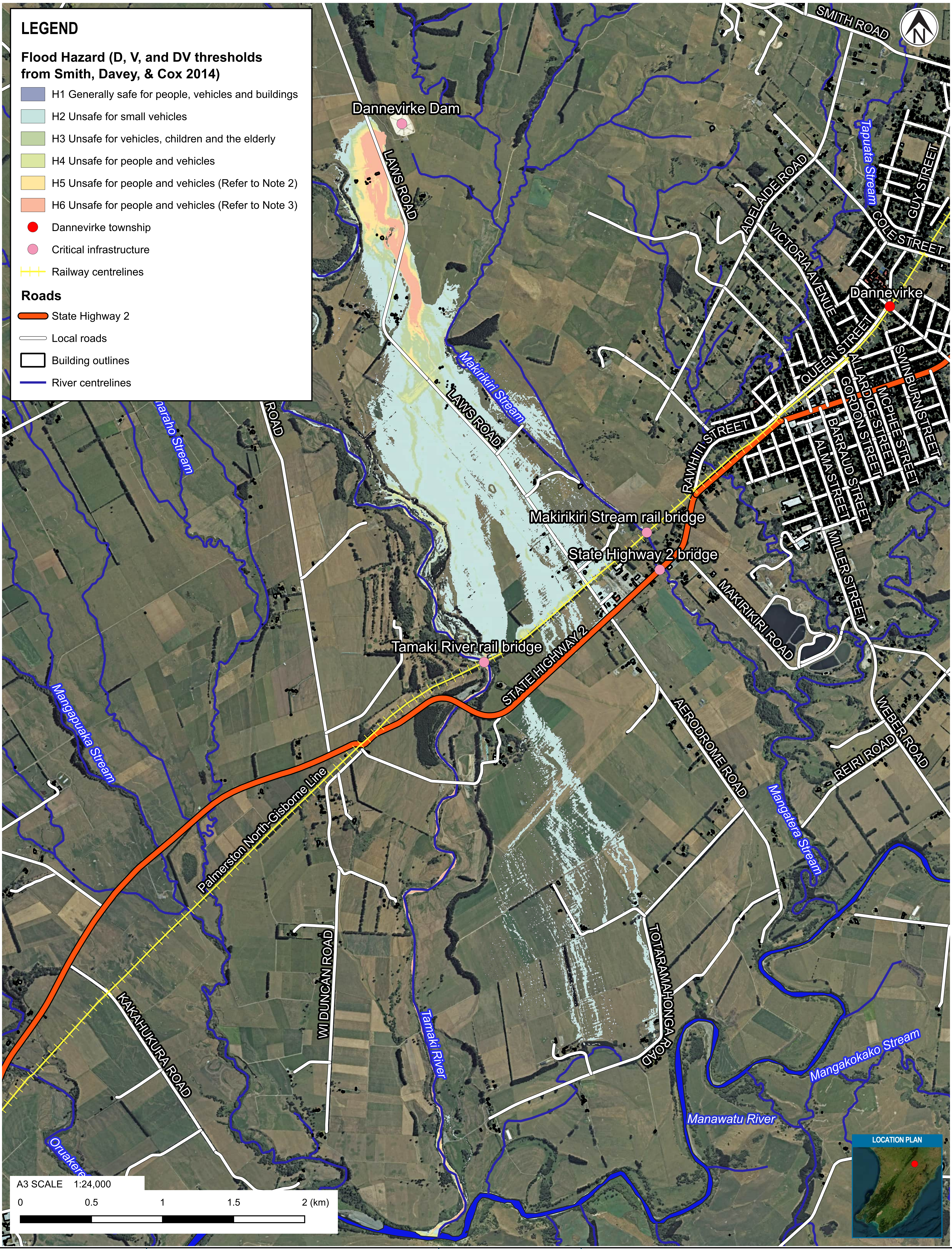
CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
WESTERN EMBANKMENT DAM BREAK VELOCITIES
SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.6 REV 1



DO NOT SCALE FROM THIS FIGURE

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NOTES:
1. Aerial imagery, road centrelines and river centrelines from LINZ 2023
2. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
3. All buildings types considered vulnerable to failure

REV	DESCRIPTION	GIS	CHK	DATE	APPROVED	DATE
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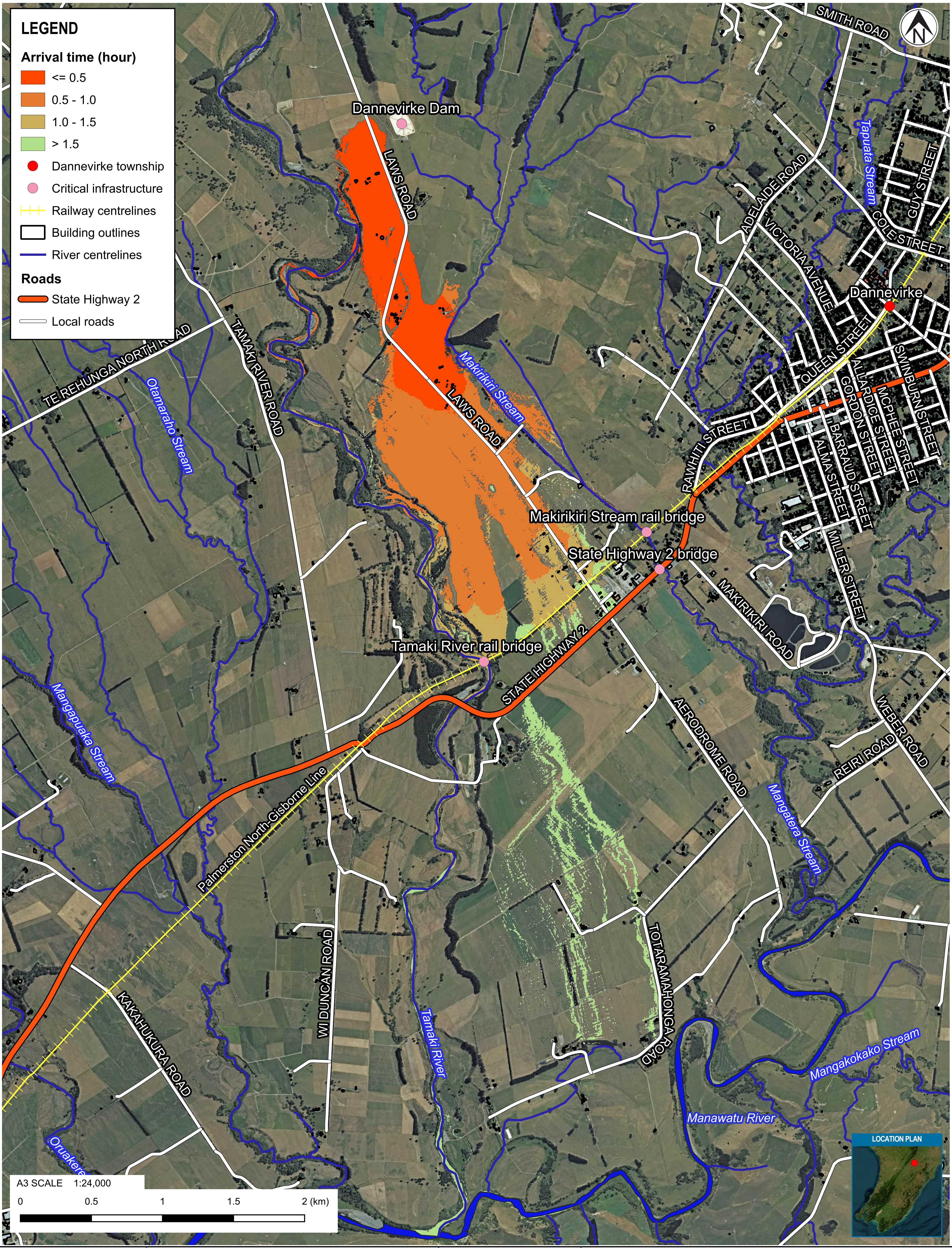
CHECKED	ACAM	JUN.23

CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
WESTERN EMBANKMENT DAM BREAK FLOOD HAZARD

SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX C.7 REV 1

Drawn by NOHU



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NOTES:
Aerial imagery, road centrelines and river centrelines from LINZ 2023

REV	DESCRIPTION	GIS	CHK	DATE	APPROVED	DATE
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1	Second version	NOHU	DMK	29/07/24		

PROJECT No.	1020688.2000	
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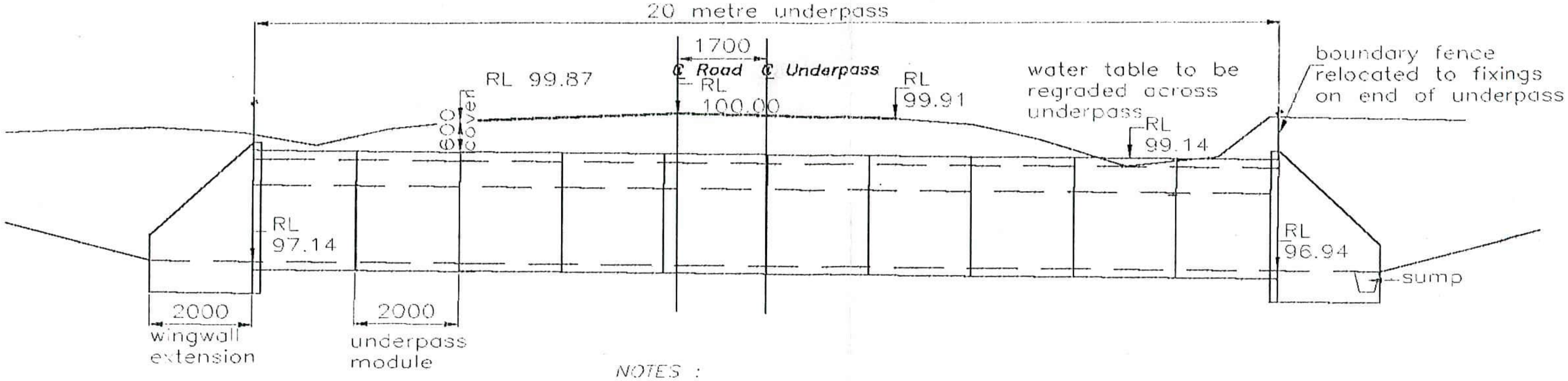
DRAWN	NOHU	JUN.23
CHECKED	ACAM	JUN.23

CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
WESTERN EMBANKMENT DAM BREAK ARRIVAL TIME
SCALE (A3) 1:24,000 **FIG No.** FIGURE APPENDIX C.8 **REV** 1

Appendix D SH2 stock underpass original construction drawing 1996

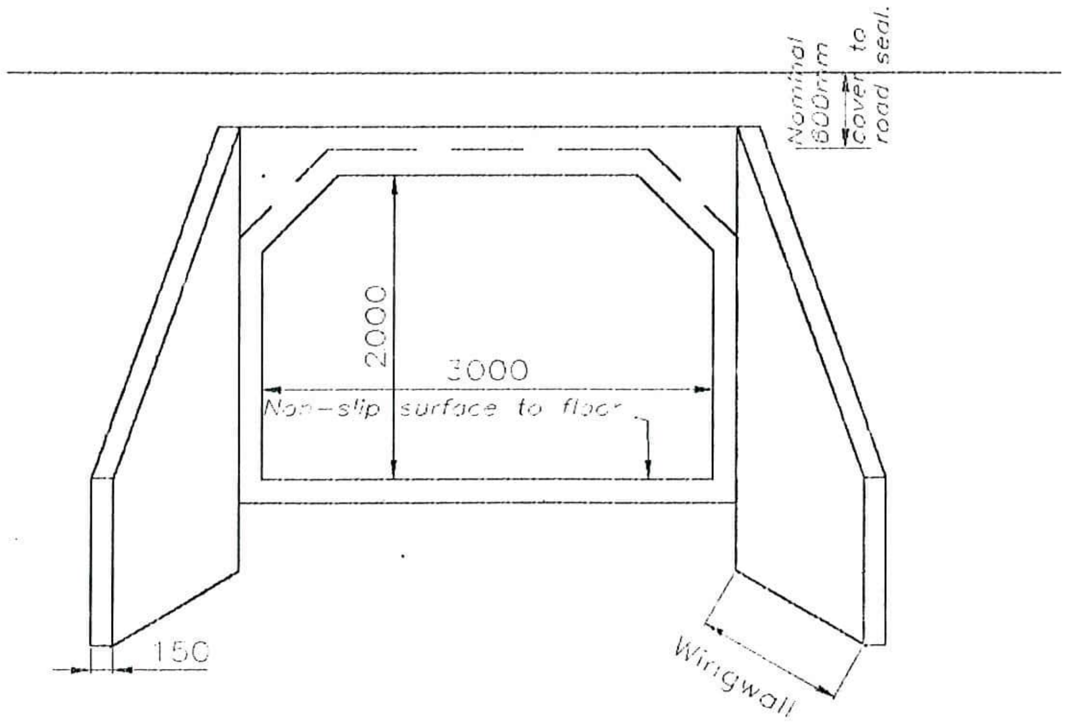


NOTES :

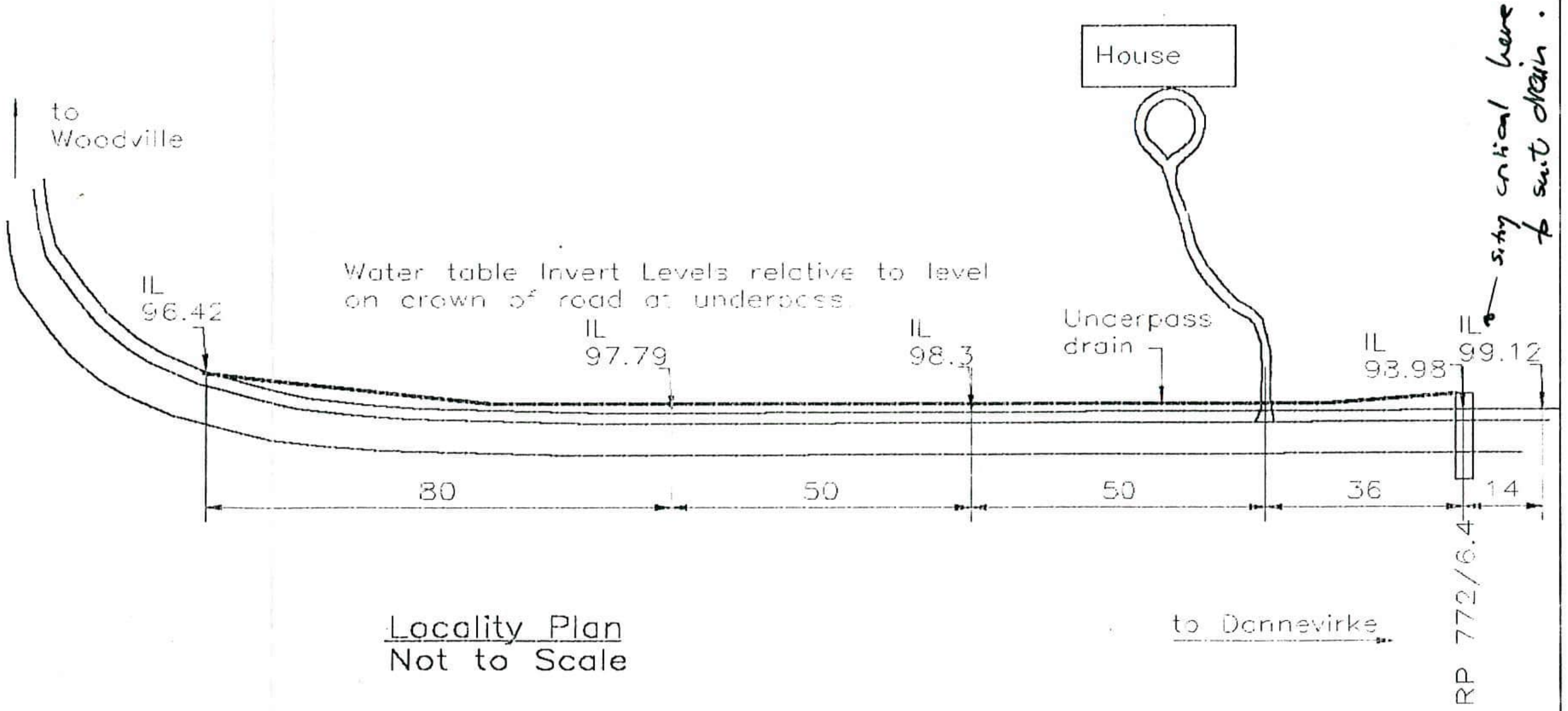
1. This drawing shall be read in conjunction with Bycroft Petherick Ltd drawings 3972 sheets W.1.B and W.3.B

Elevation
Scale 1:100

siting critical here to suit drain. 150 ø.



Typical Cross Section
Scale 1:50

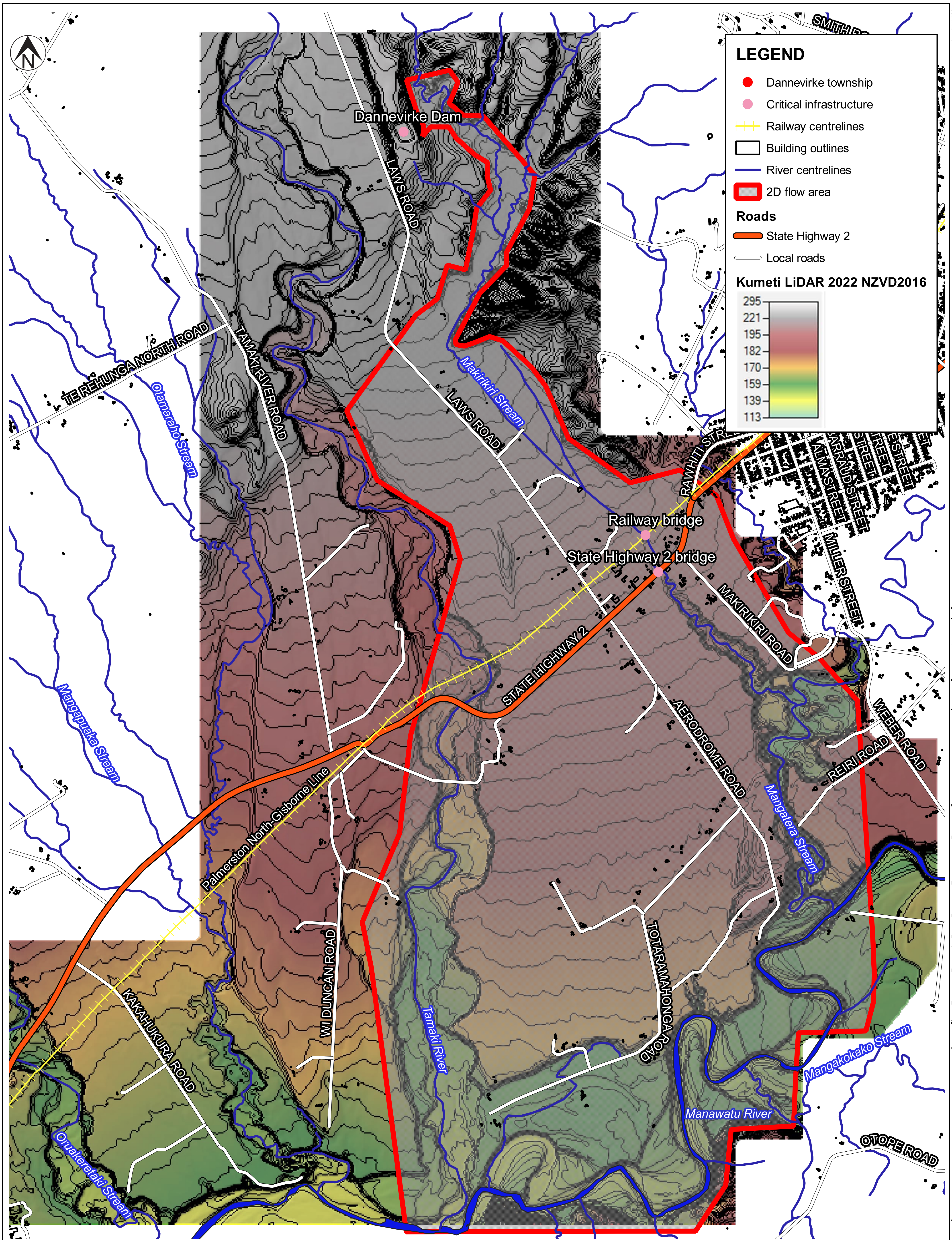


Locality Plan
Not to Scale

	Design Drawn R P Calder Date 24 September 1996 Scale As Shown	EMMETTS TECHNICAL SERVICES	Proposed Stock Underpass for P HARTRIDGE, Dannevirke SH 2, RP 772/6.4 approx. General Layout	Job No. 96/540 Drawing No.: WD 1

Appendix E HEC-RAS model geometry

- HEC-RAS model geometry for eastern embankment breach
- HEC-RAS model geometry for western embankment breach



Layout: Eastern Embankment Dam Break 2D Flow Area
Drawn by: NOHU

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NOTES:
Road centrelines and river centrelines from LINZ 2023

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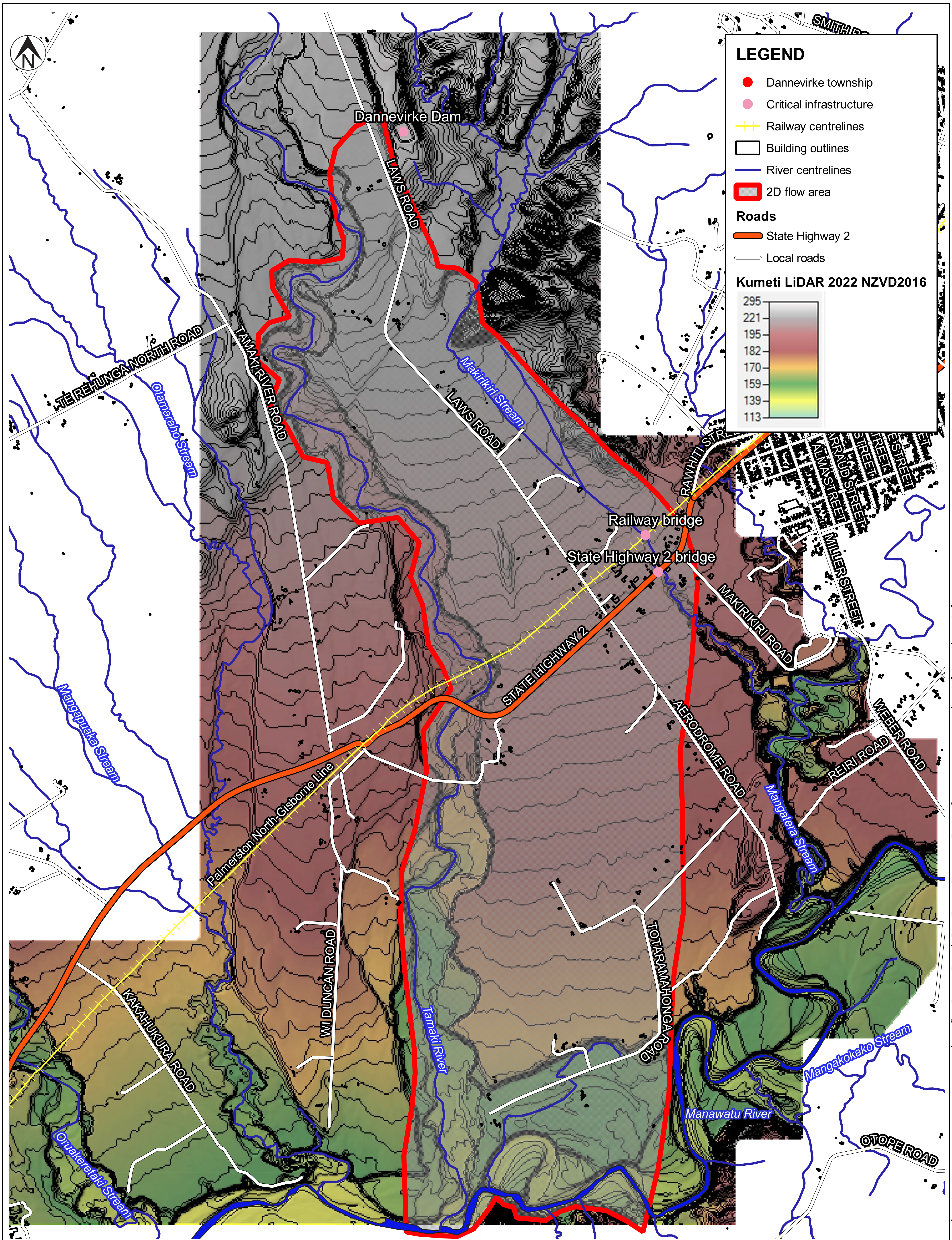
CHECKED	ACAM	JUN.23

CLIENT: TARARUA DISTRICT COUNCIL
PROJECT: DANNEVIRKE WATER SUPPLY DAM PIC
TITLE: COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION
EASTERN EMBANKMENT DAM BREAK 2D FLOW AREA
SCALE (A3): 1:24,000 FIG No. FIGURE APPENDIX F.1 REV 0



Layout: Western Embankment Dam Break 2D Flow Area

Drawn by NOHU

Tonkin+Taylor
www.tonkintaylor.co.nz
Exceptional thinking together

NOTES:
Road centrelines and river centrelines from LINZ 2023

REV	DESCRIPTION	GIS	CHK	DATE	APPROVED	DATE
0	First version	NOHU	ACAM	29/06/23		

PROJECT No.	1020688.2000	
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CHECKED	ACAM	JUN.23

CLIENT TARARUA DISTRICT COUNCIL
PROJECT DANNEVIRKE WATER SUPPLY DAM PIC
TITLE COMPREHENSIVE POTENTIAL IMPACT CLASSIFICATION WESTERN EMBANKMENT DAM BREAK 2D FLOW AREA
SCALE (A3) 1:24,000 FIG No. FIGURE APPENDIX F.2 REV 0

Appendix F RCEM Fatality rate

- Fatality Rate vs DV: Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning

Fatality Rate vs DV
Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning

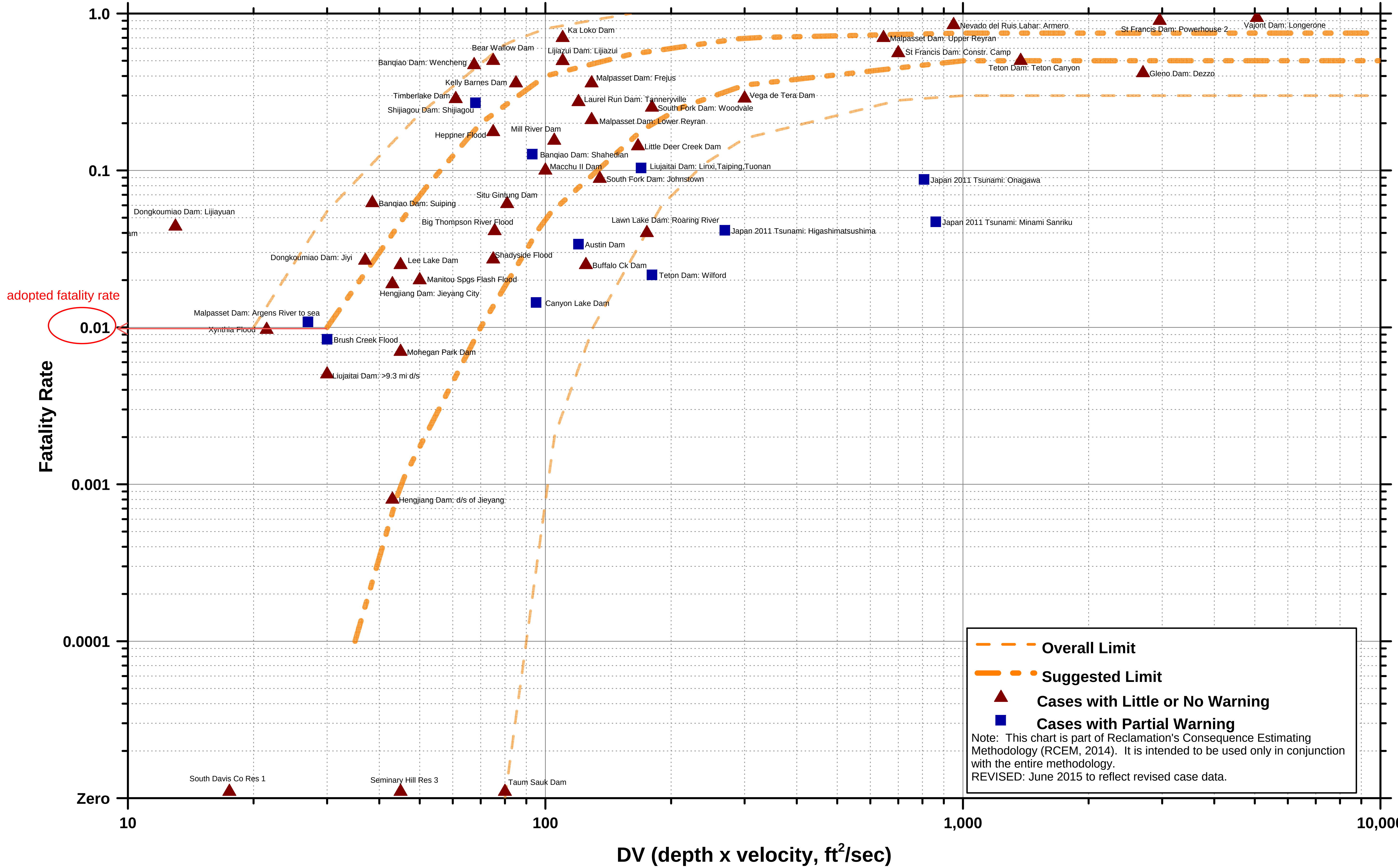

Figure 1 - Fatality Rate vs. DV - Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning

Appendix G Dam classification certificate

REGIONAL / UNITARY COUNCIL - DAM SAFETY SCHEME

FORM 1: DAM CLASSIFICATION CERTIFICATE

(Sections 135, 138 and 139, Building Act 2004)

Send or deliver your certificate to your relevant Regional Council.

Section 1: Dam

Dam name:	Dannevirke No 1 Water Supply Reservoir		
Location of dam:	Address: Laws Road, Dannevirke		
(NZTM)	Easting: 1860662.96	Northing: 5546396.43	
Additional Notes *(Refer guideline notes 3)*	The dam is 3.3 km north-west of the town centre		
Date of construction (year):	March 2011 - June 2013		
Building consent number or identification: *(if applicable)*	123041		
Purpose of dam:	○ Agricultural/Pastoral/Irrigation ○ Detention ○ Hydro-electrical Power ○ Tailings ◉ Water Supply ○ Recreation/Amenity ○ Treatment ○ Other____		
Type of dam:	◉ Earth ○ Concrete ○ Mixed ○ Rockfill ○ Unknown ○ Other____		
Height of dam (in metres): **Regulation 6 applies for the purpose of measuring a dam's height.*	20.7 m	**Dam's stored volume (in cubic metres):** *Regulation 7 applies for the purpose of measuring a dam's stored volume. (Refer Guidance notes 9)*	160,000 m3
Relevant regional authority: *(Refer Guidance notes 8)*	Horizons Regional Council		

Section 2: Potential impact classification

Potential Impact Classification
(determined under section 134B of the Building Act 2004 and regulation 9 of the Building (Dam Safety) Regulations.)

○ High ◉ Medium ○ Low

Section 3: Owner (Dam Owner) (refer guidance note 4)

Name of owner:	Tararua District Council
Chief executive of owner or equivalent (if owner is a body corporate) **if there is no chief executive, specify a person with an equivalent position in the body corporate.*	
Bryan Nicholson	

#7519-03/24

Business Address:	26 Gordon Street	
	Dannevirke	Postcode: 4942
Postal address: *(if different from business address).*	PO Box 115	
	Dannevirke	Postcode: 4942
Phone number/s	Mobile:	Business: 06 374 4080
Email address	info@tararuadc.govt.nz	

Billing Details
(Please specify the billing details for this certificate)

Full name:		
Mailing address:		
		Postcode:
Phone number/s	Mobile:	Business:
Email address:		
Preferred method of correspondence:	◯ Email	◯ Post
Purchase Order number: *(if required)*		

Section 4: Owner (Land Owner) (refer guidance note 4) (Required if different from Dam Owner)

Name of owner:		
Business Address:		
		Postcode:
Postal address: *(if different from business address).*		
		Postcode:
Phone number/s:	Mobile:	Business:
Email address:		

Section 5: Certificate of recognised engineer

I certify that the classification of the above dam as a ◯ High ◉ Medium ◯ Low potential impact dam accords with the criteria and standards for dam safety prescribed under regulation 9 of the Building (Dam Safety) Regulations 2022.

I am a recognised engineer in accordance with section 149 of the Building Act 2004 because I:

☑ meet the requirements of section 149(1)(a) and (b) of that Act; and

☑ have the qualification and competency prescribed under regulation 22 of the Building (Dam Safety) Regulations 2022.

☑ I have attached evidence that I am a recognised engineer in the Attachment section below.

☑ The dam owner has been advised they are responsible for all payments to council associated with this Dam Classification Certificate.

Signature of recognised engineer: [signature] Date 06/08/2024

Full name of recognised engineer: Dominic Alexander Fletcher

Chartered professional engineer registration number: 1017384

#7519-03/24

Section 6: Attachments

Attachments:

- [x] PIC Assessment Report documentation
- [x] Evidence of recognised engineer documentation
- [ ] Letter of authority from owner (for applicant/agent if applicable)

Guideline notes

1. Council request the completion of some additional fields beyond the mandatory requirements of Form 1 of Schedule 3 of the Building (Dam Safety) Regulations 2022. This data will be used to update Council's Dam Register and enable a better understanding of the region's dam portfolio.
2. Fees and Charges   Please refer to your relevant regional authority, as these costs / deposits may vary between councils.
3. Note: please provide any additional information regarding the dam, reservoir and/or owner details. E.g. list multiple owners if the dam straddles the boundaries of more than one property, or there are multiple dams on a single reservoir.
4. For the purpose of the Building Act and regulations, the 'dam owner' is the person who legally owns the physical dam itself. Typically, the landowner will also be the dam owner, however this will not always be the case as there are a variety of different scenarios when it comes to dam ownership. If the owner of the dam is not the same person as the owner of the land the dam is located on, there will likely be a record of this. Generally, where multiple people own the dam, they will collectively be the 'dam owner'. In most cases, it should be apparent who the owner/s of a dam is.
5. Multiple dams on a single reservoir - All classifiable dams on a single reservoir must have there own dam classification certificate.
6. s134BA - Classification of dams that are canals - A dam that is a canal that must be classified under section 134B may have different classifications for different sections of the canal and in that case each of those sections must be treated as a separate dam for the purposes of sections 134 to 139.
7. s135 - Owner must provide clarification to regional authority . [para] If already commissioned, provide within 3 months after commencement of regulations or 3 months after the dam is commissioned.
8. Regional Authority *(For Marlborough District Council, refer to their website)*

Auckland Council	Hawkes Bay Regional Council	Southland Regional Council
Bay of Plenty Regional Council	Horizons Regional Council	Taranaki Regional Council
Canterbury Reginal Council	Nelson City Council	Tasman District Council
Gisborne District Council	Northland Regional Council	Waikato Regional Council
Greater Wellington Regional Council	Otago Regional Council	West Coast Regional Council

9. Dam Stored Volume
   Clarification to DSS Regulation 7, The Building Act, sec 7 "Crest" definition includes "For the avoidance of doubt, any freeboard is part of the water retaining structure. i.e. included in Dam Stored Volume"
   This differs from: "Reservoir Capacity" i. e. The Typical volume of fluid stored up to the freeboard / spillway level and includes any fluid stored below the ground level of the dam.

Registration no:
1017384
Valid to: 31 December 2024

REGISTRATION AUTHORITY
FOR CHARTERED PROFESSIONAL ENGINEERS

Dominic Alexander Fletcher

is registered as a

Recognised Engineer
Potential Impact Classification

Veronica Dessein
Registrar

ISSUED UNDER SECTION 9 OF THE CHARTERED PROFESSIONAL ENGINEERS OF NEW ZEALAND ACT 2002
REGISTRATION AUTHORITY

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