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Lindsay Creek Flood Hazard Study



Otago
Regional
Council

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SECTION 1.0 - INTRODUCTION

1.1 Purpose

This flood study provides a comprehensive revision and update of existing information regarding the presence, extent, and severity of flood hazards within the Lindsay Creek catchment. The analyses and assessments presented in this report were developed to improve the understanding of potential flood risks and to provide updated flood hazard data that can support the Otago Regional Council (ORC) and communities in making informed decisions and implementing effective floodplain management practices. The information contained within this study is intended to assist with planning, risk awareness, and the development of strategies that promote responsible management of flood-prone areas.

1.2 Location of Study

This study is located in the Lindsay Creek catchment within Dunedin City. Areas included in this study include a portion North East Valley. Specifically, the focus of this study is fluvial flooding along Lindsay Creek which generally flows from northeast to southwest through North East Valley along North Road. The general project location is shown in Figure 1.1, and a detailed location map is shown in Figure 1.2.



Figure 1.1: General Location Map

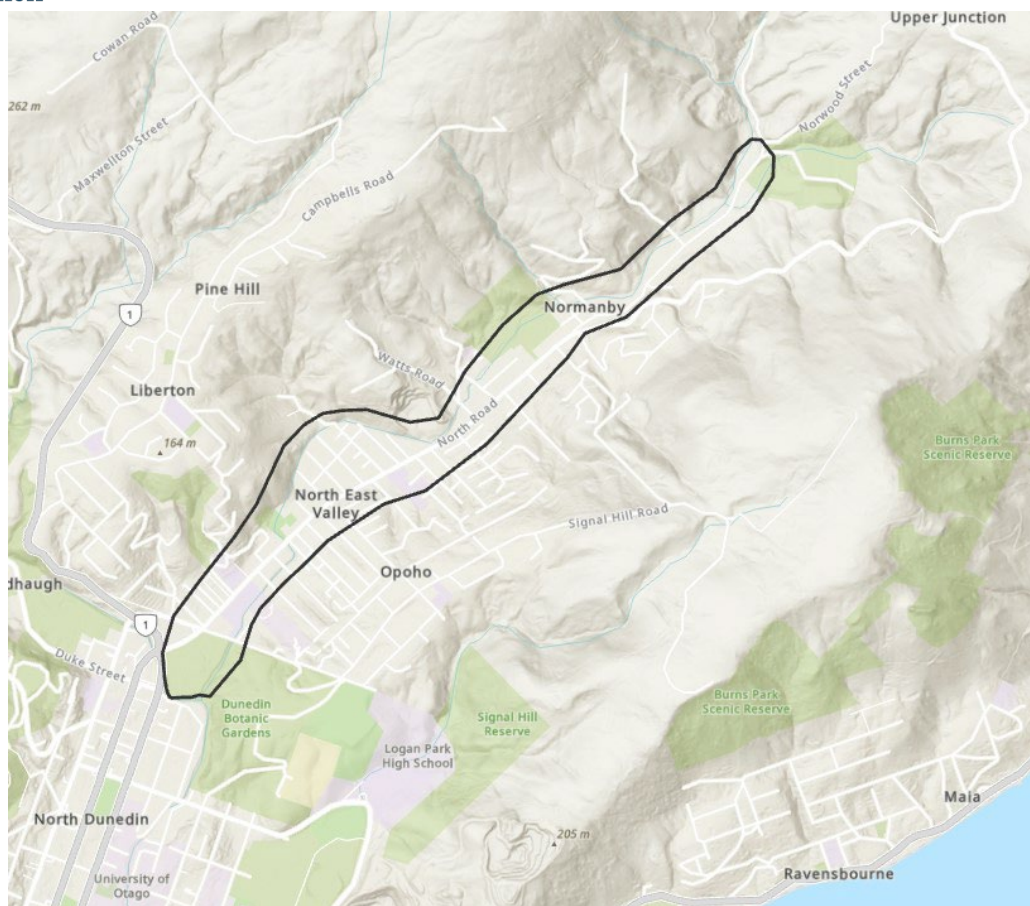


Figure 1.2: Detailed Location Map – Study area

1.3 Previous Studies

There have been several prior studies of flood hazards related to the Lindsay Creek catchment area. The following is a summary of some of the prior works and known or assessed limitations.

1. Water of Leith and Lindsay's Creek (MacLean, Wilkie, & Alexander, 1931)

This study was one of the earlier studies for the area that attempted to quantify flood discharges and suggest potential flood protection measures.

2. Lindsay Creek Flood Hazard Report (ORC, 2001)

The study included a flood frequency analysis and established baseline hydrologic information. The study also established design discharge values that were intended to inform the assessment of a proposed flood control scheme. There was no hydraulic modelling and mapping was limited to prior observation from flood events.

3. Lindsay Creek from Potters Road to the Water of Leith Confluence Hydraulic Modelling Report (OPUS, 2004)

The primary purpose of this report was to assess existing channel capacity against established design discharges and to assess potential hazard mitigation alternatives. This study developed a limited 1-Dimensional hydraulic model using MIKE 11 software. Flood and hazard mapping was coarse as there was limited topographic data available at the time. This report was used to develop a preliminary flood control scheme for the area; however, the scheme was never constructed.

4. Flood Hazard of Dunedin's Urban Streams (ORC, 2014)

This study examined flooding hazards throughout the Dunedin area and Lindsay Creek was one of several streams examined. The study was completed to support the review of Dunedin City District plan. It did not include hydraulic modelling and floodplain mapping was completed using a geomorphological approach. The approach and results were similar to the 2001 study.

5. North East Valley Catchment Rapid Flood Hazard Assessment (Stantec, 2022)

This study is the most current study known. The study used modern Infoworks ICM software and included 2-Dimensional hydraulic modelling. Mapping was completed using Lidar topographic data. This study was done as part of a rapid flood hazard assessment for Dunedin District Council (DCC) and contains several known limitations. Specifically, there was little processing of surface data to include various hydraulic controls and accurate representation of stream geometry (which Lidar did not capture due to heavy tree cover). The model was not calibrated, and the hydrology used a fluvial based rain-on-grid approach. The results were mapped in detail, but the underlying data is subject to a variety of limitations and is overly conservative as the intent was not a detailed analysis.

1.4 Considerations for Using this Report

This report has been prepared to provide an assessment of flood hazards within the project area based on the best available information, accepted engineering practice, and hydraulic modelling undertaken at the time of the study. While every effort has been made to produce representative flood extents, depths, and hazard information, all flood modelling is subject to uncertainty arising from assumptions relating to rainfall, hydrology, hydraulic model parameters, topographic data, channel conditions and future catchment changes.

At present, New Zealand does not have nationally adopted standards or guidance defining the preparation, presentation, or interpretation of flood hazard mapping. Consequently, approaches to flood modelling, hazard classification and map presentation vary between councils and practitioners. The flood hazard maps presented in this report should therefore be regarded as planning and risk management information intended to support land use planning, infrastructure management, and emergency preparedness. They are not intended to define legal flood boundaries or to be used as the sole basis for insurance underwriting, property valuation, or other property specific information, financial or legal decisions.

The hydraulic model has been developed to represent fluvial flooding associated with Lindsay Creek and does not include a detailed capacity assessment of the existing stormwater drainage

network. While the influence of the stormwater system is represented where appropriate (spatially varied discharge added), localised flooding associated with drainage blockages, pipe capacity limitations, asset condition or operational issues may not be fully reflected in the modelled results.

Flood hazard maps represent a snapshot of current catchment conditions and should be interpreted in conjunction with the accompanying technical information and an understanding of the underlying modelling assumptions. In the absence of nationally consistent standards or a formal public accreditation or review process for flood mapping in New Zealand, users should recognise that future studies, updated datasets or revised modelling approaches may result in changes to assessed flood extents or hazard classifications. This report should therefore be considered as one component of a broader flood risk assessment framework rather than a definitive statement of flood risk for any individual property.

SECTION 2.0 – AREA STUDIED

2.1 Catchment Description

Lindsay Creek drains an approximately 12.5 km² catchment on the southern slopes of Mount Cargill before joining the Water of Leith near the Dunedin Botanic Garden. The main channel is around 7 km long and flows through North East Valley, receiving runoff from a number of short, steep tributary catchments.

The upper catchment comprises steep, predominantly vegetated terrain that responds rapidly to intense rainfall, producing high velocity flows capable of transporting sediment and woody debris. As the creek enters the lower catchment, channel gradients reduce, and the surrounding land becomes increasingly urbanised. Residential development is concentrated across the valley floor and eastern slopes, while the western slopes remain largely covered by bush and farmland.

The combination of steep headwaters and urban development produces a flashy hydrological response, with flood flows reaching the developed areas of North East Valley within a relatively short period following heavy rainfall. Flooding is influenced by both the capacity of the Lindsay Creek channel and the performance of the stormwater network, with elevated creek levels limiting stormwater discharge during larger events. Flood risk is further affected by the potential for channel erosion, debris accumulation, and localised instability of the adjacent hillslopes.

Table 2.1 contains a description of the characteristics of the catchment that drains to and contributes to flooding within the study area.

Table 2.1: Catchment Characteristics

Catchment Name	Description	Approximate Catchment Area (ha)
Lindsay Creek	~7km long creek draining steep undeveloped land into an urban setting	1,200

2.2 Sources of Flooding

Lindsay Creek – Fluvial

Fluvial flooding within the Lindsay Creek catchment is primarily driven by the combination of a steep, rapidly responding upper catchment and extensive urban development across the lower valley. Intense rainfall generates high runoff rates that are conveyed quickly to the floodplain and North East Valley, resulting in short flood warning times and rapid rises in water level. Where the capacity of the creek channel is exceeded, overbank flows inundate adjacent residential, commercial and community land.

Flood hazard may also be exacerbated by sediment transport, debris accumulation and bank erosion, which can reduce channel conveyance or obstruct structures such as bridges and culverts. In addition, the presence of unstable hillslopes adjacent to parts of the channel creates the potential

for landslides or debris to partially obstruct the waterway during extreme events, increasing the extent and depth of flooding upstream.

2.3 Historical Flood Events

Historic flood events that resulted in damages were reported in 1868, 1877, 1882, 1883, 1923, 1929, 1936, 1938, 1944, 1945, 1946, 1968, 1971, and 1991. (ORC, 2001). Flow gage data is available beginning in 1979 at the North Road Bridge. Prior to 1979 the primary flood discharge estimate was from the 1929 flood event. (MacLean, Wilkie, & Alexander, 1931). The 1929 estimate appears to be an outlier and has been excluded from recent frequency analysis. Table 2.2 provides a summary of historic peak discharges. It should be noted that the 2006 and 2016 flood events did not result in significant reported damages.

Table 2.2: Historic Peak Discharges

Year	Discharge (m ³ /s)	Source of Data
1929	69.0	Historic Estimate
1991	32.3	Gage EM136
2006	29.9	Gage EM136
2015	29.9	Gage EM136

2.4 Flood Hazard Reduction Measures

Flood protection works along Lindsay Creek and within North East Valley have historically been undertaken in response to individual flood events rather than as part of a single, coordinated flood protection scheme. Consequently, there are a variety of existing channel modifications that vary in age and purpose with continuous engineered channelisation largely confined to the lower reaches downstream of North Road.

Major channel modifications followed the 1929 flood and included realignment, channel enlargement and construction of reinforced concrete retaining walls between Chambers Street and the Water of Leith. During the 1960's the concrete channel was extended approximately 125m upstream to North Road, together with associated bridge works, while further lining was installed following the 1968 flood to address erosion at the North Road bridge approaches. Additional flood wall construction was completed between Allen Street and Selwyn Street during the mid-1970s as the first stage of a wider channel upgrade programme. Although further widening and walling upstream had been proposed, the remaining stages were never implemented. Since that time, works have generally been limited to localised erosion repairs, debris collection, bank protection and maintenance of existing assets.

A comprehensive assessment of flood mitigation options was subsequently undertaken by the Otago Regional Council during 2010–2013. This work developed both a full flood protection scheme and a reduced-scope alternative for Lindsay Creek. Neither option was progressed beyond the investigation stage, with Council determining that the anticipated costs, prevailing economic conditions and community feedback did not justify implementation at that time. More recently, ORC has committed to revisiting flood risk management for Lindsay Creek through updated hazard investigations and consideration of future mitigation options. (Payan & Van Woerden, 2024)

SECTION 3.0 – ENGINEERING METHODS

3.1 General

Flood hazard assessments for the Lindsay Creek catchment were undertaken using established hydrological and hydraulic modelling techniques consistent with current engineering practice in New Zealand. The study estimates the extent, depth, velocity and hazard of flooding for a range of design rainfall events representing different probabilities of occurrence. Unless otherwise stated, flood events are described using their Annual Exceedance Probability (AEP), which represents the probability of a flood of a given magnitude being equalled or exceeded in any one year. For reference, a 10% AEP event has a one-in-ten chance of occurring in any given year, while a 1% AEP event has a one-in-one-hundred chance of occurring in any given year.

Although AEP provides a measure of the likelihood of flooding in any individual year, it does not imply that flood events occur at regular intervals. Floods of a similar or greater magnitude may occur in consecutive years, or even more than once within a single year, while extended periods may pass without an event of the same size. The probability of experiencing a particular flood increases over longer timeframes. For example, a property has approximately a 26% chance of experiencing at least one 1% AEP flood over a 30-year period.

The results presented in this report represent the predicted flood behaviour based on the available topographic, hydrological and hydraulic information, and the catchment conditions that existed at the time the study was undertaken. Flood hazard mapping should therefore be regarded as a representation of current conditions rather than a permanent depiction of flood risk. Future changes to land use, development, stormwater infrastructure, channel conditions, climate, or the availability of improved datasets may influence flood behaviour and may warrant revision of the mapping and associated hazard information.

3.2 Hydrologic Analysis

The hydrological inputs to the hydraulic model were based on the results of a recent flood frequency analysis undertaken for ORC Gage EM136 which is located near the North Road bridge at the downstream end of the study area. The flood frequency analysis provides estimates of peak flows for the selected annual exceedance probability (AEP) events and forms the hydrological basis for the flood hazard assessment. Table 3.1 shows the results from the FFA for gage EM136.

Table 3.1: Flood Frequency Analysis Gage EM136

AEP	Expected Probable Flow (m ³ /s)	Upper 90% Confidence Limit (m ³ /s)
0.2%	47.6	62.3
0.5%	42.8	55.6
1%	39.0	50.3
2%	35.0	44.7
5%	29.4	36.9
10%	24.9	30.7
20%	20.0	24.1
50%	12.4	14.5

3.3 Climate Change

As presented in section 3.2, design flood discharges adopted for the hydraulic modelling were obtained from a recent flood frequency analysis. The flood frequency analysis provides estimates of peak discharges for the required design annual exceedance probabilities under historical climate conditions. With this approach here is no underlying rainfall-runoff model used to derive these flows. Consequently, it was not possible to directly apply projected future rainfall changes to a hydrological model to derive climate-adjusted design discharges.

The Ministry for the Environment (MfE) guidance document *Tools for Estimating the Effects of Climate Change on Flood Flow: A Guidance Manual for Local Government in New Zealand* (MfE, 2010) recommends that, where practicable, the effects of climate change on flood flows should be assessed by applying projected changes in extreme rainfall to a rainfall-runoff model and deriving future flood flows through hydrological simulation. This approach accounts for catchment-specific factors influencing the conversion of rainfall to runoff, including catchment size, slope, soils, storage characteristics, and antecedent conditions.

In the absence of an available rainfall-runoff model, a sensitivity-based approach has been adopted to represent the potential effects of climate change on design flood flows. A 20% increase has been applied to the peak design discharges used as inflows to the HEC-RAS hydraulic model. This adjustment is intended to represent a plausible increase in flood magnitude associated with projected increases in extreme rainfall intensity and is applied as a sensitivity allowance rather than as a definitive prediction of future flood behaviour. The adopted 20% increase is considered appropriate for the study catchments given its rainfall-driven flood response characteristics. Previous assessments undertaken using hydrological modelling have demonstrated that increases in peak flood discharge can be of a similar magnitude to, or greater than, increases in extreme rainfall, due to nonlinear catchment responses during high-intensity rainfall events (MfE, 2010). The selected allowance is therefore considered a reasonable representation of potential future flood sensitivity in the absence of catchment-specific climate-adjusted hydrological modelling.

The resulting climate-adjusted peak discharges have been used as inputs to the HEC-RAS model to assess the potential effects of increased flood magnitude on flood levels and extents. The uncertainty associated with this simplified approach should be recognised, and the results should be interpreted as representing a sensitivity scenario rather than a precise estimate of future flood flows.

3.4 Model Discharges

For hydraulic modelling, the design peak discharges presented in Table 3.1 were assigned at appropriate locations along the modelled reach to reflect changes in contributing catchment area. As the contributing catchment area decreases upstream, the corresponding design discharges were reduced accordingly. Table 3.2 provides a summary of discharges used in the model for various AEPs.

Table 3.2: Model Discharges

Station/Location	AEP					
	0.2%	1%	2%	5%	10%	20%
5024 / 600m Upstream of Cluny St. & Norwood St. Intersection	23.0	18.8	16.9	14.2	12.0	9.7
4040 / 400m Downstream of Cluny St. & Norwood St. Intersection	11.8	9.7	8.7	7.3	6.2	5.0
3044 / End of Tannandice Street	12.8	10.5	9.4	7.9	6.7	5.4

3.5 Hydraulic Structures

The hydraulic model incorporates the principal in-channel structures that influence flood conveyance along Lindsay Creek, including a total of 12 roadway and pedestrian bridges. These structures were explicitly represented within the hydraulic model to account for their effects on flow contraction and potential overbank flooding during design flood events.

Bridge geometry was developed primarily from available as-built drawings, supplemented by site inspections and topographic survey data where required to confirm dimensions and levels. The inclusion of these structures ensures that the hydraulic model appropriately represents the influence of bridge openings, deck levels and abutments on flood behaviour throughout the study reach.

3.6 Hydraulic Analysis

Hydraulic modelling was undertaken using HEC-RAS Version 6.7, employing a coupled one-dimensional/two-dimensional (1D/2D) unsteady flow model to simulate flood behaviour within the study area. The main creek channel and hydraulic structures were represented using a one-dimensional (1D) model, while floodplain inundation and overland flow paths were simulated using a two-dimensional (2D) computational mesh.

The model terrain was developed from multiple elevation datasets. Ground elevations were based on the 2021 Otago Coastal Catchments LiDAR survey, while the creek channel geometry was refined using cross-sectional bathymetric survey data collected in 2024.

Hydraulic resistance was represented using spatially variable Manning's roughness coefficients. Floodplain roughness values were assigned using a raster dataset derived from the 2018 New Zealand Land Cover Database (LCDB), with each land cover class assigned an appropriate Manning's *n* value. Initial roughness values were subsequently refined during model calibration to achieve an appropriate match with the observed flood levels from the 2016 flood event. A summary of the adopted Manning's *n* values is provided in Table 3.3.

Table 3.3: Roughness Coefficients

Land Cover	Manning's "n"
Built Up Area	0.08
Urban Parkland Open Space	0.03
Exotic Forest	0.08
Gorse/Broom	0.035
High Producing Exotic Grassland	0.035
Indigenous Forest	0.08

3.7 Model Calibration & Validation

The hydraulic model was calibrated against the 2015 flood event using surveyed post-flood debris marks collected throughout the Lindsay Creek catchment. Debris marks provide an indication of the peak flood level and were used as the primary dataset for assessing model performance.

Calibration involved comparing the modelled peak flood elevation with the surveyed debris mark elevations and refining key model parameters, including channel and floodplain roughness, to achieve an appropriate level of agreement while maintaining physically realistic hydraulic behaviour. Consideration was also given to the representation of hydraulic structures, channel geometry and overland flow paths to ensure the model adequately reflected observed flood behaviour.

Overall, the calibrated model demonstrated good agreement with the surveyed flood levels and reproduced the general pattern and extent of flooding observed during the 2015 event. Minor differences between modelled and observed flood levels are expected and reflect the inherent uncertainties associated with flood modelling, including the accuracy of surveyed debris marks, estimation of the flood inflow hydrograph, topographic data, and assumptions regarding channel and floodplain conditions at the time of the event. Appendix A provides a summary of the model calibration comparing surveyed debris marks to the calibrated water surface elevation.

3.8 Summary of Hydrologic and Hydraulic Analyses

Table 3.4 provides a Summary of Hydrologic and Hydraulic Analysis.

Table 3.4: Summary of Hydrologic and Hydraulic Analysis

Flooding Source	Lindsay Creek - Fluvial
Catchment Area	1,200 Ha
Study Limits	600m Upstream of Cluny St. & Norwood St. Intersection to the Confluence with the Water of the Leith
Hydrologic Methods	Flood Frequency Analysis Gage EM136
Hydraulic Model	HEC-RAS 6.7 (1D/2D Combined)
Outputs	Inundation and Hazard Maps for the 1%, and 0.2% AEPs
Special Consideration	The influence of local stormwater systems are represented where appropriate (spatially varied discharge added) but the study did not consider details on pluvial flooding and adjacent storm sewer network

Table B1 in Appendix B provides a summary of the modelled scenarios.

SECTION 4.0 – MAPPING

4.1 Vertical and Horizontal Control

Flood hazard mapping was completed using the model outputs within the HEC-RAS software. The reference horizontal and vertical datums are NZTM 2000 and NZVD 2016 respectively.

4.2 Terrain and Survey Data

For mapping purposes, the terrain data was developed from the 2021 Otago Coastal Catchments LiDAR survey. The lidar has a vertical accuracy specification of ± 0.2 m (95%) and a horizontal accuracy specification of ± 1.0 m (95%).

4.3 Floodplain Inundation Mapping

Floodplain boundaries were mapped by overlaying the modelled maximum water surface elevations over the terrain data. The model incorporated the available topographic and hydraulic information to simulate the distribution of floodwaters across the floodplain and identify areas susceptible to inundation for the various hydrologic scenarios.

4.4 Flood Hazard Assessment Mapping

Hazard categories were assessed/calculated in accordance with the general guidance provided in the Australian Rainfall and Runoff (ARR) Guidelines. (McLuckie, Babister, Smith, & Thompson, 2014) Flood hazard is assessed by considering the combined effects of floodwater depth and flow velocity, recognising that the level of risk to people, vehicles, and structures is influenced by both the depth of inundation and the speed at which floodwaters are moving. While shallow, slow-moving water generally presents a lower hazard, increasing depths and velocities can significantly increase the potential for instability, structural damage, and risk to life.

The hazard classifications were derived by applying the ARR hazard methodology to the hydraulic model results. The simulated flood depth and velocity were combined to calculate a flood hazard value, which was then assigned to the corresponding hazard category. These categories provide a consistent framework for identifying areas of lower, medium, higher, and extreme hazard, assisting with floodplain management, emergency planning, land-use assessment, and the communication of flood risk.

The adopted hazard categories are illustrated graphically in Figure 4.1.

Hazard Classification	Description (and defined limits)
H1	Relatively benign flow conditions. No vulnerability constraints. ($D < 0.3$ m, $V < 2.0$ m/s, or $V \times D < 0.3$)
H2	Unsafe for small vehicles. ($D < 0.5$ m, $V < 2.0$ m/s, or $V \times D < 0.6$)
H3	Unsafe for all vehicles, children and the elderly. ($D < 1.2$ m, $V < 2.0$ m/s, or $V \times D < 0.6$)
H4	Unsafe for all pedestrians and vehicles. ($D < 2.0$ m, $V < 2.0$ m/s, or $V \times D < 1.0$)
H5	Unsafe for all pedestrians and vehicles. Buildings require special engineering design and construction. ($D < 4.0$ m, $V < 4.0$ m/s, or $V \times D < 4.0$)
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. ($D > 4.0$ m, $V > 4.0$ m/s, or $V \times D > 4.0$)

Source: (D. McLuckie et. al., 2014)

Figure 4.1: Hazard Classification – Australian Rainfall Runoff Guidelines

4.5 Summary of Mapped Outputs

Table B2 in Appendix B provides a summary of maps developed for this study. Mapped model results are included with this report.

REFERENCES

- MacLean, F. W., Wilkie, J. M., & Alexander, J. G. (1931). *Water of Leith & Lindsay's Creek*.
- McLuckie, D., Babister, M., Smith, G., & Thompson, R. (2014). *Updating National Guidance on Best Practice Flood Risk Management*.
- MfE. (2010). *Tools for Estimating the Effects of Climate Change on Flood Flow: A Guidance Manual for Local Government in New Zealand*.
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- ORC. (2001). *Lindsay Creek Flood Hazard Report*.
- ORC. (2014). *Flood Hazard of Dunedin's Urban Streams*.
- Payan, J.-L., & Van Woerden, T. (2024). *North East Valley Flood Mitigation Risk - ORC Committee Paper*.
- Stantec. (2022). *North East Valley Catchment Rapid Flood Hazard Assessment*.

APPENDICES

APPENDIX A: CALIBRATION SUMMARY

Point	Northing	Easting	Surveyed Debris Mark (m)	Modelled Water Surface (m)	Difference (m)
215	4919540.78	1407696	23.479	23.72	-0.241
216	4919567.75	1407707	24.445	23.86	0.585
220	4919572.39	1407711	24.103	23.92	0.183
221	4919620.07	1407754	24.463	24.64	-0.177
222	4919652.58	1407800	24.785	25.01	-0.225
223	4919690.45	1407804	25.451	25.43	0.021
247	4919771.92	1407804	25.991	26.22	-0.229
248	4919796.29	1407816	26.291	26.41	-0.119
249	4919931.44	1407887	27.338	27.56	-0.222
250	4919959.47	1407918	27.542	27.87	-0.328
200	4919996.51	1407980	28.986	28.48	0.506
203	4919941.54	1408249	30.939	30.82	0.119
204	4919933.33	1408299	31.386	31.25	0.136
205	4919923.22	1408358	32.435	32.03	0.405
206	4919910.18	1408422	33.014	32.95	0.064
208	4919911.73	1408444	33.373	33.27	0.103
209	4919925.79	1408488	33.824	34.25	-0.426
210	4920090.4	1408584	36.163	36.53	-0.367
224	4920195.62	1408630	37.947	38.58	-0.633
227	4920262.4	1408698	39.636	39.89	-0.254
225	4920350.24	1408755	41.112	41.76	-0.648
226	4920501.64	1408877	45.586	46.01	-0.424
228	4920506.85	1408932	46.816	47.06	-0.244
230	4920574.42	1409014	49.304	49.27	0.034
231	4920583.8	1409309	56.231	56.19	0.041
232	4920583.77	1409308	56.265	56.17	0.095
234	4920584.09	1409304	56.154	56.06	0.094
238	4920659.53	1409395	59.455	59.36	0.095
239	4920800.19	1409463	63.1	63.27	-0.17
240	4920833.06	1409515	65.707	65.45	0.257
241	4920845.43	1409545	66.249	66.48	-0.231
				Average (m)	-0.071

Horizontal Coordinate System: NZTM

Vertical Coordinates: NZVD16

APPENDIX B

Table B1: Summary of Model Scenarios

Scenario ID	Description	Model Plan	Geometry	Flow	AEP	Climate Change	Development Condition	Purpose
S1	Calibration	Calibration.p01	Leith_Lindsay_Existing.g01	2016 Flood	-	No	Existing	Calibration/Baseline
S2	Existing Conditions 1% AEP Flood	E_100_FFA.p02	Leith_Lindsay_Existing.g01	Q100_FFA	1%	No	Existing	Flood Hazard Mapping
S3	Existing Conditions 2% AEP Flood	E_50_FFA.p03	Leith_Lindsay_Existing.g01	Q50_FFA	2%	No	Existing	Investigation
S4	Existing Conditions 0.2% AEP Flood	E_500_FFA.p05	Leith_Lindsay_Existing.g01	Q500_FFA	0.2%	No	Existing	Flood Hazard Mapping
S5	Existing Conditions 1% AEP Climate Change	F_100_FFA.p05	Leith_Lindsay_Existing.g01	Q100_CC	1%	Yes	Existing	Future Flood Risk
S6	Existing Conditions 0.2% AEP Climate Change	F_500_FFA.p05	Leith_Lindsay_Existing.g01	Q100_CC	0.2%	Yes	Existing	Future Flood Risk

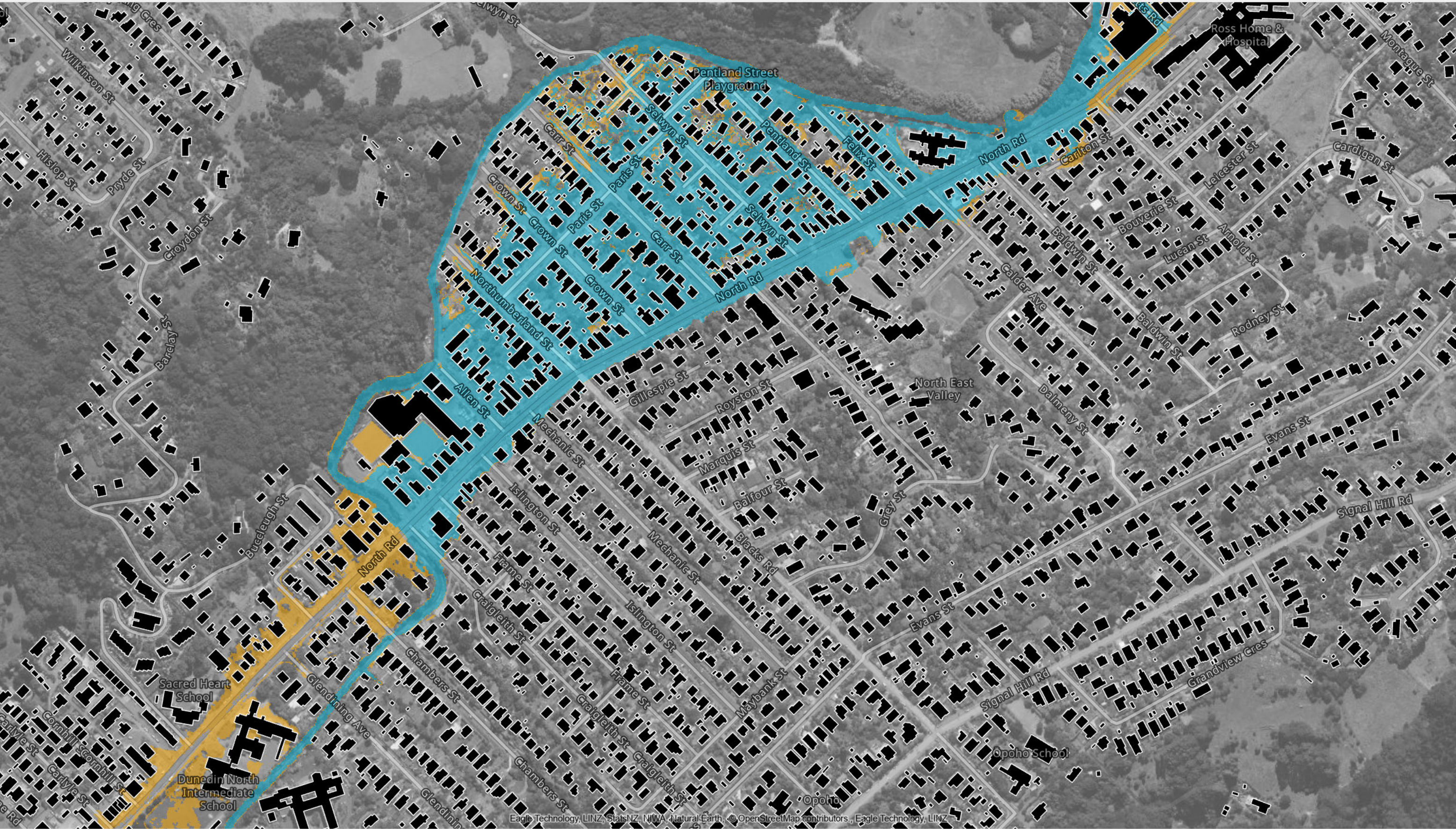
Table B2: Summary of Maps

Map ID	Scenarios Mapped	Output Type	Description
1.1	S2, S4	Flood Extent	Flood Inundation Mapping – Lindsay Creek STA. 0+00 to 21+00
1.2	S2, S4	Flood Extent	Flood Inundation Mapping – Lindsay Creek STA. 21+00 to 37+00
1.3	S2, S4	Flood Extent	Flood Inundation Mapping – Lindsay Creek STA. 37+00 to 49+00
2.1	S3	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 0+00 to 21+00
2.2	S3	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 21+00 to 37+00
2.3	S3	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 37+00 to 49+00
2.4	S4	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 0+00 to 21+00
2.5	S4	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 21+00 to 37+00
2.6	S4	Flood Hazard	Flood Hazard Mapping – Lindsay Creek STA. 37+00 to 49+00
3.1	S5, S6	Future Flood Extent	Flood Inundation Mapping Future – Lindsay Creek STA. 0+00 to 21+00
3.2	S5, S6	Future Flood Extent	Flood Inundation Mapping Future – Lindsay Creek STA. 21+00 to 37+00
3.3	S5, S6	Future Flood Extent	Flood Inundation Mapping Future – Lindsay Creek STA. 37+00 to 49+00

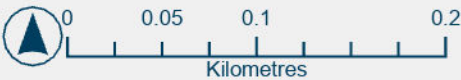
MAPS

Map 1.1 Flood Hazard Areas

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study

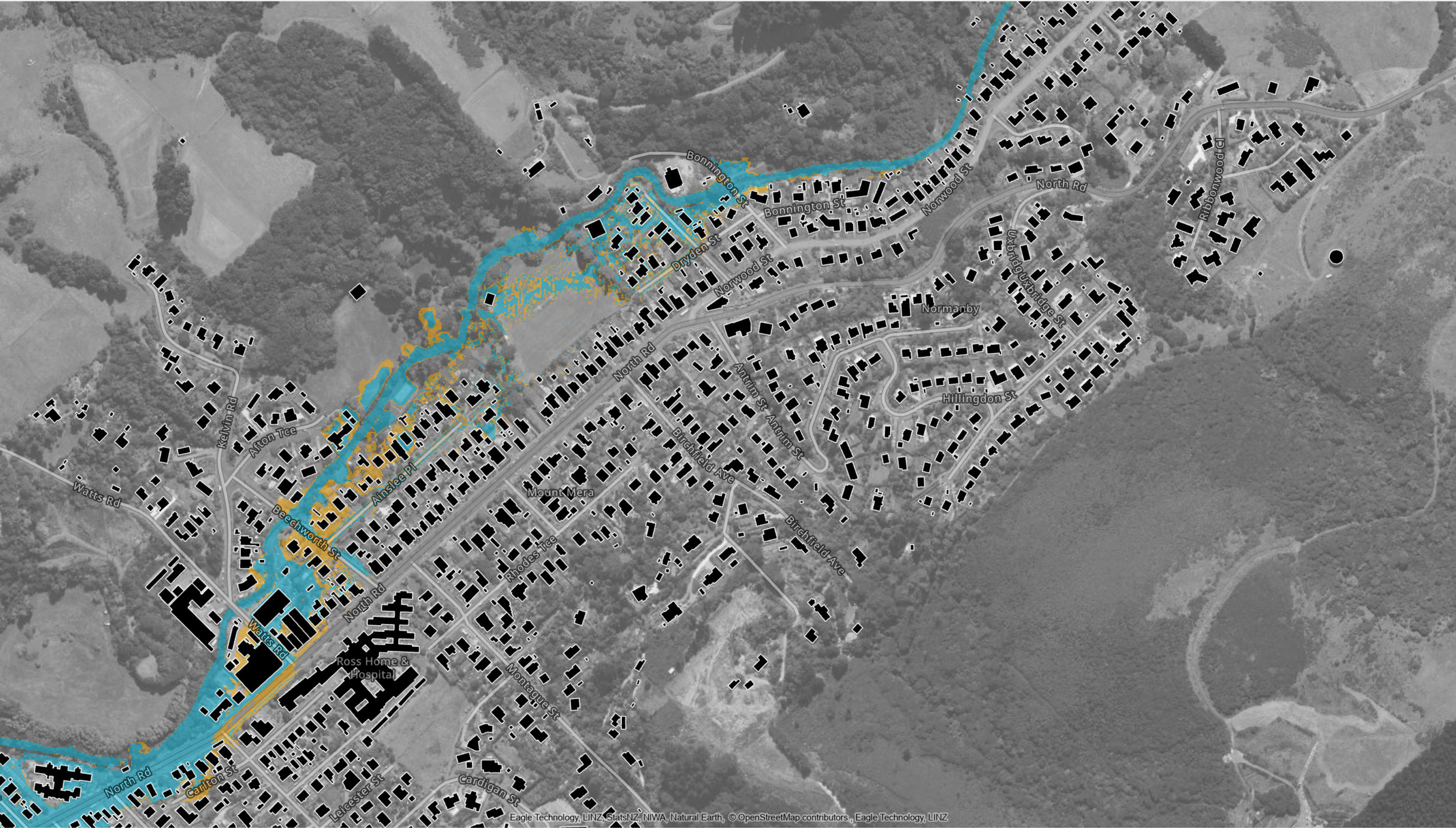


0.2% AEP FLOOD HAZARD (500YR)
1% AEP FLOOD HAZARD (100YR)

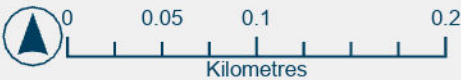


Map 1.2 Flood Hazard Areas

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



- 0.2% AEP FLOOD HAZARD (500YR)
- 1% AEP FLOOD HAZARD (100YR)



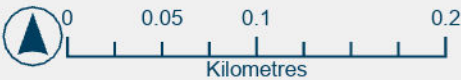
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Map 1.3 Flood Hazard Areas

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



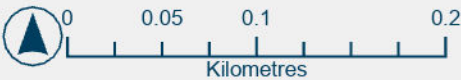
- 0.2% AEP FLOOD HAZARD (500YR)
- 1% AEP FLOOD HAZARD (100YR)



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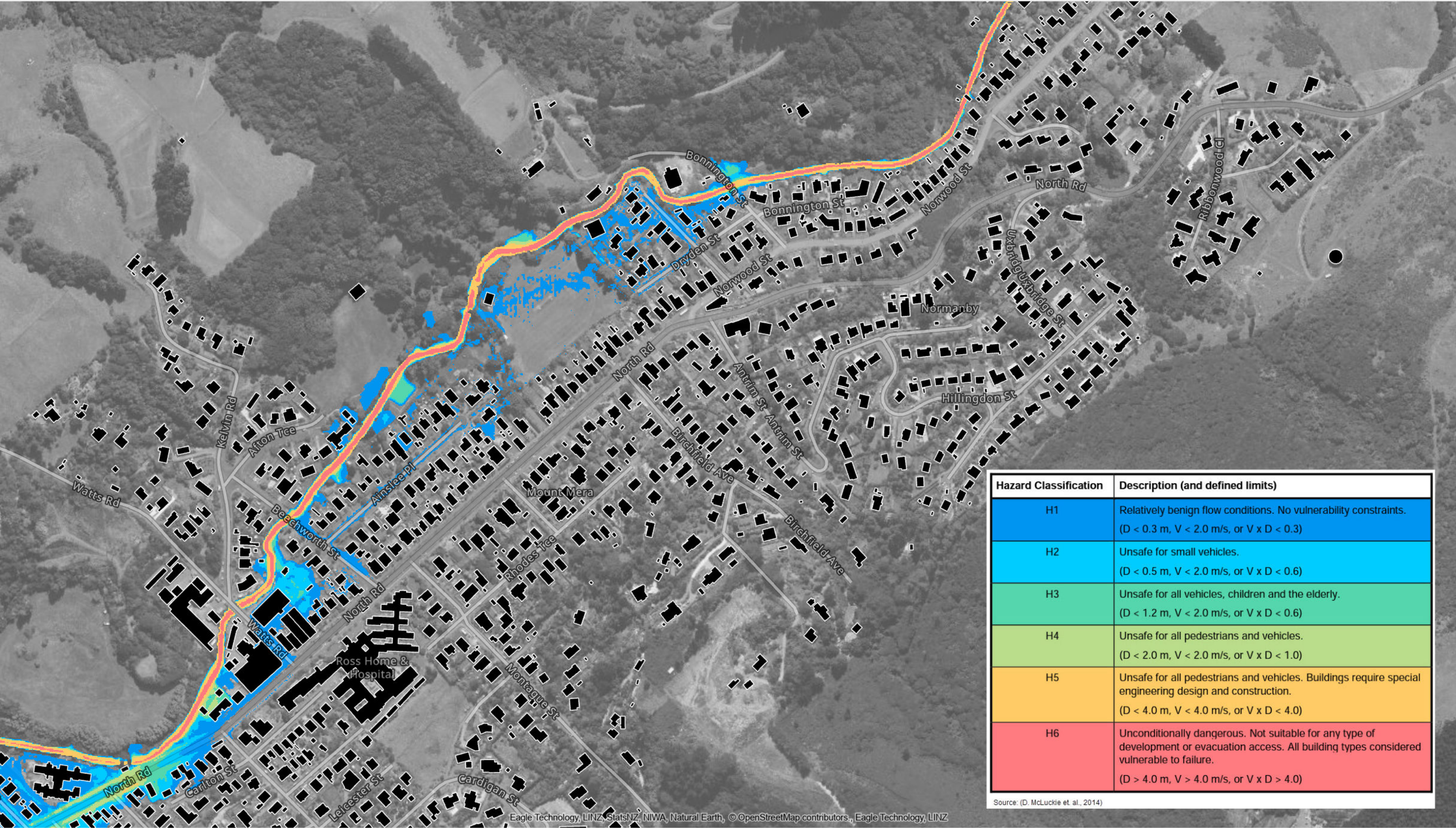
Map 2.1 Flood Hazard Rating

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



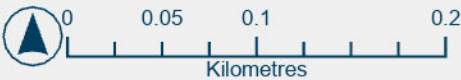
Map 2.2 Flood Hazard Rating

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



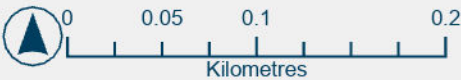
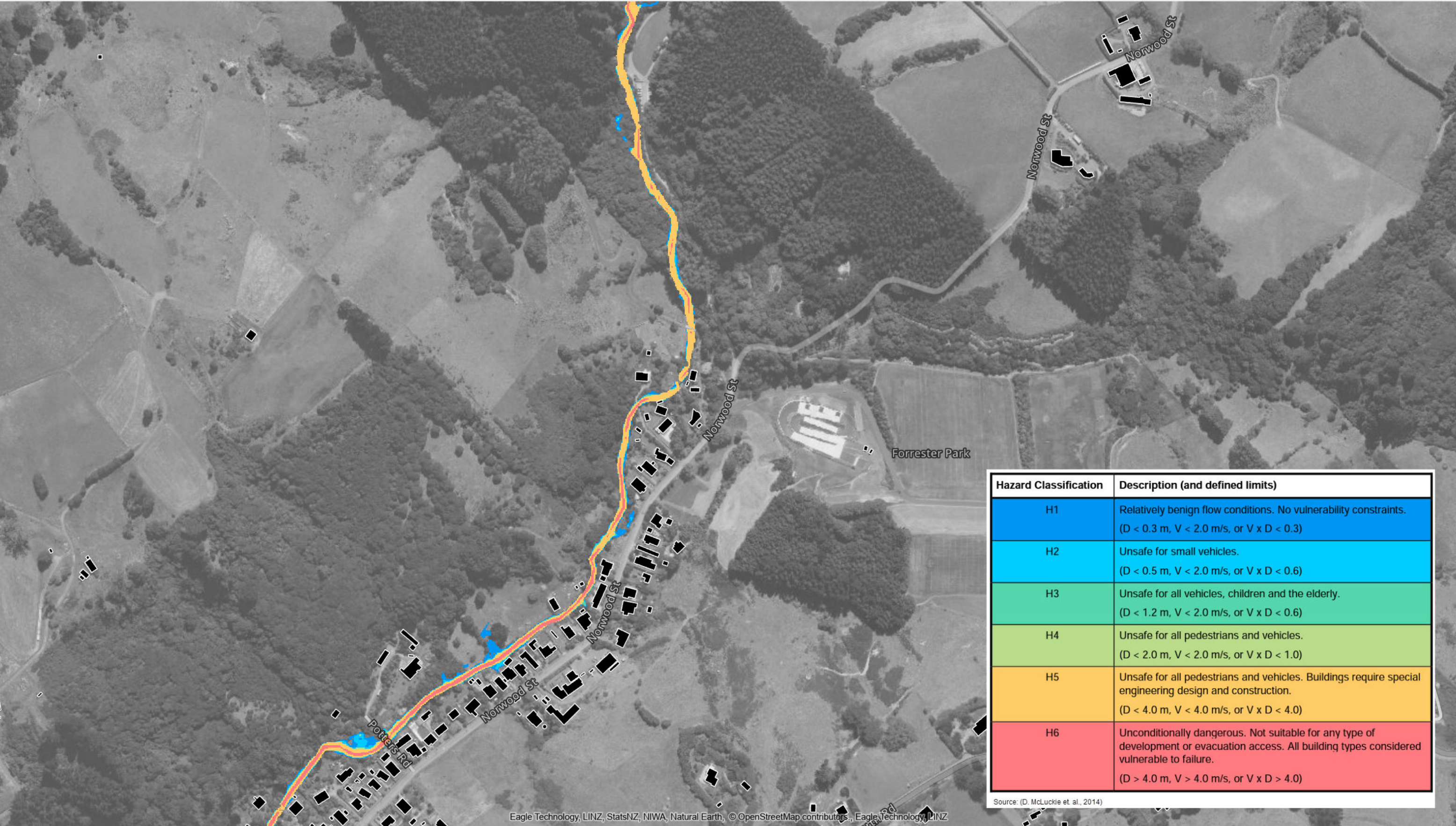
Hazard Classification	Description (and defined limits)
H1	Relatively benign flow conditions. No vulnerability constraints. ($D < 0.3\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.3$)
H2	Unsafe for small vehicles. ($D < 0.5\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.6$)
H3	Unsafe for all vehicles, children and the elderly. ($D < 1.2\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.6$)
H4	Unsafe for all pedestrians and vehicles. ($D < 2.0\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 1.0$)
H5	Unsafe for all pedestrians and vehicles. Buildings require special engineering design and construction. ($D < 4.0\text{ m}$, $V < 4.0\text{ m/s}$, or $V \times D < 4.0$)
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. ($D > 4.0\text{ m}$, $V > 4.0\text{ m/s}$, or $V \times D > 4.0$)

Source: (D. McLuckie et al., 2014)



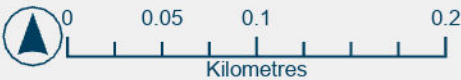
Map 2.3 Flood Hazard Rating

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



Map 2.4 Flood Hazard Rating

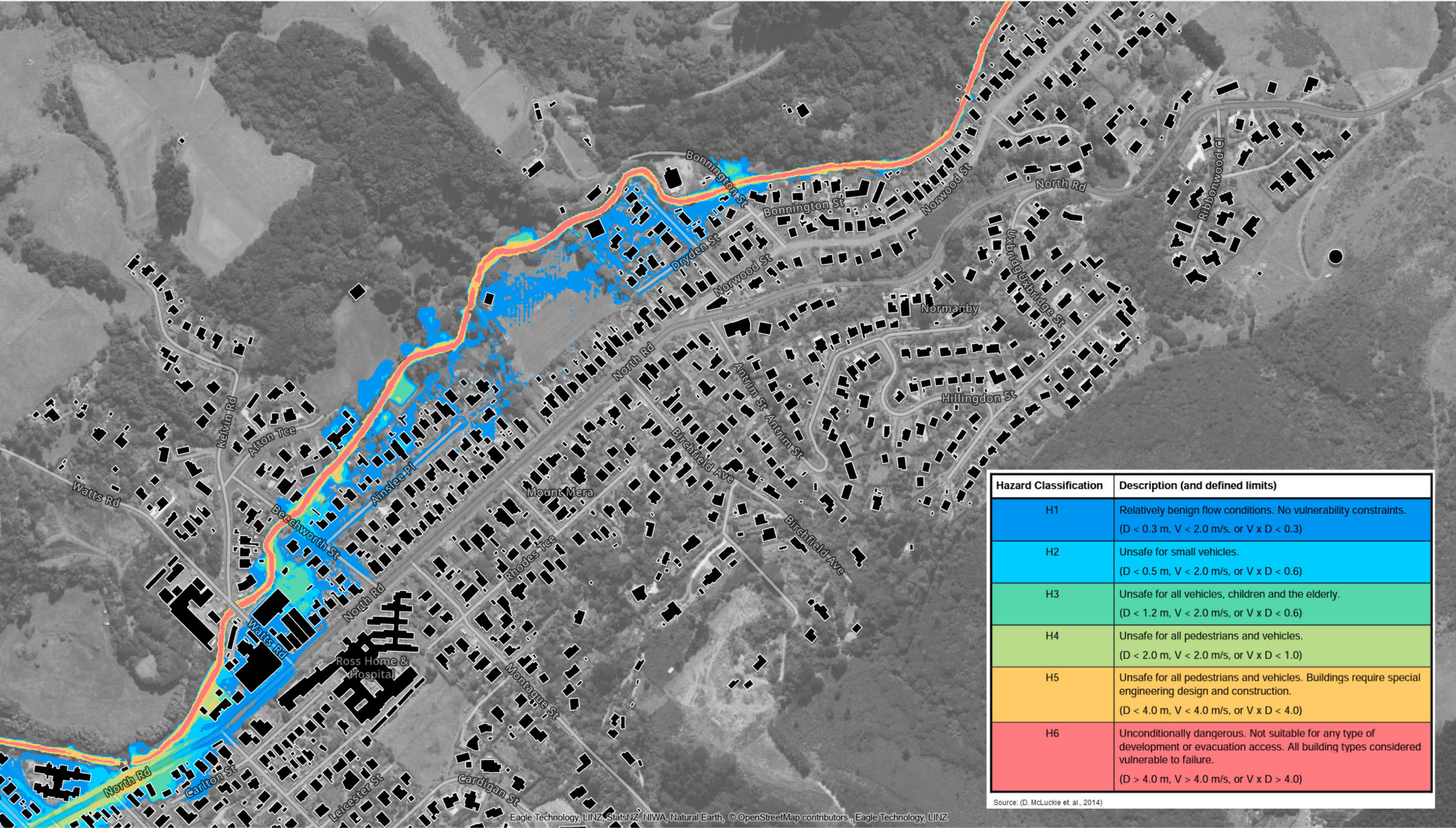
Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



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Map 2.5 Flood Hazard Rating

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study

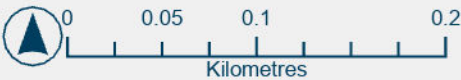


Hazard Classification	Description (and defined limits)
H1	Relatively benign flow conditions. No vulnerability constraints. ($D < 0.3\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.3$)
H2	Unsafe for small vehicles. ($D < 0.5\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.6$)
H3	Unsafe for all vehicles, children and the elderly. ($D < 1.2\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 0.6$)
H4	Unsafe for all pedestrians and vehicles. ($D < 2.0\text{ m}$, $V < 2.0\text{ m/s}$, or $V \times D < 1.0$)
H5	Unsafe for all pedestrians and vehicles. Buildings require special engineering design and construction. ($D < 4.0\text{ m}$, $V < 4.0\text{ m/s}$, or $V \times D < 4.0$)
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. ($D > 4.0\text{ m}$, $V > 4.0\text{ m/s}$, or $V \times D > 4.0$)

Source: (D. McLuckie et al., 2014)

0.2% AEP HAZARD RATING

■ H1
 ■ H2
 ■ H3
 ■ H4
 ■ H5
 ■ H6



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Map 2.6 Flood Hazard Rating

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



0.2% AEP HAZARD RATING

H1

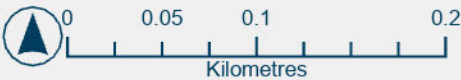
H2

H3

H4

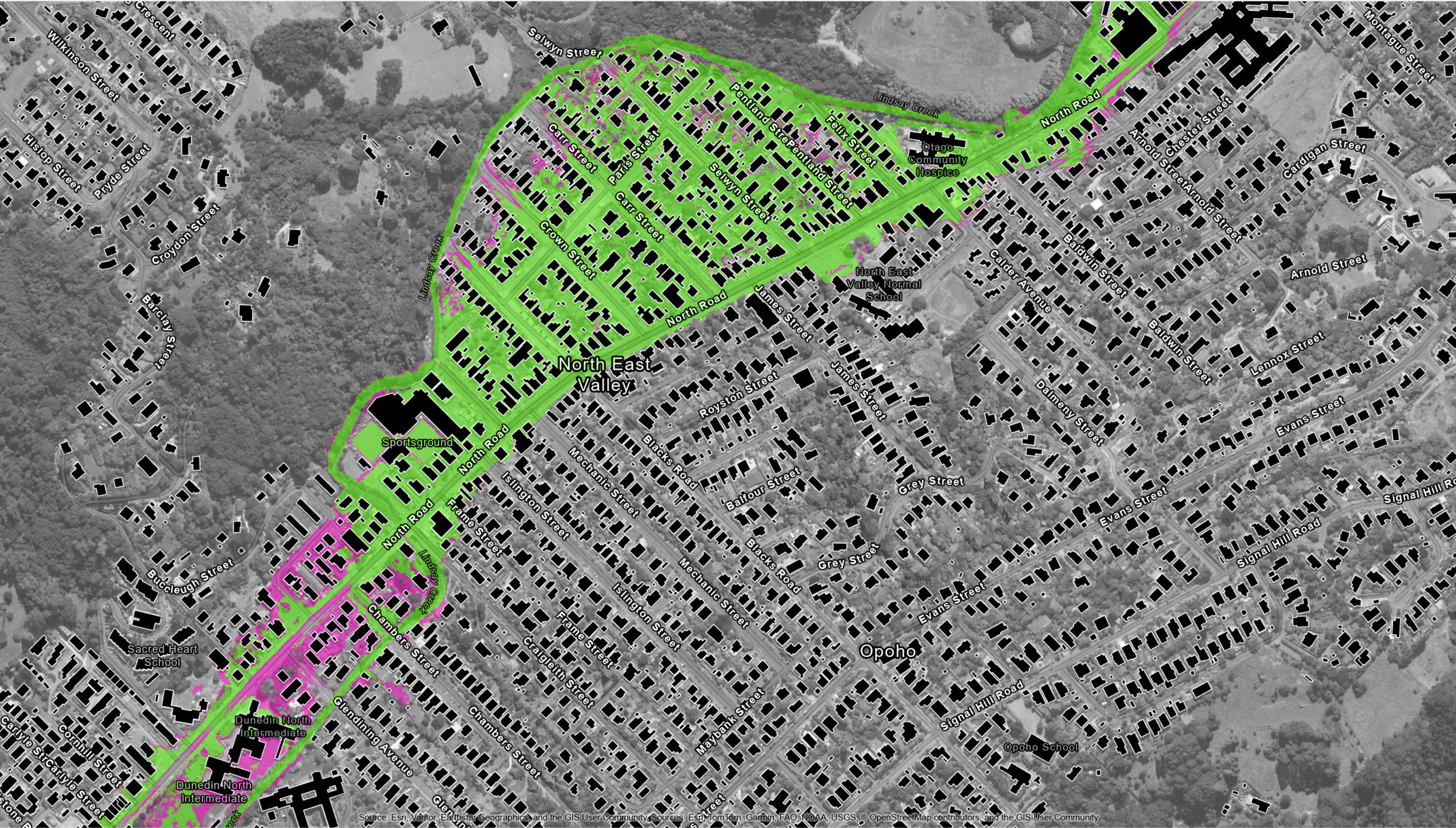
H5

H6

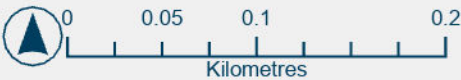


Map 3.1 Flood Hazard Areas - Future

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



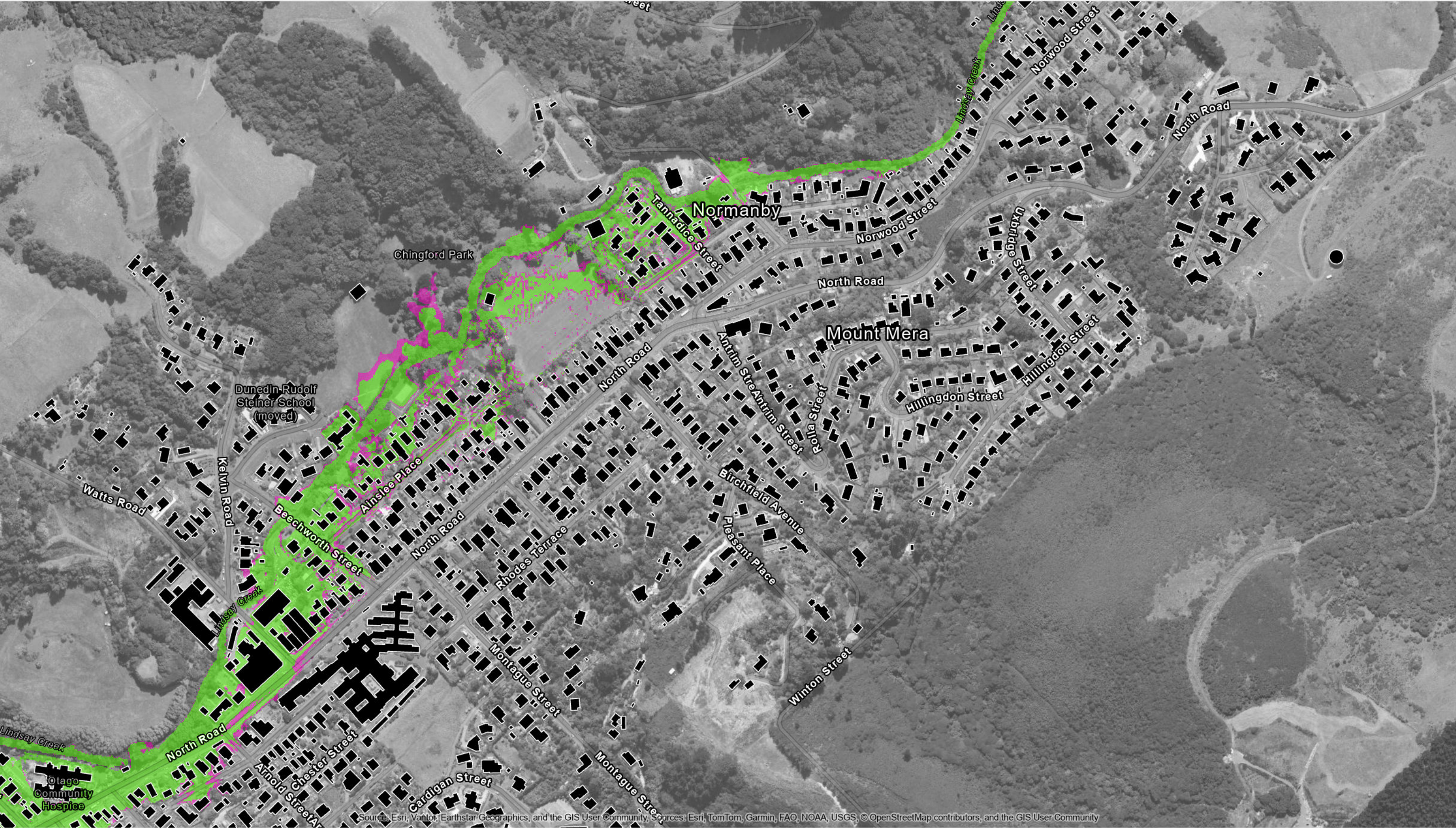
- 1% AEP FLOOD HAZARD (100YR) - FUTURE
- 0.2% AEP FLOOD HAZARD (500YR) - FUTURE



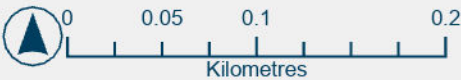
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Map 3.2 Flood Hazard Areas - Future

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



- 1% AEP FLOOD HAZARD (100YR) - FUTURE
- 0.2% AEP FLOOD HAZARD (500YR) - FUTURE



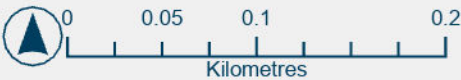
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Map 3.3 Flood Hazard Areas - Future

Northeast Valley Flood (Lindsay Creek) Flood Hazard Study



- 1% AEP FLOOD HAZARD (100YR) - FUTURE
- 0.2% AEP FLOOD HAZARD (500YR) - FUTURE



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