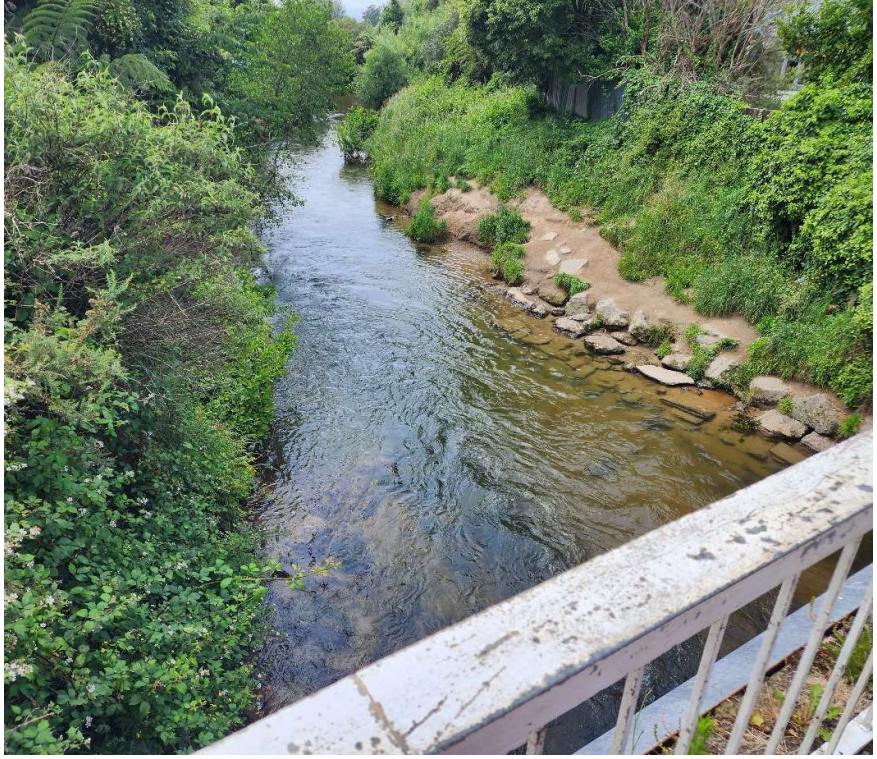
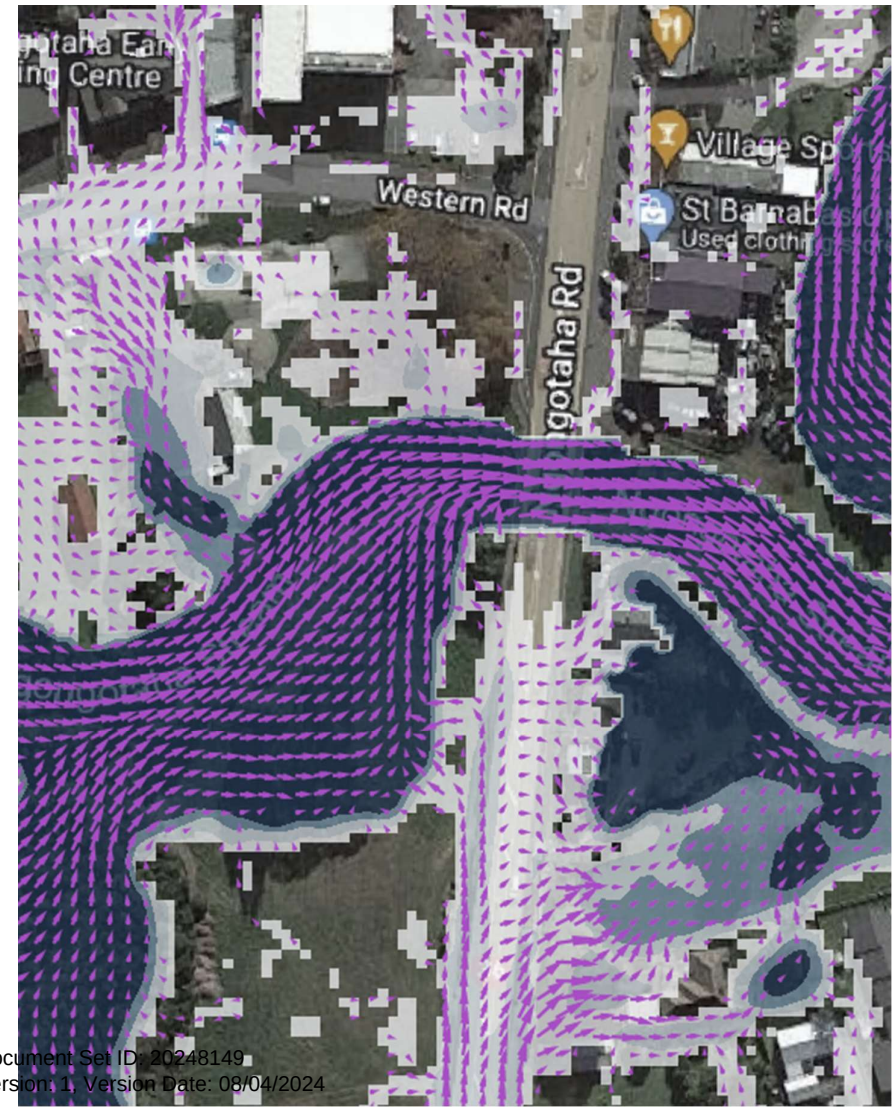


TUFLOW

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# Ngongotahā Flood Modelling

## *Model Build and Design Scenarios Report*

*Date 22/03/2024*

Excellence Heart Innovation

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# NGONGOTAHĀ FLOOD MODELLING: MODEL BUILD AND DESIGN SCENARIOS REPORT

| | |
|---|---|
| Project number | J000627 |
| Document title | Ngongotahā Flood Modelling: Model Build And Design Scenarios Report |
| Version number | 2.0 |
| Date | 22/03/2024 |
| Project manager | Chusit Apirumanekul |
| Additional technical contributors | Rathika Jebamony; Dr Brad Scarfe; Amy Waters; Carl Johnson; Mahalakshmi Kalyansundar. |

| VERSION | DATE | DESCRIPTION | AUTHOR | REVIEWED |
|---|---|---|---|---|
| 1.0 | 16/02/2024 | First model build and design run report | Chusit Apirumanekul; Maha Kalyansundar | Dr Brad Scarfe |
| 2.0 | 22/03/2024 | Revision based on reviewers' comments | Chusit Apirumanekul; | Dr Brad Scarfe |
| | | | | |
| | | | | |



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# EXECUTIVE SUMMARY

Rotorua Lakes Council (RLC) identified Ngongotahā in the Rotorua Spatial Plan 2018 as a key growth area that requires a flood model that covers the wider Ngongotahā area. This report summaries the flood model build process and application to a series of design event simulations. The specific objectives of this study are to:

- build and validate a TUFLOW flood model for catchments that are part of the Ngongotahā township; and
- to simulate the flooding conditions 0.2%, 1% and 10% Annual Exceedance Probability (AEP) design events.

This report includes:

- an overview of the study location;
- summary of model features and model build process;
- model verification and sensitivity analysis;
- application to flood hazard mapping; and
- conclusions and recommendations.

The model validation was completed against an approximately 1 % AEP event that occurred in April 2018. Previous flood model extents and property level flood incident records were used to successfully validate the model. The following design runs were completed for both current and future climates. Freeboard has not been included in the model simulations.

| | |
|---|---|
| Design events completed | • 10 % AEP scenario<br>  • 10 % AEP rainfall and 50 % AEP lake level – current climate (2020)<br>  • 50 % AEP rainfall and 10 % AEP lake level – current climate (2020)<br>  • 10 % AEP rainfall and 50 % AEP lake level – climate change (2130, RCP8.5)<br>  • 50 % AEP rainfall and 10 % AEP lake level – climate change (2130, RCP8.5)<br>• 1 % Annual Exceedance Percentage (AEP) scenario<br>  • 1% AEP rainfall and 5 % AEP lake level – current climate (2020)<br>  • 5% AEP rainfall and 1 % AEP lake level – current climate (2020)<br>  • 1% AEP rainfall and 5 % AEP lake level – climate change (2130, RCP8.5)<br>  • 5% AEP rainfall and 1 % AEP lake level – climate change (2130, RCP8.5)<br>• 0.2 % AEP scenario<br>  • 0.2 % AEP rainfall and 0.5 % AEP lake level – current climate (2020)<br>  • 0.5 % AEP rainfall and 0.2 % AEP lake level – current climate (2020)<br>  • 0.2 % AEP rainfall and 0.5 % AEP lake level – climate change (2130, RCP8.5)<br>  • 0.5 % AEP rainfall and 0.2 % AEP lake level – climate change (2130, RCP8.5) |

The model can be considered robust to support growth planning, hazard identification, catchment planning and concept level engineering design. For use in more detailed applications the following additional model improvement could be considered:

- use of more sophisticated upper catchment hydrological methods;
- validation against a 10 % AEP event;



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- validation against measured discharges in the lower Ngongotahā and Waiteti Streams;
- additional investigation into flood incident reporting for events outside of April 2018;
- survey of secondary channels and flow paths in areas of interest;
- incorporation of bridges;
- stormwater asset survey in the areas when doing detailed engineering design;
- additional sensitivity analysis such as network blockage scenarios and impact of antecedent moisture conditions; and
- identification of any areas where groundwater may impact flood predictions.



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# 1. BACKGROUND

## 1.1. BACKGROUND

Rotorua Lakes Council (RLC) identified Ngongotahā in the Rotorua Spatial Plan 2018 as a key growth area. However, while work has been undertaken to assess the flood risk throughout urban Rotorua, this work excluded the Ngongotahā area and there are information gaps to support growth planning (RLC, 2022).

To address the information gap, RLC requires a flood model of the *wider Ngongotahā area*. This model is intended to inform the RLC Future Development Strategy and district plan changes to address natural hazards (RLC, 2022). The model is also intended to provide a simulation capability to understand potential future stormwater infrastructure projects and changes in the catchment.

## 1.2. OBJECTIVES

This objectives of this study are to:

- build and validate a TUFLOW flood model for catchments that are part of the Ngongotahā township; and
- to simulate the flooding conditions 0.2%, 1% and 10% Annual Exceedance Probability (AEP) design events.

## 1.3. REPORT STRUCTURE

This report includes:

- an overview of the study location;
- summary of model features and model build process;
- model verification and sensitivity analysis;
- application to flood hazard mapping; and
- conclusions.



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# 2. STUDY LOCATION OVERVIEW

## 2.1. LOCATION

The Ngongotahā township is of approximately 5,000 and is located west of Lake Rotorua within the Bay of Plenty region. It is at the base of a number of substantial catchments in regional terms, with the Ngongotahā and Waiteti Streams being the most significant water ways.

Figure 2-1 shows the location of Ngongotahā relative to Lake Rotorua, the flood model extent, catchments and key monitoring stations of relevance to this study. Readers are referred to Standway *et al*. (2018) for additional geographic information in the context of flooding.

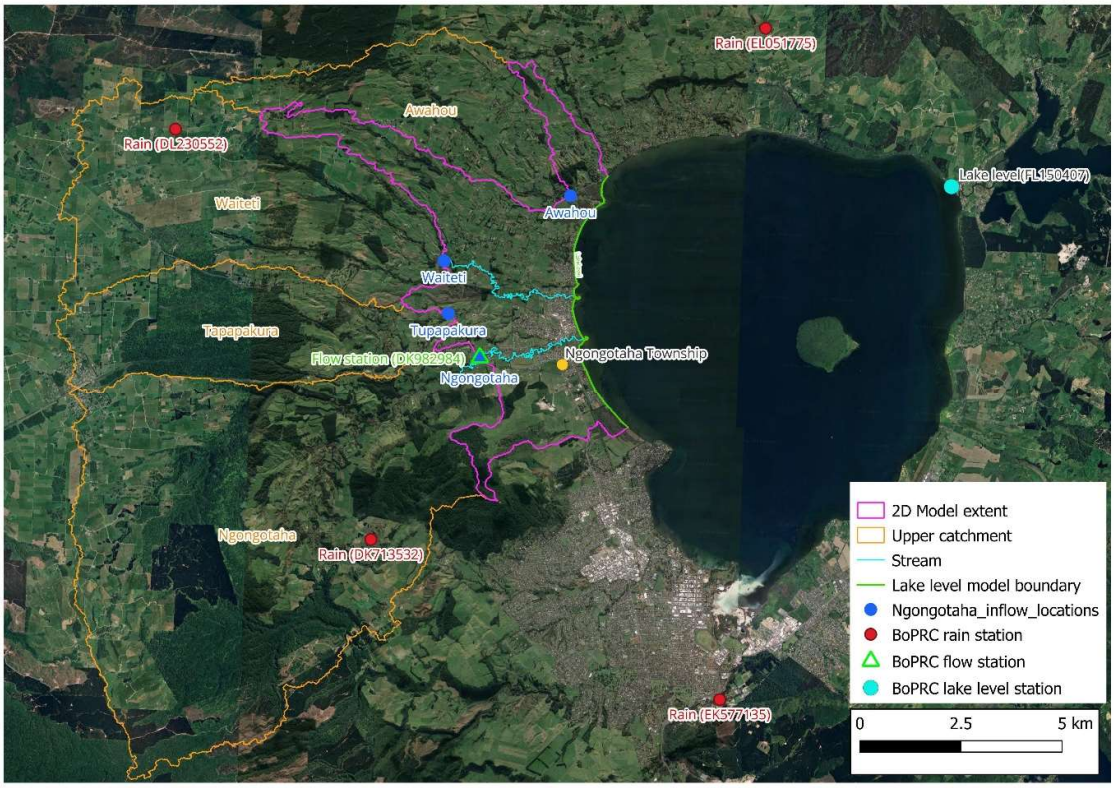



*Figure 2-1. **Ngongotahā location map with catchments, flood model extent and key Bay of Plenty Regional Council (BROPC) monitoring stations.***

## 2.2. HISTORIC FLOODING

A 2007 model of the Ngongotahā Stream identified three historical events that have flood level records available (BOPRC, 2007). These were used to support building the model:

- 17 December 2005 at $m^3/s$;
- 1 May 1999 at 23.5 $m^3/s$; and
- 5 January 1986 at 44 $m^3/s$.



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A significant Ngongotahā Steam flooding event of 72 $m^3/s$ (Standway *et al*., 2018) occurred on 29 April 2018. This event led to an independent review (Standway *et al*., 2018) to understand the contributing factors behind the flooding and to make recommendations to prevent or minimise the risk and effects of future flood events. One such recommendation results in the Ngongotahā Flood Review Project which is focused on workstreams that include:

- Civil Defence and readiness;
- engineering and modelling;
- upper catchment management; and
- planning and consenting framework review.

## 2.3. GEOLOGY

The specific soil types used in the model are shown in Figure 2-2. The soil types were derived from the New Zealand Land Resource Inventory Soil[1] layer and the land cover (Figure 2-3). Many of the soil types can be generally classified as *well draining.* This is a driver for infiltration of flood waters to the ground.

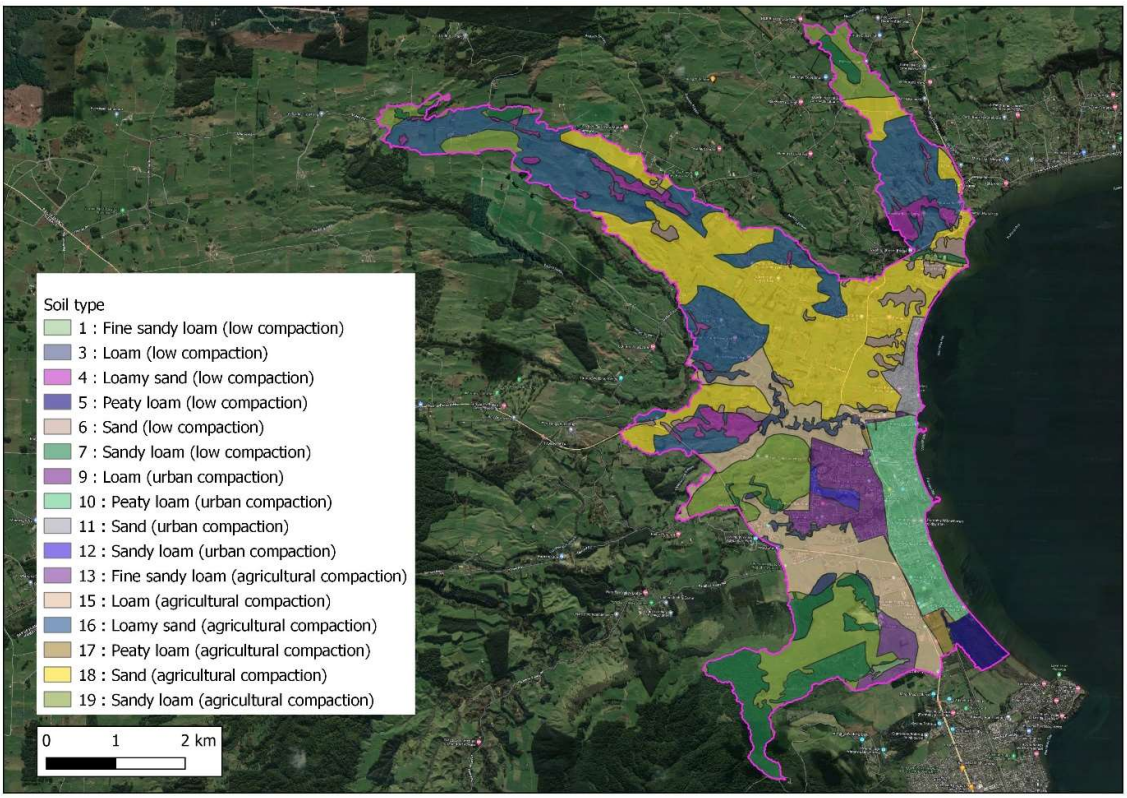



*Figure 2-2. Soil types used in the TUFLOW flood model.*

[1] https://lris.scinfo.org.nz/layer/48066-nzlri-soil/



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## 2.4. EXISTING LAND COVER

The land cover layer in the model (Figure 2-3) is a combination of available zoning, land cover and building footprint data.

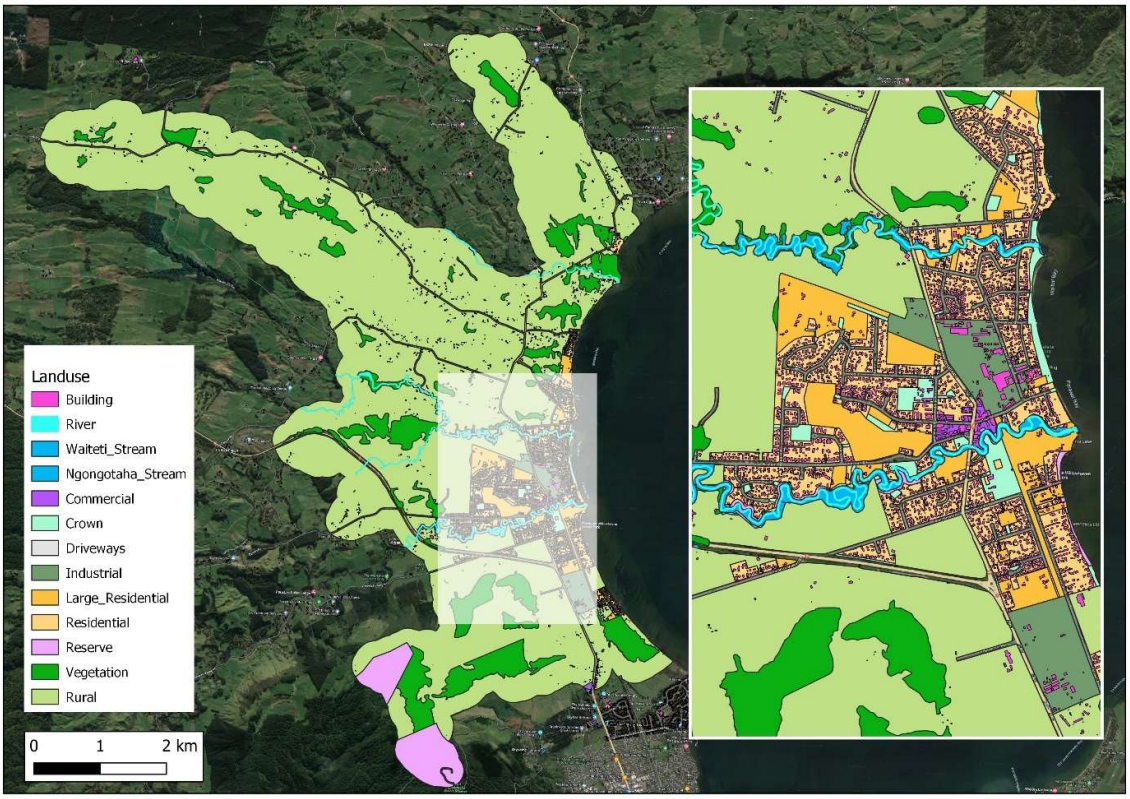



*Figure 2-3. Land cover layer used in the TUFLOW flood model to set the model roughness coefficients.*

## 2.5. STORMWATER SYSTEM

While the Ngongotahā township is limited in size, the existing urban environment is serviced by a stormwater network. The specific network included in the model is shown in Figure 2-4.



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*Figure 2-4. Stormwater networks used in the one-dimensional (1D) network component of the TUFLOW flood model.*

## 2.6. LOCATIONS OF INTEREST

The flood depths and extent shown in Figure 2-5 from BOPRC (2007) show key locations to consider during model verification. Inundated buildings shown in Figure 2-6 are also relevant for model verification.



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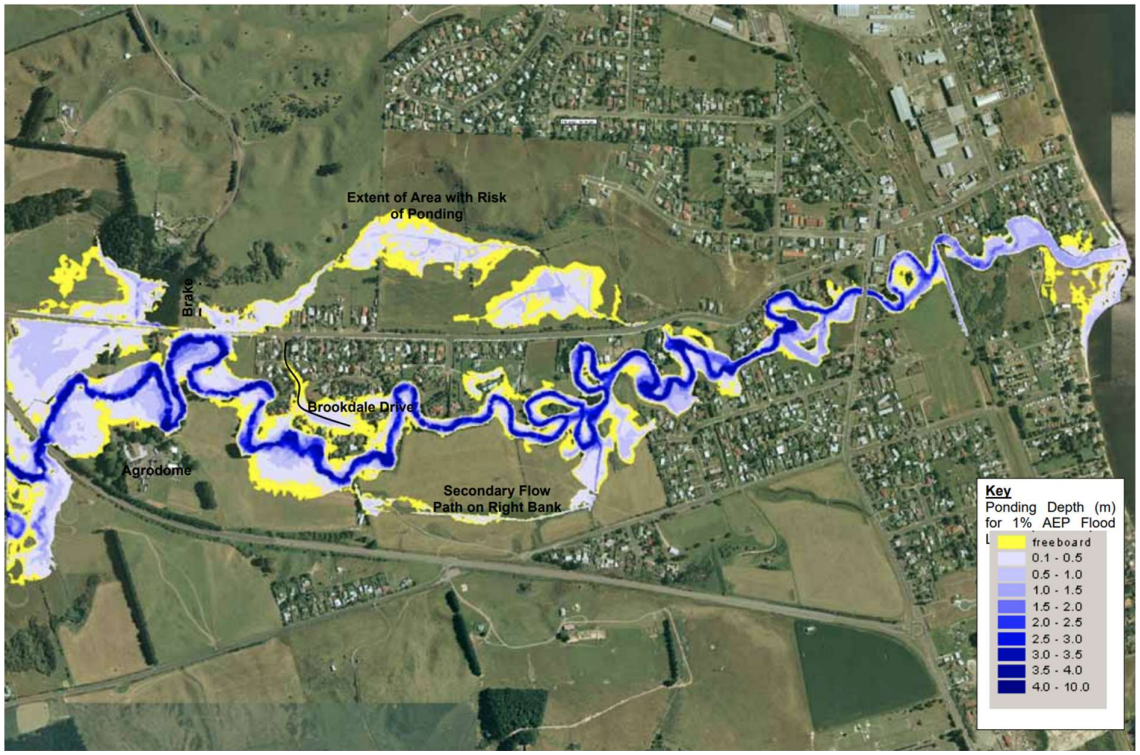



*Figure 2-5. 1 % AEP flood depths and extents with additional areas associated with freeboard uncertainty (from BOPRC, 2007).*

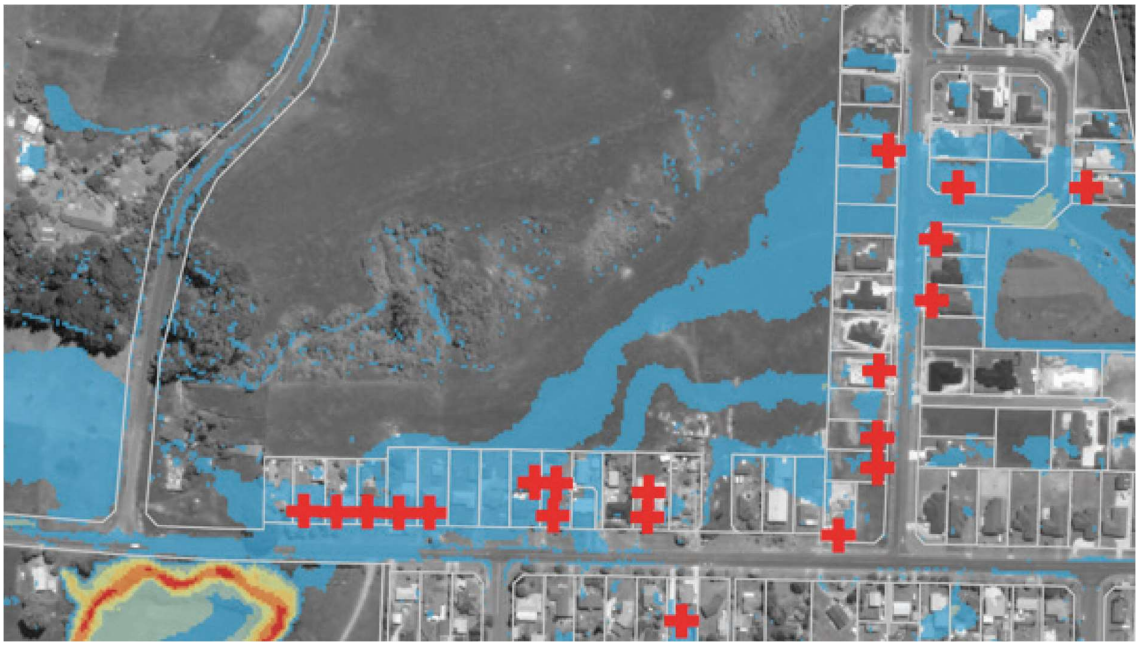


*Figure 2-6. Location of inundated dwellings from April 29 2018 flood event (*Standway *et al., 2018).*



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# 3. FLOOD MODEL BUILD

## 3.1. MODEL OVERVIEW

The model developed for this study uses the TUFLOW HPC software and has these key characteristics:

- upper hill catchments input discharges to the upper extents of the 2d model;
- rain on grid method is applied to the 2D model domain;
- the 1D stormwater network is coupled to the 2D model domain;
- TUFLOW Quadtree is applied to allow different topographic and flood features to be represented at different grid cell sizes;
- TUFLOW Sub-grid Sampling calculates hydraulic parameters from underlaying DEM resolution using multiple points, rather than using one point in the model cell size; and
- major rivers are represented using higher resolution cells than the flood plain.

The following sections outline data sources, model schematistation details, approach to boundary conditions as well limitations, constraints and assumptions that need to be considered when using the model and model outputs.

## 3.2. DATA SOURCES

Table 3-1. below details the sources of key data used to create the model. No site-specific survey has been supplied or collected for this model build.

*Table 3-1. Source of data used for the model.*

| DATA | DETAILS | SOURCE | RECEIVED |
|---|---|---|---|
| Updated LiDAR (2019-2022) | • LiDAR for the whole Bay of Plenty region captured from October 2019 to October 2022<br>• Received in NZVD2016 and converted to Moturiki Vertical Datum 1953 by Awa | LINZ | October 2023 |
| 2018 LiDAR | • LiDAR for urban areas in the Bay of Plenty region captured between 2018 and 2019. This was merged with the 2011 dataset to create a continuous dataset for the model build.<br>• Later replaced by 2019-2022 LiDAR | LINZ | September 2022 |
| 2011 LiDAR | • This was merged with the 2018 dataset to create a continuous dataset for the model build.<br>• Later replaced by 2019-2022 LiDAR<br>• Attributed to BOPLASS Ltd | BOPRC FTP site | July 2019 |



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| DATA | DETAILS | SOURCE | RECEIVED |
|---|---|---|---|
| NZVD2016-MOT53 Conversion raster | • Conversion raster for New Zealand vertical datum 2016 to Moturiki 1953 | LINZ | September 2022 |
| RLC Zoning layer | • Zoning layer for Ngongotahā to approximate land cover | RLC | September 2022 |
| Buildings Outlines | • Used to embed buildings in the model via increased roughness and elevated footprints | LINZ | May 2023 |
| Road centre lines | • Road centrelines for the Ngongotahā area | LINZ | September 2022 |
| Observed discharge data | • Ngongotahā stream discharge data for TUFLOW model inputs | BOPRC | November 2022 |
| Observed rainfall data | • Recorded rainfalls at the gauges for TUFLOW model inputs | BOPRC | September 2023 |
| Information for model validation | • Recorded flood levels and depths for 2018 event along Ngongotahā stream and Western Road<br>• Approximate extent of overland flow path from BOPRC hydraulic model for 2018 event<br>• Affected properties in 2018 | BOPRC | October 2023 |
| Drainage Data | • Drainage layer by Waka Kotahi<br>• Kiwirail culverts<br>• RLC SW pipe network | RLC | August 2023 |
| Design rainfall | • HIRDS v4 | NIWA | September 2021 |
| Design flows | • Ngongotahā design peak flows were obtained from the hydraulic modelling of the Ngongotahā Stream | BOPRC | March 2022 |
| Ngongotahā Stream model components | • Ngongotahā Stream model DEM, roughness layer and land cover to represent Mannings' n | BOPRC via PDP | March 2023 |
| Waiteti Stream model components | • Waiteti Stream model DEM, roughness layer and land cover to represent Mannings' n | BOPRC via PDP | May 2023 |
| Observed information during the April 2018 event | • Water level, water depth at specific locations and affected properties for validation purpose | BOPRC | October 2023 |



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| DATA | DETAILS | SOURCE | RECEIVED |
|---|---|---|---|
| Surveyed debris level | • Surveyed flood debris level at some locations for validation purpose | BOPRC | August 2023 |
| Simulated overland flow path during the April 2018 event | • Map of overland flow path from the April 2018 for validation purpose | BOPRC | October 2023 |
| Hydrographs for April 2018 and design event | • Ngongotahā river hydrograph in DHI format | BOPRC | August 2023 |

## 3.3. MODEL SCHEMATISATION

Descriptions of model components are defined in Table 3-2.

*Table 3-2. Details of model components.*

| COMPONENT | DETAILS |
|---|---|
| Purpose | • Provide RLC with a simulation capability to understand growth scenarios, plan stormwater infrastructure projects and understand changes in the catchment. |
| Software | • TUFLOW HPC 2023-03-AA |
| Coordinate system | • New Zealand Transverse Mercator 2000 |
| Vertical datum | • Moturiki Vertical Datum 1953 |
| Modelling approach | • 2D rain on grid model coupled with 1D stormwater network approach. The stormwater was comprised of pipes, culverts, pits and manholes and overland flow was modelled by 2D component. Flow exchanges between 1D and 2D components were included in the TUFLOW model. The Ngongotahā and Waiteti stream channels shape and roughness layers were sourced from existing TUFLOW river channel models. |

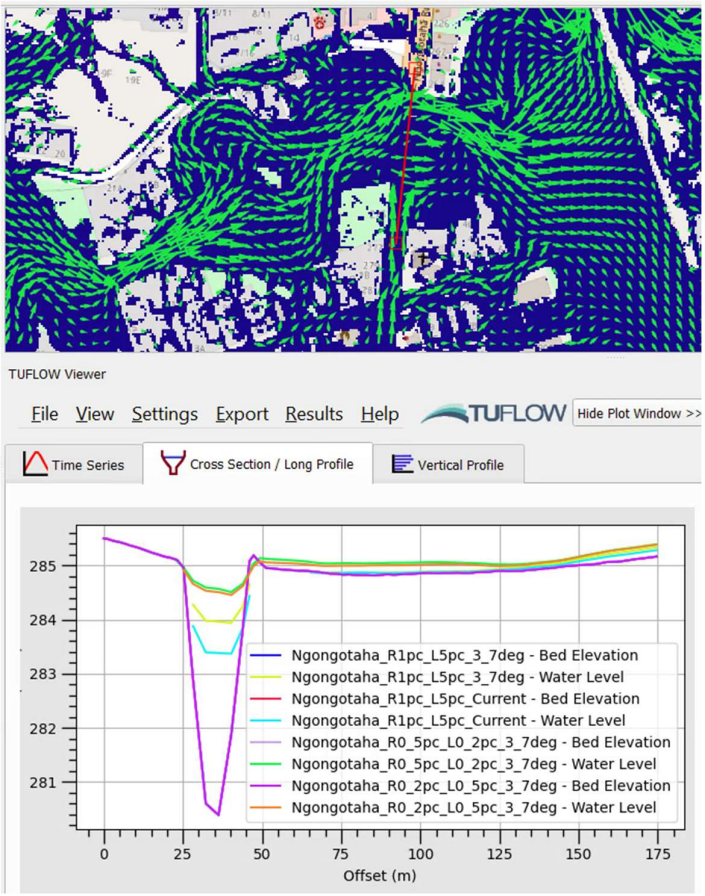


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| COMPONENT | DETAILS |
|---|---|
| Hydrological approach | • Rain-on-grid (direct rainfall) approach was applied to the 2D extent.<br>• Subcatchment-based approach was used for four upper catchment inflows as upstream flow boundaries for TUFLOW model.<br>  ○ The catchments were derived from the LiDAR data and BOPRC peer reviewer recommended scaling the Ngongotahā gauged flow to the other catchments using an area transposition method. This was recommended to maintain consistency with other models in the locations (e.g. Ngongotahā channel and Waetiti Stream channels).<br>  ○ To consider climate change in design boundary conditions, NIWA augmentation factors and time of concentration for each catchment was incorporated into the analysis.<br>  ○ An assessment of this method is as follows:<br>  ▪ Advantages:<br>  ▪ Simple method and easy application<br>  ▪ Allows for calculation of both design storms and observed storm events.<br>  ▪ Alligns to existing models.<br>  ▪ Disadvantages:<br>  ▪ Not recommended for catchments < 10 km2.<br>  ▪ Not recommended when catchment sizes differ by a few orders of magnitude.<br>  ▪ Assumes peak discharge is only correlated to catchment size.<br>  ▪ Does not account for volume differences across different storm durations.<br>  ▪ Slope is not accounted for, and due to Ngongotahā Stream's catchment having the gentlest slope of the upper catchments, the method will likely underestimate the peak discharge of the nearby steeper catchments. |
| Digital Elevation Model (DEM) | • DEM was derived from the 2019-2022 LiDAR with 1m resolution. The model was initially built with merged 2018 LiDAR and 2011 LiDAR and later replaced with the 2019-2022 LiDAR when it was available. Design runs were completed with the 2019-2022 LiDAR.<br>• A Quadtree mesh (nesting of the grid cell) has been configured to allow higher resolution of grid cell size over the focused areas and lower resolution in topographically or hydraulically simple locations (Figure 3-2).<br>• TUFLOW's Sub-grid Sampling (SGS) approach (using multiple points for grid cell elevations in a single cell) has been applied for more accurate representation of the topography (such as open channel, small drainage ditch and etc) and hydraulic conveyance.<br>• The largest cell size is 8 x 8 m, refined to 4 x 4 m in main channels, and down to 2 x 2 m in the urban area.<br>• Surveyed cross sections used in the PDP/BOPRC hydraulic river models of Waiteti and Ngongotahā Streams that are integrated into the model DEM.<br>• Building layouts are considered in the DEM by being elevated 100mm.<br>• Refer to Figure 3-1. for the DEM used for TUFLOW model. |
| 2D open channels | • 2D channels form part of the rain on grid 2D DEM. |



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| COMPONENT | DETAILS |
|---|---|
| Stormwater network | • Stormwater network is included as a 1D coupled comment. It was not explicitly included in the interim rapid flood hazard assessment outlined in Appendix A.<br>• Flows conveyed by large culverts (≥ 900 mm diameter) have been represented by lowering the mesh elevations (i.e. digging out crossings). |
| Bridges | Major bridges are not included in the model as survey information was not supplied. For the extreme events (such as 1% AEP and 0.2% AEP events), the bridge did not overtop as the flows exited the rightbank before the bridge and overtopped the road to the downstream (see below figure).<br> |
| Hydrological losses | • Infiltration losses have been applied to the model via initial losses and continuing losses in the 2D model component.<br>• Soil classification has been utilised to define the extent of loss parameters.<br>• Parameters were approximated using the Tauranga City Council Stormwater Modelling Guidelines and recent fieldwork undertaken in the Kāpiti Coast District Council area.<br>• Road centre lines were buffered to better represent road extents because the zoning over predicts impervious surfaces. |



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| COMPONENT | DETAILS |
|---|---|

- Losses for different soil types are shown in below table based on Tauranga City Modelling Guidelines. Refer to Figure 2-2. for soil types over the Ngongotahā catchment.

| Soil ID | Soil type | Initial loss (mm) | Continuous loss (mm/hour) |
|---|---|---|---|
| 1 | Fine sandy loam (low compaction) | 0 | 20 |
| 3 | Loam (low compaction) | 0 | 13 |
| 4 | Loamy sand (low compaction) | 0 | 61 |
| 5 | Peaty loam (low compaction) | 0 | 7 |
| 6 | Sand (low compaction) | 0 | 210 |
| 7 | Sandy loam (low compaction) | 0 | 26 |
| 9 | Loam (urban compaction) | 0 | 3.9 |
| 10 | Peaty loam (urban compaction) | 0 | 10.5 |
| 11 | Sand (urban compaction) | 0 | 63 |
| 12 | Sandy loam (urban compaction) | 0 | 7.8 |
| 13 | Fine sandy loam (agriculture compaction) | 0 | 6 |
| 15 | Loam (agriculture compaction) | 0 | 3.9 |
| 16 | Loamy sand (agriculture compaction) | 0 | 18.3 |
| 17 | Peaty loam (agriculture compaction) | 0 | 2.1 |
| 18 | Sand (agriculture compaction) | 0 | 63 |
| 19 | Sandy loam (agriculture compaction) | 0 | 7.8 |

- TUFLOW uses soil classifications (Figure 2-2) and land cover (Figure 2-3) to make decisions on imperviousness and infiltrations. For instance, roads, buildings and other impervious areas are treated as imperviousness.



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<table>
<tr><th>COMPONENT</th><th>DETAILS</th></tr>
<tr><td>Hydraulic Roughness</td><td>
<ul>
<li>Roughness coefficients have been applied to the model based on a combination of land use and land cover in Figure 2-3.</li>
<li>Zoning layer shapefiles have been utilised to define the extent of roughness parameters.</li>
<li>Road centre lines were buffered to better represent road extents.</li>
<li>Parameters were approximated using the Tauranga City Council Stormwater Modelling Guideline and Wellington Water’s Modelling specifications. Ngongotahā and Waiteti Stream values were provided by PDP from their models that are under development to maintain consistency. The model contains the explicit values used and below is a summary.</li>
</ul>
<table>
<tr><th>Classification</th><th>Mannings's n values</th></tr>
<tr><td>Residential</td><td>0.04 - 0.067</td></tr>
<tr><td>Commercial</td><td>0.016</td></tr>
<tr><td>Industrial</td><td>0.1</td></tr>
<tr><td>Crown</td><td>0.04</td></tr>
<tr><td>Road and driveway</td><td>0.014 - 0.016</td></tr>
<tr><td>Road buffer</td><td>0.025-0.1</td></tr>
<tr><td>Water buffer</td><td>0.1</td></tr>
<tr><td>Water</td><td>0.02</td></tr>
<tr><td>Building</td><td>0.02</td></tr>
<tr><td>Rural</td><td>0.04-0.05</td></tr>
<tr><td>Vegetation</td><td>0.1</td></tr>
<tr><td>Reserve</td><td>0.04</td></tr>
<tr><td>Roads</td><td>0.016</td></tr>
<tr><td>Trees</td><td>0.15</td></tr>
<tr><td>Scrub</td><td>0.15</td></tr>
<tr><td>Low density scrub</td><td>0.07</td></tr>
<tr><td>Ngongotahā stream</td><td>0.03-0.18</td></tr>
<tr><td>Waiteti stream</td><td>0.03-0.1</td></tr>
</table>
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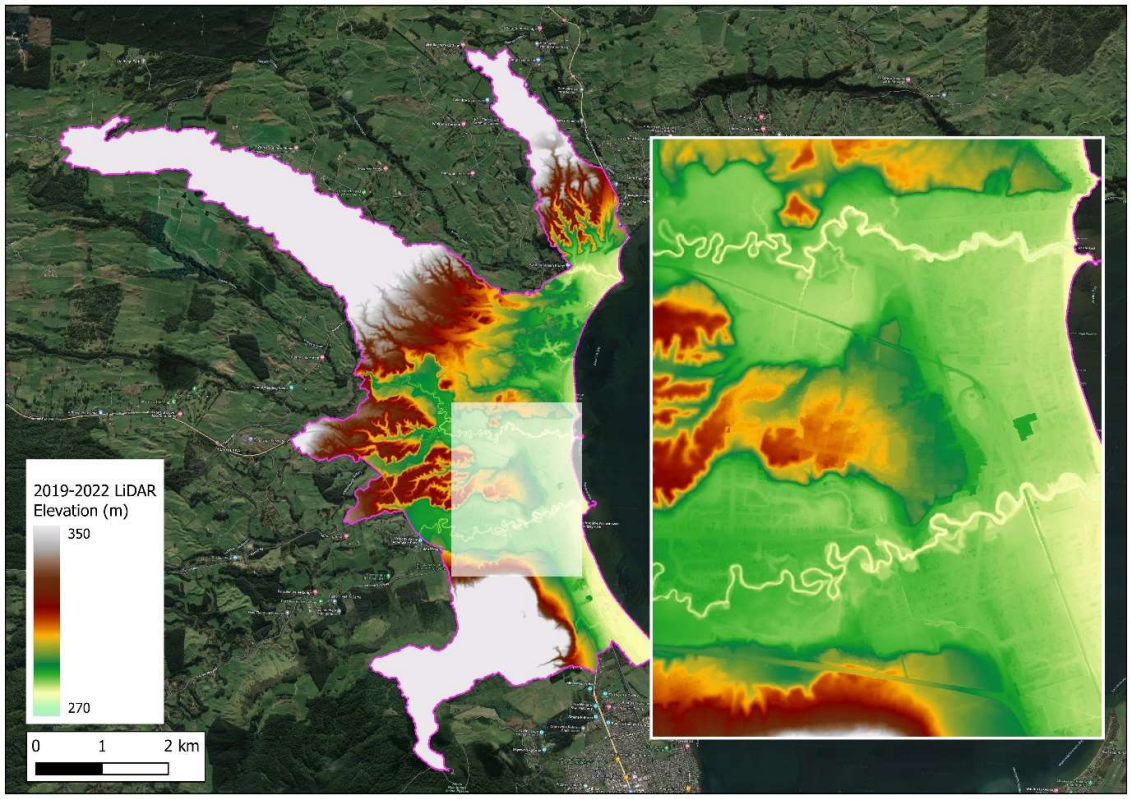



*Figure 3-1. Digital Elevation Model (DEM) for TUFLOW flood extent.*




*Figure 3-2. Zones of different mesh resolution to be used by TUFLOW Quadtree (nesting level).*



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## 3.4. BOUNDARY CONDITIONS

The different boundary conditions for the model are defined in the table below.

<table>
<tr><th>BOUNDARY</th><th>DETAILS</th></tr>
<tr><td>Rainfall for design events</td><td>
<ul>
<li>Rainfall depths have been sourced from HIRDS v4 as 2 x 2 km grids.</li>
<li>A 48-hour nested rainfall profile, peaking at 75% has been applied to the model extent as required by draft BOPRC Hydraulic Modelling Guidelines.</li>
<li>Current climate considers the 2020 year with 0.3° C temperature rise from the HIRDS historical data (1986-2005).</li>
<li>Climate change considers the 2130 year with 3.68° C temperature rise from the HIRDS historical data (1986-2005) under the Representative Concentration Pathway (RCP 8.5). This includes the hydrological discharge estimates for upper catchment as well as rainfalls applied in the 2D domain.</li>
<li>Percentage augmentation factors per 1° C from NIWA HIRDs were used to adjust rainfall for future climates.</li>
</ul>
</td></tr>
<tr><td>Rainfall for model validation</td><td>
<ul>
<li>Rainfall event during 28 April to 1 May 2018 was used to validate the flood modelling. Recorded rainfalls from observed stations from the BOPRC Environmental Data Portal were used as inputs for flood modelling. Figure 2-1 shows locations of the observed stations used.</li>
</ul>
</td></tr>
<tr><td>Inflows</td><td>
<ul>
<li>Inflows from the upper catchments are discharged into the 2D model. Refer to Figure 2-1 for upper catchment extents and inflow locations.</li>
<li>Only the Ngongotahā stream’s catchment has flow gauging recorded. Inflows have been calculated for all other upper catchments using the area transposition method outlined in Section 3.1.</li>
<li>Observed hydrograph from Ngongotahā Stream’s 1996 storm event was used to inform the hydrograph shape of the design events. This aligns with BOPRC (2007) approach.</li>
<li>For other ungauged upper catchments (Tapapakura, Waiteti and Awahou catchments – refer to Figure 2-1), peak flow for the Ngongotahā catchment is scaled proportionally for each ungauged catchment based on the area and time of concentration.</li>
<li>Ngongotahā current and future design peak flows were obtained from the hydraulic modelling of the Ngongotahā Stream (via BOPRC, March 2022). Inflows of the modelled streams for current climate and climate change (2130 RCP8.5) are shown below.</li>
</ul>
<table>
<tr><th rowspan="2">ARI event (year)</th><th colspan="2">Ngongotahā</th><th colspan="2">Waitetī</th><th colspan="2">Tupapakura</th><th colspan="2">Awahou</th></tr>
<tr><th>Current climate (m³/s)</th><th>Climate change – 2130 (m³/s)</th><th>Current climate (m³/s)</th><th>Climate change – 2130 (m³/s)</th><th>Current climate (m³/s)</th><th>Climate change – 2130 (m³/s)</th><th>Current climate (m³/s)</th><th>Climate change – 2130 (m³/s)</th></tr>
<tr><td>2</td><td>23</td><td>31</td><td>12</td><td>17</td><td>9</td><td>12</td><td>7</td><td>10</td></tr>
<tr><td>10</td><td>44</td><td>61</td><td>24</td><td>34</td><td>17</td><td>24</td><td>13</td><td>19</td></tr>
<tr><td>20</td><td>52</td><td>73</td><td>28</td><td>41</td><td>20</td><td>28</td><td>16</td><td>23</td></tr>
<tr><td>100</td><td>74</td><td>105</td><td>40</td><td>58</td><td>28</td><td>41</td><td>22</td><td>33</td></tr>
<tr><td>200</td><td>84</td><td>119</td><td>46</td><td>66</td><td>32</td><td>46</td><td>25</td><td>37</td></tr>
<tr><td>500</td><td>99</td><td>141</td><td>54</td><td>79</td><td>37</td><td>55</td><td>30</td><td>44</td></tr>
</table>
</td></tr>
</table>



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<table>
<tr><th>BOUNDARY</th><th>DETAILS</th></tr>
<tr><td>Lake Levels</td><td>
<ul>
<li>The extent of the lake level boundary is presented in Figure 2-1.</li>
<li>Design lake levels under different ARI events are obtained from the ‘Rotorua Lakes Design Levels Technical Report (BOPRC, July 2022).</li>
</ul>
<table>
<tr><th>ARI event (year)</th><th>Rotorua Lake level (Moturiki 1953) – General Extreme Value (GEV) distribution</th></tr>
<tr><td>2</td><td>280.09 m</td></tr>
<tr><td>2.33</td><td>280.12 m</td></tr>
<tr><td>5</td><td>280.21 m</td></tr>
<tr><td>10</td><td>280.28 m</td></tr>
<tr><td>20</td><td>280.35 m</td></tr>
<tr><td>50</td><td>280.43 m</td></tr>
<tr><td>100</td><td>280.48 m</td></tr>
<tr><td>200</td><td>280.53 m</td></tr>
<tr><td>500</td><td>280.60 m</td></tr>
</table>
<ul>
<li>No adjustment for climate has been applied to the lake level as it is not expected to increase significantly based on recommendation in the ‘Rotorua Lakes Design Levels Technical Report.</li>
<li>Lake level from the Rotorua station during 28 Apr – 1 May 2018 was applied to the downstream boundary for model validation run.</li>
</ul>
</td></tr>
</table>

## 3.5. KNOWN LIMITATIONS AND CONSTRAINTS

The table below includes a range of issues that should be considered when using the model or interpreting any outputs.

| LIMITATION / CONSTRAINT | DETAILS |
|---|---|
| DEM | • The 2019-2022 LiDAR has a vertical accuracy of +/-0.2 m and horizontal accuracy of +/-1.0 m.<br>• The LiDAR with NZVD 2016 vertical datum has been converted to Moturiki 1953 using a LINZ supplied gridded correction surface and no local ground truthing.<br>• The raw LiDAR data was processed and aggregated into 1 x 1 m bins by the survey provider. |
| Overland Flow | • Fine features that may influence the direction of flow have not been resolved in the model, such as kerbs, fences and walls. |
| Stream flows | • The upstream reaches of the open channels have not been refined with cross-section data and so errors in the LiDAR surface will impair the model’s conveyance estimates. |



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| LIMITATION / CONSTRAINT | DETAILS |
|---|---|
| Stormwater Network | • Cuts into the 2D grid were to represent the culvert will not accurately represent inlet losses and the flood depth results and flood extents in the vicinity of these area may have limitations.<br>• No pipe network conveying flows directly into the lake or across the catchment has been included.<br>• Streetview has a new scruffy dome at the SH5 and SH26 intersection but this was not in the supplied network data. |
| Hydrology | • The supplied zoning layer is not sufficiently resolved to accurately represent the spatial variability of the 2D surface initial and continuous losses across the catchment. Conservatively low estimates of loss have been applied.<br>• The area-transposition method used to estimate inflows from the upper catchments has only been approximately verified.<br>• The climate change adjustment was based on the change factor per 1° increase defined in HIRDS v4. |
| Lake level | • No assessment of gradients across the lake have been incorporated into the lake boundary level. |
| Validation | • The only long-term river stage data available is on the Ngongotahā River, located at the upstream model boundary (Figure 2-1). This means no validation comparing April 2018 modelled hydrograph to measured hydrograph was possible. |
| Model applications | • The model can be used for growth planning, hazard identification, catchment planning and concept level engineering design. The resolution and quality of the source data and boundary conditions are fundamental drives of flooding at property scale.<br>• When using the model outputs for setting of building floor levels some consideration should be made including:<br>  • the assessment should be completed by a quality expert<br>  • multiple modelled scenario levels should be considered (rain / tide / 10yr / 100 yr / current climate / future climate) to understand flood behaviour and level sensitivity<br>  • the assessment should draw on a range of information such as recent survey DEM, public network data, aerial photography, analysis of structures such as fences, walls and recent development around the site. |

## 3.6. ASSUMPTIONS



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The table below includes a range of assumptions that were made during the study that should be considered when using the model or interpreting any outputs.

| TYPE | ASSUMPTION |
|---|---|
| Overland Flow | • LiDAR is suitable for use in the hydraulic model and the merging of the 2011 and 2018 datasets will not cause unreasonable results around the merged areas.<br>• Zoning layer is suitable to represent the spatial variability of the roughness in the 2D extent. |
| Data | • Data received is accurate and appropriate for use in the model. |
| Stream flow | • The supplied DEMs are representing the channels beds are fit for purpose. |
| Stormwater network | • The supplied network is complete and accurate.<br>• No changes to the network occur in climate change scenarios. |
| Hydrology | • The supplied zoning layer is suitable to represent the spatial variability of the 2D surface initial and continuous losses.<br>• Hydrological losses estimates are sufficiently low to account for uncertainties in the model parameterisation.<br>• The area-transposition method used is suitable for estimating inflows from the upper catchments. |
| Model validation | • Model validated successfully against the April 2018 flood event.<br>• The validation event characteristics are suitable to represent the design events simulated. |
| Structures | • Bridges do not overtop and inclusion in the model has minimal impacts on results. |



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# 4. MODEL VERIFICATION AND DISCUSSION

## 4.1. VALIDATION

A validation event has been simulated to understand suitability of Ngongotahā flood model build to represent large flood events. This event was the historic flood between 28 April – 1 May 2018 and Figure 4-1. shows recorded rainfalls from the BOPRC stations during the event. These observed rainfalls were used to form validation model boundary conditions.

Model validation was carried out by comparison between the modelled predictions and actual observations of the event in the field (approximate depths, water levels and affected properties) including simulated flood extent and flood depths of the April 2018 event from the hydraulic model of BoPRC.

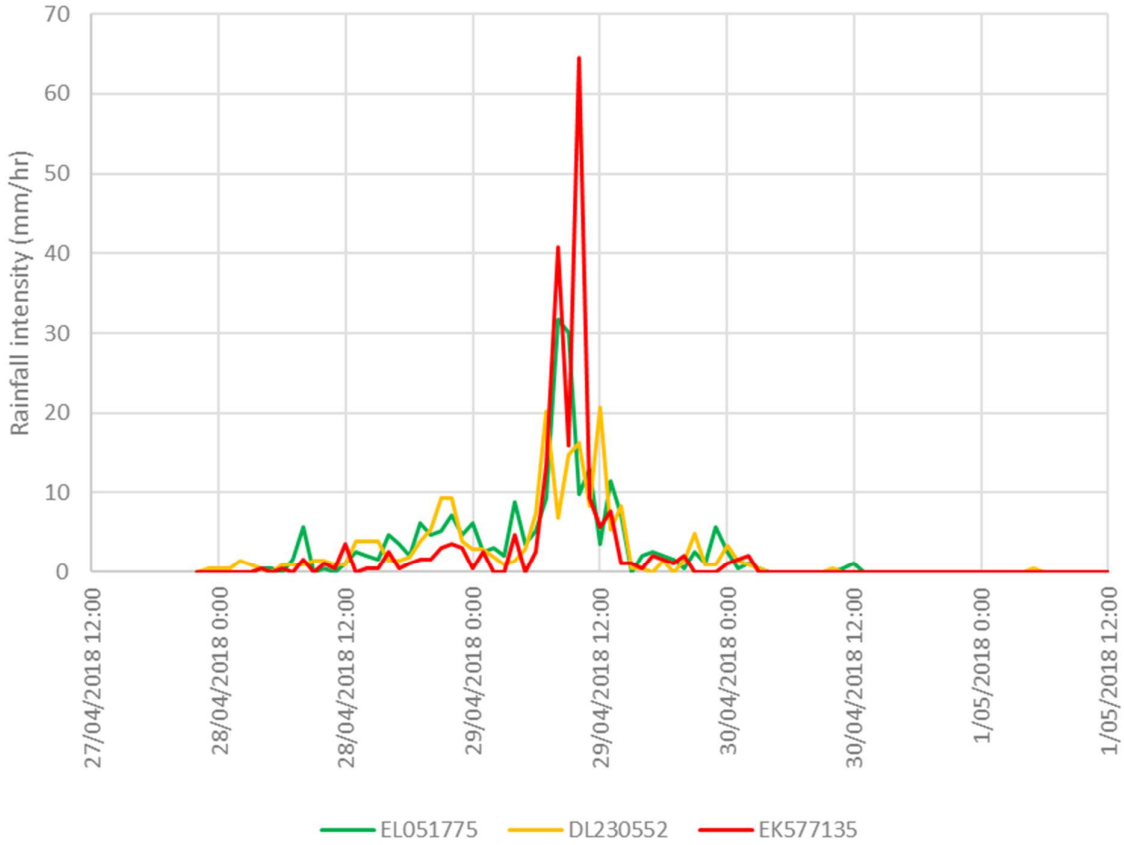



*Figure 4-1. Recorded rainfalls from BOPRC stations during the 2018 flood event.*

Simulated results of the flood extent show good agreement with the properties identified as impacted by the event. Figure 4-2 shows a supplied map image with blue and red dots showing impacted properties. The blue dots are called “affected”, which we assume to be that the property had flood waters on the site. The red dots are classed as unsanitary / needing repairs, and assumed to have flood waters in buildings. Generally speaking, the red and blue dots are within the modelled flood extent.



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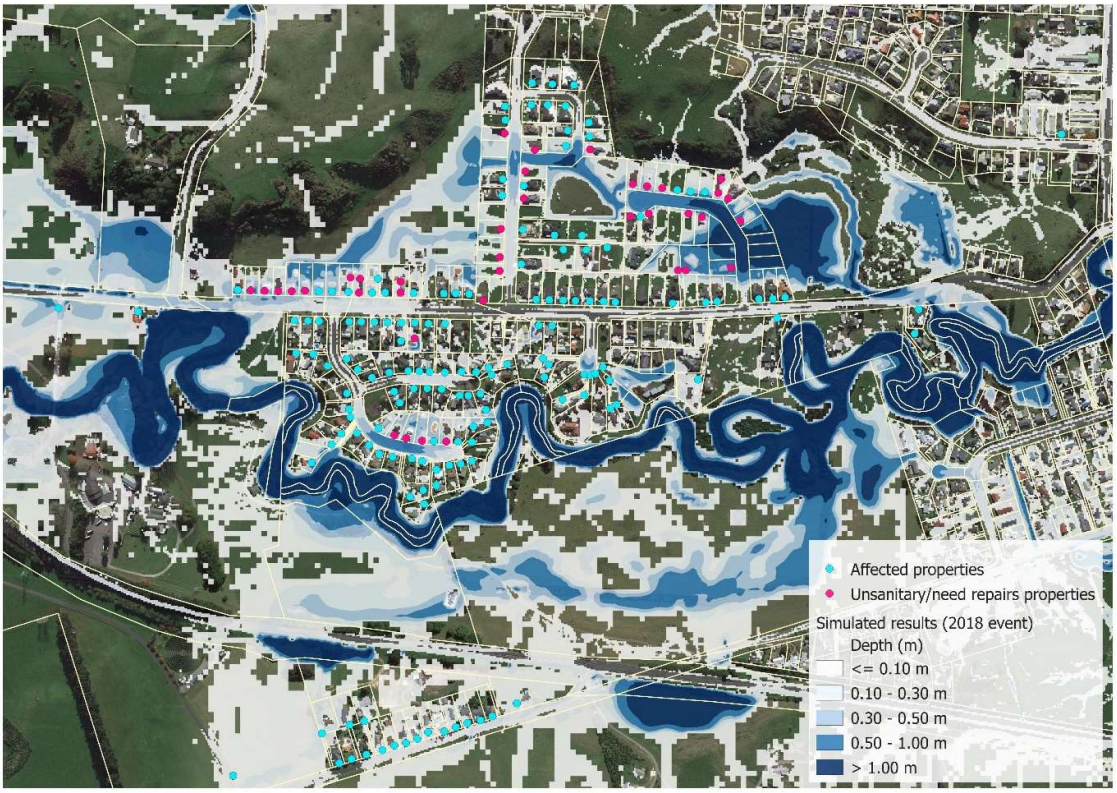



*Figure 4-2. Comparison of the simulated 2018 flood depths by Awa with alignment between modelled flood extent and flood buildings (red dots). General alignment with flood waters on affected properties (blue dots).*

Key modelled overland flowpaths from a map supplied by BOPRC were validated as shown in Figure 4-3. Generally the flowpaths match, with the new model having a slightly wider extent in places where water depths are 0.10-0.30 m. It is not known what minimum depth criteria was used in the BOPRC map, however 0.10 m is common practice.



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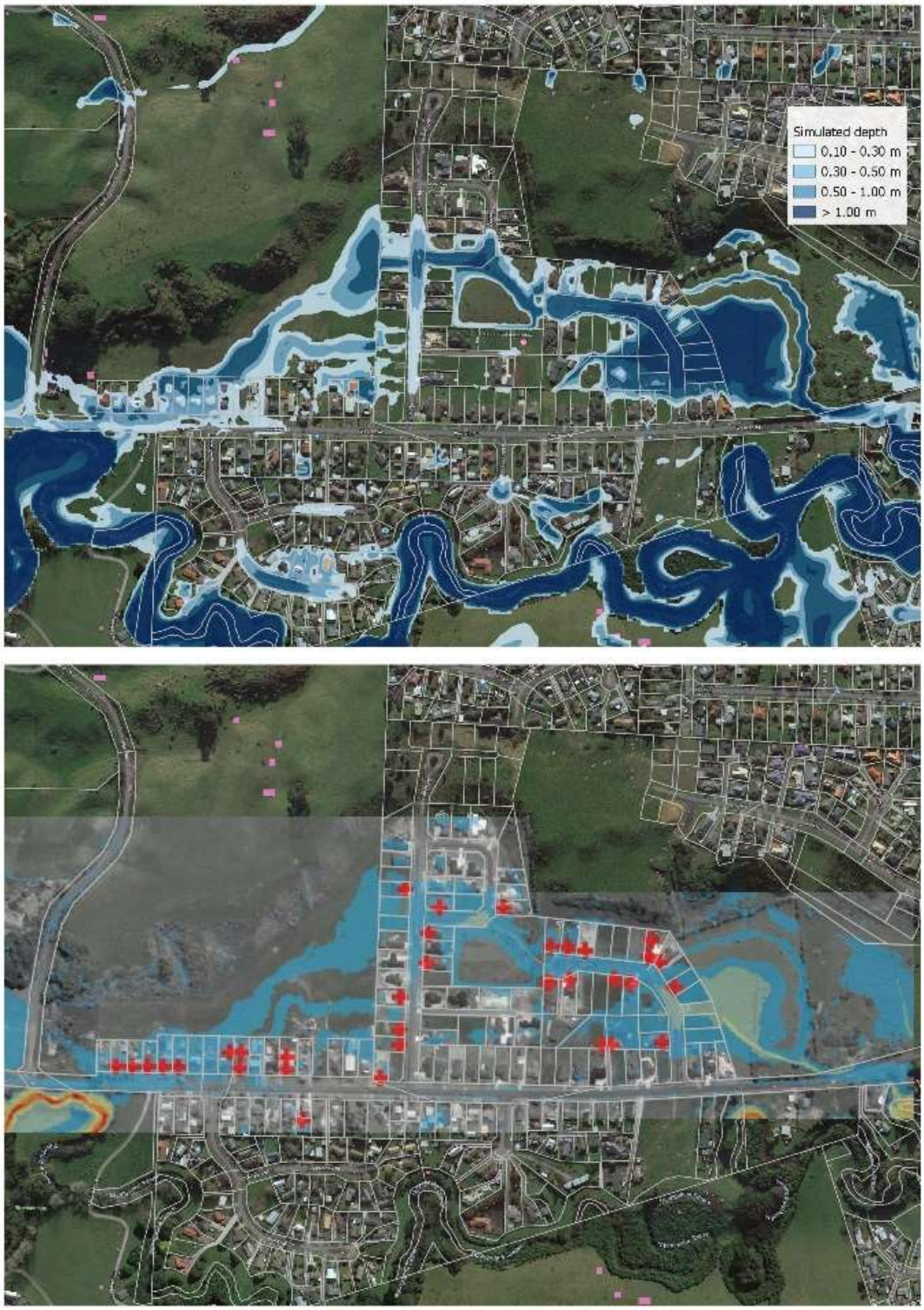



*Figure 4-3. Simulated flood depth during 29 April 2018 by Awa model (left) and approximate overland flow path from BOPRC (right) during the same event.*

A site visit was conducted on 13 December 2023 to confirm locations and conditions of culverts and stormwater assets in some areas, as well as to understand the landscape and major flow paths. The visit found that some culverts along the SH5 are not situated in the same locations as shown in the



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Waka Kotahi stormwater asset database. The locations of those culverts were adjusted according to the actual situations to improve accuracy of asset location.

It was observed using the site visit that some culverts and pits are blocked by debris, leaves and sediment but this is not accounted for in the model. Typically, a blocked scenario test as a sensitivity analysis is completed to understand the impacts but this has not been done.

Also during the site visit, key areas where the model predicted flooding were visited to assess the reasonableness of the flood prediction in context of the landscape. The locations visited indicated that the flooding predictions and visited flow paths were reasonable.

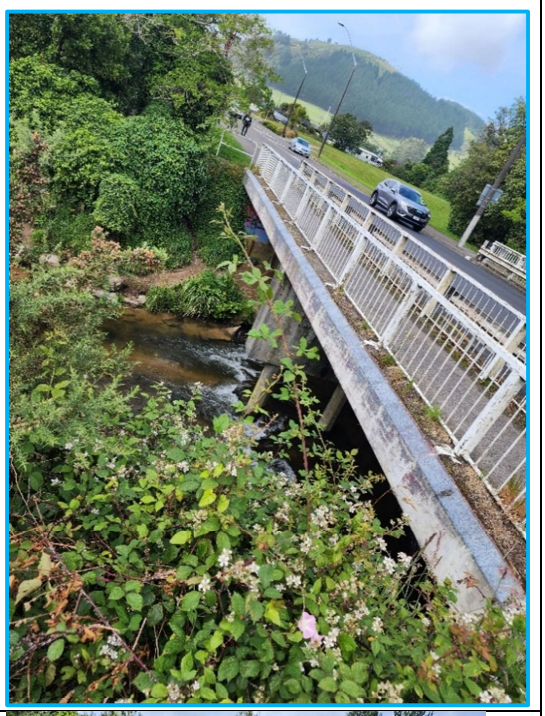
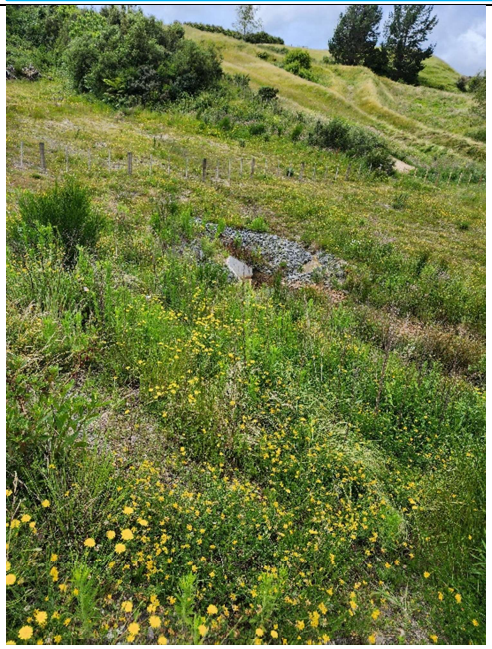
Some example locations of interest visited are outlined and compared to the model in Table 4-1.

*Table 4-1. Comparison of model results and detail to site visit observations.*

| MODEL | SITE VISIT |
|---|---|
| Flooding around Munro Place and Munro Place Reserve (1% AEP rainfall event). The Munro Place Reserve accessway is operating as an overland flow path.  |   |



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| | |
|---|---|
| Flooding around the Ngongotahā Stream at Ngongotahā Rd. As previously discussed, the bridge is not predicted to overtop during 1 % AEP storm (2130).<br> |  |
| An error in the location of the Waka Kotahi culvert data was observed near the intersection of Dansey Rd and SH5. The location in the model was updated based on site observation and estimated as below.<br> |  |



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## 4.2. SENSITIVITY TESTS

Two sensitivity tests were completed to understand if the model changed based on:

1. infiltration rate; and
2. updating the DEM from 2011-2018 LiDAR to 2019-2022 LiDAR.

For infiltration rate tests, rates were increased and decreased by 20 percentage to see the impacts on flood depths. The flood depths where then compared and changes in flood depths investigated. For the 2018 event, which is approximately equivalent to 1% AEP rainfall event, we found that increasing and decreasing infiltration rates for all soil types has insignificant impacts on the maximum flood depths. When increasing infiltration, the impact of results is not significant (Figure 4-4.). When decreasing infiltration, the areas that change from dry to wet are localised around river channels where development is less likely to occur (Figure 4-5).

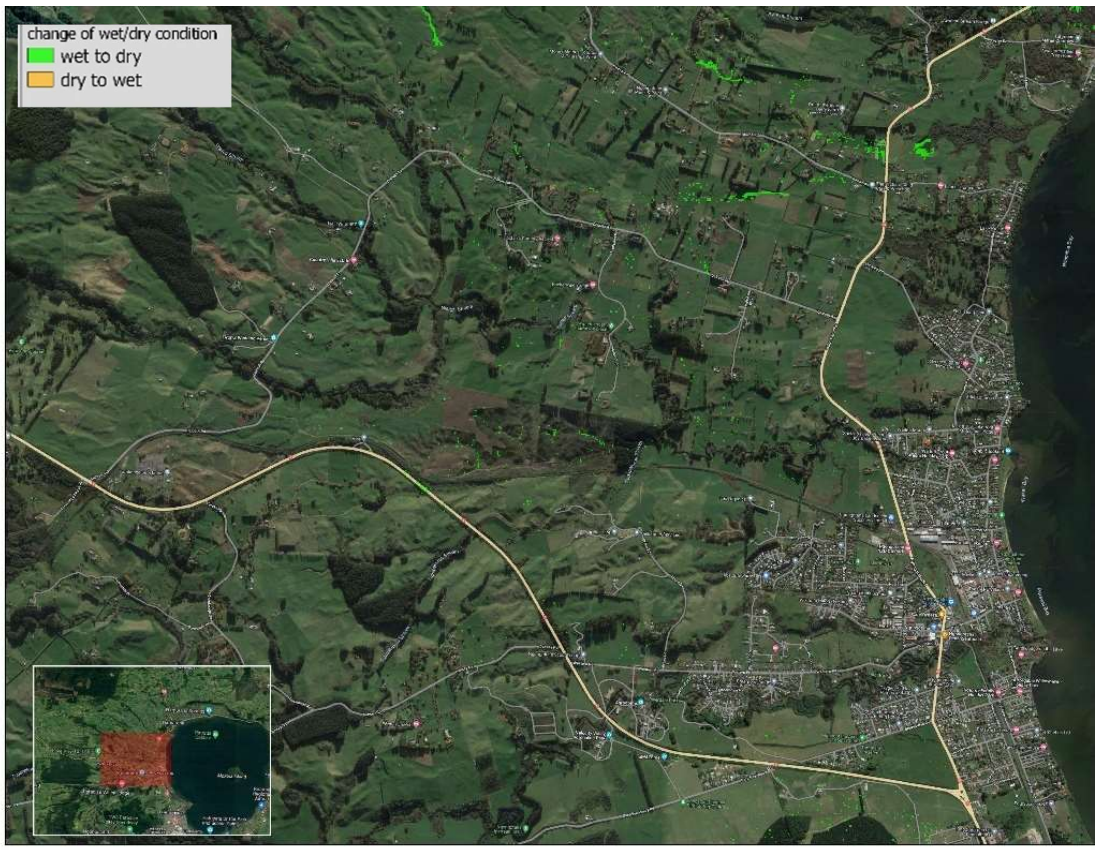



*Figure 4-4. Impact of changing of dry/wet conditions was not significant. This example increased infiltration rate by 20% for the 2018 flood event.*



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*Figure 4-5 Impact of changing of dry/wet conditions was not significant. This example decreased infiltration rate by 20% for the 2018 flood event.*

A similar approach was used to test the impacts of simulated flood depths from changes to the DEM. The model was run with a 1% AEP climate change event and at a high level, the difference modelling results is driven by differences in the DEM. The larger differences are focused on slopes, trees and grasslands, which isn't uncommon between LiDAR datasets. There are some locations around some building that have some differences, but this could be explained by activities like building decks / earth works. Based on the assessment, the datasets are very close and it is concluded that the 2019-2022 LiDAR can be used for the final design runs and flood mapping. Difference in flood depth (new DEM minus old DEM) is presented in Figure 4-6..



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*Figure 4-6. Difference in flood depth (2019-2022 LiDAR minus 2011-2018 LiDAR) under the 1 % AEP rainfall event and 20 %AEP lake level with climate change (2130).*



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# 5. FLOOD MAPPING

## 5.1. SCENARIOS

A number of design event scenarios have been completed with sub-scenarios relating to the combination of rainfall and lake level events. The sub-scenarios are useful because the enveloped maximum of these represent a combined view of either sub-scenario occurring. The list of design runs completed for both current and future climates are listed below. No freeboard has been included in the model simulations.

| | |
|---|---|
| Design events completed | • 10 % AEP scenario<br>  • 10 % AEP rainfall and 50 % AEP lake level – current climate (2020)<br>  • 50 % AEP rainfall and 10 % AEP lake level – current climate (2020)<br>  • 10 % AEP rainfall and 50 % AEP lake level – climate change (2130, RCP8.5)<br>  • 50 % AEP rainfall and 10 % AEP lake level – climate change (2130, RCP8.5)<br>• 1 % Annual Exceedance Percentage (AEP) scenario<br>  • 1% AEP rainfall and 5 % AEP lake level – current climate (2020)<br>  • 5% AEP rainfall and 1 % AEP lake level – current climate (2020)<br>  • 1% AEP rainfall and 5 % AEP lake level – climate change (2130, RCP8.5)<br>  • 5% AEP rainfall and 1 % AEP lake level – climate change (2130, RCP8.5)<br>• 0.2 % AEP scenario<br>  • 0.2 % AEP rainfall and 0.5 % AEP lake level – current climate (2020)<br>  • 0.5 % AEP rainfall and 0.2 % AEP lake level – current climate (2020)<br>  • 0.2 % AEP rainfall and 0.5 % AEP lake level – climate change (2130, RCP8.5)<br>  • 0.5 % AEP rainfall and 0.2 % AEP lake level – climate change (2130, RCP8.5) |

## 5.2. FLOOD MAPS PRODUCED

Flood models are rich with information showing the propagation of flooding a time steps throughout an event, producing flood depths, levels, velocities and other parameters. This detailed information however is difficult to report in a general sense unless a particular study question is required to be answered. For the benefit of providing useable output, a range of common outputs have been produced as GIS raster layers. Each scenario (e.g. 1% climate change AEP) is enveloped to map the maximum of each sub-scenario (e.g. rain vs lake level dominant) resulting in GIS raster layers representing the peak for each scenario and climate (i.e. 10 %, 1 % and 0.2 % for 2020 and 2130).

These GIS rasters have been generated:

- maximum flood depth;
- flood surface level;
- flood hazard; and
- the sub-scenario source for the maximum depth.

In Appendix B, C and D the following summary maps representing enveloped scenarios are provided:

- maximum flood depth;
- flood hazard; and



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- the sub-scenario source for the maximum depth.

Flood hazard in this study is based on the Australian Institute for Disaster Resilience (2017) and is quantified by depth and velocity as shown in Figure 5-1. These maps are used to inform growth planning, stormwater management and emergency responses.

The sub-scenarios source that caused the maximum flood depth for each scenario is useful to understand the predominance of rainfall and lake level on the maximum flooding conditions for each scenario.

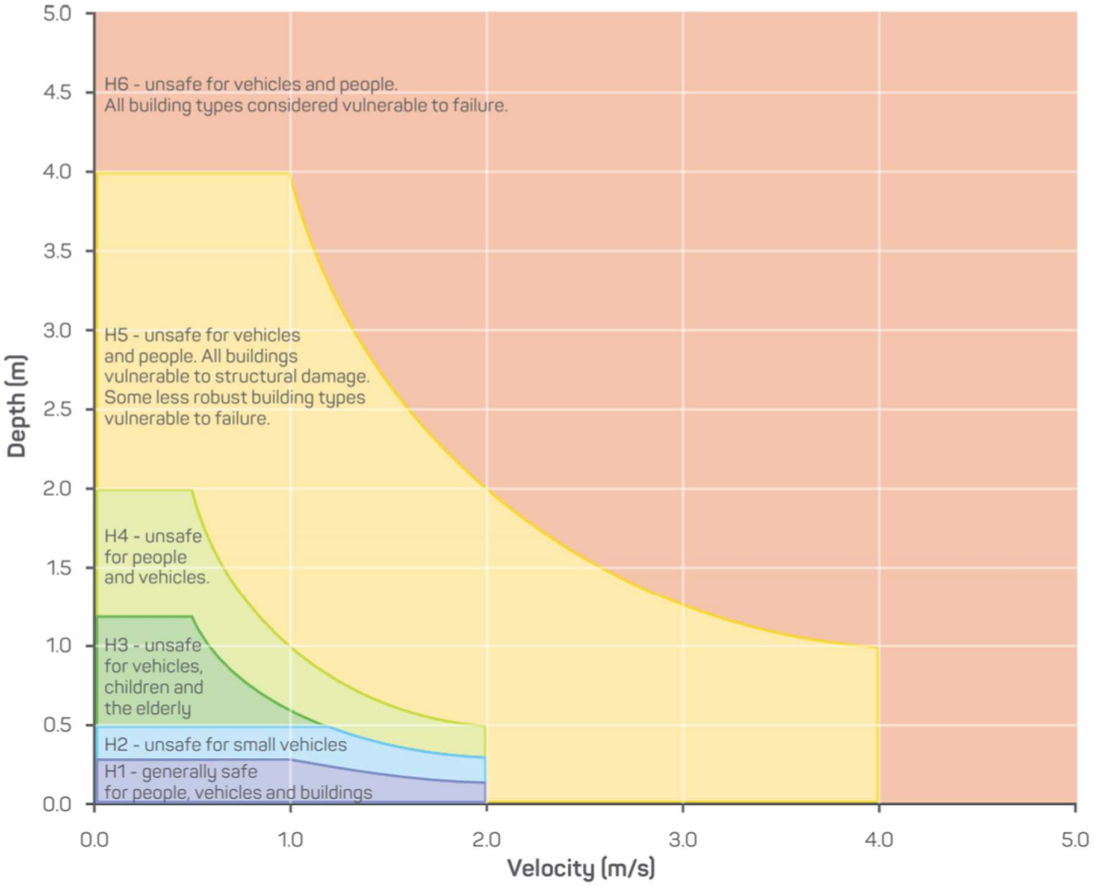



*Figure 5-1 Flood hazard classification by the Australian Disaster Resilience Handbook Collection*



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# 6. CONCLUSIONS

A TUFLOW HPC model has been created using:

- hydrological approaches consistent with recent BOPRC modelling in the area;
- 2019-2022 LiDAR based DEM;
- RLC's stormwater asset data;
- an approach to account for the impact of building food prints on flooding;
- BOPRC measured rainfall and flow;
- BOPRC channel detail from existing models of Ngongotahā and Waiteti Steams;
- BOPRC provided design flows and NIWA HIRDs design rainfall; and
- BOPRC measured and design lake levels.

The TUFLOW software provide a stable and well validated methodology for flood mapping and the model produced in this study can be considered robust to support growth planning, hazard identification, catchment planning and concept level engineering design.

While the modelling software and approach are best practice, the quality of source data and boundary conditions are always a limitation for a model. As a part of improving the model over time, a number of recommendations for improvement of the model are listed below;

- use of more sophisticated upper catchment hydrological methods;
- validation against a 10 % AEP event;
- validation against measured discharges in the lower Ngongotahā and Waiteti Streams;
- additional investigation into flood incident reporting for events outside of April 2018;
- survey of secondary channels and flow paths in areas of interest;
- incorporation of bridges;
- stormwater asset survey in the areas when doing detailed engineering design;
- convergence testing of different model resolutions to improve model run time;
- use the model results along with other information to assess building floor level, in order to identify analysis steps and areas of uncertainty in the model that can be improved.
- additional sensitivity analysis such as network blockage scenarios and impact of antecedent moisture conditions; and
- identification of any areas where groundwater may impact flood predictions.



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# 7. REFERENCES

Australian Institute for Disaster Resilience, 2017. *Australian Disaster Resilience Handbook Collection: Flood Hazard*. Guideline 7-3, Supporting document for the implementation of Australian, 30p.

Bay of Plenty Regional Council, 2022. Rotorua Lakes Design Levels Technical Report 2022, Operations Publication 2022/03, July 2022, 29.

Bay of Plenty Regional Council, 2007. *Hydraulic Modelling of the Ngongotahā Stream Addendum I – Newly Available Aerial Survey Information.* Bay of Plenty Regional Council Report File Ref 200 04 52 27 April 2007,

Rotorua Lakes Council, 2022. *Request for Expressions of Interest for Contract 22/027: Ngongotahā Flood Model.* Procurement documentation, 21p.

Standway, J., Flavell, T., van Voorthuysen, R., Christensen, K., 2018. *Independent Review Ngongotahā Flood Event 29 April 2018.* Jointly commissioned by Rotorua Lakes District Council and Bay of Plenty Regional Council. Report dated December 2018, 110p.



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# APPENDIX A – RAPID FLOOD HAZARD ASSESSMENT

This is a memo outlining an initial rapid flood assessment completed during the early phases of the model build process to support growth planning.



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# MEMO

| | | | |
|---|---|---|---|
| **TO:** | Kim Smith | **DATE:** | 28/03/2023 |
| **FROM:** | Amy Waters | **PROJECT NO.:** | J0006247 |
| **COPY:** | Rathika Jebamony; Dr Brad Scarfe; Carl Johnson | | |
| **SUBJECT:** | Ngongotahā Rapid Flood Hazard Assessment (v2.0) | | |

## OVERVIEW

Awa Environmental has been engaged by Rotorua Lakes Council (RLC) to develop a coupled 1D/2D hydraulic stormwater model for the Ngongotahā catchment. A Rapid Flood Hazard Assessment (RFHA) has been prioritised to support associated planning analysis and to develop an understanding of areas potentially prone to flooding.

A RFHA is a quick assessment modelling methodology used to assess flooding where timeframes are short. Rainfall is usually applied directly to a 2D surface and stormwater pipe network and detailed structures are not represented. A RFHA does not give the same level of detail/accuracy as a typical flood model study used in District planning. Therefore, results should be interpreted with caution, guided by experts who understand the limitations and assumptions highlighted in this memo.

## PURPOSE

The focus of the RFHA reported in this memo is to develop a preliminary understanding of the flooding associated with a 1% AEP, 2130 climate, rainfall-dominant scenario. The results from the simulation will be used by RLC for targeting efforts for their Future Development Strategy. A more detailed model to support further planning analysis is currently being prepared separately.

This memo summarises the model build process up to the point of the RFHA.

## MODEL OVERVIEW

Key summary information about the Ngongotahā RFHA model is in Table 1.

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*Table 1. Overview of Ngongotahā RFHA model.*

| | SUMMARY |
|---|---|
| Purpose | • Provide RLC with a high-level understanding of areas prone to areas for interim use before a detailed hydraulic model is completed. |
| Software | • TUFLOW 2020-10-AE |
| Coordinate system | • New Zealand Transverse Mercator 2000 |
| Vertical datum | • Moturiki Vertical Datum 1953 |
| Design events | • 1% Annual Exceedance Percentage (AEP) rainfall with climate change (2130 with a 3.7°C temperature rise) event |

## DATA RECEIVED

The data received or downloaded via online portals is shown in Table 2. This information was utilised in the Ngongotahā RFHA model.

*Table 2. Data sources for data incorporate in the RFHA model.*

| DATA | DETAILS | SOURCE | RECEIVED |
|---|---|---|---|
| 2018 LiDAR | • LiDAR for urban areas in the Bay of Plenty region | • LINZ | • September 2022 |
| 2011 LiDAR | • LiDAR for the whole Bay of Plenty region | • BOPRC FTP site | • July 2019 |
| NZVD-MOT53 Conversion raster | • Conversion raster for New Zealand vertical datum 2016 to Moturiki 1953 | • LINZ | • September 2022 |
| RLC Zoning layer | • Zoning layer for Ngongotahā to approximate land cover | • RLC | • September 2022 |
| Road centre lines | • Road centrelines for the Ngongotahā area | • LINZ | • September 2022 |
| Discharge data | • Ngongotahā stream discharge data | • BOPRC | • November 2022 |
| Drainage Data | • Drainage layer by Waka Kotahi<br>• Kiwirail culverts<br>• RLC SW pipe network | • RLC | • September 2022 |
| Rainfall | • HIRDS v4 | • NIWA | • September 2021 |

# MODEL COMPONENTS

Hydraulic model components are summarized in Table 3 below.

*Table 3. RFHA model components.*

| COMPONENT | DETAILS |
|---|---|
| Overland Flow | • A 2D quadtree mesh has been configured using TUFLOW's Subgrid Sampling (SGS) approach.<br>• The largest cell size is 16 x 16 m, refined to 4 x 4 m in main channels, and down to 2 x 2 m in the urban area.<br>• SGS sampling is at 4 m by default and 1 m (matching the LiDAR data resolution) in both the main channels and the urban area.<br>• The grid cell elevations were sampled from 2018 1 x 1 m LiDAR and the 2011 2 x 2 m LiDAR outside of the 2018 LiDAR extent. This was achieved by merging the 2011 and 2018 dataset, prioritising the 2018 data.<br>• Refer to Figure 1 for the 2D extents. |
| Pipe Network | • Pipe network is not explicitly included in the RFHA.<br>• Flows conveyed by large culverts (≥ 900 mm diameter) have been represented by lowering the mesh elevations (i.e. digging out crossings). |
| Hydrological Losses | • Rainfall losses have been applied to the model via initial losses and continuing losses.<br>• Zoning layer shapefiles have been utilised to define the extent of loss parameters.<br>• Parameters were approximated using the Tauranga City Modelling Specification and recent fieldwork undertaken in the Kāpiti Coast District Council area.<br>• Road centre lines were buffered to better represent road extents because the zoning over predicts impervious surfaces.<br>• Refer to Figure 1 for spatially varying loss categories and Table 4 for losses applied to each category. |
| Hydraulic Roughness | • Roughness has been applied to the model using Manning's n.<br>• Zoning layer shapefiles have been utilised to define the extent of roughness parameters.<br>• Road centre lines were buffered to better represent road extents.<br>• Refer to Figure 1 for spatially varying categories and Table 4 for Manning's n values applied to each category.<br>• Parameters were approximated using the Tauranga City Council's and Wellington Water's Modelling specifications. |


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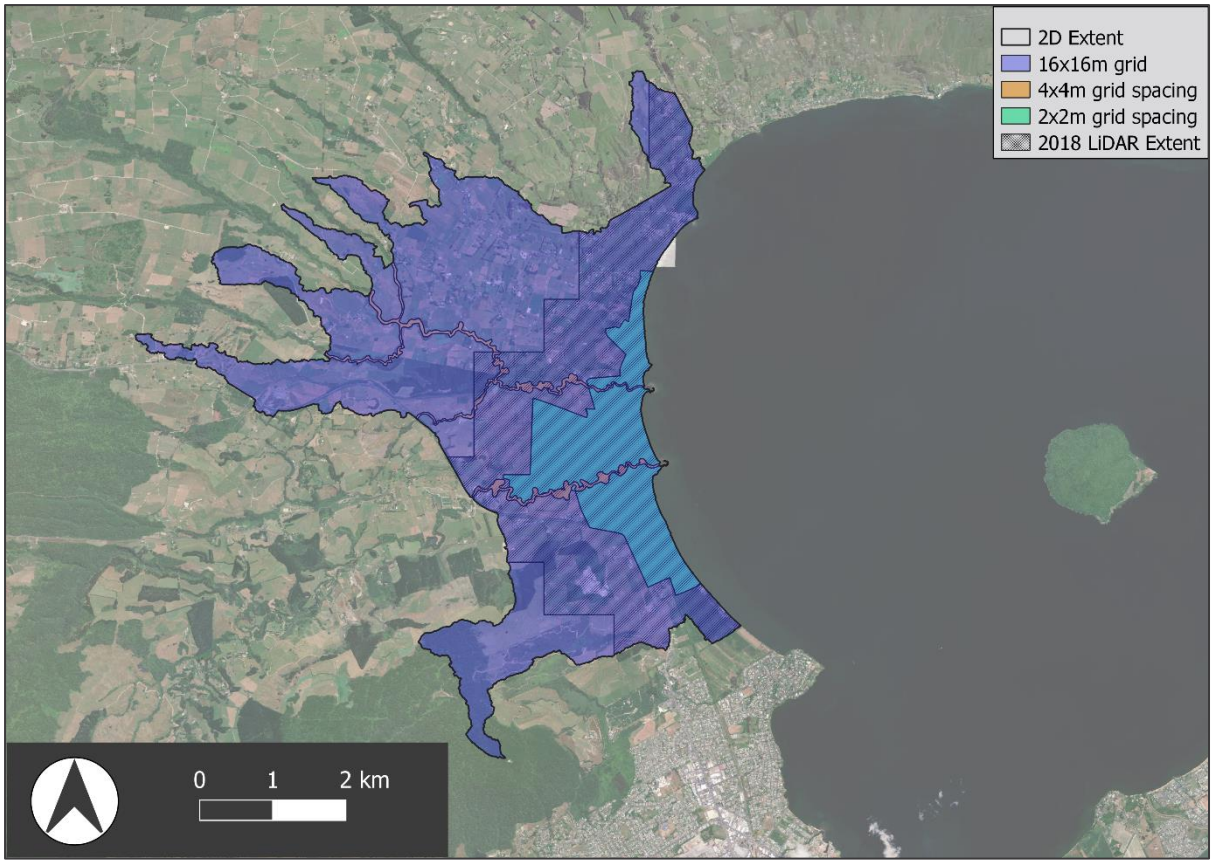



*Figure 1. 2D extent of RFHA, mesh refinement areas, and extent of 2018 LiDAR within the catchment.*

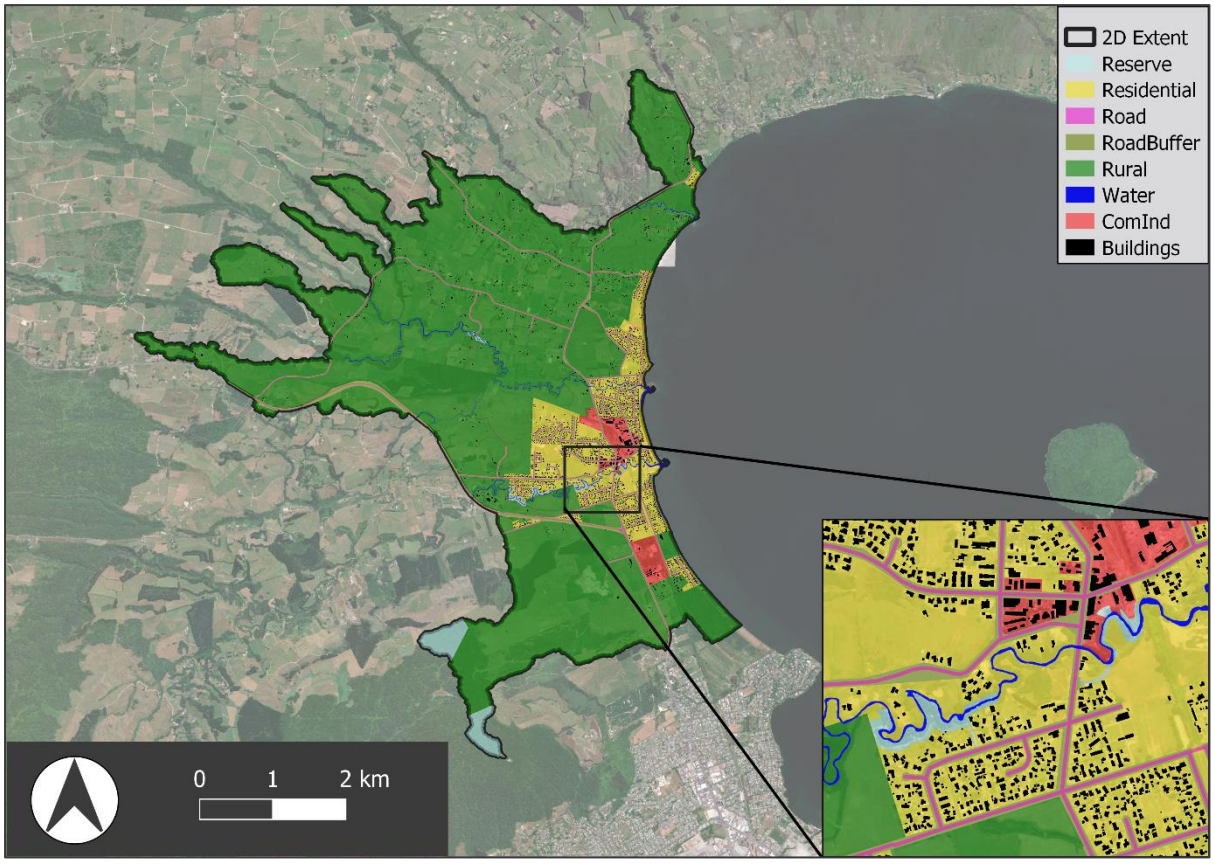



*Figure 2. Land cover categories defined by zoning and roads used to distribute hydrological loss and hydraulic roughness parameters.*



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*Table 4. Hydrological loss and hydraulic roughness parameters applied to the model.*

| CATEGORY | INITIAL LOSS (mm) | CONTINUING LOSS (mm/hr) | MANNING'S N |
|---|---|---|---|
| Buildings | 0 | 0 | 0.02 |
| Reserve | 20 | 400 | 0.2 |
| Rural | 10 | 115 | 0.04 |
| Water | 0 | 0 | 0.029 |
| Residential | 5 | 28 | 0.067 |
| Commercial and Industrial | 5 | 5 | 0.08 |
| Road | 0 | 0 | 0.017 |
| Road Kerb/berm | 5 | 10 | 0.025 |



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# BOUNDARY CONDITIONS

The boundary conditions applied to the RFHA model are summarised in Table 5.

*Table 5. Boundary conditions overview.*

| COMPONENT | DETAILS |
|---|---|
| Rainfall | • Rainfall depths have been sourced from HIRDS v4 2 x 2 km grids.<br>• A 48-hour nested rainfall profile, peaking at 50% has been applied to model extent presented in Figure 1.<br>• The profile varies spatially to align with the HIRDS v4 grid.<br>• The 1% ARI rainfall depths for the current climate have been adjusted for climate change (2130 with a 3.7° C temperature rise) using the augmentation factors provided in the HIRDSv4 report[1].<br>• Refer to Figure 3 for the climate change-adjusted nested profile applied to the model. Note, this will differ slightly for each HIRDS grid cell. |
| Inflows | • Inflows from the upper catchments have been applied to the model. Refer to Figure 4 for upper catchment extents and inflow locations.<br>• Only the Ngongotahā stream's catchment has flow gauging recorded: inflows have been calculated for all other upper catchments.<br>• Time of concentration for each catchment has been calculated using an average of the Ramser-Kirpich, Bransby-Williams, and U.S. Soil Conservation Service methods.<br>• Hydrograph shape was taken from the Ngongotahā Stream's 1996 storm event. This shape aligns with boundary conditions of the Ngongotahā Stream model[2].<br>• Peak Q100 discharge for the upper catchments, other than the Ngongotahā's, was calculated using BOPRC's transposition method[3]. The Ngongotahā Stream's discharge was used as a reference.<br>• Climate change was applied by increasing the peak discharge for each catchment by 65%, this increase was estimated in a small hydrological model. |
| Lake levels | • The 5% AEP design event lake level is applied to the downstream boundary as recommended by BOPRC[3].<br>• The extent of the lake level boundary is presented in Figure 4.<br>• The level was set to 280.36 m MOT53 with no adjustment for climate as it is not expected to increase significantly[4]. |

[1] NIWA (2018) *High-Intensity Rainfall Design System, Version 4.* Report prepared for Envirolink. NIWA report number 2018022CH
[2] BOPRC, 2022. *Hydraulic modelling of the Ngongotahā Stream.*
[3] BOPRC, 2012. *Hydrological and Hydraulic Guidelines* ISSN: 1179 9609.
[4] BOPRC, 2022. *Rotorua Lakes Design Levels Technical Report 2022.*



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Version: 1, Version Date: 08/04/2024

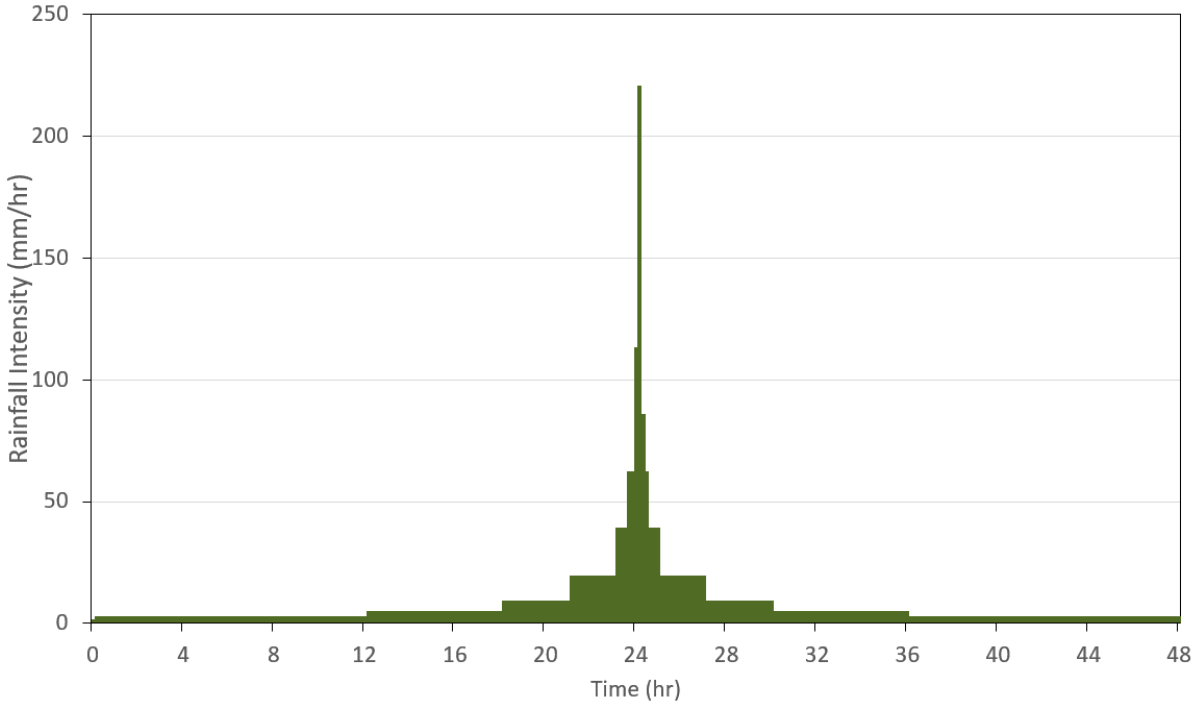



*Figure 3. Nested rainfall profile for 1% AEP, 2130-climate event (a 3.7° C temperature rise).*

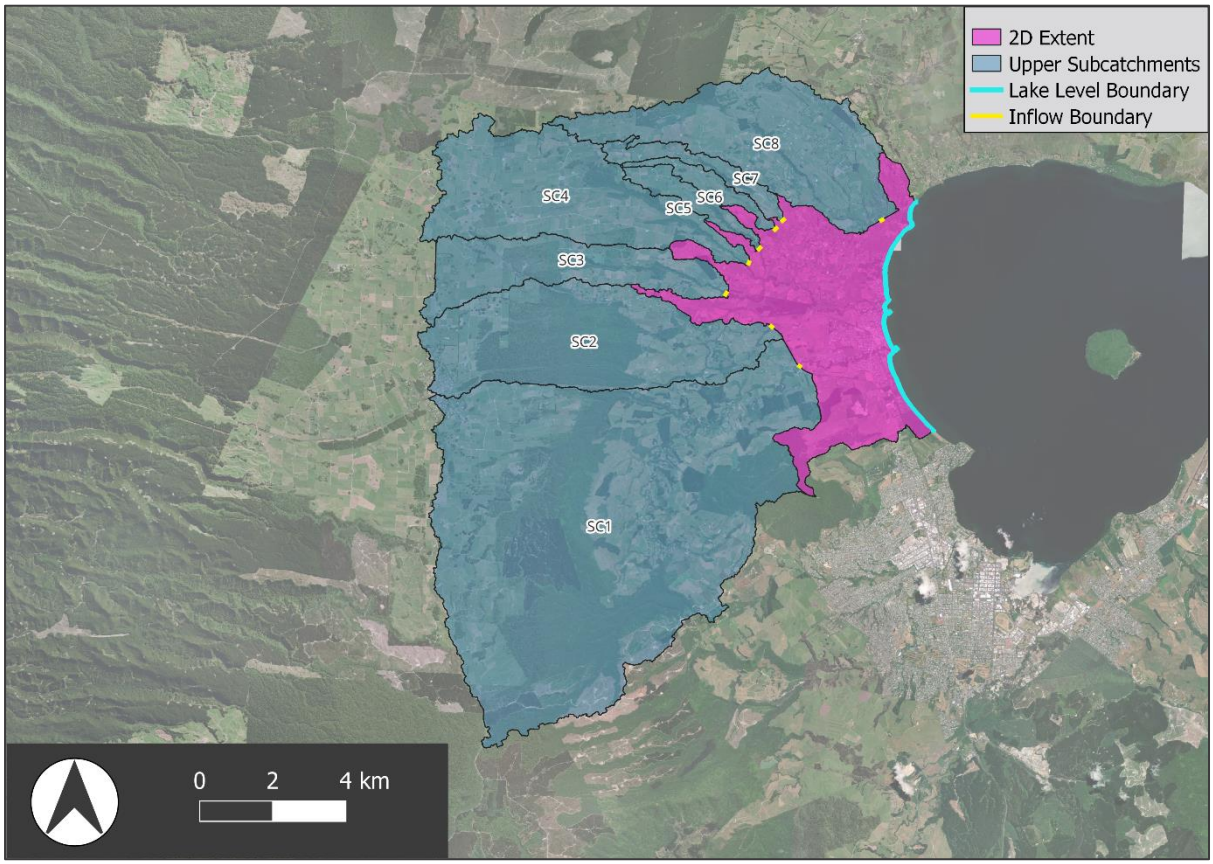



*Figure 4. Upper subcatchments and boundary locations for the Ngongotahā RFHA model.*



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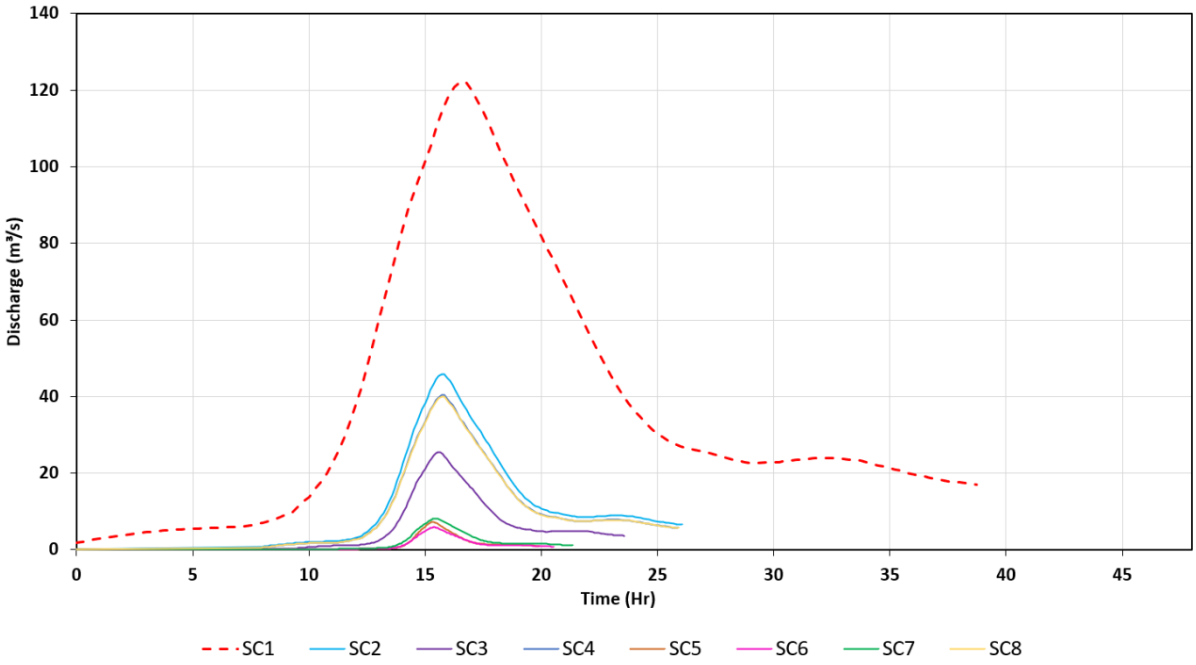



*Figure 5. Applied inflow hydrographs for the RFHA upper catchments.*

## LIMITATIONS AND CONSTRAINTS

A RFHA is prone to limitations due to the rapid development of the model and lack of certain detail that influences hydraulic processes. Table 6 lists a range of matters that should be considered when interpreting the results of this study.

*Table 6. Limitations and constraints of Ngongotahā RFHA.*

| AREA | DETAILS |
|---|---|
| Overland Flow | • Fine features that may influence the direction of flow, such as kerbs, fences and walls, have not been resolved in the model.<br>• The vertical accuracy of the 2018 LiDAR is +/-0.2 m.<br>• The 2018 LiDAR has been converted to MOT53 using a gridded surface with a resolution of approximately 10 $km^2$, the conversion accuracy in the order of +/-0.02 m. |
| Data | • Not all available data has been applied to the model. |
| Stream flow | • Channels have not been refined with cross-section data and so errors in the LiDAR surface will impair the model's conveyance estimates. |
| Pipe Network | • Large culverts cut into the 2D will not accurately represent inlet losses. The flood depth results, and hence flood extents, in the vicinity of culverts are therefore unlikely to be accurate.<br>• No pipe network conveying flows directly into the lake or across the catchment has been included.<br>• Pipe network, such as culverts, pipes, and drainage pits are entirely excluded from the model. |



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| AREA | DETAILS |
|---|---|
| Hydrology | • The supplied zoning layer is not sufficiently resolved to accurately represent the spatial variability of the 2D surface initial and continuous losses across the catchment. Detailed land cover data was not available. Conservatively low estimates of loss have been applied.<br>• The area-transposition method used to estimate inflows from the upper catchments has only been approximately verified.<br>• The climate change adjustment of 65% peak flow is based on a small hydrological model study and is expected to overestimate peak flows as a nested storm was used.<br>• Inflow hydrographs may change in the later stages of the model build. |
| Verification | • The results have not been verified against known flood prone areas. |

## ASSUMPTIONS

A number of assumptions have been made during the model build process. Table 7 lists key assumptions that should be taken into consideration when interpreting the results.

*Table 7. Assumptions made during the RFHA model build.*

| AREA | DETAILS |
|---|---|
| Overland Flow | • LiDAR is suitable for use in the hydraulic model and the merging of the 2011 and 2018 datasets will not cause unreasonable results around the merged areas.<br>• Zoning layer is suitable to represent the spatial variability of the roughness in the 2D extent for the purposes of the RFHA. |
| Data | • Data received is accurate and appropriate for use in the model. |
| Stream flow | • The LiDAR representation of channels beds is sufficient for an RFHA. |
| Pipe Network | • The exclusion of pipes is reasonable to produce RFHA results. |
| Hydrology | • The supplied zoning layer is suitable to represent the spatial variability of the 2D surface initial and continuous losses.<br>• Hydrological losses estimates are sufficiently low to account for uncertainties in the model parameterisation.<br>• The area-transposition method used is suitable for estimating inflows from the upper catchments.<br>• The climate change adjustment of 65% peak flow is suitable for the representation of increased rainfall. |

## CONCLUSIONS

The RHHA is suitable as high level flood information to support strategic growth planning. The flood information will be improved once the full model build report and completed hydraulic model are delivered in 2023. Once the full model results are available, this memo and results from the RFHA should be considered to be superseded.



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AMY WATERS

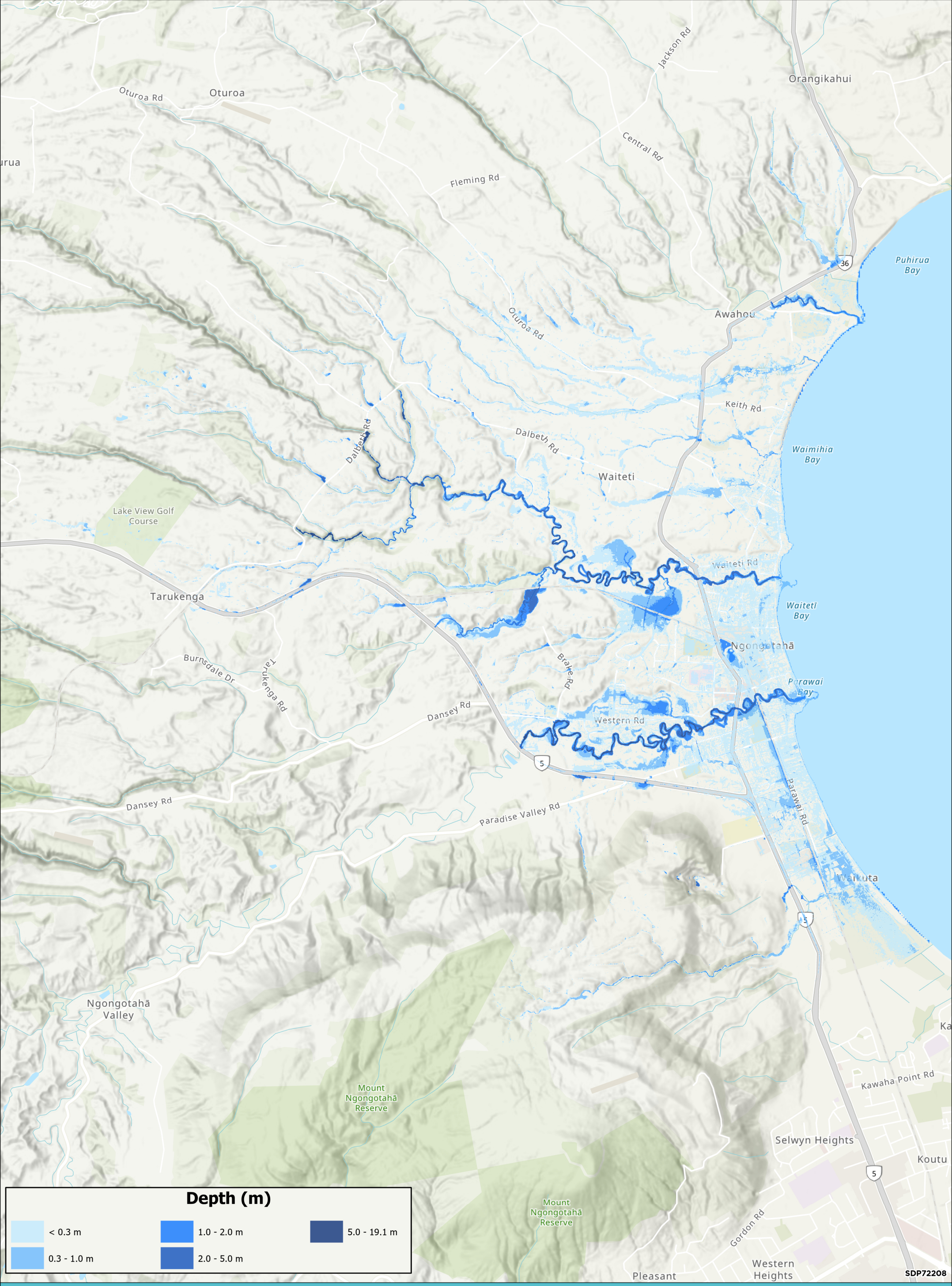
HYDRAULIC MODELLER

a: 4 Williamson Ave, Grey Lynn, Auckland 1021

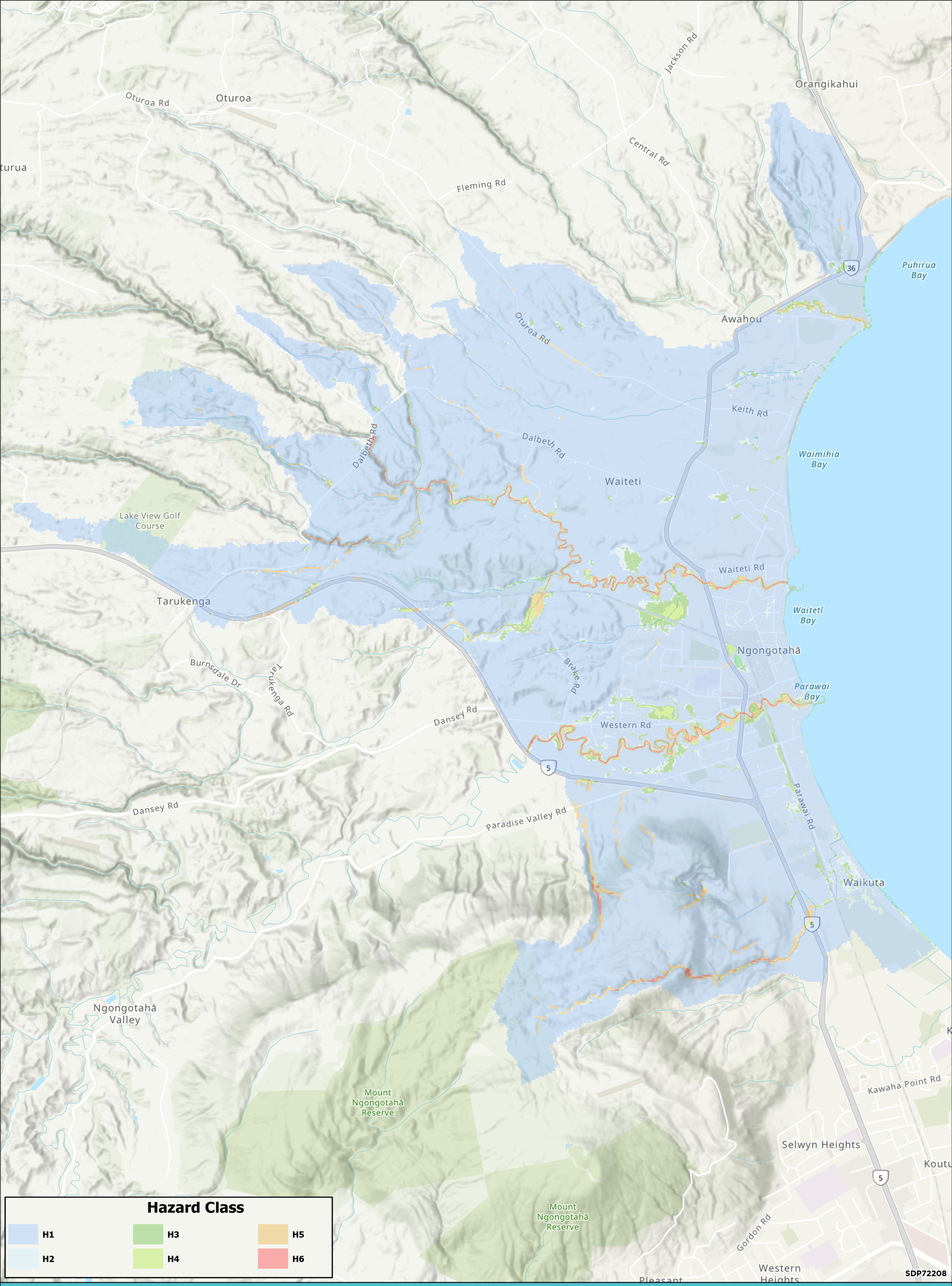
m: +64 27 728 7258 e: amy.waters@awa.kiwi w: www.awa.kiwi



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# Ngongotaha Rapid Model - 1%AEP 3.7degCC Hazard Class

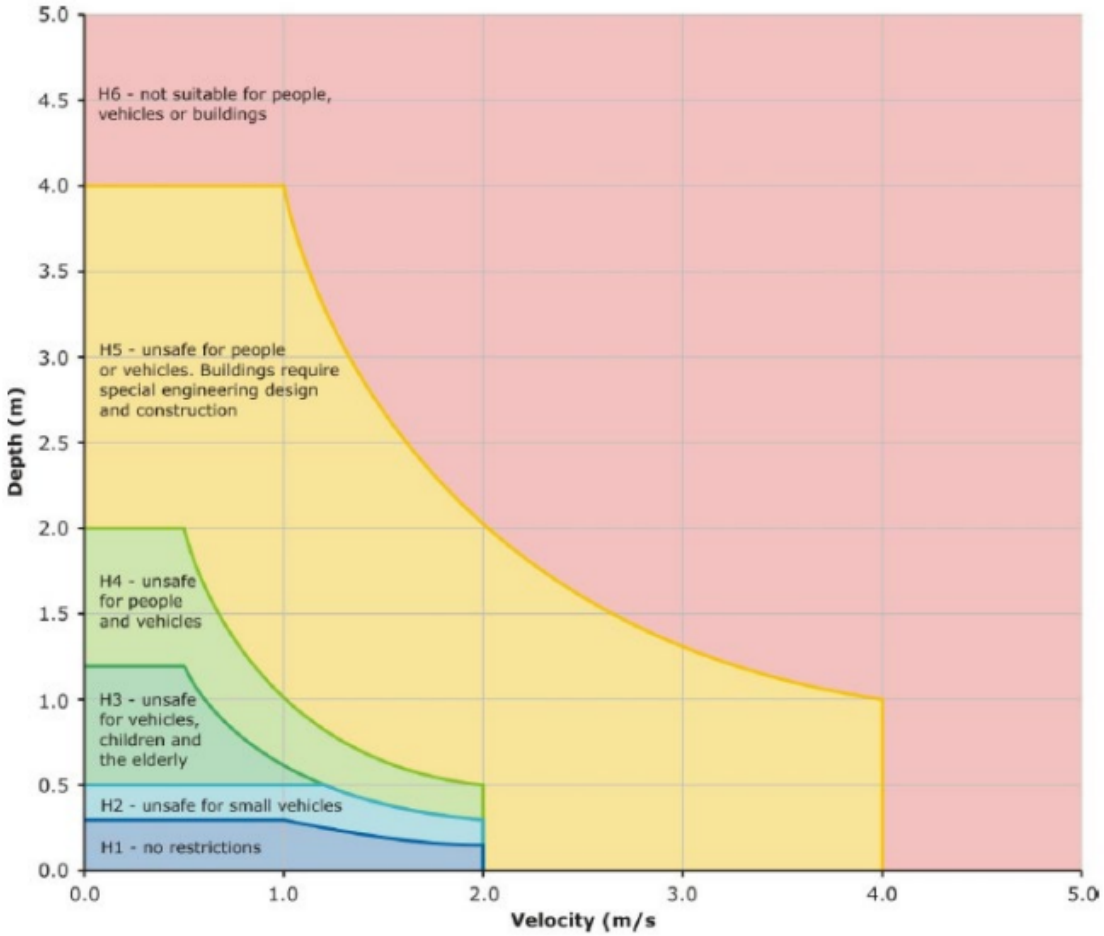
NZTM Projection

0 500 1,000 2,000 3,000 Metres

ROTORUA LAKES COUNCIL

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Version: 1, Version Date: 08/04/2024

Flood hazard category as outlined by Australian Emergency Management Institute in 2014. ZAEM1 output values are 0 (zero) for no hazard and 1 to 6 for H1 to H6 respectively.




| Hazard Classification | Description |
|---|---|
| H1 | Relatively benign flow conditions. No vulnerability constraints. |
| H2 | Unsafe for small vehicles. |
| H3 | Unsafe for all vehicles, children and the elderly. |
| H4 | Unsafe for all people and all vehicles. |
| H5 | Unsafe for all people and all vehicles. Buildings require special engineering design and construction. |
| H6 | Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure. |

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# APPENDIX B – MAXIMUM FLOOD DEPTH MAPS

The following summary maps are provided as enveloped maximums of these rain and lake sub-scenarios:

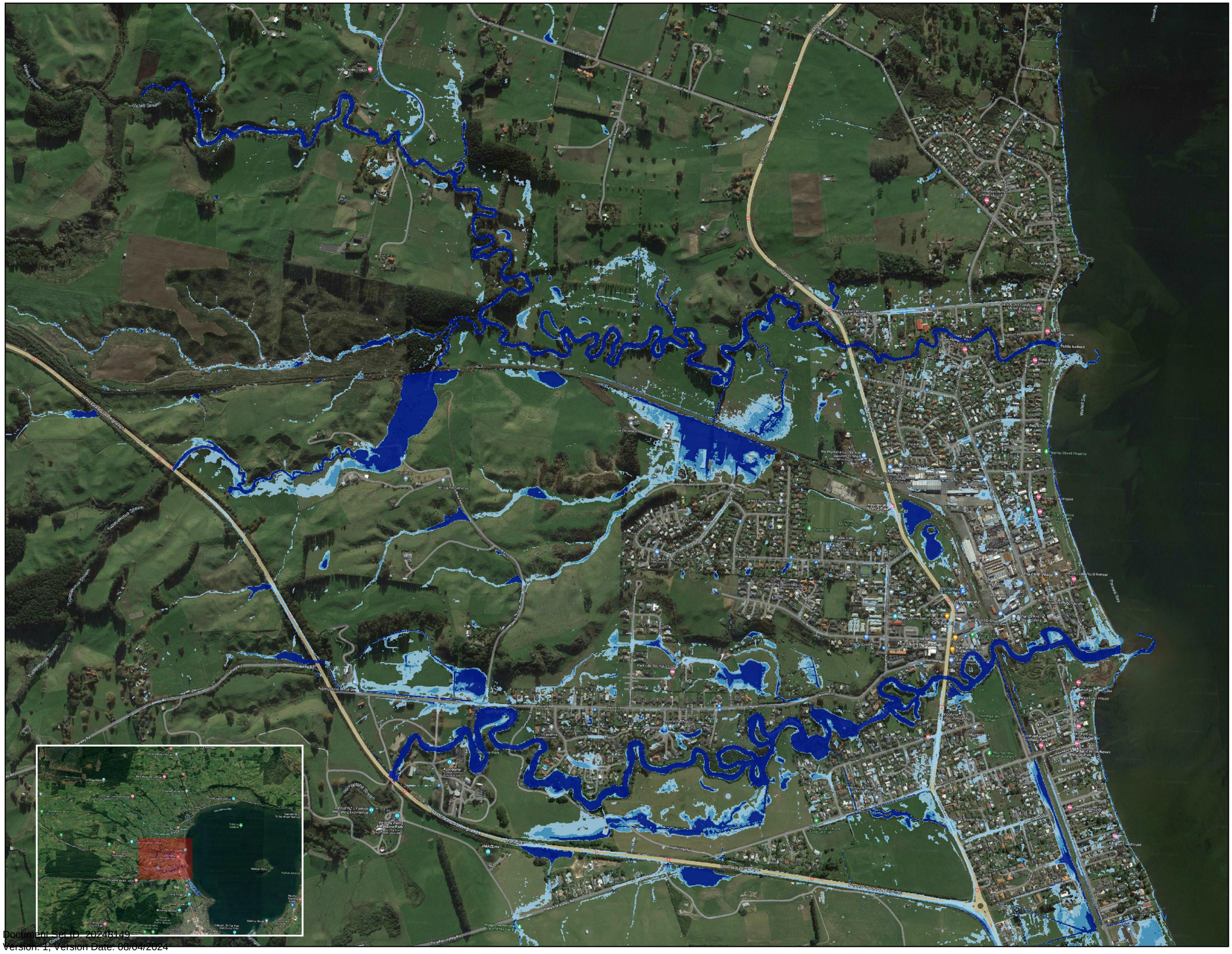
1. 10% AEP scenario – current climate (2020);
2. 10% AEP scenario – climate change (2130);
3. 1% AEP scenario – current climate (2020);
4. 1% AEP scenario – climate change (2130);
5. 0.2% AEP scenario – current climate (2020); and
6. 0.2% AEP scenario – climate change (2130).



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# Rotorua Lakes Council - Ngongotahā catchment

## Maximum flood depth for 10% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

**Depth (m)**

- 0.10 - 0.30 m
- 0.30 - 0.50 m
- > 0.50 m

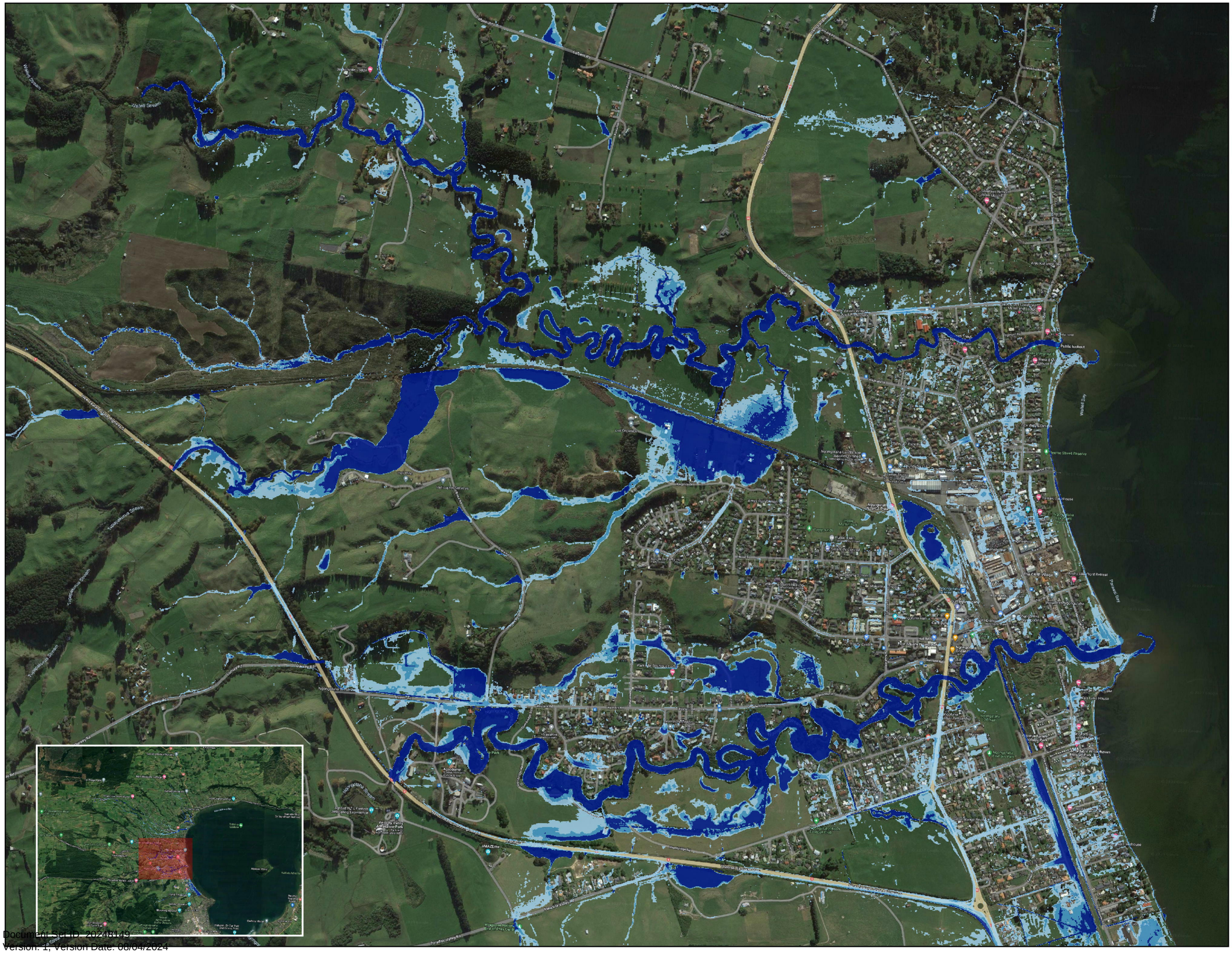
Maximum flood depths are enveloped maximums from these sub-scenarios.

- 10%AEP rainfall+50%AEP lake
- 50%AEP rainfall+10%AEP lake

Document Set ID: 20248149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

## Maximum flood depth for 10% AEP event - climate change (2130)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

### Depth (m)

- 0.10 - 0.30 m
- 0.30 - 0.50 m
- > 0.50 m

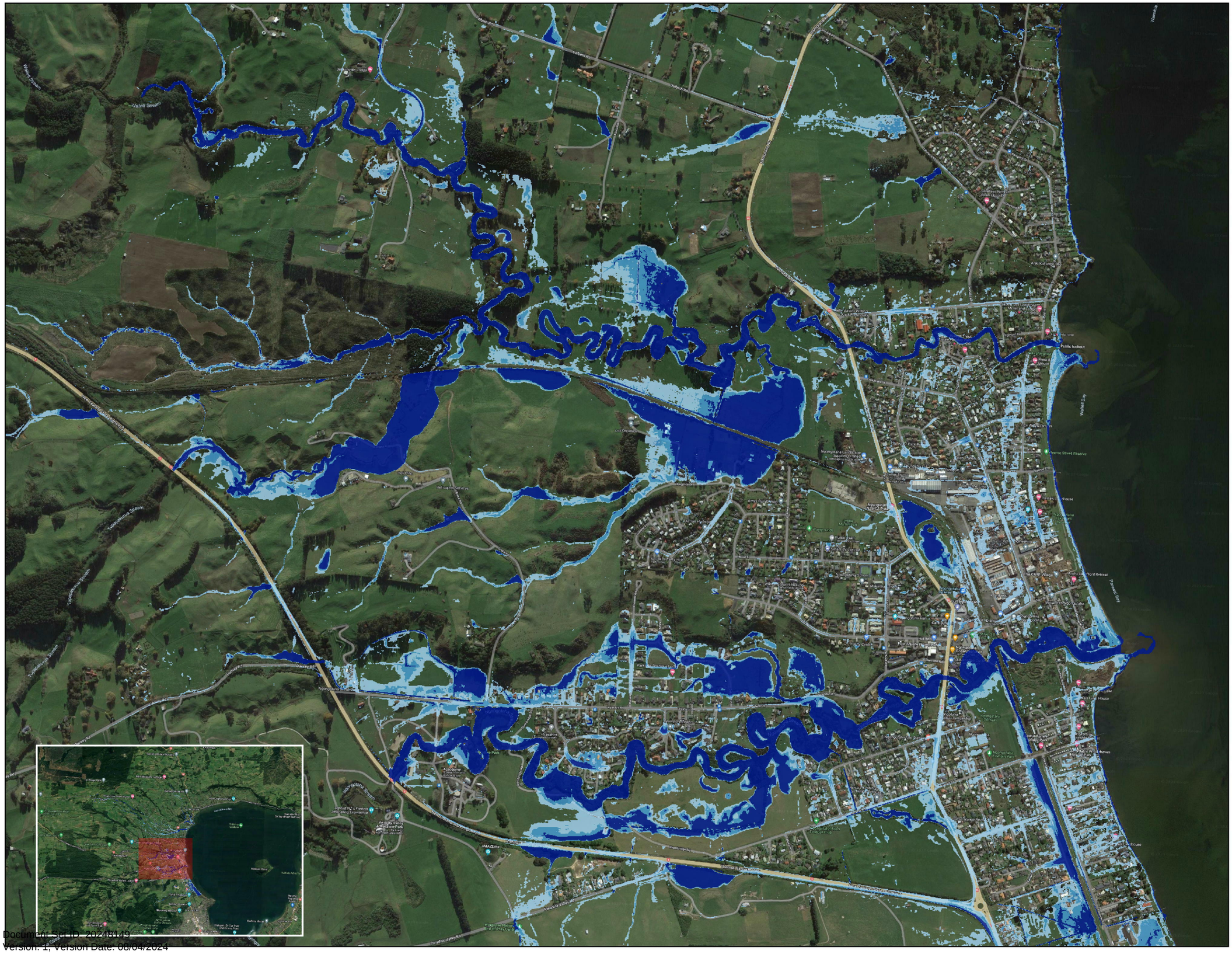
Maximum flood depths are enveloped maximums from these sub-scenarios.

- 10%AEP rainfall+50%AEP lake
- 50%AEP rainfall+10%AEP lake

Document Set ID: 20248145
Version: 1, Version Date: 08/04/2024

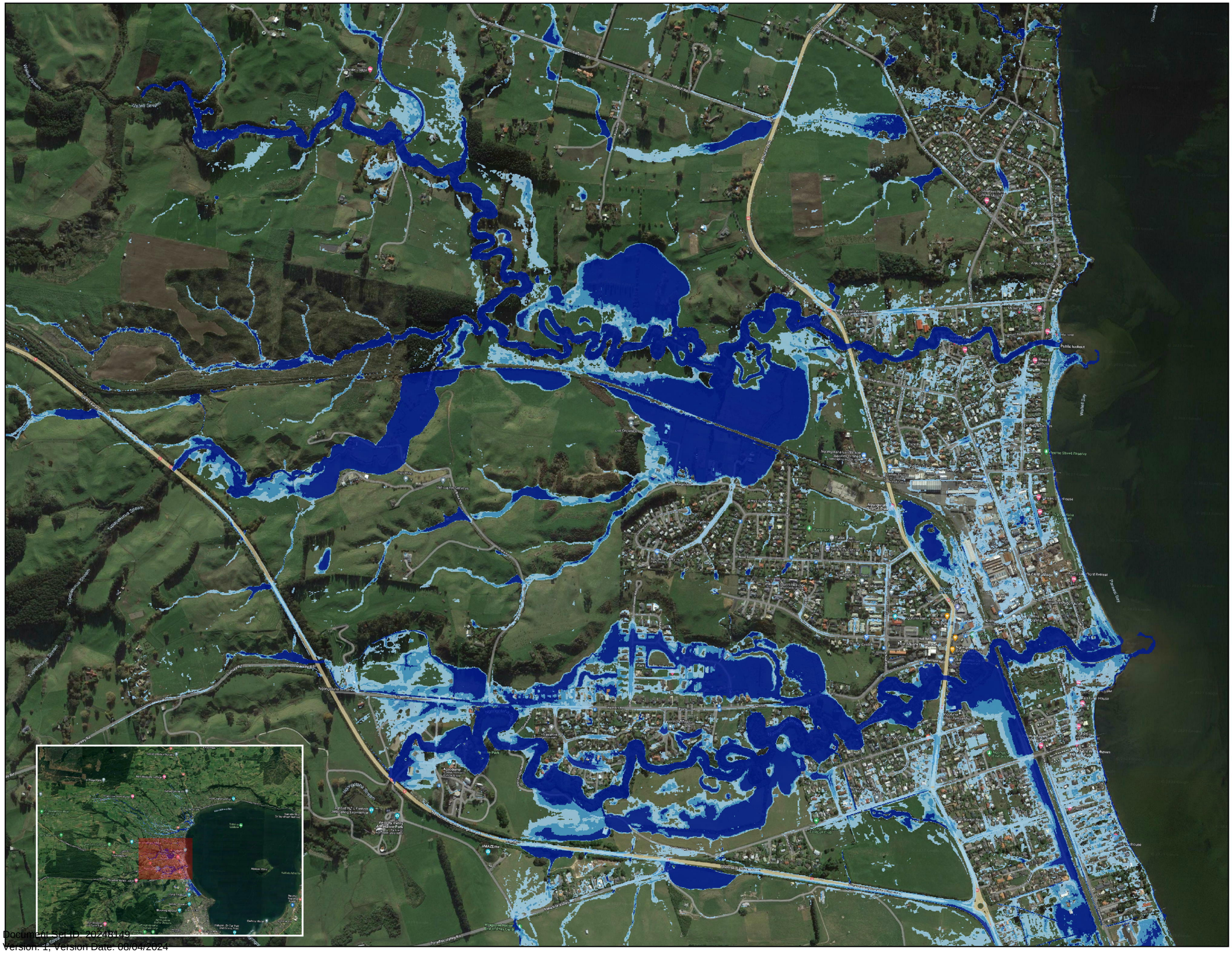
# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood depth for 1% AEP event - current climate (2020)


Waiteti Stream
Ngongotaha Stream
Waiwhakaiho River
Lake Rotorua
Waiwhakaiho Stream
Ngongotaha Stream
Waiteti Stream
Ngongotaha Rd
Ngongotaha Valley Rd
Ngongotaha Rd
Waiteti Rd
Waiteti Rd
Ngongotaha Valley Rd
Ngongotaha Rd
Ngongotaha Rd
Ngongotaha

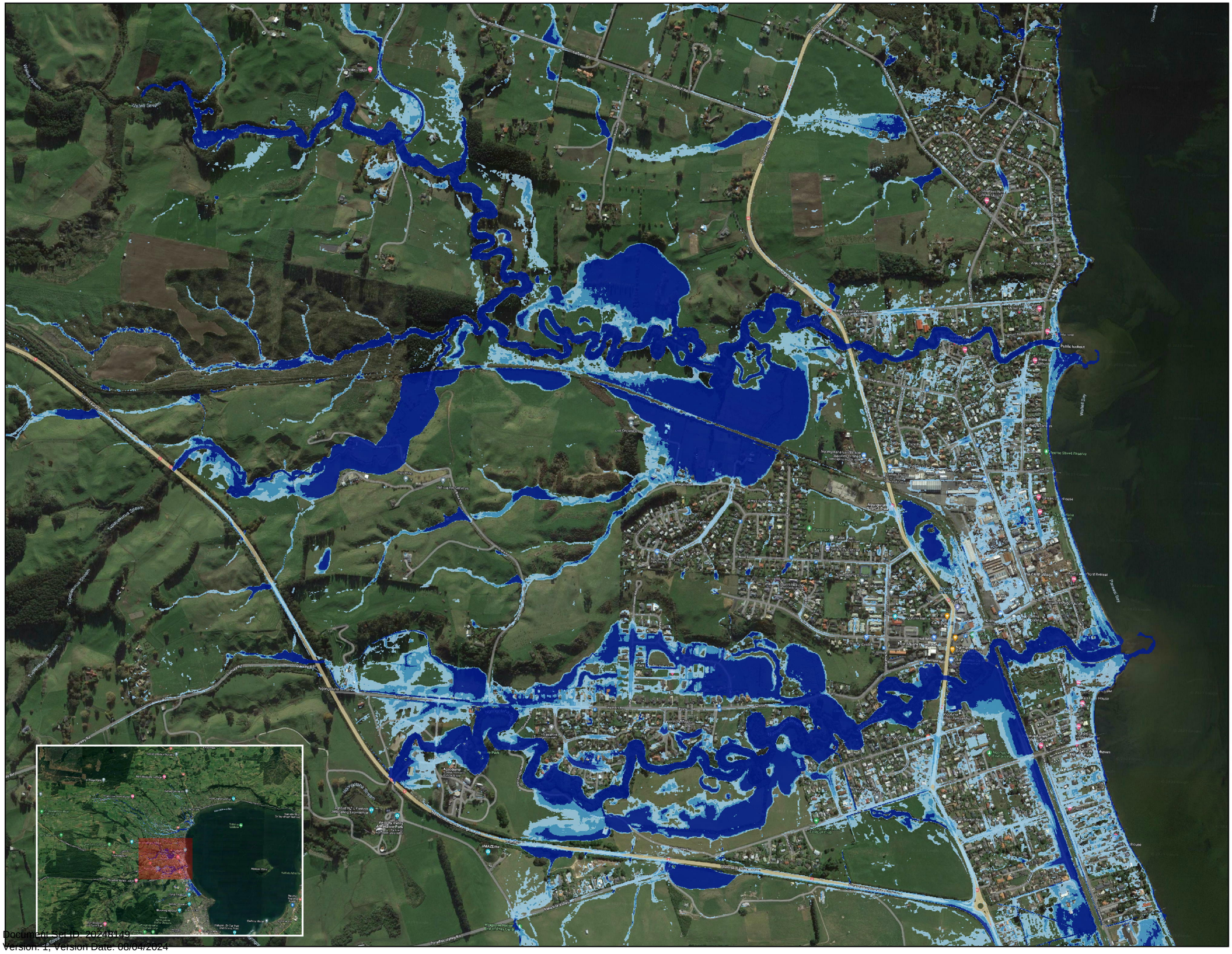
# Rotorua Lakes Council - Ngongotahā catchment

## Maximum flood depth for 1% AEP event - climate change (2130)


Waiteti Stream
Ngongotaha Stream
Utuhina Stream
Waiteti Stream
Waiteti Bay
Public lookout
Ngongotaha Stream
Ngongotaha Rapids
Ngongotaha Rapids Walkway
Ngongotaha Rapids Walkway
Ngongotaha Rapids Walkway

# Rotorua Lakes Council - Ngongotahā catchment

## Maximum flood depth for 0.2% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

### Depth (m)

- 0.10 - 0.30 m
- 0.30 - 0.50 m
- > 0.50 m

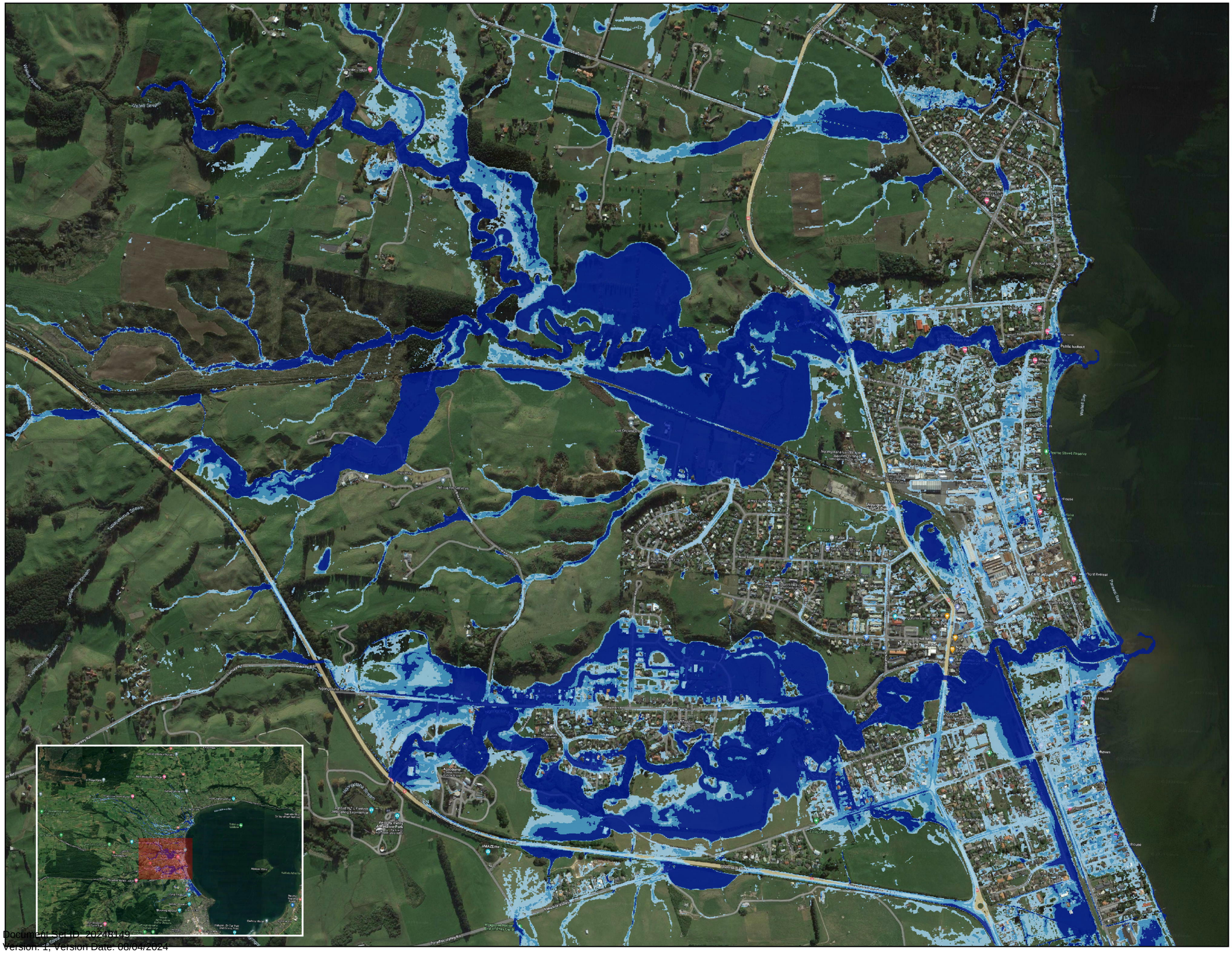
Maximum flood depths are enveloped maximums from these sub-scenarios.

- 0.2%AEP rainfall+0.5%AEP lake
- 0.5%AEP rainfall+0.2%AEP lake

Document Set ID: 20248145
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

## Maximum flood depth for 0.2% AEP event - climate change (2130)


Waiteti Stream
Waiteti Stream
Ngongotaha Stream
Ngongotaha Stream
Ngongotaha

# APPENDIX C – MAXIMUM FLOOD HAZARD MAPS

The following summary hazard maps are provided as provided as enveloped maximums of these rain and lake sub-scenarios:

1. 10% AEP scenario – current climate (2020);
2. 10% AEP scenario – climate change (2130);
3. 1% AEP scenario – current climate (2020);
4. 1% AEP scenario – climate change (2130);
5. 0.2% AEP scenario – current climate (2020); and
6. 0.2% AEP scenario – climate change (2130).



Document Set ID: 20248149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 10% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Flood hazard

Australian Emergency Management Institute classification

- H2
- H3
- H4
- H5
- H6

Maximum flood hazards are enveloped maximums from these sub-scenarios.

- 10%AEP rainfall+50%AEP lake
- 50%AEP rainfall+10%AEP lake

Document Set ID: 20240149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 10% AEP event - climate change (2130)


Waiteti Stream
Tuhirangi Stream
Ngongotaha Stream
Waiteti Bay
Ngongotaha Lake Domain
Ngongotaha Public Toilets
Ngongotaha Scout Group
Ngongotaha Cemetery
Ngongotaha Valley Road
Ngongotaha Rd
Public toilets
Public toilet
Waiteti Marae
Ngongotaha Holiday Park
Ngongotaha Lakeside Motel
Ngongotaha Lodge
Ngongotaha Valley Store
Ngongotaha Valley Golf Course
Ngongotaha Valley Cemetery
Ngongotaha Valley Rd
Ngongotaha Valley Rd / Paradise Valley Rd
Ngongotaha Valley Rd / Tauhara Rd
Ngongotaha Valley Rd / Waiteti Rd
Ngongotaha Valley Rd / Ngongotaha Rd
Ngongotaha Valley Rd / Ngongotaha Stream
Ngongotaha Valley Rd / Tuhirangi Stream
Ngongotaha Valley Rd / Waiteti Stream
Ngongotaha Valley Rd / Waiteti Bay
Ngongotaha Valley Rd / Waiteti Bay
Ngongotaha Valley Rd / Waiteti Bay

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 1% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Flood hazard

Australian Emergency Management Institute classification

- H2
- H3
- H4
- H5
- H6

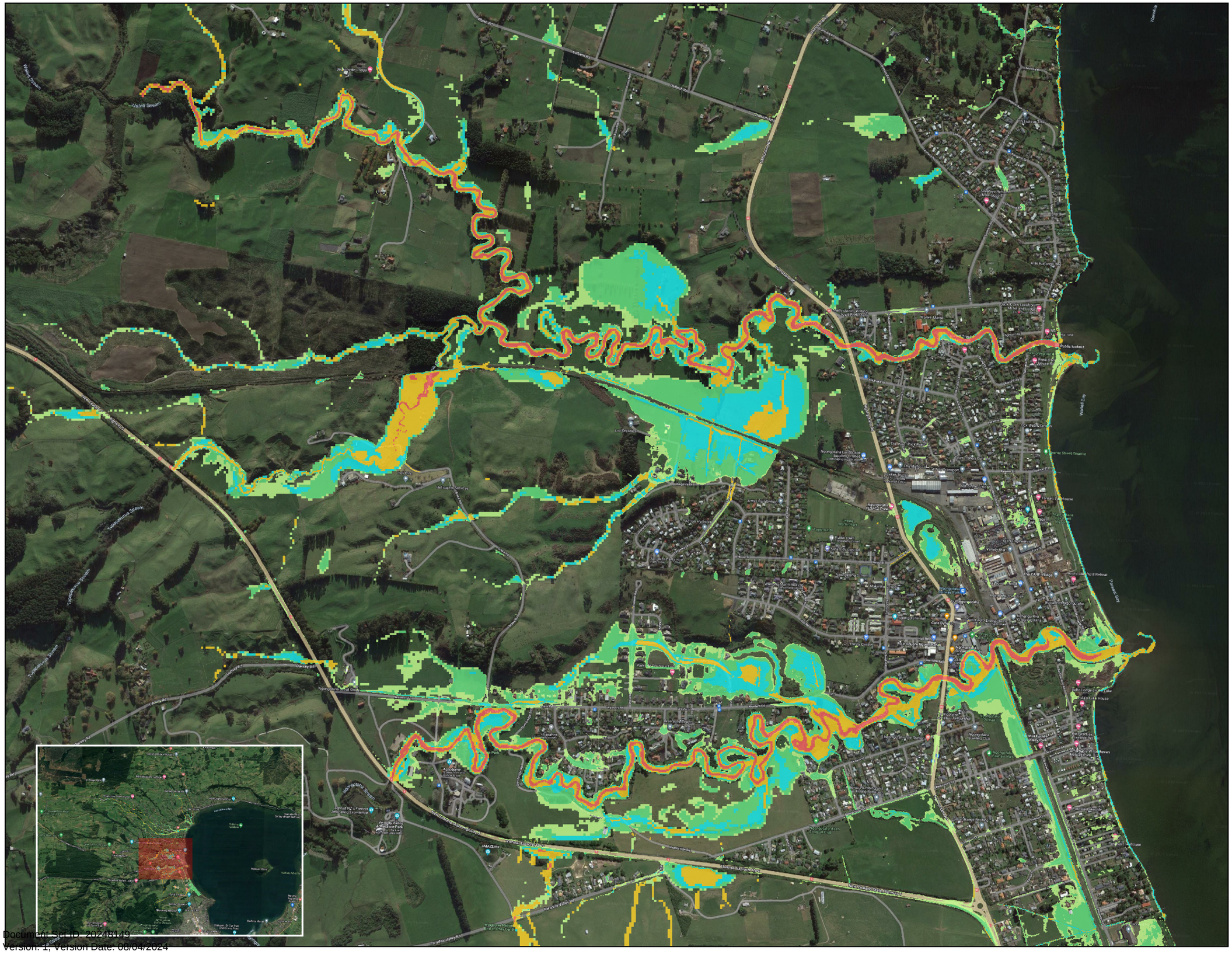
Maximum flood hazards are enveloped maximums from these sub-scenarios.

- 1%AEP rainfall+5%AEP lake
- 5%AEP rainfall+1%AEP lake

Document Set ID: 20240149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 1% AEP event - climate change (2130)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Flood hazard

Australian Emergency Management Institute classification

- H2
- H3
- H4
- H5
- H6

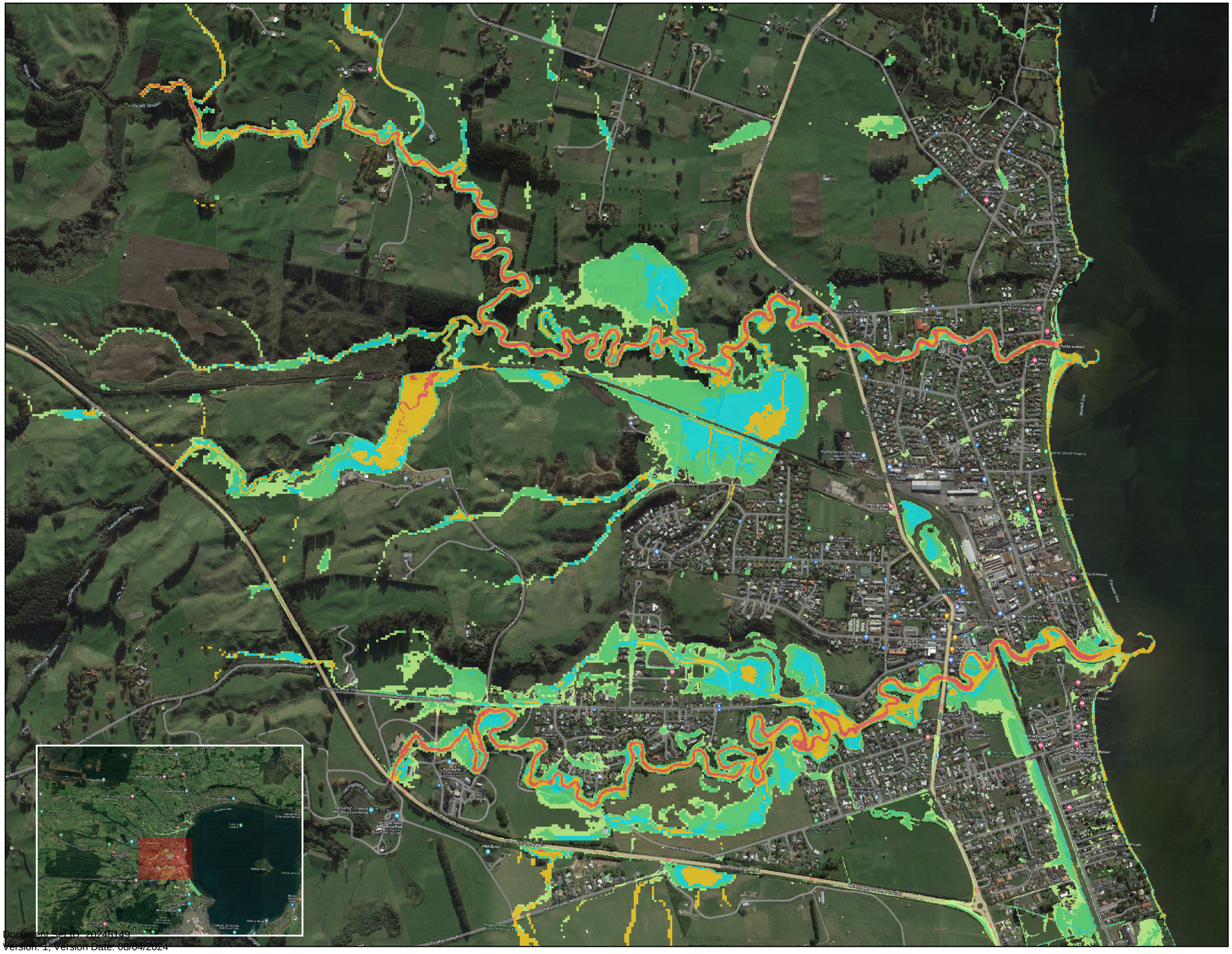
Maximum flood hazards are enveloped maximums from these sub-scenarios.

- 1%AEP rainfall+5%AEP lake
- 5%AEP rainfall+1%AEP lake

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Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 0.2% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Flood hazard

Australian Emergency Management Institute classification

- H2
- H3
- H4
- H5
- H6

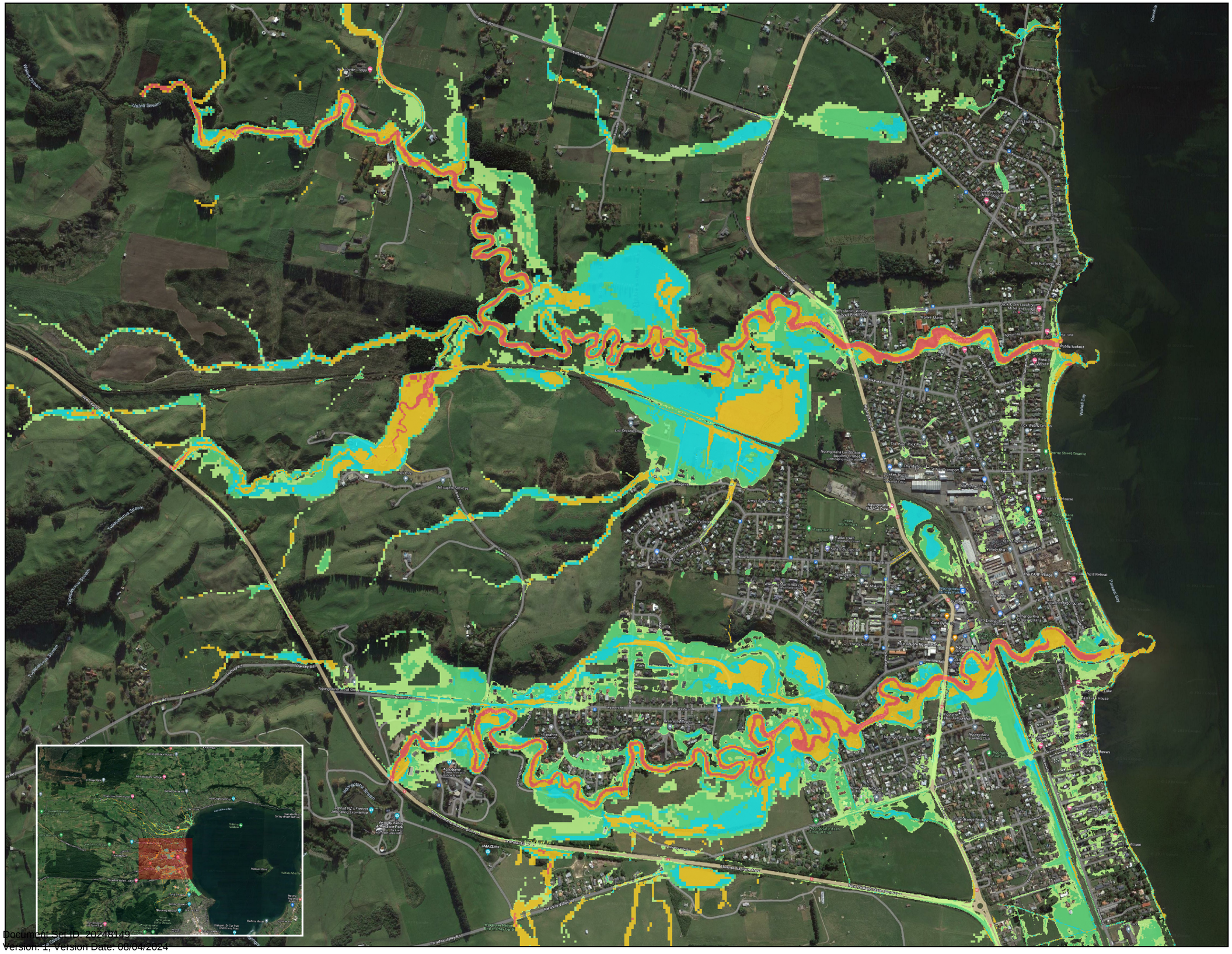
Maximum flood hazards are enveloped maximums from these sub-scenarios.

- 0.2%AEP rainfall+0.5%AEP lake
- 0.5%AEP rainfall+0.2%AEP lake

Document Set ID: 20240149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Maximum flood hazard for 0.2% AEP event - climate change (2130)


Waiteti Stream
Waiteti Stream
Ngongotaha Stream
Ngongotaha Stream
Ngongotaha Stream
Waiteti Stream
Waiteti Stream
Waiteti

# APPENDIX D – SOURCE OF FLOOD DEPTHS

The following maps show which sub-scenario (rain or lake) produces the highest flood depth:

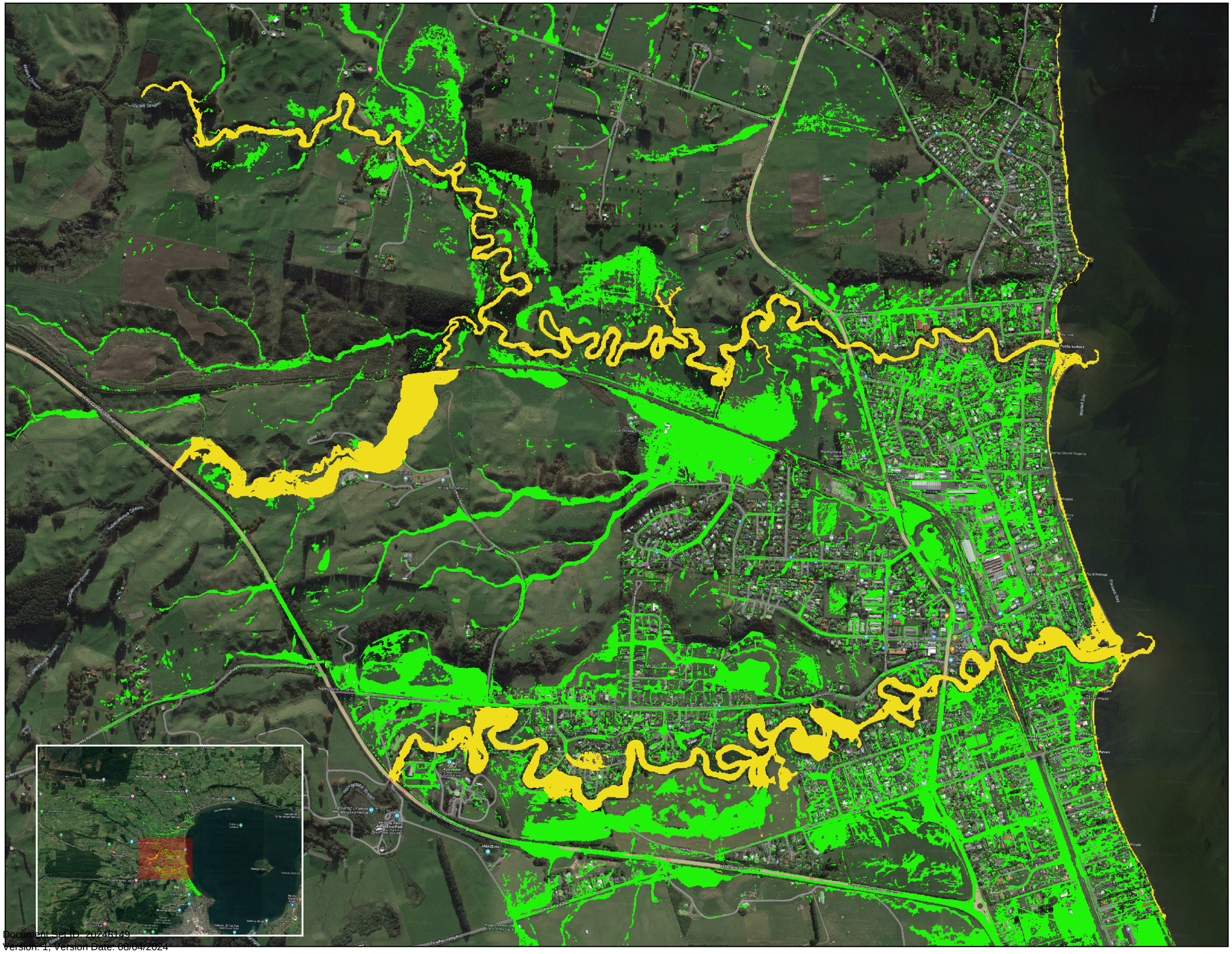
1. 10% AEP scenario – current climate (2020);
2. 10% AEP scenario – climate change (2130);
3. 1% AEP scenario – current climate (2020);
4. 1% AEP scenario – climate change (2130);
5. 0.2% AEP scenario – current climate (2020); and
6. 0.2% AEP scenario – climate change (2130).



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Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 10% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Source of maximum flood depth

- 50%AEP Rain+10%AEP Lake
- 10%AEP Rain+50%AEP Lake

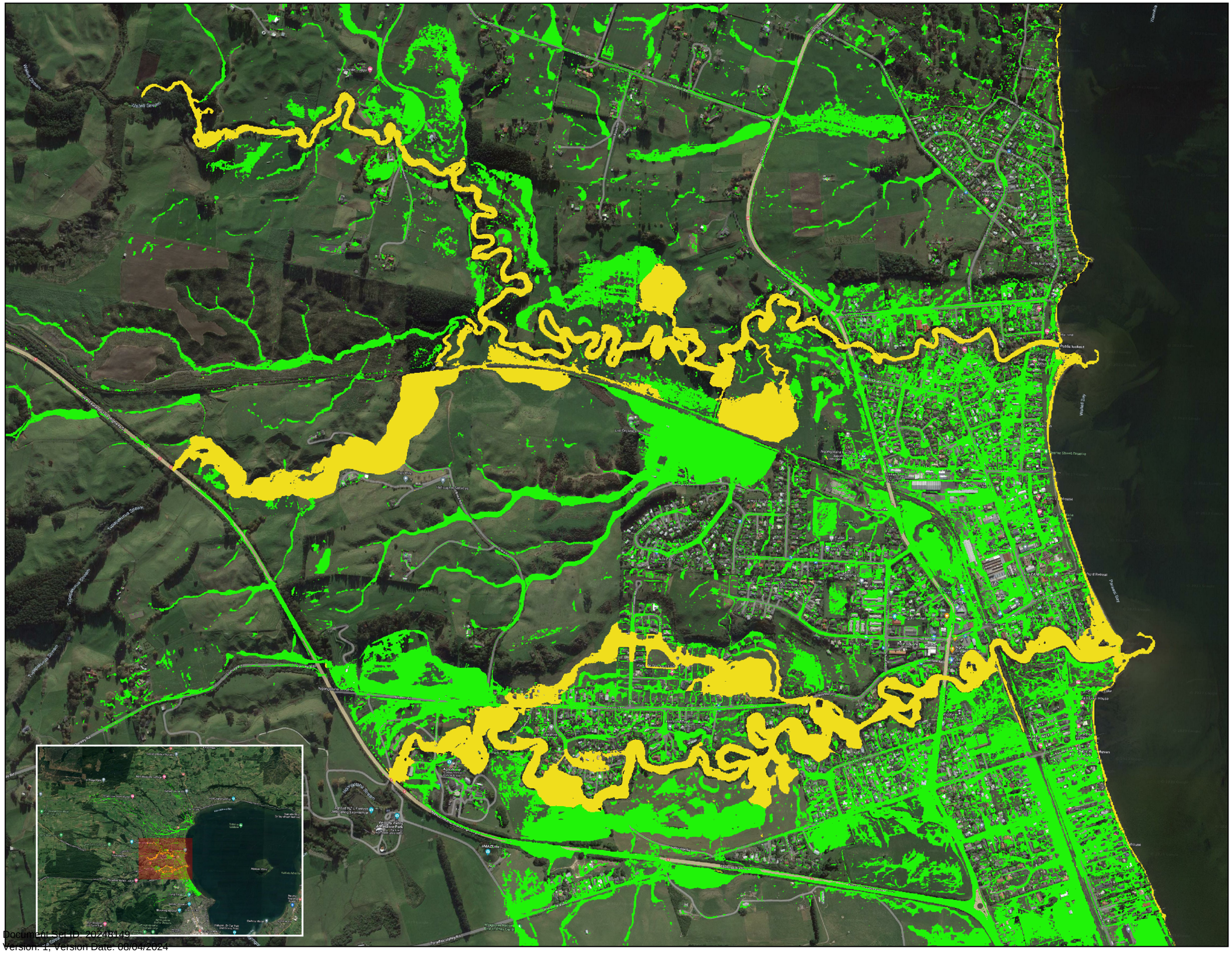
Maximum flood depths are sourced from these sub-scenarios.

- 10%AEP rainfall+50%AEP lake
- 50%AEP rainfall+10%AEP lake

Document Set ID: 20240149
Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 10% AEP event - climate change (2130)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Source of maximum flood depth

- 50%AEP Rain+10%AEP Lake
- 10%AEP Rain+50%AEP Lake

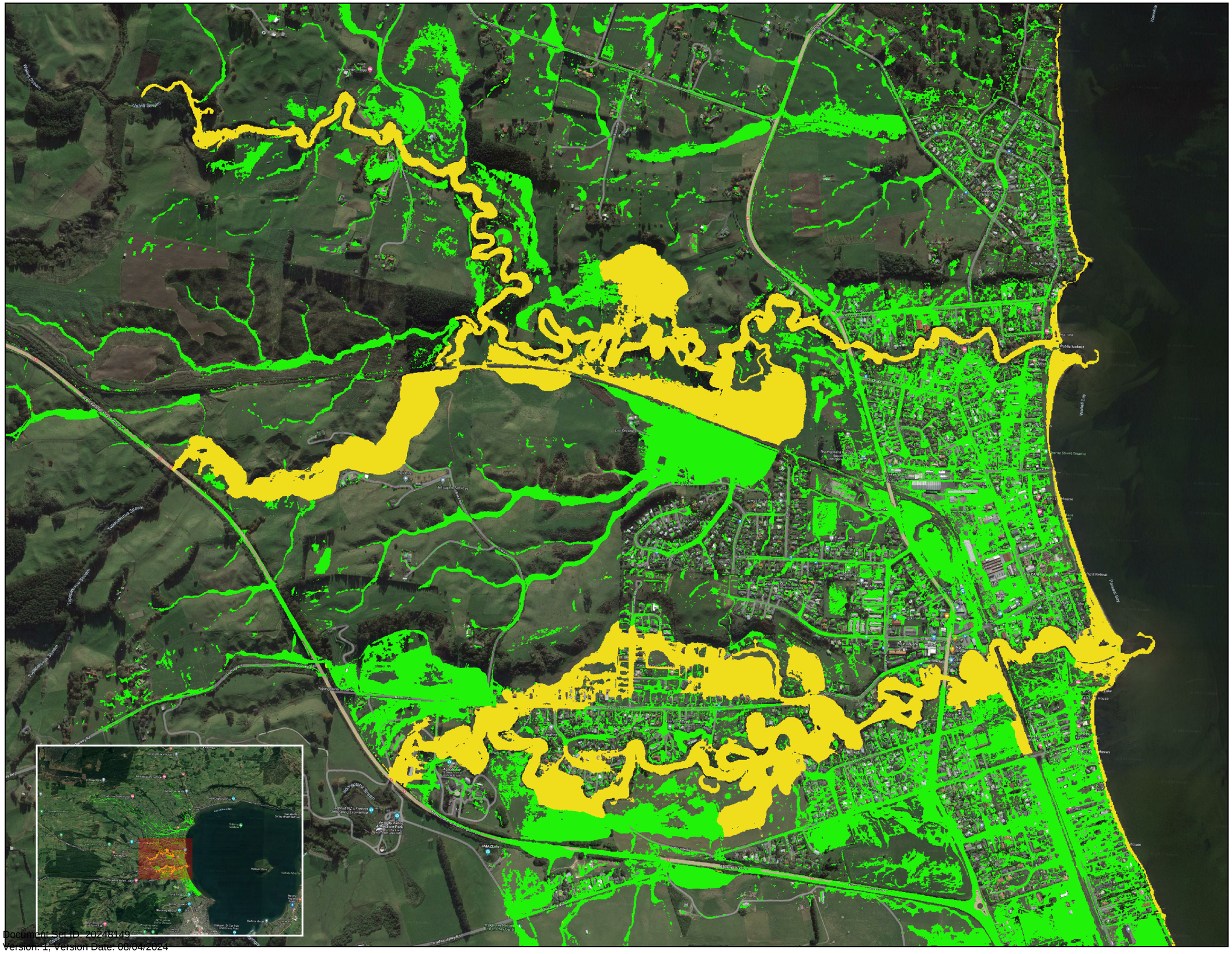
Maximum flood depths are sourced from these sub-scenarios.

- 10%AEP rainfall+50%AEP lake
- 50%AEP rainfall+10%AEP lake

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Version: 1, Version Date: 08/04/2024

# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 1% AEP event - current climate (2020)




Prepared by:
Awa Environmental Ltd

1 Ghuznee Street
Wellington, Te Aro 6011
www.awa.kiwi

0 400 m

## Source of maximum flood depth

- 5%AEP Rain+1%AEP Lake
- 1%AEP Rain+5%AEP Lake

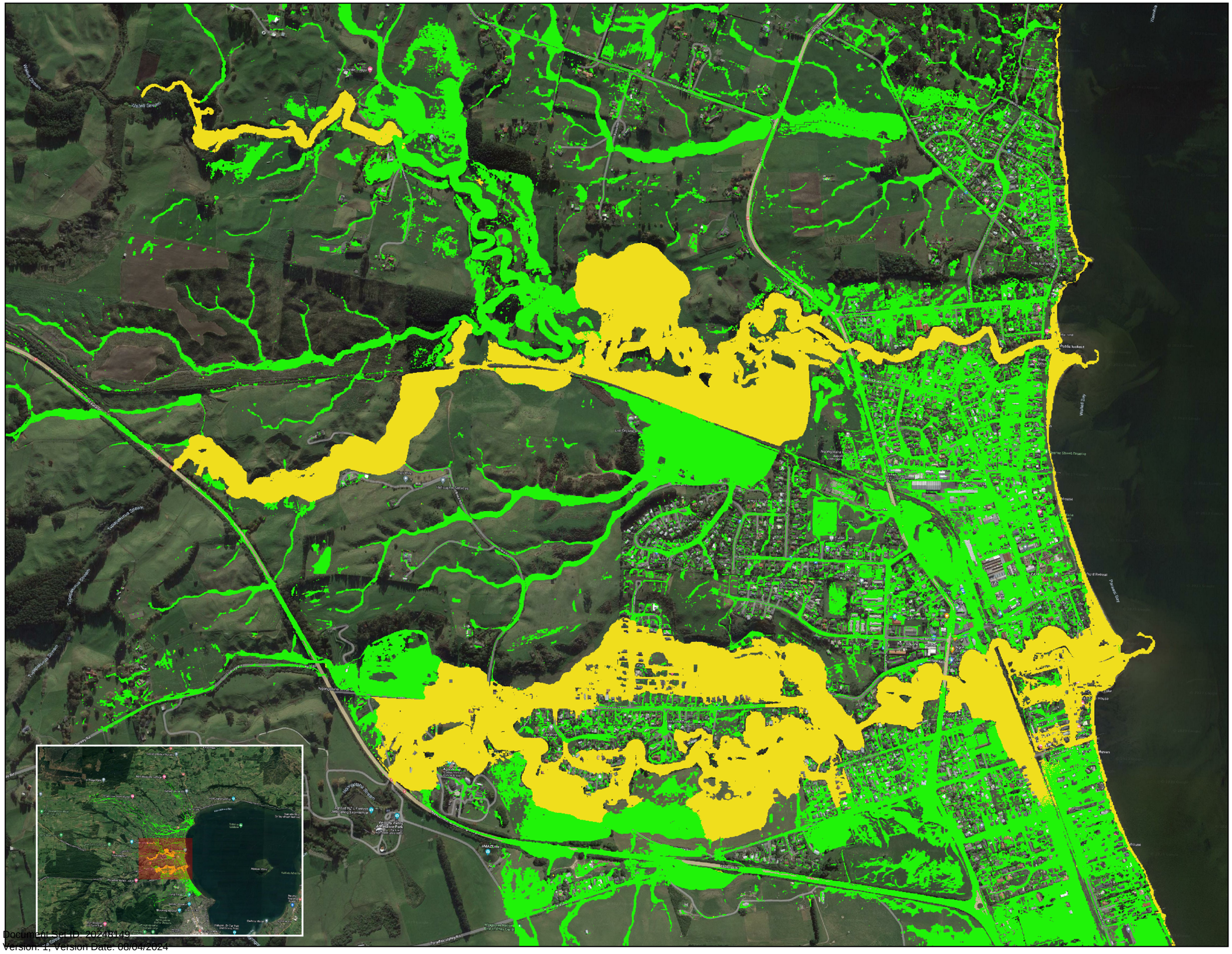
Maximum flood depths are sourced from these sub-scenarios.

- 1%AEP rainfall+5%AEP lake
- 5%AEP rainfall+1%AEP lake

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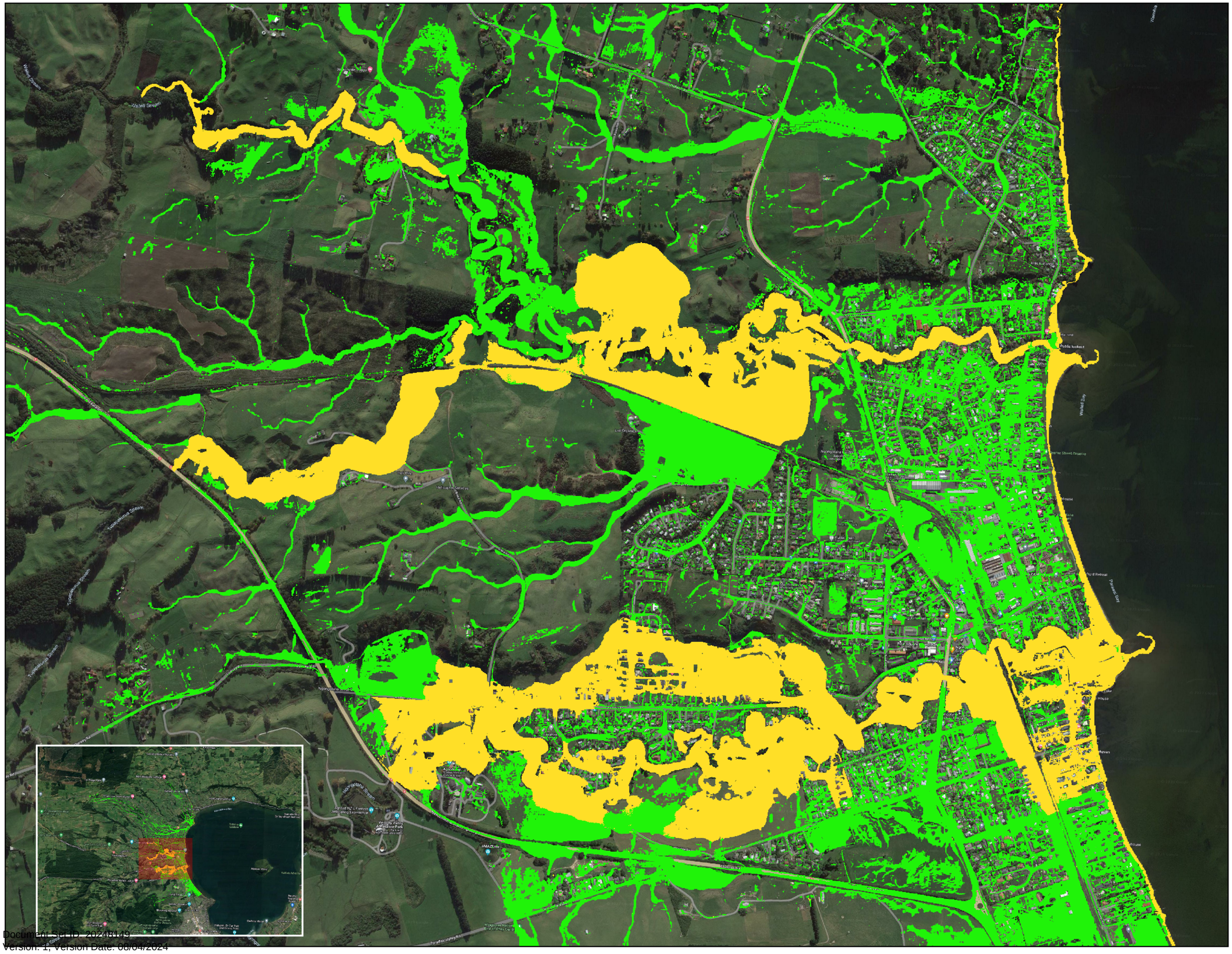
# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 1% AEP event - climate change (2130)


Waiteti Stream
Waiteti Stream
Ngongotaha Stream
Ngongotaha Stream
Waiteti Stream
Waiteti Stream
Waiteti

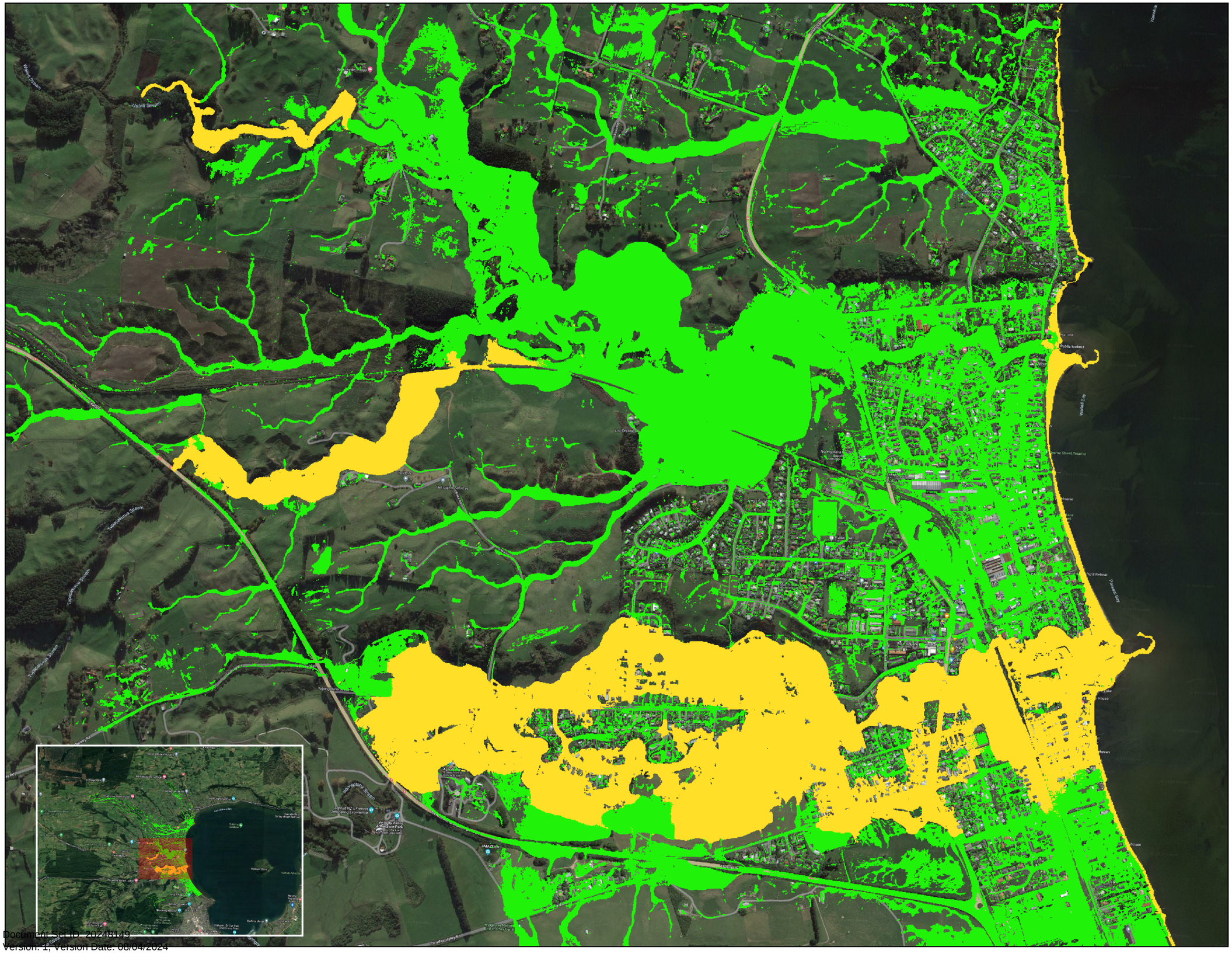
# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 0.2% AEP event - current climate (2020)


Waiteti Stream
Ngongotaha Stream
Tapuaeharuru Stream
Waiteti Bay
Public toilets
Pleasure Island Reserve
Pleasure Island Drive
Ngongotaha Reserve
Ngongotaha Cemetery
Ngongotaha Rd
Ngongotaha Valley Rd
Ngongotaha Valley Motorsport Park
Rotorua Raceway
Rotorua Airport
Rotorua Golf Course
Rotorua Lakes
Rotorua Lakes Council
Rotorua Lakes Council Offices
Rotorua Lakes Council Depot
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# Rotorua Lakes Council - Ngongotahā catchment

Source of maximum flood depths for 0.2% AEP event - climate change (2130)




Prepared by:
Awa Environmental Ltd

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Wellington, Te Aro 6011
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0 400 m

## Source of maximum flood depth

- 0.2%AEP Rain+0.5%AEP Lake
- 0.5%AEP Rain+0.2%AEP Lake

Maximum flood depths are sourced from these sub-scenarios.

- 0.2%AEP rainfall+0.5%AEP lake
- 0.5%AEP rainfall+0.2%AEP lake

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