REPORT

# Flood Hazard Mapping

## Te Kuiti, Pio Pio, Awakino, Marokopa, Kiritehere and Waitomo

**Prepared for**
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# 1 Introduction

The purpose of the work undertaken was to provide Waitomo District Council (WDC) with an understanding of which areas of urban and peri-urban Te Kuiti and Piopio are susceptible to surface flooding in response to significant rainfall events. In these areas, flood models were used to develop anticipated flood depths and extents. In addition, assessments were also carried out covering the areas of Awakino, Marakopa, Kiritihere and Waitomo Valley Road with a view to providing WDC with an understanding of the areas within which flood hazard should be considered in granting of consents.

The areas within which flood hazard assessments were undertaken are shown in Figure 1.1 below. In undertaking these assessments it is important to note that two different assessment approaches were adopted, with the more-detailed model-based approach having been used for Te Kuiti and Piopio, and a more approximate approach for the remaining areas.

Assessments were carried out in all areas for floods of expected Annual Exceedance Probability (AEP) of 1% under current climatic conditions (no allowance for climate change). In addition, events of 5% AEP for present-day climate were also carried out for Te Kuiti and Piopio. For future climate scenarios, the modelling analyses for Te Kuiti and Piopio were repeated using a 2120 future time horizon based on each of three different Representative Concentration Pathways (RCP's) to cover a range of potential outcomes.

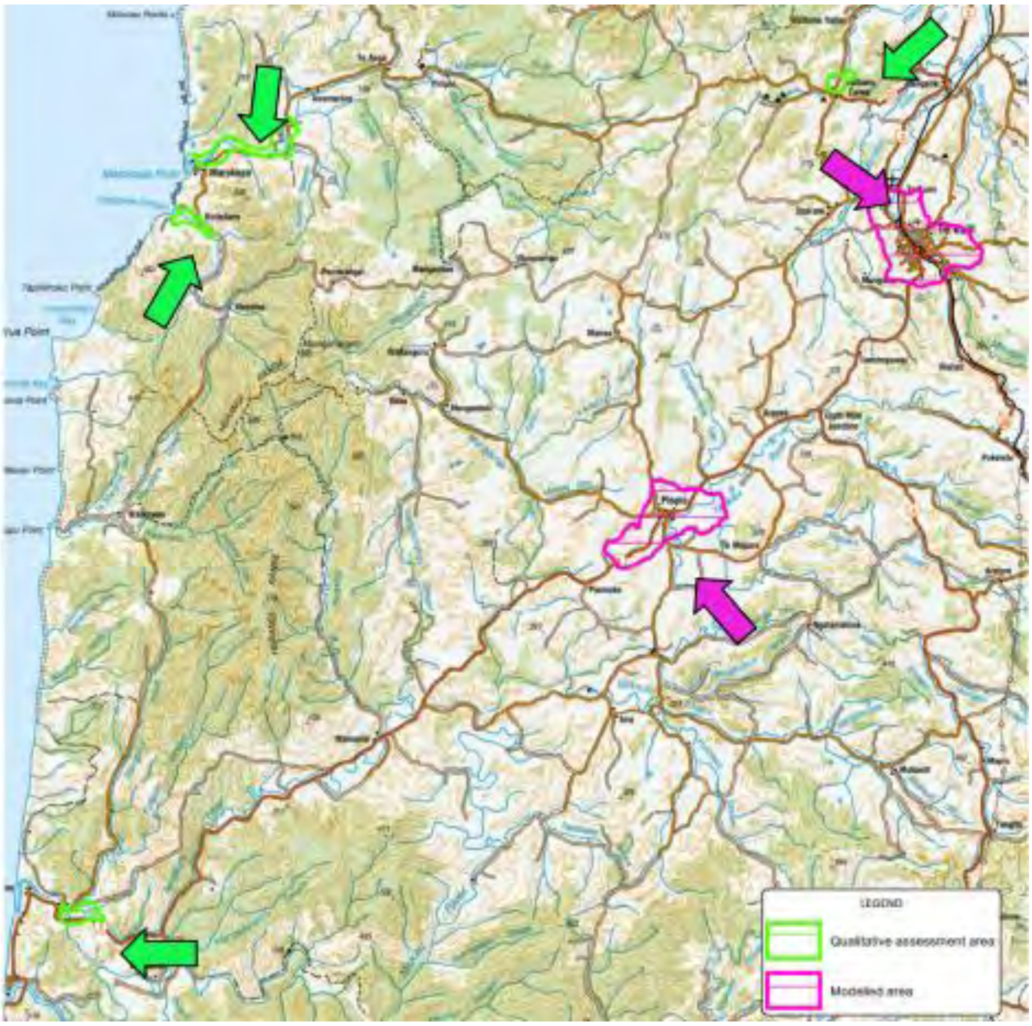


*Figure 1.1: Assessment areas and types*

# 2 Assessment methodology

For the Te Kuiti and Piopio areas, detailed hydraulic models were used to conduct the assessments. These made use of topographical information, rainfall data, roughness data and tailwater levels to develop the pattern of surface flow likely to occur in response to rainfall events of the given probabilities. The hydrological assessment undertaken to provide input to these models is described in detail in Section 3 of this report.

For the areas of Kiritihere and Marokopa, all of the areas of interest were contained within the fine resolution DEM. This made it possible to accurately map floodplain extents, as long as a water surface was available. To generate the water surface, 1%AEP present-day peak flows were referenced from the NIWA online peak flood estimation tool[1] and applied as a steady state input at the upstream extent of a simplified 2D model covering the area of interest. An upper estimated present-day storm tide water level, referenced from the Waikato Regional Council Coastal Inundation Tool[2], was applied as a downstream tailwater. Using this combination of inputs, an inundation extent was mapped.

For the Awakino area, only the lower part of the area of interest was covered by high resolution DEM. The same process as described for Kiritihere and Marokopa above was applied, recognising that this only covered part of the area of interest. Following the generation of a water surface, the floodplain area was estimated by reference to the downstream floodplain extent obtained by modelling, taking into account observations made during the site visit. In this way the floodplain extent was extended upstream.

For the Waitomo Valley Road area, no model was able to be developed using the above methodology. Instead the approach suggested in the original scope of works was followed, where a qualitative floodplain extent was estimated, based on the following:

- Hydraulic constriction at the Waitomo Valley Road bridge over the Waitomo Stream.
- Vegetation types and observed drainage network.

Further detail on the key drainage characteristics of each area is given in Section 4 of this report.

[1] https://gis.niwa.co.nz/arcgis/rest/services/HYDRO/Flood_Statistics_Henderson_Collins_V2/MapServer
[2] http://coastalinundation.waikatoregion.govt.nz/#

# 3 Hydrology

The hydrological analysis forms the basis of the inputs to the hydraulic models developed for Te Kuiti and Piopio. For each of these two areas a hydrological analysis has been completed, including the following items:

- Catchment characteristics:
  - Delineation of the catchments draining into the hydraulic model areas, namely, the Mangaokewa Stream draining to Te Kuiti and the Mokau River draining to Piopio.
  - Measurement of catchment areas and long sections along the longest watercourses and calculation of equal area slopes for these water courses.
  - Estimation of the catchment time of concentrations for the two catchments and the corresponding lag times.
  - Assessment of the rainfall loss regime (SCS curve number (CN) for the catchments based on soil permeability from the Landcare Research Soil Permeability map and land use from Google Earth imagery.
- Rainfall:
  - Assessment of storm rainfall characteristics and generation of hyetographs for the two catchments and the hydraulic model areas using HIRDS V4 storm rainfall and temporal distributions for storm durations of 1, 6, 12, 24, 48 and 72 hours.
- Flood analyses:
  - Simulation of inflow hydrographs to the two hydraulic model areas for 20 year and 100 year average recurrence interval (ARI) events for current climatic conditions and 100 year ARI events with rainfall projected to 2101-2120 according to RCP 4.5, RCP 6.0 and RCP 8.5 using the SCS Unit Hydrograph method as implemented in HEC-HMS.
  - Acquisition of the flow record for Mangaokewa Stream at Te Kuiti from Environment Waikato and frequency analysis to estimate flood peaks for 20 and 100 year ARI.
  - Comparison of simulated hydrograph peaks with frequency analysis results and adjustment of model parameters as required.
  - Generation of inflow hydrographs and rain-on-grid time series for 20 and 100 year ARI present day and 100 year ARI with climate change projected according to RCP 4.5, RCP 6.0 and RCP 8.5.

## 3.1 Catchment characteristics

The catchments (yellow shading) and hydraulic model areas (beige shading) are shown in Figure 3.1 and the catchment characteristics are summarised in Table 3.1.

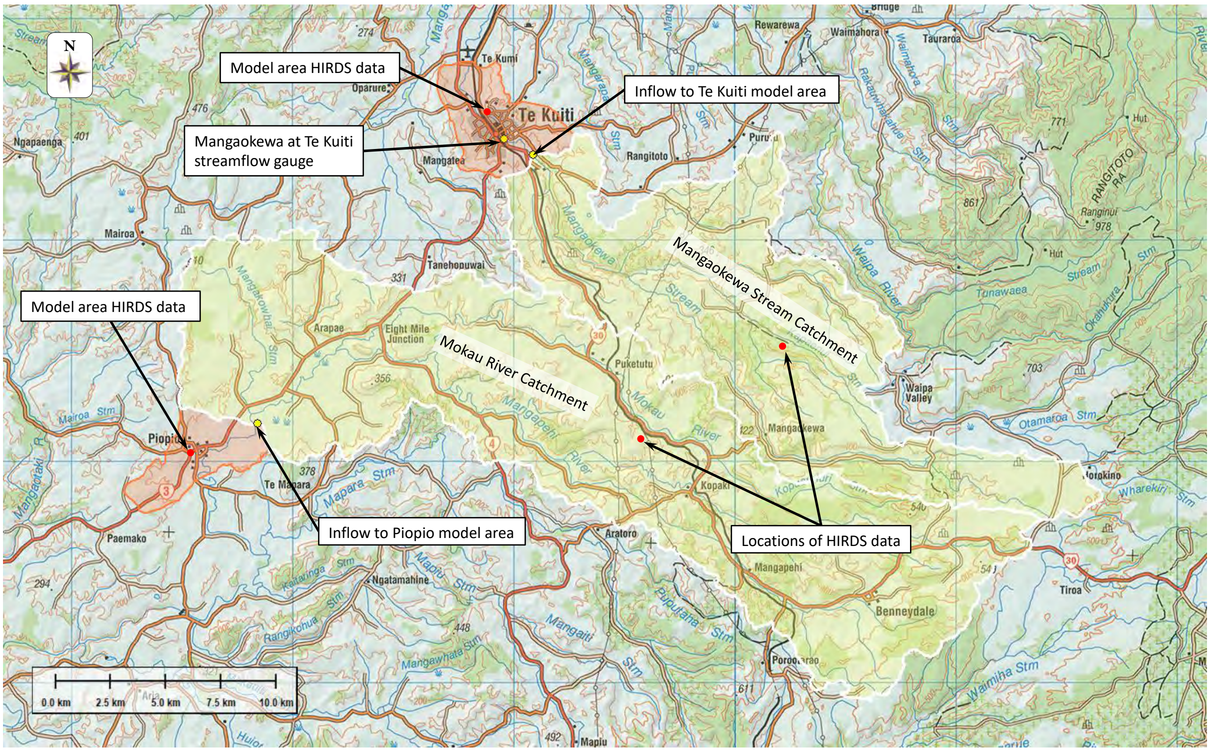


*Figure 3.1: Location of catchments and model areas*

**Table 3.1: Catchment characteristics**

| Characteristic | Mangaokewa to streamflow gauge | Mangaokewa to model area | Mokau to model area |
|---|---|---|---|
| Catchment area ($km^2$) | 173 | 168 | 293 |
| Longest water course (km) | 43 | 41 | 55 |
| Equal area slope (m/m) | 0.0079 | 0.0087 | 0.0036 |
| Forest area (%) | 15 | 16 | 15 |
| Pasture (%) | 85 | 84 | 85 |
| Soil Group | Predominantly Group B (Landcare Research Soil Permeability Map) | | |
| Estimated Curve Number (CN) | 60 | 60 | 60 |
| Adopted model parameters after calibration[1] | | | |
| Adopted CN after calibration | 53 | 53 | 53 |
| Soil storage (S) (mm) | 225 | 225 | 225 |
| Initial abstraction (Ia) (mm) (0.2S) | 45 | 45 | 45 |
| Time of Concentration Tc (hours) | 12.5 | 11.8 | 18.7 |
| Lag (minutes) | 501 | 472 | 747 |

1 Section 3.3.1 Model calibration

## 3.2 Rainfall

Design rainfall data was obtained from the HIRDS V4 database for locations near the centre of each of the catchments. These data were used to generate hyetographs using the HIRDS temporal distributions (north of North Island selected) for 20 and 100 year ARI, historic climate, and 100 year ARI with climate change projected to 2101-2120 time horizon for RCP 4.5, RCP 6.0 and RCP 8.5

scenarios. Aerial reduction factors (ARF) were calculated using the general formula in the HIRDS V4 document and used to adjust point rainfall to catchment rainfall. The hyetographs for the Mangaokewa and Mokau catchments are included in Appendix A.

## 3.3 Rainfall-runoff model

An event based rainfall-runoff model was set up in HEC-HMS and calibrated to simulate design hydrographs.

### 3.3.1 Model calibration

Flow has been measured in the Mangaokewa Stream at Te Kuiti by Waikato Regional Council (WRC) since 1983 (site number 414.13). The annual maxima were obtained from WRC and the flood frequency distribution determined. The results are shown in Figure 3.2 and tabulated in Table 3.2.

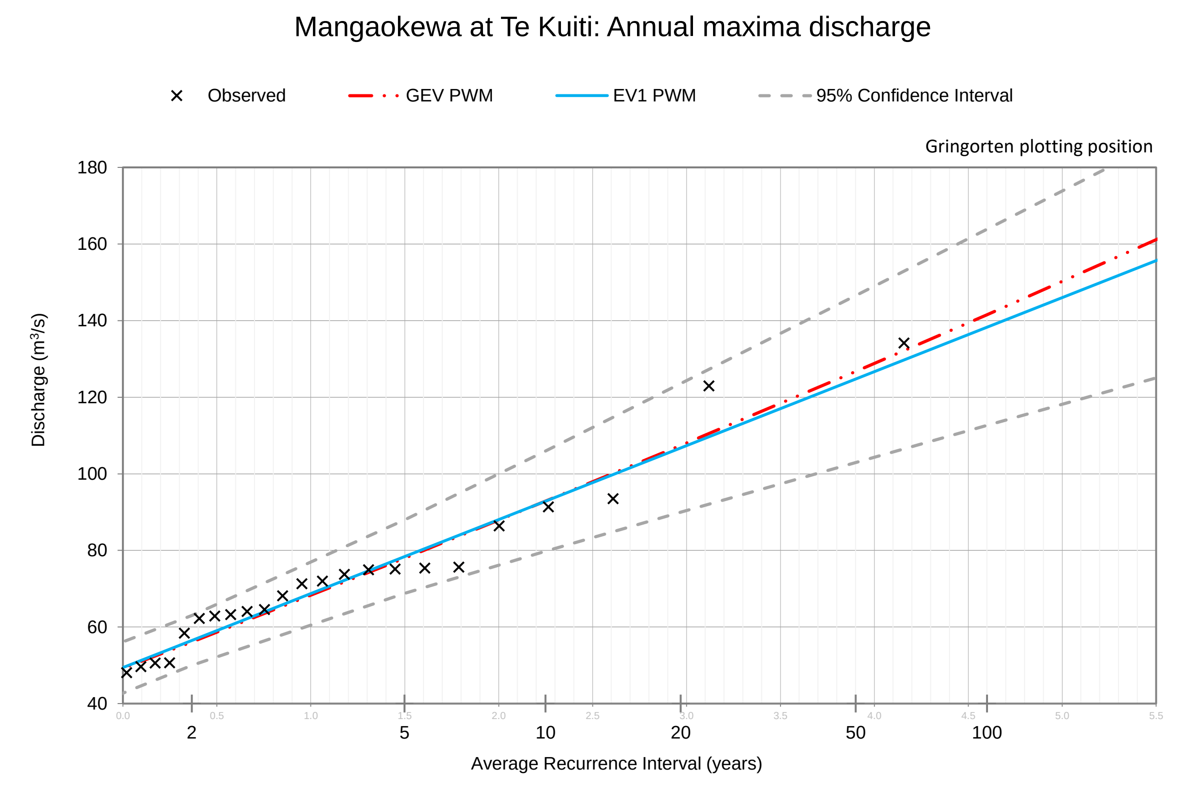


*Figure 3.2: Mangaokewa at Te Kuiti: Flood frequency distribution*

**Table 3.2: Mangaokewa flood frequency results**

| ARI (years) | Discharge | | |
|---|---|---|---|
| | 95% lower estimate | Extreme Value Type 1 | 95% upper estimate |
| 20 | 90 | 107 | 124 |
| 100 | 113 | 138 | 164 |

The rainfall-runoff model parameters (CN, Ia and Lag) were adjusted so that the simulated peak discharge generated using the present day 20 year and 100 year ARI design rainfall, input to HEC-HMS as HIRDS V4 hyetographs (Appendix A), were within the bounds set by the 95 percentile confidence bands. Simulated 20 year and 100 year ARI hydrograph peaks of 92 $m^3/s$ and 158 $m^3/s$ respectively were generated with model parameters CN 53, Ia 45 and Lag 500 minutes. Relative to the flood frequency results, the 20 year ARI flood peak from the model is underestimated by 14% and the 100 year ARI flood peak is overestimated by 14%, but both are within the 95% confidence band.

Based on calibration results for the Mangaokewa Stream, CN 53, Ia 45 with Lag of 472 and 747 minutes (calculated using the formula for Tc) were adopted for the Mangaokewa and Mokau streams draining into the hydraulic model areas respectively.

## 3.4 Design hydrographs

The calibrated HEC-HMS model was used to generate design hydrographs for input to the Te Kuiti and Piopio hydraulic model areas. The hydrograph peaks are summarised in Table 3.3 and the 48 hour storm hydrographs are shown in Figure 3.3 and Figure 3.4 for the Mangaokewa and Mokau catchments respectively.

**Table 3.3: Mangaokewa and Mokau catchments: Simulated peak discharge into model area**

| **Mangaokewa** | | | | | |
|---|---|---|---|---|---|
| **Storm duration** | **6 hour** | **12 hour** | **24 hour** | **48 hour** | **72 hour** |
| **Scenario** | **Peak discharge ($m^3/s$)** | | | | |
| Present day 20 year ARI | 10 | 32 | 61 | 90 | **93** |
| 100 year ARI | | | | | |
| Present day | 31 | 72 | 117 | **153** | 151 |
| RCP 4.5 | 52 | 104 | 152 | **188** | 180 |
| RCP 6.0 | 67 | 125 | 175 | **209** | 198 |
| RCP 8.5 | 82 | 146 | 197 | **230** | 215 |
| **Mokau** | | | | | |
| Present day 20 year ARI | 9 | 33 | 73 | 121 | **134** |
| 100 year ARI | | | | | |
| Present day 100 year ARI | 31 | 78 | 140 | 207 | **217** |
| RCP 4.5 | 53 | 113 | 184 | 254 | **260** |
| RCP 6.0 | 69 | 137 | 212 | 284 | **287** |
| RCP 8.5 | 85 | 160 | 240 | **313** | 233 |

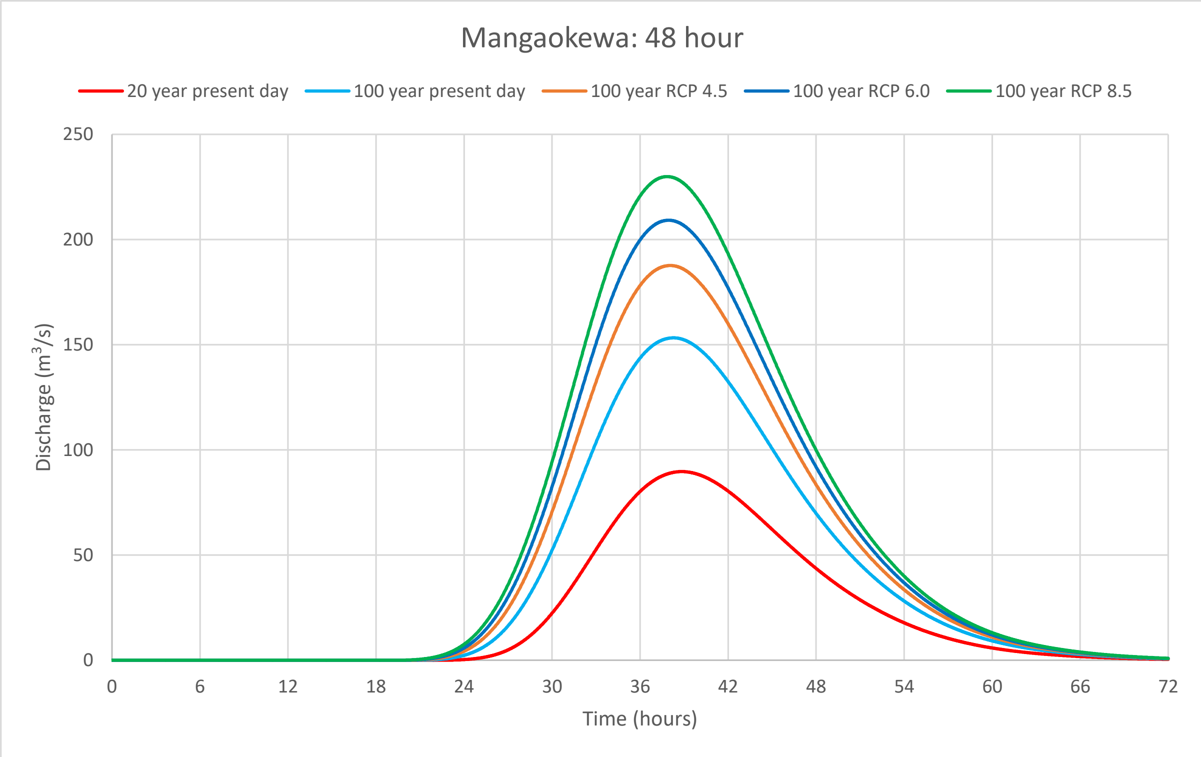


*Figure 3.3: Mangaokewa Catchment: 48 hour hydrographs*

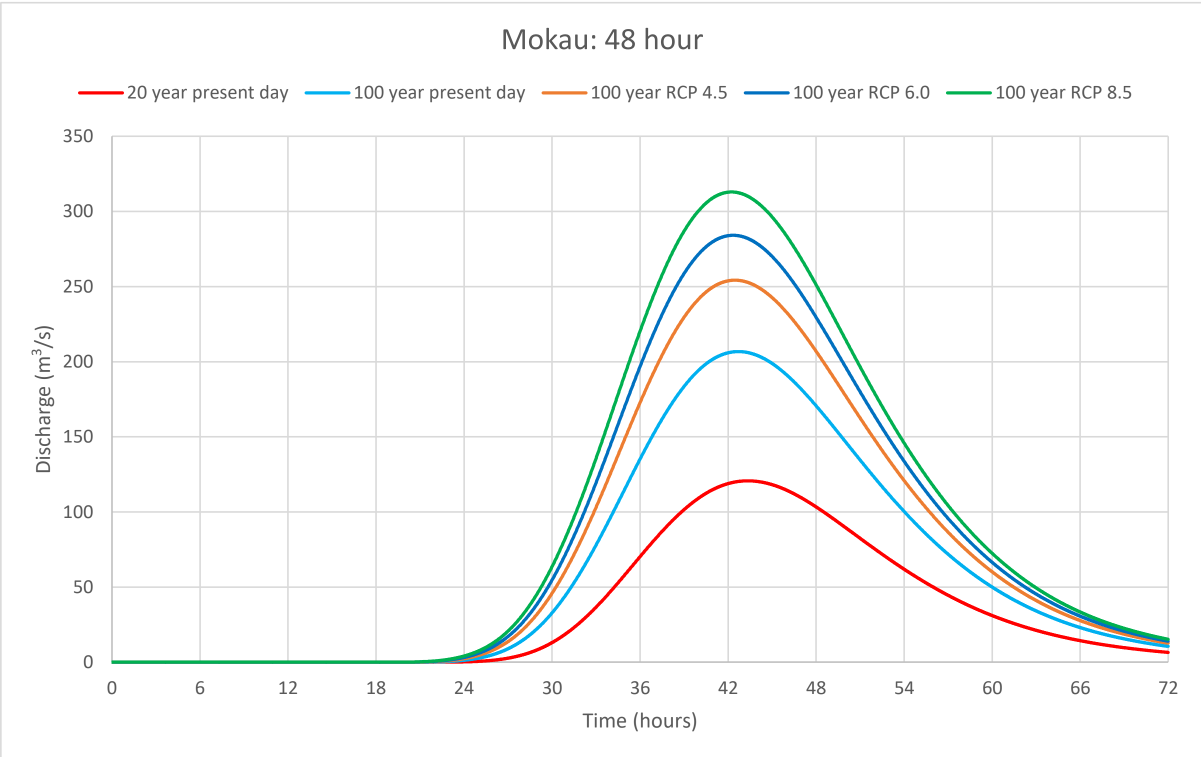


*Figure 3.4: Mokau Catchment: 48 hour hydrographs*

# 4 Hydraulic assessment

Table 4.1 provides a summary of the key parameters and inputs for the Te Kuiti and Piopio hydraulic models. For the other assessment areas, a less detailed approach was adopted, as described in Table 4.1 below.

**Table 4.1: Summary of hydraulic model parameters and inputs**

| | | |
|---|---|---|
| **Model software** | TUFLOW HPC version 2018-03-AB (64 bit single precision) software | |
| **Model cell size** | 4 m by 4 m | |
| **Time step** | The TUFLOW HPC model applies an adaptive time step based on a maximum Courant number of 1. | |
| **Viscosity** | The default viscosity approach in TUFLOW HPC is a Smagorinsky method. The default Smagorinsky coefficient of 0.20 has been adopted for this modelling. | |
| **Model area** | 19.1 km² around Te Kuiti, as shown in Figure 4.2.<br>14.5 km² around Piopio, as shown in Figure 4.8. | |
| **Model topography** | Te Kuiti | The model topography has been created from three different Digital Elevation Model (DEM) sources:<br>• 4 m DEM provided by Waitomo District Council for most of model area<br>• 8 m DEM sourced from LINZ Data Service and derived from 20 m contours to fill gaps in the above<br>• DEM for the low flow channel in the Mangaokewa Stream downstream of Te Kuiti, created by interpolating between surveyed cross sections provided by Waikato Regional Council.<br>Further adjustments have been made using polygons to:<br>• Interpolate through obstructions in the channel caused by bridges and culverts<br>• Interpolate across a buffer zone between the different DEM sources to ensure smooth transitions in the model topography<br>Coverage for each data source is shown in Figure 4.1. |
| | Piopio | Two different DEM sources have been used for Piopio:<br>• 2 m DEM provided by Waitomo District Council for the township<br>• 8 m DEM sourced from LINZ Data Service and derived from 20 m contours for the remaining area. The accuracy of the hydraulic model results is limited by the lack of detail in the DEM in these areas.<br>Further adjustments have been made using polygons to:<br>• Extrapolate levels for the Mokau River upstream of the area covered by the 2m DEM, as the 8m DEM has insufficient detail in this area<br>• Interpolate through obstructions to the channel caused by bridges and culverts<br>• Interpolate across a buffer zone between the different DEM sources to ensure smooth transitions in the model topography.<br>Coverage for each data source is shown in Figure 4.7. |
| **Upstream boundary** | Inflow hydrographs for the Mokau River and Mangaokewa Stream have been applied at the upstream model extents. A 48 hour storm duration has been used for all events. | |
| **Downstream boundary** | A HQ boundary has been applied at the downstream model extents on the Mokau River and Mangaokewa Stream. This allows water to leave the model using a stage-discharge relationship based on the slope. | |

| | |
|---|---|
| **Rainfall** | Rainfall has been applied to each cell within the model extents based on a 48 hour storm duration hyetograph using design rainfall data obtained from the HIRDS V4 database. |
| **Infiltration** | Soil infiltration has been modelled using the Horton method. The Horton parameters applied to each soil drainage category are provided in Table 4.2. These losses are an initial estimate and further work including sensitivity analysis is needed to assess if they are appropriate.<br>Soil drainage categories for each model extent have been obtained from:<br>• Landcare Research's S-map Online for Te Kuiti.<br>• Landcare Research's Fundamental Soil Layers for Piopio. |
| **Roughness** | Manning's n roughness values applied to each grid cell based on assigned land use categories. Land use categories have been defined based on three sources:<br>• The Land Cover Database (LCDB) version 4.1 sourced from the LRIS Portal.<br>• Building footprints provided by Waitomo District Council.<br>• Road centrelines sourced from LINZ Data Service. Low roughness values have been applied to 10m wide polygon along each road centreline. |
| **Model Scenarios** | Five design storm events have been run for both the Te Kuiti and Piopio models:<br>• Present day 20yr ARI event.<br>• Present day 100yr ARI event.<br>• 100yr ARI with RCP4.5 climate change scenario.<br>• 100yr ARI with RCP6 climate change scenario.<br>• 100yr ARI with RCP8.5 climate change scenario. |

**Table 4.2: Soil infiltration parameters**

| Soil drainage category | Initial loss (mm) | Initial loss rate (mm/hr) | Final loss rate (mm/hr) | Exponential decay rate (1/hr) |
|---|---|---|---|---|
| Very poorly drained | 0 | 0.5 | 0.45 | 0.4176 |
| Poorly drained | 0 | 2 | 1.5012 | 0.29412 |
| Imperfectly drained | 0 | 3.5 | 2.9988 | 0.25632 |
| Moderately drained | 0 | 8 | 1 | 0.23256 |
| Well drained | 0 | 25 | 22.5 | 0.20844 |

## 4.1 Te Kuiti

### 4.1.1 Topographical information

The 2D model was developed using topographical data from three major sources. These were (1) the detailed DEM available from Waikato Regional Council (WRC), (2) the coarse DEM available from LINZ and (3) stream cross section information from WRC. For the selected 2D model extent, a blend of these three sources of information was required, done as follows.

A hierarchy was established, with the data from the cross section survey being taken as the most applicable, followed by the detailed DEM and finally the coarse DEM. The interface between coarse and fine DEM's was blended by removing a 20 m wide stretch of the coarse DEM, at the interface with the fine DEM. Following this the 20 m wide strip was interpolated between coarse and fine DEM's to give a smooth transition between the two. In this way all of the fine DEM was used, with reliance on the coarse DEM only in the absence of any other data.

Where the fine DEM was found to include bridges over major waterways, the DEM was adjusted by "burning" in the waterway to remove bridge obstructions.

The respective data sources are shown on an overlay in Figure 4.1. The resulting DEM covering the model domain is shown in Figure 4.2.

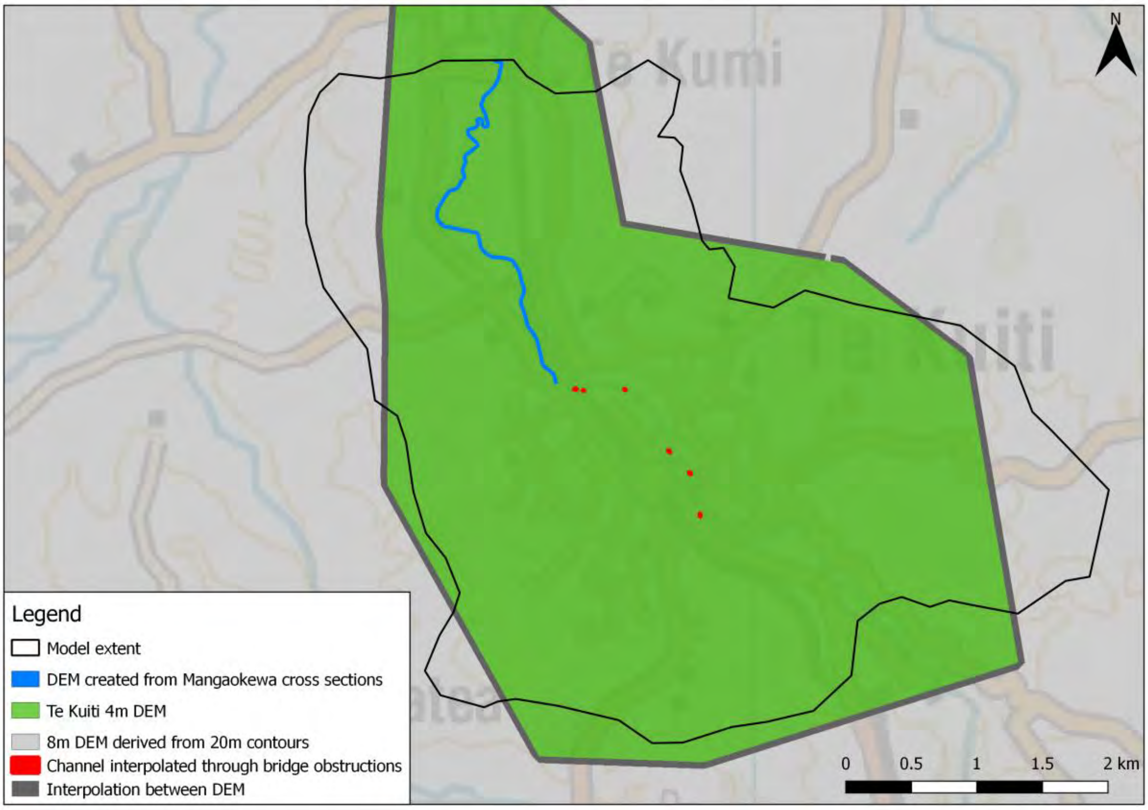


*Figure 4.1: Topographical data sources for Te Kuiti*

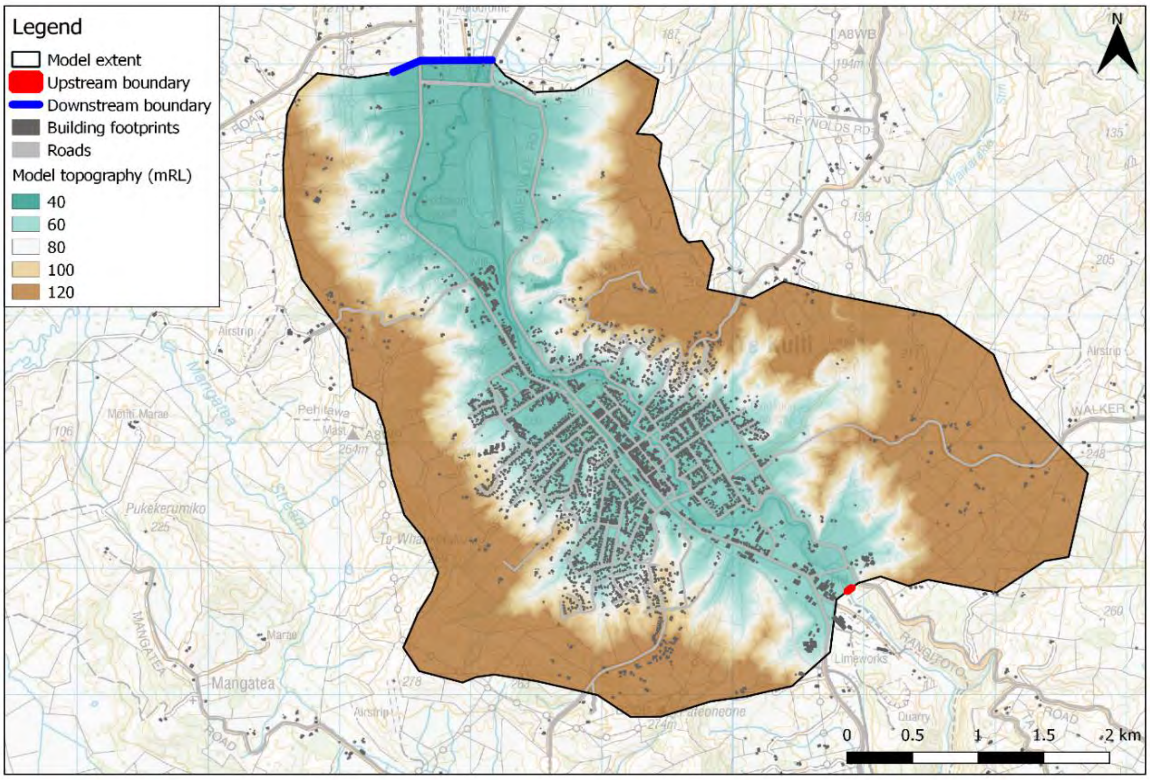


*Figure 4.2: Te Kuiti model extent*

### 4.1.2 Surface water network

Drainage through Te Kuiti is dominated by flow in the Mangaokewa River, an example of which is shown in Figure 4.3. It has an upstream catchment of some 173 $km^2$, with a flow recorder installed close to the pumping station in Waitete Road, shown in Figure 4.4. This flow recorder has records dating back to 1983, and therefore provides reasonably robust peak flow frequency estimates.

We have sourced the previous modelling assessment[3] for Te Kuiti, undertaken by Waikato Regional Council, and have made use of this in our assessment.

The Mangaokewa River flows from south to north through Te Kuiti and splits the urbanised areas to those on the true left and true right sides of the river. On the true left (western) side, surface drainage is affected by the railway line embankment, through which drainage needs to pass in order to reach the river. In these areas there are several drainage intakes that convey runoff to the river, examples of which are shown in Figure 4.5 and Figure 4.6. On the eastern side of the river, surface runoff is collected within the urban stormwater network and conveyed to the river via the pipe and overland flow path network.

*Figure 4.3: Mangaokewa River through Te Kuiti*

*Figure 4.4: Gauge location on Mangaokewa River*

*Figure 4.5: Drainage to river from western side*

*Figure 4.6: Outlet to river in Te Kuiti*

[3] Environment Waikato (2004), *Hydraulic Investigation, Mangaoweka Stream, Te Kuiti Urban Area*, Environment Waikato Technical Report 2004/28, ISSN 1172-4005, 15 November 2004.

## 4.2 Piopio

### 4.2.1 Topographical information

The 2D model for Piopio was developed using topographical data from two major sources. These were (1) the detailed DEM available from Waikato Regional Council (WRC) and (2) the coarse DEM available from LINZ. For the selected 2D model extent, a blend of these two sources of information was required, done as follows.

The interface between coarse and fine DEM's was blended by removing a 20 m wide stretch of the coarse DEM, at the interface with the fine DEM. Following this the 20m wide strip was interpolated between coarse and fine DEM's to give a smooth transition between the two. In this way all of the fine DEM was used, with reliance on the coarse DEM only in the absence of any other data.

Where the fine DEM was found to include bridges over major waterways, the DEM was adjusted by "burning" in the waterway to remove bridge obstructions. However, in many cases smaller culverts were left in a "blocked" state in order to show a conservative flood extent. This assumption was backed up by observations of these culverts made during a site visit, where many were shown to be largely blocked by vegetation and debris. The sources of topographical information used in the model are shown in Figure 4.7. The model layout is shown in Figure 4.8.

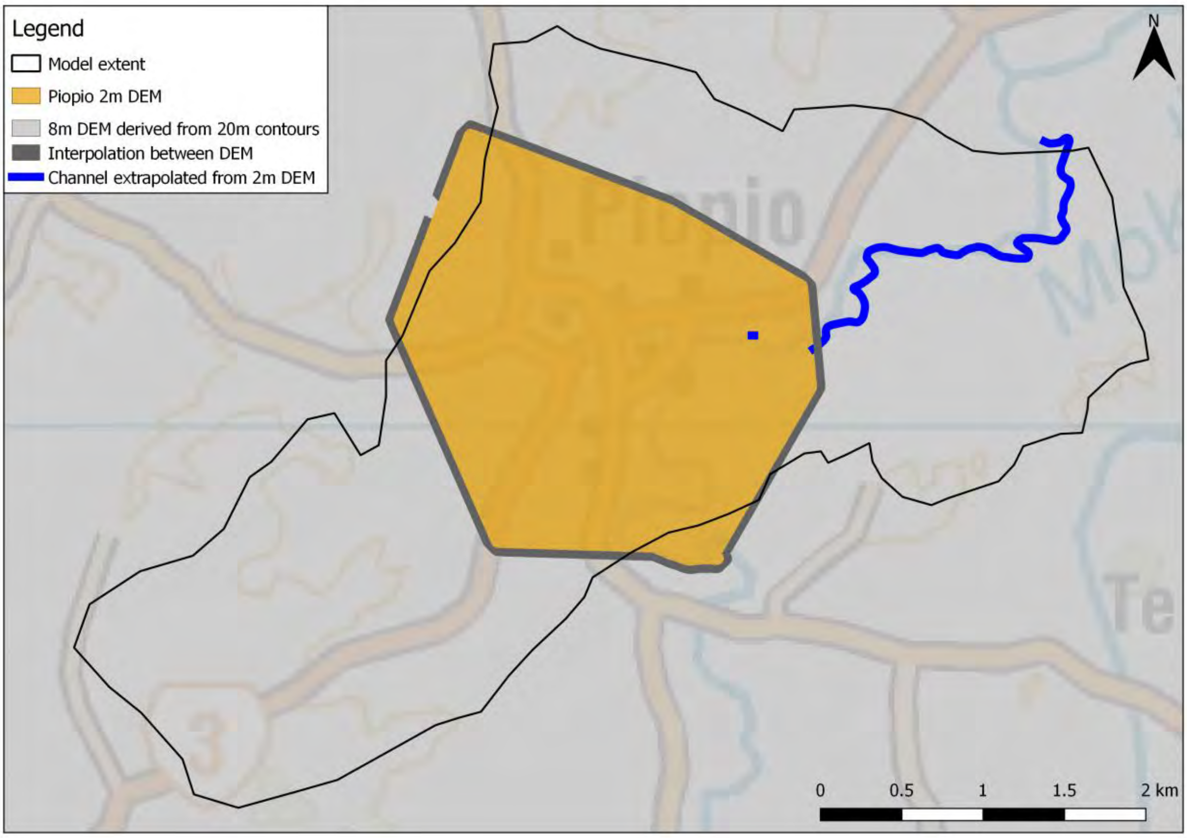


*Figure 4.7: Topographical data sources for Piopio*

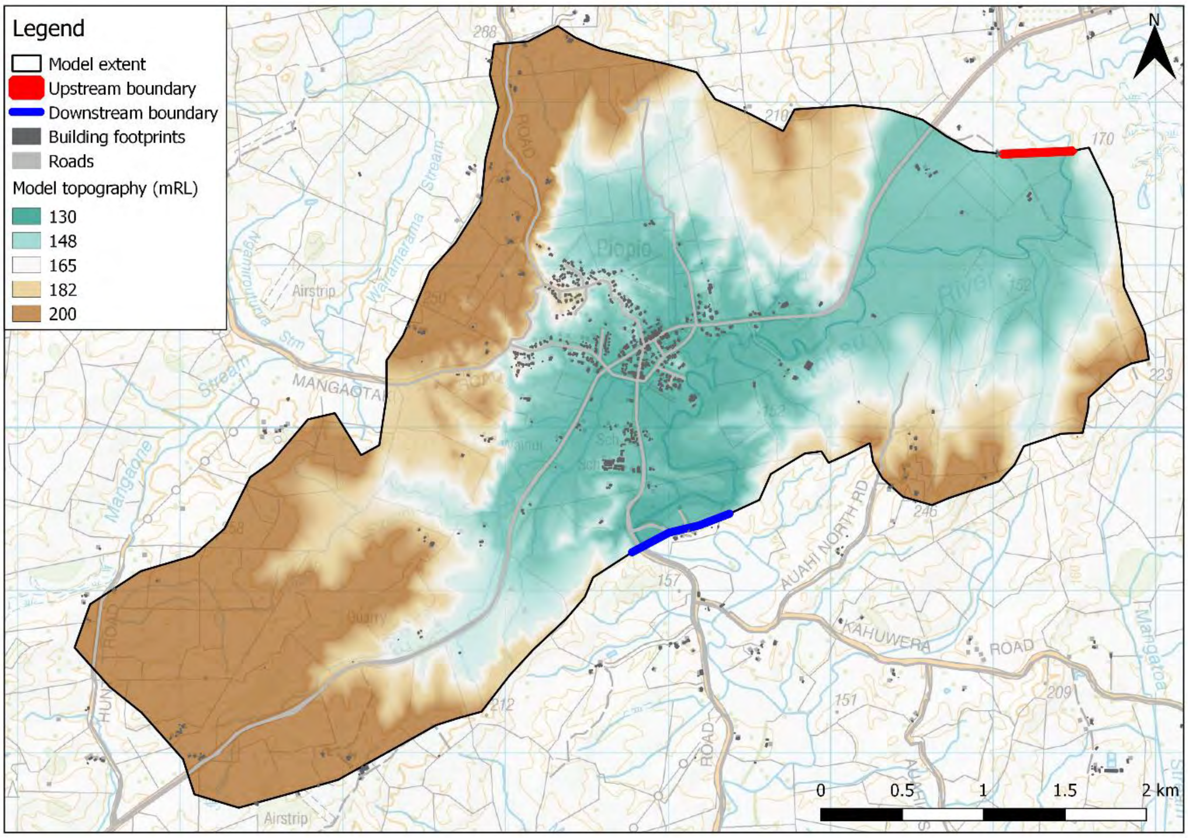


*Figure 4.8: Piopio model extent*

### 4.2.2 Surface water network

The township of Piopio lies adjacent to an upper reach of the Mokau River. There are several other tributary streams that join the Mokau River in and around the township, all of which pose potential flood hazard. Of these, the Piopio Stream that passes through the southern edge of the urbanised area is reasonably significant in a flood context due to the flat ground in the vicinity of its confluence with the Mokau River. Similarly, the Kurutahi Stream at the northern side of Piopio has the potential to convey high flood flows and cause surface ponding, especially close to the confluence with the Mokau River. In Figure 4.9 the Kurutahi Stream is shown, together with the bridge at SH3. In Figure 4.10 the same stream is shown, but also with the culvert located downstream of the SH3 bridge.

There are no gauging sites that are relevant to this area for use in model calibration.

In the northern part of Piopio, drainage to the Mokau River is impeded by limited crossings beneath State Highway 3. Flooding from the Mokau River is also a potential threat to urbanised areas Piopio. Towards the southern part of Piopio, the main flood mechanism is a lack of drainage capacity in the Piopio Stream, as evident in Figure 4.11 and Figure 4.12. For this reason, all of the catchment of the Piopio Stream was included in the 2D model extent used for this work.

*Figure 4.9: Kurutahi Stream showing SH3 bridge*

*Figure 4.10: Kurutahi Stream showing culvert downstream of SH3 bridge*

*Figure 4.11: Piopio Stream at southern edge of Piopio*

*Figure 4.12: Tributary to Piopio Stream*

## 4.3 Awakino

The subject area for the proposed floodplain extent assessment did not include Awakino township itself, but was focussed more on areas located upstream. However, in order to conduct the assessment it was necessary to include the whole river system to the mouth. Not all of the assessment area was included in high resolution DEM available, and reliance had to be made on an 8 m DEM, derived from contours at 20 m intervals, available from LINZ.

In this area, the high resolution and coarse resolution DEM's did not marry well at the edges, with the 8 m DEM ending at an elevation of 20 mRL. Because much of the lower floodplain is at elevation below this, inundation extents in areas of course DEM were assessed qualitatively using aerial photographs, field observations and exiting drainage features

Drainage in the Awakino area is dominated by the Awakino River. The flood extents expected in this area were estimated as being driven by an extreme river flood, rather than by extreme local rainfall.

Within Awakino township itself, existing buildings are located close to the river, as shown in Figure 4.13. State Highway 3 runs adjacent to the true left bank of the Awakino River as shown in Figure

4.14. The State Highway also crosses the floodplain several kilometres upstream of Awakino on a raised embankment, as shown in Figure 4.15. In the same area, existing houses have been built with floor levels raised well above surrounding ground level, with an example shown in Figure 4.16.

*Figure 4.13: Awakino township looking upstream, Awakino River on right*

*Figure 4.14: Awakino River looking downstream towards Awakino township*

*Figure 4.15: SH3 crossing the Awakino floodplain*

*Figure 4.16: Houses adjacent to Awakino River*

## 4.4 Marokopa

The settlement of Marokopa is located close to the mouth of the Marokopa River (see Figure 4.17), and can be accessed via Marokopa Road. This road follows the river for several kilometres upstream.

All of the interest area at Marokopa was included in the high resolution DEM available, which extends from the coast to the bridge over the river at Marokopa Road. Part of the township is located on an isthmus with river frontage on both sides, both east and west. The eastern riverfront is shown in Figure 4.18. In this figure a recent flood debris line is visible, indicating that the river level had recently been close to overtopping.

*Figure 4.17: Marokopa township at the mouth of the Marokopa River*

*Figure 4.18: Marokopa riverfront*

The floodplain of the Marokopa River is reasonably well defined, characterised by flat swampy ground which is drained by a network of farm drains.

## 4.5 Kiritihere

South of Marokopa, the township of Kiritihere is located on the coast at the mouth of the Kiritihere Stream. The floodplain is grazed (see Figure 4.19), and drained by a series of farm drains.

*Figure 4.19: Kiritihere Stream floodplain, bridge on extreme right*

## 4.6 Waitomo Valley Road

The primary drainage feature of the Waitomo Valley Road area is Waitomo Stream, which meanders through a flat floodplain to the north of Waitomo Caves. A notable tributary joins this stream just downstream of the Waitomo Valley Road bridge, draining the area north of State Highway 37.

The DEM available through LINZ was found to be deficient for the purpose of flood hazard assessment, being too coarse for a meaningful analysis to be undertaken. Flood hazard in this area was assessed qualitatively, based on existing drainage features and hydraulic controls.

Waitomo Valley Stream shows signs of erosion on the banks, as shown by placed rock visible in Figure 4.20.

*Figure 4.20: Waitomo Valley Stream downstream of Waitomo Valley Road*

# 5 Flood hazard mapping

In Appendix B the flood hazard maps developed as outlined above are presented. These have been plotted showing the original target interest areas.

In the maps prepared for Te Kuiti and Piopio, the predicted flood depths were developed through hydrological and hydraulic modelling, using a 2D rain-on-grid model with lumped catchment inflows. In the resulting flood maps, inundation depths have been shown. Also available in the source model result files are flood velocity and flow direction, flood hazard index and instantaneous flood depth and velocity outputs (as opposed to only maxima). Sample maximum flood depth and flood velocity plots are shown in Figure 5.1 and Figure 5.2 respectively.

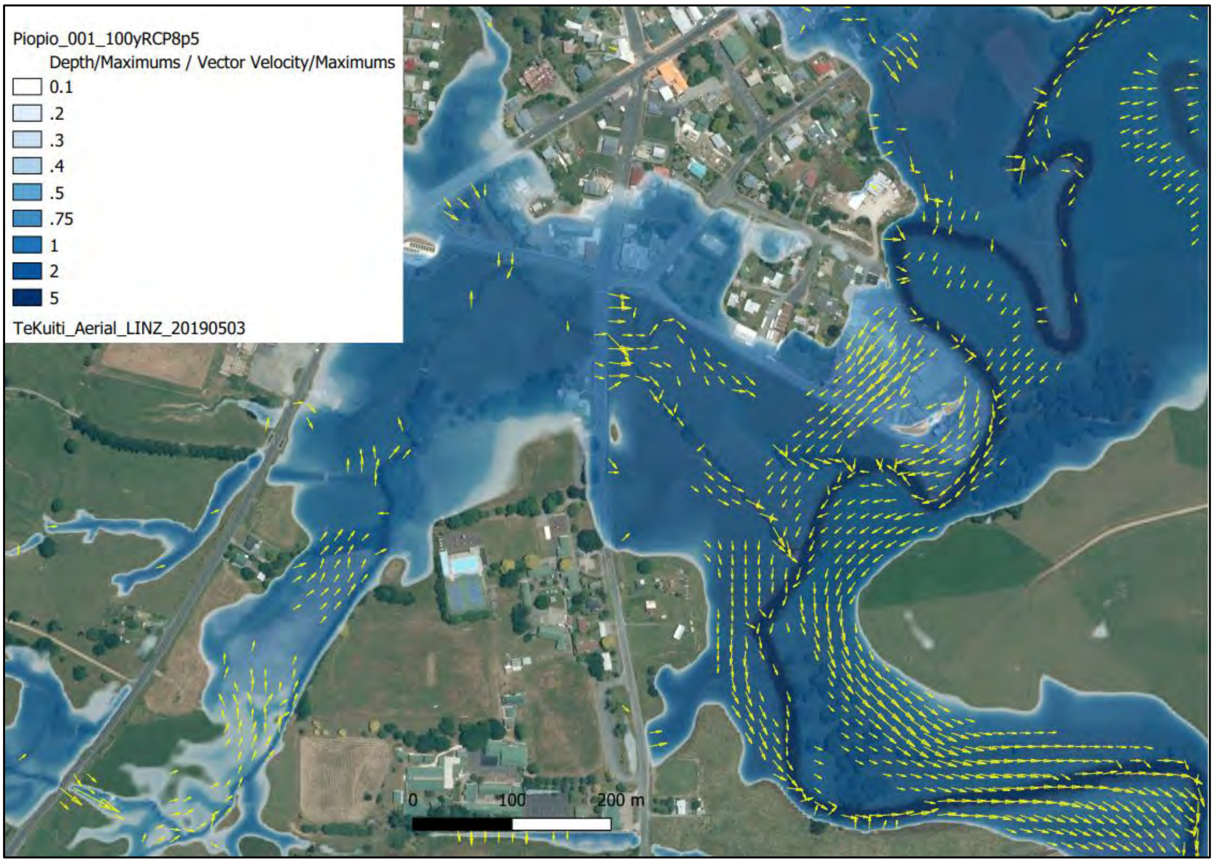


*Figure 5.1: Sample maximum flood depth output*

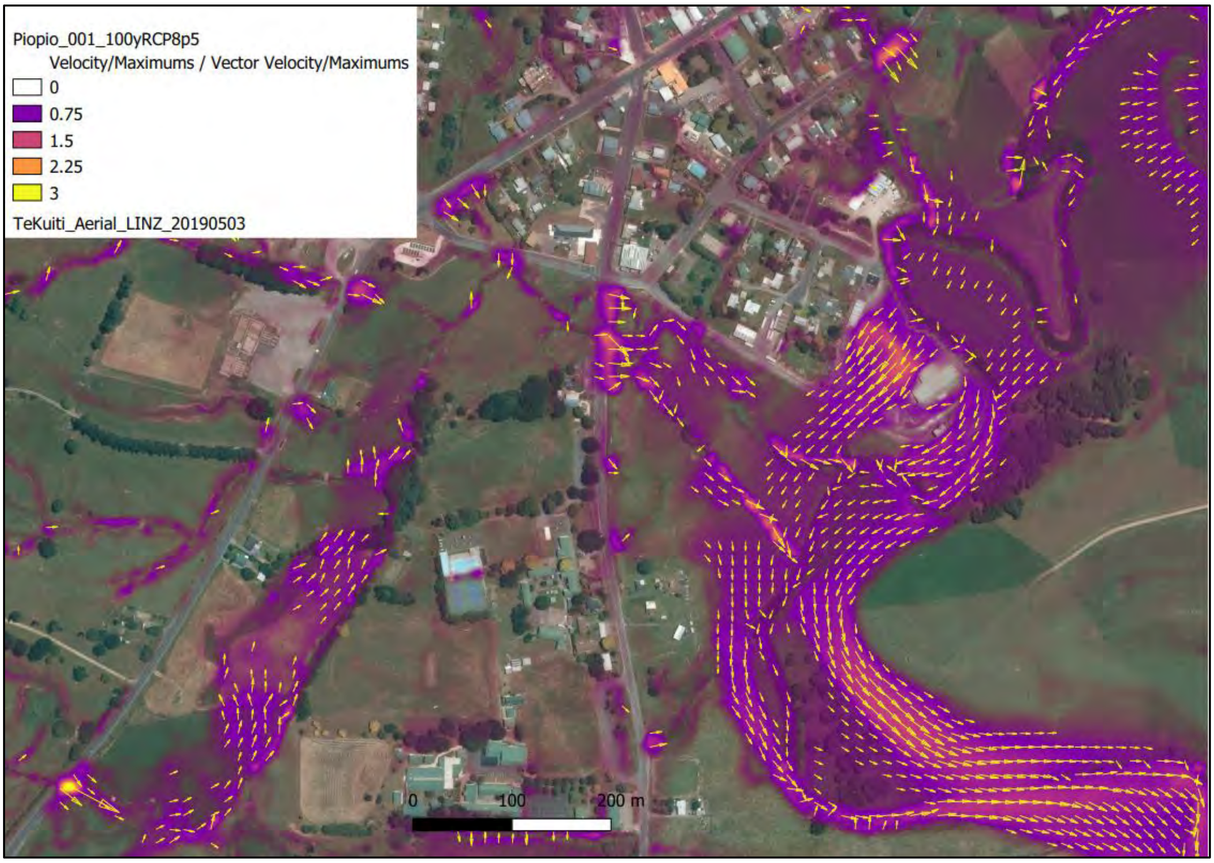


*Figure 5.2: Sample maximum flood velocity output*

This information, comprising depth, velocity and flow direction, can be used in assessment of likely impacts on proposed development and also in assessment of effects of development on surrounding areas. These models are able to be adapted to simulate future land uses, with the ability to predict effects from these.

For the areas of Marokopa, Kiritihere, Waitomo Valley Road and Awakino, the flood map outputs indicate extent only, with the exception of some areas were flood depths have also been calculated. We recommend use of these maps to be for indicative flood extent determination only. This means that the areas likely to be prone to flood hazard are those included in the mapped areas, but no indication of velocity or flow direction is given. In these areas, scenario investigation, as outlined above for Te Kuiti and Piopio, is not possible using the information that has been developed.

In all areas potentially prone to inundation, it is possible to undertake works to mitigate flood hazard. Such works can include changes to ground levels and diversion of flows. If development is targeted for an area shown to be currently prone to inundation, this does not necessarily mean that the effects cannot be mitigated. However, any changes to ground levels and flow paths from those at the time of this assessment may have an effect on the inundation extents predicted and mapped. Periodic review, based on the amount and scale of changes in landform in each of these areas, is recommended.

# 6 Applicability

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

Tonkin & Taylor Ltd

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Authorised for Tonkin & Taylor Ltd by:

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Project Director

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# Appendix A: Hyetographs

- **1 hour hyetographs**
- **6 hour hyetographs**
- **12 hour hyetographs**
- **24 hour hyetographs**
- **48 hour hyetographs**
- **72 hour hyetographs**

### Mangaokewa catchment: 1 hour hyetographs (mm)

| Scenario | 20 year<br>ARF 0.73 | 100 year<br>ARF 0.70 | | | |
|---|---|---|---|---|---|
| Time (minutes) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1.19 | 1.55 | 1.85 | 2.03 | 2.21 |
| 10 | 0.92 | 1.20 | 1.43 | 1.57 | 1.71 |
| 15 | 1.50 | 1.96 | 2.34 | 2.57 | 2.79 |
| 20 | 2.35 | 3.06 | 3.66 | 4.02 | 4.36 |
| 25 | 3.37 | 4.39 | 5.25 | 5.77 | 6.26 |
| 30 | 4.28 | 5.57 | 6.66 | 7.32 | 7.94 |
| 35 | 4.43 | 5.77 | 6.90 | 7.58 | 8.22 |
| 40 | 3.80 | 4.94 | 5.91 | 6.50 | 7.05 |
| 45 | 2.82 | 3.67 | 4.39 | 4.83 | 5.24 |
| 50 | 1.83 | 2.38 | 2.84 | 3.12 | 3.39 |
| 55 | 1.08 | 1.41 | 1.69 | 1.85 | 2.01 |
| 60 | 0.62 | 0.81 | 0.96 | 1.06 | 1.15 |

### Mokau catchment: 1 hour hyetographs (mm)

| Scenario | 20 year<br>ARF 0.66 | 100 year<br>ARF 0.62 | | | |
|---|---|---|---|---|---|
| Time (minutes) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 1.07 | 1.37 | 1.64 | 1.80 | 1.95 |
| 10 | 0.83 | 1.06 | 1.27 | 1.39 | 1.51 |
| 15 | 1.36 | 1.74 | 2.08 | 2.28 | 2.47 |
| 20 | 2.12 | 2.71 | 3.24 | 3.56 | 3.86 |
| 25 | 3.04 | 3.89 | 4.65 | 5.11 | 5.55 |
| 30 | 3.86 | 4.94 | 5.90 | 6.49 | 7.04 |
| 35 | 3.99 | 5.11 | 6.11 | 6.71 | 7.28 |
| 40 | 3.42 | 4.38 | 5.24 | 5.76 | 6.24 |
| 45 | 2.54 | 3.26 | 3.89 | 4.28 | 4.64 |
| 50 | 1.64 | 2.10 | 2.52 | 2.77 | 3.00 |
| 55 | 0.98 | 1.25 | 1.49 | 1.64 | 1.78 |
| 60 | 0.56 | 0.71 | 0.85 | 0.94 | 1.02 |

**Mangaokewa catchment: 6 hour hyetographs (mm)**

| Scenario | 20 year<br>ARF 0.89 | 100 year<br>ARF 0.88 | | | |
|---|---|---|---|---|---|
| **Time (hours)** | **Historic** | | **RCP 4.5** | **RCP 6.0** | **RCP 8.5** |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.25 | 1.91 | 2.49 | 2.91 | 3.16 | 3.39 |
| 0.50 | 0.61 | 0.79 | 0.93 | 1.01 | 1.08 |
| 0.75 | 0.74 | 0.97 | 1.13 | 1.23 | 1.32 |
| 1.00 | 0.91 | 1.19 | 1.39 | 1.51 | 1.62 |
| 1.25 | 1.12 | 1.47 | 1.71 | 1.86 | 2.00 |
| 1.50 | 1.38 | 1.80 | 2.10 | 2.28 | 2.45 |
| 1.75 | 1.68 | 2.20 | 2.56 | 2.78 | 2.99 |
| 2.00 | 2.03 | 2.66 | 3.10 | 3.36 | 3.62 |
| 2.25 | 2.44 | 3.19 | 3.71 | 4.03 | 4.33 |
| 2.50 | 2.88 | 3.76 | 4.39 | 4.76 | 5.12 |
| 2.75 | 3.35 | 4.37 | 5.10 | 5.54 | 5.95 |
| 3.00 | 3.81 | 4.98 | 5.80 | 6.30 | 6.77 |
| 3.25 | 4.23 | 5.53 | 6.45 | 7.00 | 7.52 |
| 3.50 | 4.58 | 5.99 | 6.98 | 7.58 | 8.14 |
| 3.75 | 4.81 | 6.29 | 7.33 | 7.96 | 8.55 |
| 4.00 | 5.34 | 6.98 | 8.14 | 8.84 | 9.49 |
| 4.25 | 5.83 | 7.61 | 8.87 | 9.63 | 10.35 |
| 4.50 | 5.29 | 6.91 | 8.06 | 8.75 | 9.40 |
| 4.75 | 4.51 | 5.90 | 6.87 | 7.46 | 8.02 |
| 5.00 | 3.66 | 4.78 | 5.57 | 6.05 | 6.50 |
| 5.25 | 2.84 | 3.71 | 4.33 | 4.70 | 5.05 |
| 5.50 | 2.14 | 2.80 | 3.26 | 3.54 | 3.81 |
| 5.75 | 1.58 | 2.07 | 2.41 | 2.62 | 2.82 |
| 6.00 | 1.16 | 1.51 | 1.77 | 1.92 | 2.06 |

**Mokau catchment: 6 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.87 | 100 year ARF 0.85 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.25 | 1.83 | 2.39 | 2.78 | 3.02 | 3.24 |
| 0.50 | 0.58 | 0.76 | 0.89 | 0.96 | 1.03 |
| 0.75 | 0.71 | 0.93 | 1.08 | 1.18 | 1.27 |
| 1.00 | 0.88 | 1.14 | 1.33 | 1.45 | 1.55 |
| 1.25 | 1.08 | 1.40 | 1.64 | 1.78 | 1.91 |
| 1.50 | 1.32 | 1.72 | 2.01 | 2.18 | 2.34 |
| 1.75 | 1.61 | 2.10 | 2.45 | 2.66 | 2.86 |
| 2.00 | 1.95 | 2.54 | 2.96 | 3.22 | 3.46 |
| 2.25 | 2.34 | 3.05 | 3.55 | 3.86 | 4.14 |
| 2.50 | 2.76 | 3.60 | 4.20 | 4.56 | 4.90 |
| 2.75 | 3.21 | 4.18 | 4.88 | 5.29 | 5.69 |
| 3.00 | 3.65 | 4.76 | 5.55 | 6.03 | 6.47 |
| 3.25 | 4.06 | 5.29 | 6.17 | 6.70 | 7.20 |
| 3.50 | 4.39 | 5.73 | 6.67 | 7.25 | 7.79 |
| 3.75 | 4.61 | 6.02 | 7.01 | 7.61 | 8.18 |
| 4.00 | 5.12 | 6.68 | 7.78 | 8.45 | 9.08 |
| 4.25 | 5.58 | 7.28 | 8.49 | 9.22 | 9.90 |
| 4.50 | 5.07 | 6.61 | 7.70 | 8.37 | 8.99 |
| 4.75 | 4.33 | 5.64 | 6.57 | 7.14 | 7.67 |
| 5.00 | 3.50 | 4.57 | 5.33 | 5.78 | 6.21 |
| 5.25 | 2.72 | 3.55 | 4.14 | 4.50 | 4.83 |
| 5.50 | 2.05 | 2.68 | 3.12 | 3.39 | 3.64 |
| 5.75 | 1.52 | 1.98 | 2.31 | 2.51 | 2.69 |
| 6.00 | 1.11 | 1.45 | 1.69 | 1.83 | 1.97 |

**Mangaokewa catchment: 12 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.93 | 100 year ARF 0.92 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.5 | 1.69 | 2.19 | 2.51 | 2.71 | 2.89 |
| 1.0 | 0.63 | 0.82 | 0.94 | 1.01 | 1.08 |
| 1.5 | 0.81 | 1.05 | 1.20 | 1.29 | 1.38 |
| 2.0 | 1.04 | 1.35 | 1.54 | 1.66 | 1.77 |
| 2.5 | 1.34 | 1.74 | 1.99 | 2.14 | 2.29 |
| 3.0 | 1.72 | 2.23 | 2.56 | 2.75 | 2.94 |
| 3.5 | 2.20 | 2.85 | 3.27 | 3.52 | 3.76 |
| 4.0 | 2.79 | 3.62 | 4.14 | 4.46 | 4.76 |
| 4.5 | 3.49 | 4.53 | 5.18 | 5.58 | 5.96 |
| 5.0 | 4.29 | 5.57 | 6.38 | 6.87 | 7.33 |
| 5.5 | 5.16 | 6.70 | 7.67 | 8.26 | 8.81 |
| 6.0 | 6.03 | 7.84 | 8.98 | 9.67 | 10.31 |
| 6.5 | 6.84 | 8.88 | 10.17 | 10.95 | 11.69 |
| 7.0 | 7.47 | 9.70 | 11.11 | 11.96 | 12.77 |
| 7.5 | 7.83 | 10.17 | 11.65 | 12.55 | 13.39 |
| 8.0 | 7.64 | 9.93 | 11.37 | 12.24 | 13.07 |
| 8.5 | 7.13 | 9.25 | 10.60 | 11.41 | 12.18 |
| 9.0 | 6.21 | 8.06 | 9.23 | 9.94 | 10.61 |
| 9.5 | 5.08 | 6.60 | 7.56 | 8.14 | 8.69 |
| 10.0 | 3.96 | 5.15 | 5.89 | 6.35 | 6.77 |
| 10.5 | 2.97 | 3.86 | 4.42 | 4.76 | 5.08 |
| 11.0 | 2.17 | 2.82 | 3.23 | 3.48 | 3.72 |
| 11.5 | 1.56 | 2.03 | 2.33 | 2.50 | 2.67 |
| 12.0 | 1.12 | 1.45 | 1.66 | 1.79 | 1.91 |

**Mokau catchment: 12 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.91 | 100 year ARF 0.90 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.5 | 1.63 | 2.11 | 2.42 | 2.60 | 2.78 |
| 1.0 | 0.61 | 0.79 | 0.90 | 0.97 | 1.04 |
| 1.5 | 0.78 | 1.01 | 1.16 | 1.24 | 1.33 |
| 2.0 | 1.00 | 1.30 | 1.49 | 1.60 | 1.71 |
| 2.5 | 1.29 | 1.67 | 1.91 | 2.06 | 2.20 |
| 3.0 | 1.66 | 2.15 | 2.46 | 2.65 | 2.83 |
| 3.5 | 2.12 | 2.75 | 3.14 | 3.39 | 3.61 |
| 4.0 | 2.69 | 3.48 | 3.99 | 4.29 | 4.58 |
| 4.5 | 3.37 | 4.35 | 4.99 | 5.37 | 5.73 |
| 5.0 | 4.14 | 5.36 | 6.13 | 6.60 | 7.05 |
| 5.5 | 4.98 | 6.44 | 7.38 | 7.94 | 8.48 |
| 6.0 | 5.83 | 7.54 | 8.64 | 9.30 | 9.92 |
| 6.5 | 6.60 | 8.54 | 9.79 | 10.54 | 11.24 |
| 7.0 | 7.21 | 9.33 | 10.69 | 11.51 | 12.28 |
| 7.5 | 7.56 | 9.79 | 11.21 | 12.07 | 12.88 |
| 8.0 | 7.38 | 9.55 | 10.94 | 11.78 | 12.57 |
| 8.5 | 6.88 | 8.90 | 10.20 | 10.98 | 11.72 |
| 9.0 | 5.99 | 7.76 | 8.88 | 9.56 | 10.21 |
| 9.5 | 4.91 | 6.35 | 7.28 | 7.83 | 8.36 |
| 10.0 | 3.83 | 4.95 | 5.67 | 6.11 | 6.52 |
| 10.5 | 2.87 | 3.72 | 4.26 | 4.58 | 4.89 |
| 11.0 | 2.10 | 2.72 | 3.11 | 3.35 | 3.57 |
| 11.5 | 1.51 | 1.95 | 2.24 | 2.41 | 2.57 |
| 12.0 | 1.08 | 1.39 | 1.60 | 1.72 | 1.83 |

**Mangaokewa catchment: 24 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.95 | 100 year ARF 0.94 | | | |
|---|---|---|---|---|---|
| **Time (hours)** | **Historic** | | **RCP 4.5** | **RCP 6.0** | **RCP 8.5** |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 1.17 | 1.51 | 1.70 | 1.81 | 1.91 |
| 2 | 0.59 | 0.76 | 0.85 | 0.91 | 0.96 |
| 3 | 0.83 | 1.07 | 1.20 | 1.28 | 1.36 |
| 4 | 1.18 | 1.53 | 1.72 | 1.83 | 1.94 |
| 5 | 1.68 | 2.17 | 2.44 | 2.61 | 2.76 |
| 6 | 2.38 | 3.08 | 3.46 | 3.69 | 3.91 |
| 7 | 3.34 | 4.31 | 4.84 | 5.16 | 5.47 |
| 8 | 4.58 | 5.91 | 6.65 | 7.09 | 7.51 |
| 9 | 6.12 | 7.90 | 8.88 | 9.47 | 10.03 |
| 10 | 7.87 | 10.16 | 11.42 | 12.18 | 12.89 |
| 11 | 9.63 | 12.43 | 13.97 | 14.90 | 15.78 |
| 12 | 11.10 | 14.32 | 16.10 | 17.17 | 18.18 |
| 13 | 11.89 | 15.34 | 17.25 | 18.39 | 19.48 |
| 14 | 11.00 | 14.20 | 15.96 | 17.02 | 18.02 |
| 15 | 10.17 | 13.14 | 14.76 | 15.74 | 16.67 |
| 16 | 8.78 | 11.34 | 12.74 | 13.59 | 14.39 |
| 17 | 7.14 | 9.22 | 10.36 | 11.05 | 11.70 |
| 18 | 5.53 | 7.14 | 8.02 | 8.55 | 9.06 |
| 19 | 4.13 | 5.33 | 5.99 | 6.38 | 6.76 |
| 20 | 3.00 | 3.87 | 4.35 | 4.64 | 4.91 |
| 21 | 2.14 | 2.76 | 3.10 | 3.31 | 3.50 |
| 22 | 1.51 | 1.95 | 2.19 | 2.34 | 2.47 |
| 23 | 1.06 | 1.37 | 1.54 | 1.64 | 1.74 |
| 24 | 0.75 | 0.96 | 1.08 | 1.15 | 1.22 |

**Mokau catchment: 24 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.93 | 100 year ARF 0.93 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 1.13 | 1.46 | 1.64 | 1.75 | 1.85 |
| 2 | 0.57 | 0.73 | 0.82 | 0.88 | 0.93 |
| 3 | 0.81 | 1.04 | 1.16 | 1.24 | 1.31 |
| 4 | 1.15 | 1.47 | 1.66 | 1.77 | 1.87 |
| 5 | 1.63 | 2.10 | 2.36 | 2.52 | 2.67 |
| 6 | 2.31 | 2.97 | 3.34 | 3.56 | 3.77 |
| 7 | 3.24 | 4.16 | 4.68 | 4.99 | 5.28 |
| 8 | 4.44 | 5.71 | 6.42 | 6.85 | 7.25 |
| 9 | 5.94 | 7.63 | 8.58 | 9.15 | 9.69 |
| 10 | 7.63 | 9.82 | 11.03 | 11.77 | 12.46 |
| 11 | 9.34 | 12.01 | 13.50 | 14.40 | 15.25 |
| 12 | 10.76 | 13.84 | 15.55 | 16.59 | 17.57 |
| 13 | 11.53 | 14.83 | 16.66 | 17.77 | 18.82 |
| 14 | 10.67 | 13.72 | 15.42 | 16.44 | 17.41 |
| 15 | 9.87 | 12.69 | 14.26 | 15.21 | 16.11 |
| 16 | 8.52 | 10.95 | 12.31 | 13.13 | 13.90 |
| 17 | 6.93 | 8.90 | 10.01 | 10.67 | 11.30 |
| 18 | 5.36 | 6.90 | 7.75 | 8.27 | 8.75 |
| 19 | 4.00 | 5.15 | 5.78 | 6.17 | 6.53 |
| 20 | 2.91 | 3.74 | 4.20 | 4.48 | 4.74 |
| 21 | 2.07 | 2.67 | 3.00 | 3.20 | 3.39 |
| 22 | 1.46 | 1.88 | 2.12 | 2.26 | 2.39 |
| 23 | 1.03 | 1.32 | 1.49 | 1.58 | 1.68 |
| 24 | 0.72 | 0.93 | 1.04 | 1.11 | 1.18 |

**Mangaokewa catchment: 48 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.96 | 100 year ARF 0.96 | | | |
|---|---|---|---|---|---|
| **Time (hours)** | **Historic** | | **RCP 4.5** | **RCP 6.0** | **RCP 8.5** |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 1.33 | 1.71 | 1.89 | 2.01 | 2.11 |
| 4 | 0.67 | 0.85 | 0.94 | 1.00 | 1.05 |
| 6 | 0.98 | 1.25 | 1.39 | 1.47 | 1.55 |
| 8 | 1.43 | 1.83 | 2.03 | 2.15 | 2.26 |
| 10 | 2.09 | 2.67 | 2.96 | 3.13 | 3.30 |
| 12 | 3.01 | 3.85 | 4.27 | 4.52 | 4.76 |
| 14 | 4.27 | 5.47 | 6.07 | 6.42 | 6.76 |
| 16 | 5.94 | 7.60 | 8.43 | 8.92 | 9.39 |
| 18 | 7.99 | 10.23 | 11.34 | 12.01 | 12.64 |
| 20 | 10.31 | 13.20 | 14.63 | 15.49 | 16.30 |
| 22 | 12.59 | 16.12 | 17.86 | 18.91 | 19.90 |
| 24 | 14.38 | 18.42 | 20.41 | 21.61 | 22.74 |
| 26 | 16.15 | 20.68 | 22.91 | 24.26 | 25.53 |
| 28 | 17.79 | 22.78 | 25.24 | 26.73 | 28.13 |
| 30 | 15.19 | 19.45 | 21.55 | 22.82 | 24.02 |
| 32 | 11.67 | 14.95 | 16.56 | 17.54 | 18.46 |
| 34 | 8.27 | 10.59 | 11.73 | 12.42 | 13.07 |
| 36 | 5.52 | 7.07 | 7.84 | 8.30 | 8.73 |
| 38 | 3.55 | 4.55 | 5.04 | 5.33 | 5.61 |
| 40 | 2.23 | 2.85 | 3.16 | 3.35 | 3.52 |
| 42 | 1.38 | 1.76 | 1.95 | 2.07 | 2.18 |
| 44 | 0.85 | 1.08 | 1.20 | 1.27 | 1.34 |
| 46 | 0.52 | 0.67 | 0.74 | 0.78 | 0.82 |
| 48 | 0.32 | 0.41 | 0.46 | 0.48 | 0.51 |

**Mokau catchment: 48 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.95 | 100 year ARF 0.95 | | | |
|---|---|---|---|---|---|
| **Time (hours)** | **Historic** | | **RCP 4.5** | **RCP 6.0** | **RCP 8.5** |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 1.31 | 1.67 | 1.85 | 1.96 | 2.07 |
| 4 | 0.66 | 0.84 | 0.93 | 0.98 | 1.03 |
| 6 | 0.96 | 1.23 | 1.36 | 1.44 | 1.51 |
| 8 | 1.41 | 1.80 | 1.99 | 2.11 | 2.22 |
| 10 | 2.05 | 2.62 | 2.90 | 3.07 | 3.23 |
| 12 | 2.96 | 3.77 | 4.18 | 4.43 | 4.66 |
| 14 | 4.21 | 5.36 | 5.94 | 6.29 | 6.62 |
| 16 | 5.84 | 7.45 | 8.25 | 8.74 | 9.20 |
| 18 | 7.86 | 10.02 | 11.11 | 11.76 | 12.38 |
| 20 | 10.14 | 12.93 | 14.32 | 15.17 | 15.96 |
| 22 | 12.39 | 15.79 | 17.49 | 18.52 | 19.49 |
| 24 | 14.15 | 18.04 | 19.99 | 21.16 | 22.27 |
| 26 | 15.89 | 20.25 | 22.44 | 23.76 | 25.01 |
| 28 | 17.51 | 22.31 | 24.72 | 26.18 | 27.55 |
| 30 | 14.95 | 19.05 | 21.11 | 22.35 | 23.53 |
| 32 | 11.49 | 14.64 | 16.22 | 17.18 | 18.08 |
| 34 | 8.13 | 10.37 | 11.49 | 12.17 | 12.80 |
| 36 | 5.43 | 6.93 | 7.68 | 8.13 | 8.55 |
| 38 | 3.49 | 4.45 | 4.93 | 5.22 | 5.50 |
| 40 | 2.19 | 2.79 | 3.09 | 3.28 | 3.45 |
| 42 | 1.36 | 1.73 | 1.91 | 2.03 | 2.13 |
| 44 | 0.83 | 1.06 | 1.18 | 1.25 | 1.31 |
| 46 | 0.51 | 0.65 | 0.72 | 0.77 | 0.81 |
| 48 | 0.32 | 0.40 | 0.45 | 0.47 | 0.50 |

**Mangaokewa catchment: 72 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.97 | 100 year ARF 0.97 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 1.67 | 2.12 | 2.34 | 2.46 | 2.58 |
| 6 | 0.97 | 1.23 | 1.35 | 1.42 | 1.49 |
| 9 | 1.50 | 1.91 | 2.10 | 2.21 | 2.32 |
| 12 | 2.32 | 2.95 | 3.24 | 3.42 | 3.58 |
| 15 | 3.54 | 4.49 | 4.94 | 5.21 | 5.46 |
| 18 | 5.30 | 6.73 | 7.40 | 7.80 | 8.18 |
| 21 | 7.70 | 9.79 | 10.76 | 11.35 | 11.90 |
| 24 | 10.74 | 13.65 | 15.00 | 15.82 | 16.60 |
| 27 | 14.14 | 17.96 | 19.74 | 20.82 | 21.84 |
| 30 | 17.24 | 21.90 | 24.07 | 25.39 | 26.62 |
| 33 | 19.17 | 24.35 | 26.77 | 28.23 | 29.61 |
| 36 | 20.44 | 25.97 | 28.55 | 30.10 | 31.57 |
| 39 | 18.33 | 23.29 | 25.60 | 27.00 | 28.32 |
| 42 | 14.77 | 18.77 | 20.63 | 21.76 | 22.82 |
| 45 | 10.94 | 13.89 | 15.27 | 16.11 | 16.89 |
| 48 | 7.60 | 9.65 | 10.61 | 11.19 | 11.74 |
| 51 | 5.05 | 6.42 | 7.05 | 7.44 | 7.80 |
| 54 | 3.26 | 4.14 | 4.55 | 4.80 | 5.04 |
| 57 | 2.07 | 2.62 | 2.88 | 3.04 | 3.19 |
| 60 | 1.29 | 1.64 | 1.81 | 1.91 | 2.00 |
| 63 | 0.81 | 1.03 | 1.13 | 1.19 | 1.25 |
| 66 | 0.50 | 0.64 | 0.70 | 0.74 | 0.78 |
| 69 | 0.31 | 0.40 | 0.44 | 0.46 | 0.48 |
| 72 | 0.20 | 0.25 | 0.28 | 0.29 | 0.30 |

**Mokau catchment: 72 hour hyetographs (mm)**

| Scenario | 20 year ARF 0.96 | 100 year ARF 0.96 | | | |
|---|---|---|---|---|---|
| Time (hours) | Historic | | RCP 4.5 | RCP 6.0 | RCP 8.5 |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 1.64 | 2.08 | 2.28 | 2.41 | 2.53 |
| 6 | 0.95 | 1.20 | 1.32 | 1.39 | 1.46 |
| 9 | 1.47 | 1.87 | 2.05 | 2.16 | 2.27 |
| 12 | 2.27 | 2.88 | 3.17 | 3.34 | 3.50 |
| 15 | 3.47 | 4.40 | 4.83 | 5.10 | 5.35 |
| 18 | 5.20 | 6.58 | 7.23 | 7.63 | 8.00 |
| 21 | 7.56 | 9.57 | 10.52 | 11.10 | 11.64 |
| 24 | 10.54 | 13.35 | 14.68 | 15.48 | 16.23 |
| 27 | 13.87 | 17.57 | 19.31 | 20.36 | 21.36 |
| 30 | 16.91 | 21.42 | 23.55 | 24.83 | 26.04 |
| 33 | 18.80 | 23.82 | 26.18 | 27.61 | 28.96 |
| 36 | 20.05 | 25.40 | 27.92 | 29.45 | 30.88 |
| 39 | 17.98 | 22.78 | 25.04 | 26.41 | 27.70 |
| 42 | 14.49 | 18.36 | 20.18 | 21.28 | 22.32 |
| 45 | 10.73 | 13.59 | 14.94 | 15.76 | 16.52 |
| 48 | 7.45 | 9.44 | 10.38 | 10.95 | 11.48 |
| 51 | 4.95 | 6.28 | 6.90 | 7.28 | 7.63 |
| 54 | 3.20 | 4.05 | 4.45 | 4.70 | 4.93 |
| 57 | 2.03 | 2.57 | 2.82 | 2.98 | 3.12 |
| 60 | 1.27 | 1.61 | 1.77 | 1.87 | 1.96 |
| 63 | 0.79 | 1.00 | 1.10 | 1.16 | 1.22 |
| 66 | 0.49 | 0.62 | 0.69 | 0.72 | 0.76 |
| 69 | 0.31 | 0.39 | 0.43 | 0.45 | 0.47 |
| 72 | 0.19 | 0.25 | 0.27 | 0.28 | 0.30 |

# Appendix B: Flood depth maps

**Te Kuiti**

- **Figure 01: Maximum flood depths – 20 year ARI rainfall event**
- **Figure 02: Maximum flood depths – 100 year ARI rainfall event**
- **Figure 03: Maximum flood depths – 100 year ARI rainfall event – RCP4.5**
- **Figure 04: Maximum flood depths – 100 year ARI rainfall event – RCP6**
- **Figure 05: Maximum flood depths – 100 year ARI rainfall event – RCP8.5**

**Piopio**

- **Figure 06: Maximum flood depths – 20 year ARI rainfall event**
- **Figure 07: Maximum flood depths – 100 year ARI rainfall event**
- **Figure 08: Maximum flood depths – 100 year ARI rainfall event – RCP4.5**
- **Figure 09: Maximum flood depths – 100 year ARI rainfall event – RCP6**
- **Figure 10: Maximum flood depths – 100 year ARI rainfall event – RCP8.5**

**Awakino**

- **Figure 11: Maximum flood extent – 100 year ARI rainfall event**

**Kiritihere**

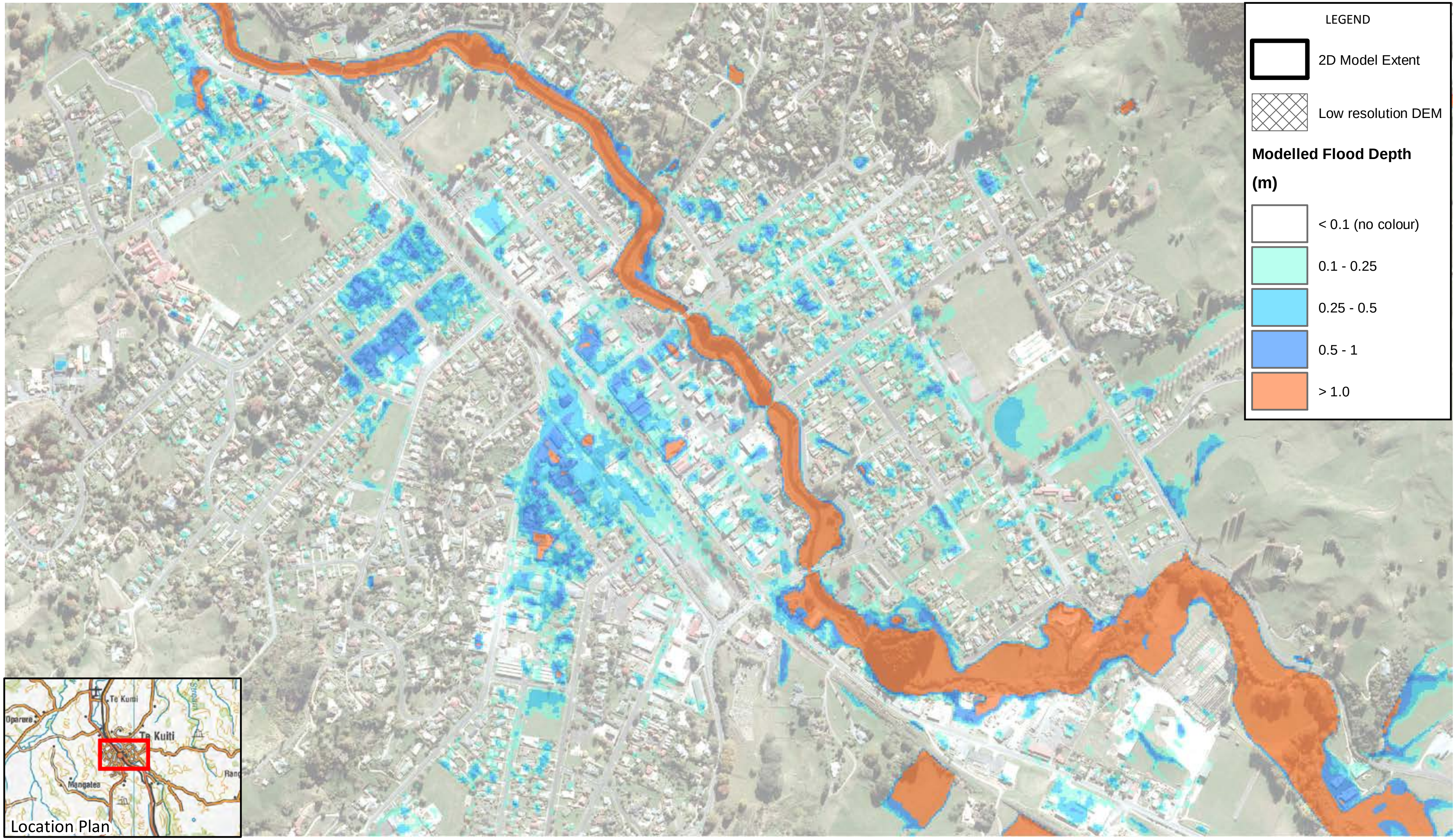
- **Figure 12: Maximum flood extent – 100 year ARI rainfall event**

**Marokopa**

- **Figure 13: Maximum flood extent – 100 year ARI rainfall event**

**Waitomo Valley Road**

- **Figure 14: Maximum flood extent – 100 year ARI rainfall event**




Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE
F01_TeKuiti_020y_01.mxd

SCALE (AT A4 SIZE)
1:10,000

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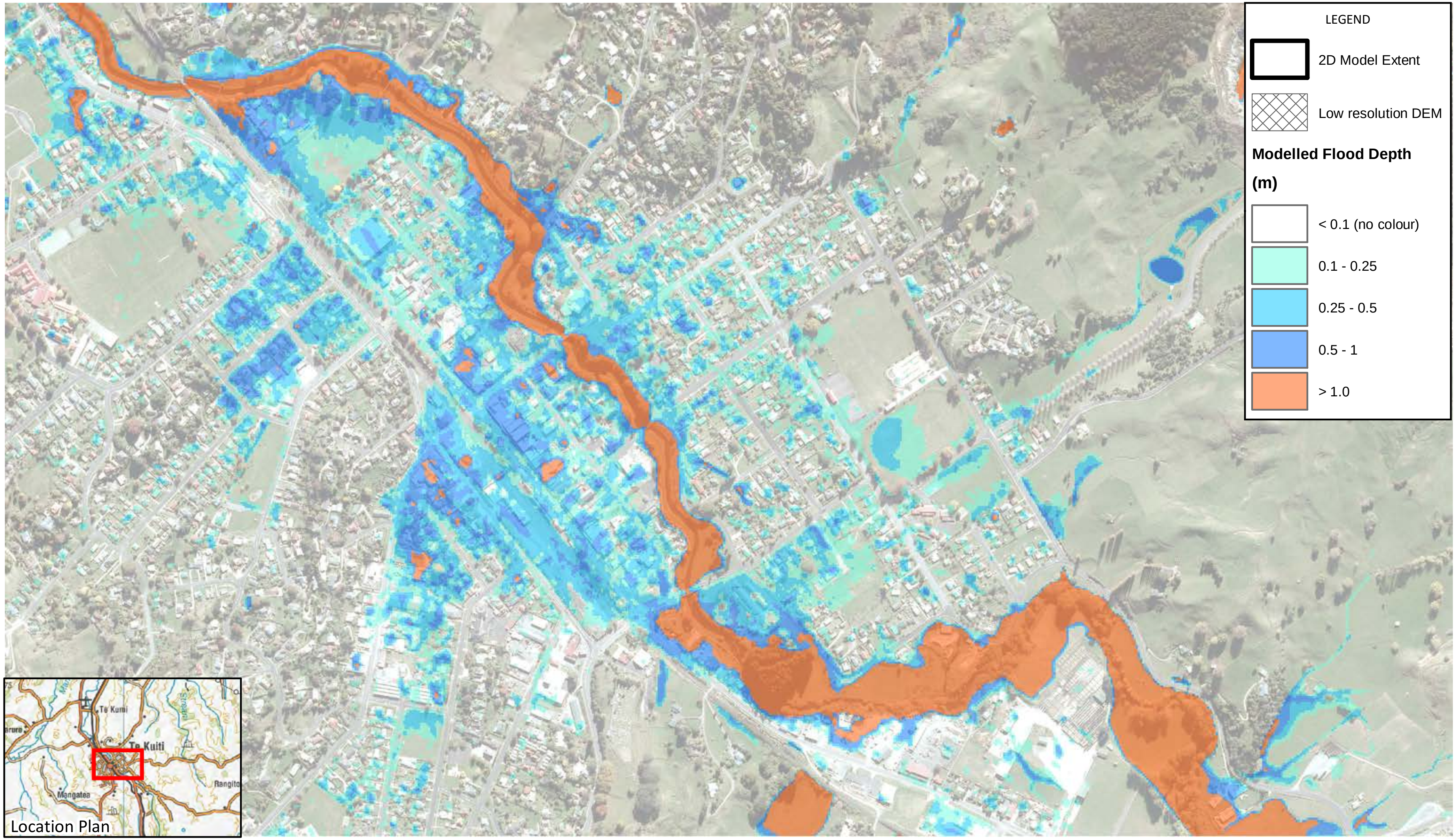
# Waitomo District Council

## Te Kuiti Flood Hazard Assessment
## Preliminary Modelled Flood Depths
## 20 year ARI rainfall event

FIGURE No. Figure 01

Rev. 0

Path: T:\Hamilton\Projects\1004962\1004962.0020\WorkingMaterial\GIS\Figures\20190503_PrelimResults\F01_TeKuiti_020y_01.mxd Date: 3/09/2019 Time: 11:47:24 AM




Path: T:\Hamilton\Projects\1004962\1004962.0020\WorkingMaterial\GIS\Figures\20190503_PrelimResults\F02_TeKuiti_100y_01.mxd Date: 3/09/2019 Time: 11:51:37 AM

Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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SCALE (AT A4 SIZE)
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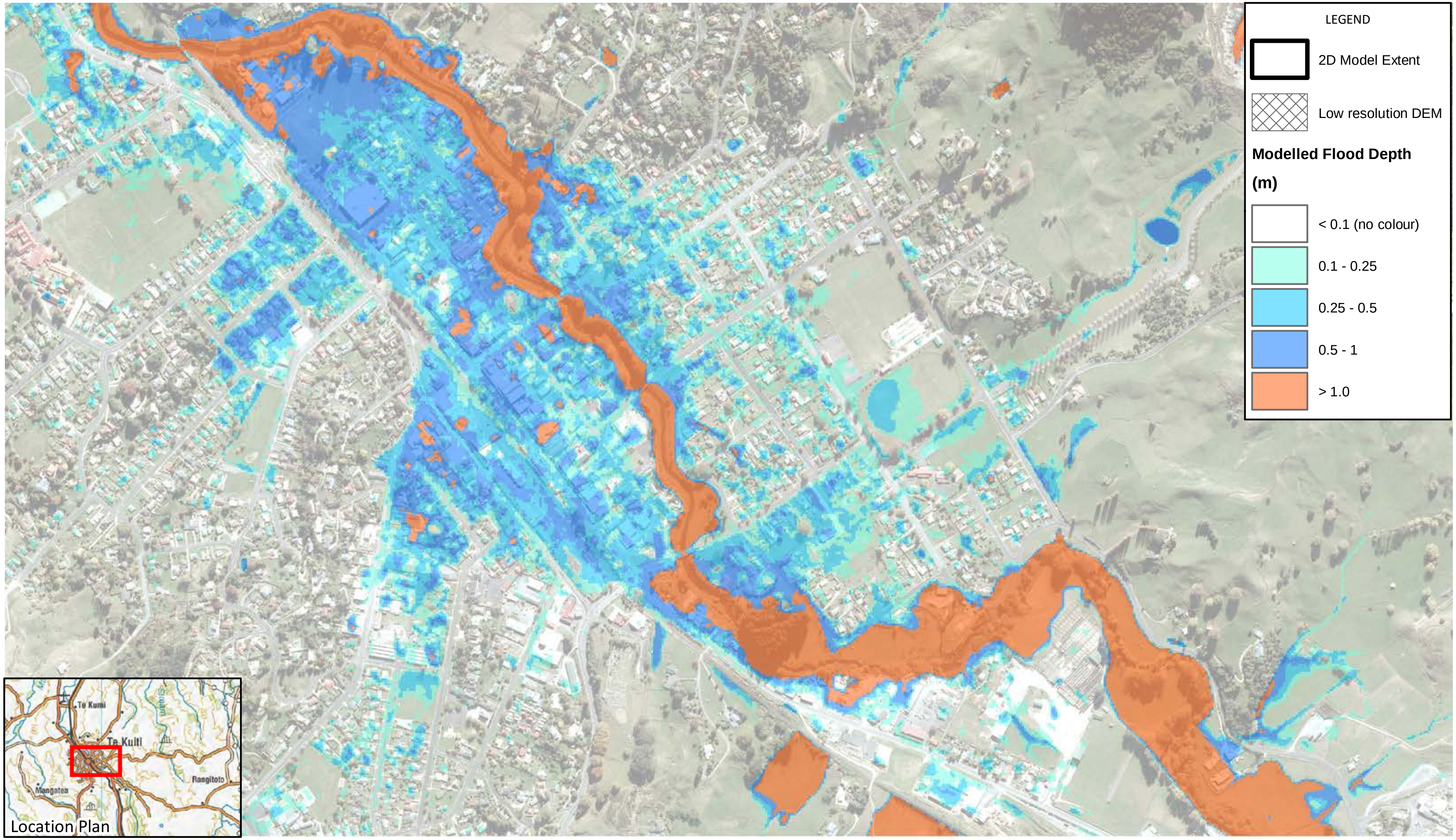
# Waitomo District Council

## Te Kuiti Flood Hazard Assessment
## Preliminary Modelled Flood Depths
## 100 year ARI rainfall event

FIGURE No. Figure 02

Rev. 0




Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE F03_TeKuiti_100y45_01.mxd

SCALE (AT A4 SIZE) 1:10,000

PROJECT No. 1004962.0020

# Waitomo District Council

## Te Kuiti Flood Hazard Assessment

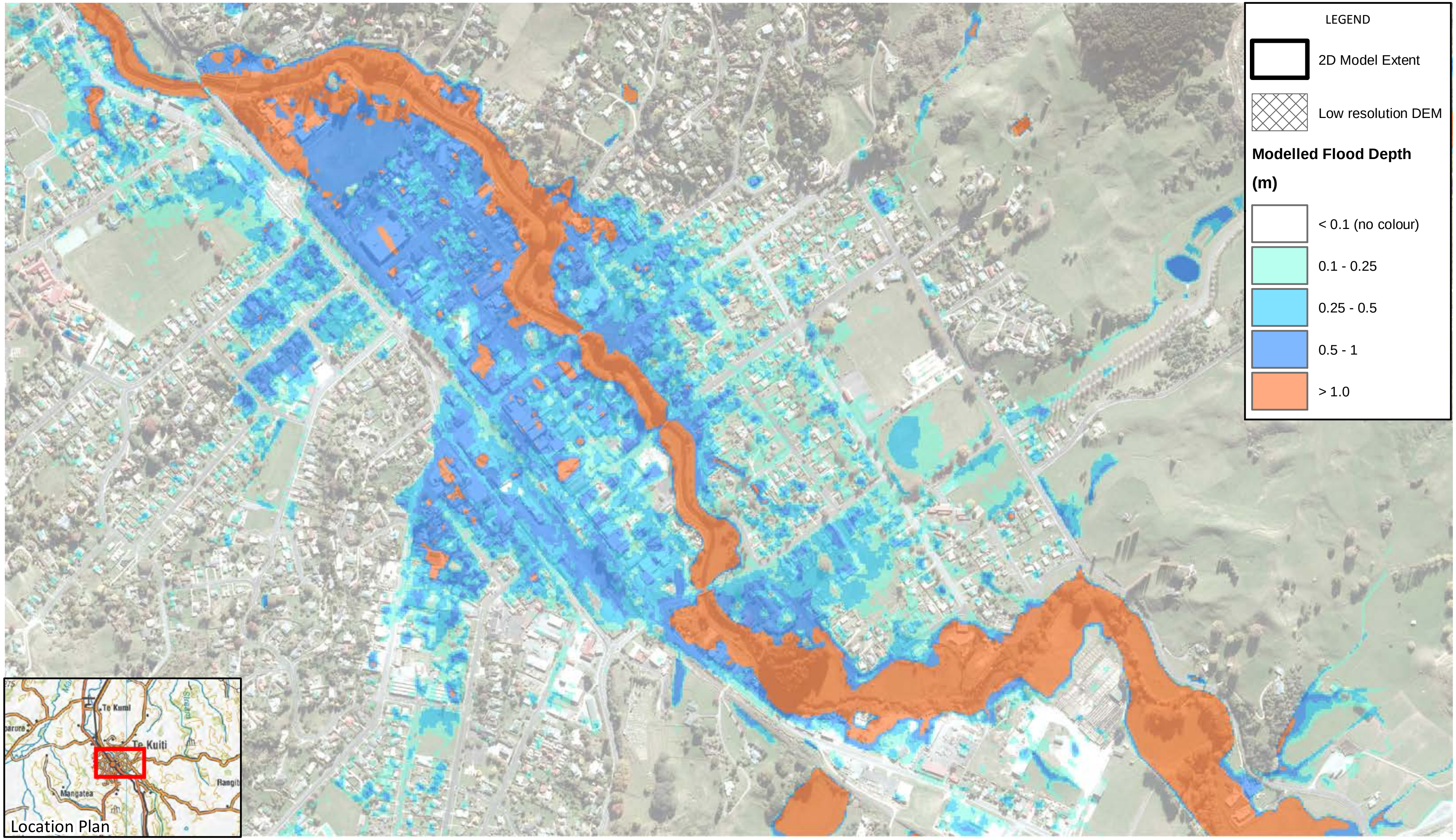
## Preliminary Modelled Flood Depths

## 100 year ARI rainfall event + RCP4.5 climate change scenario

FIGURE No. Figure 03

Rev. 0

Path: T:\Hamilton\Projects\1004962\1004962.0020\WorkingMaterial\GIS\Figures\20190503_PrelimResults\F03_TeKuiti_100y45_01.mxd Date: 3/09/2019 Time: 11:53:53 AM




Path: T:\Hamilton\Projects\1004962\1004962.0020\WorkingMaterial\GIS\Figures\20190503_PrelimResults\F04_TeKuiti_100y6_01.mxd Date: 3/09/2019 Time: 11:56:47 AM

Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE F04_TeKuiti_100y6_01.mxd

SCALE (AT A4 SIZE) 1:10,000

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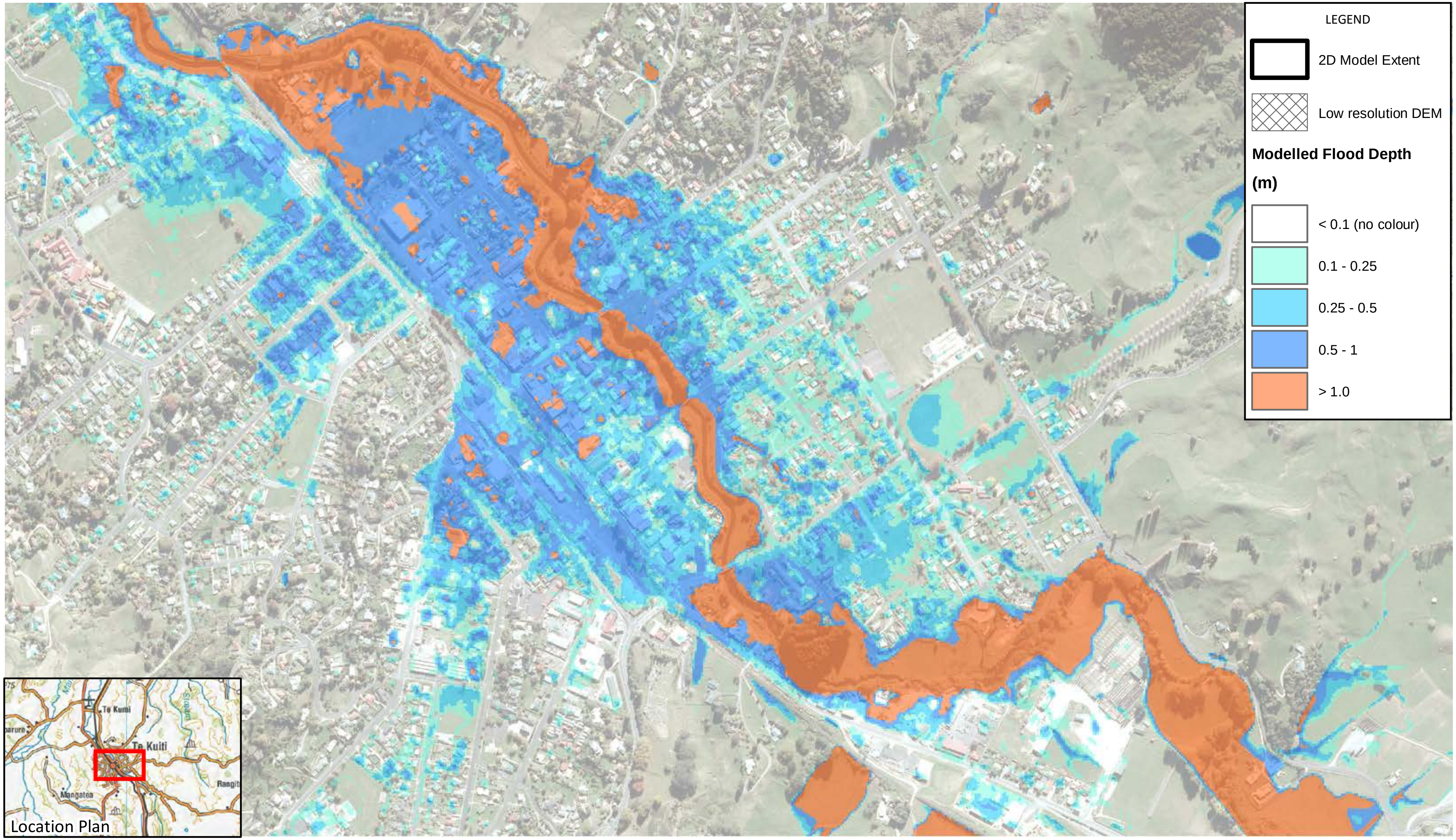
# Waitomo District Council

Te Kuiti Flood Hazard Assessment
Preliminary Modelled Flood Depths
100 year ARI rainfall event + RCP6 climate change scenario

FIGURE No. Figure 04

Rev. 0




Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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F05_TeKuiti_100y85_01.mxd

SCALE (AT A4 SIZE)
1:10,000

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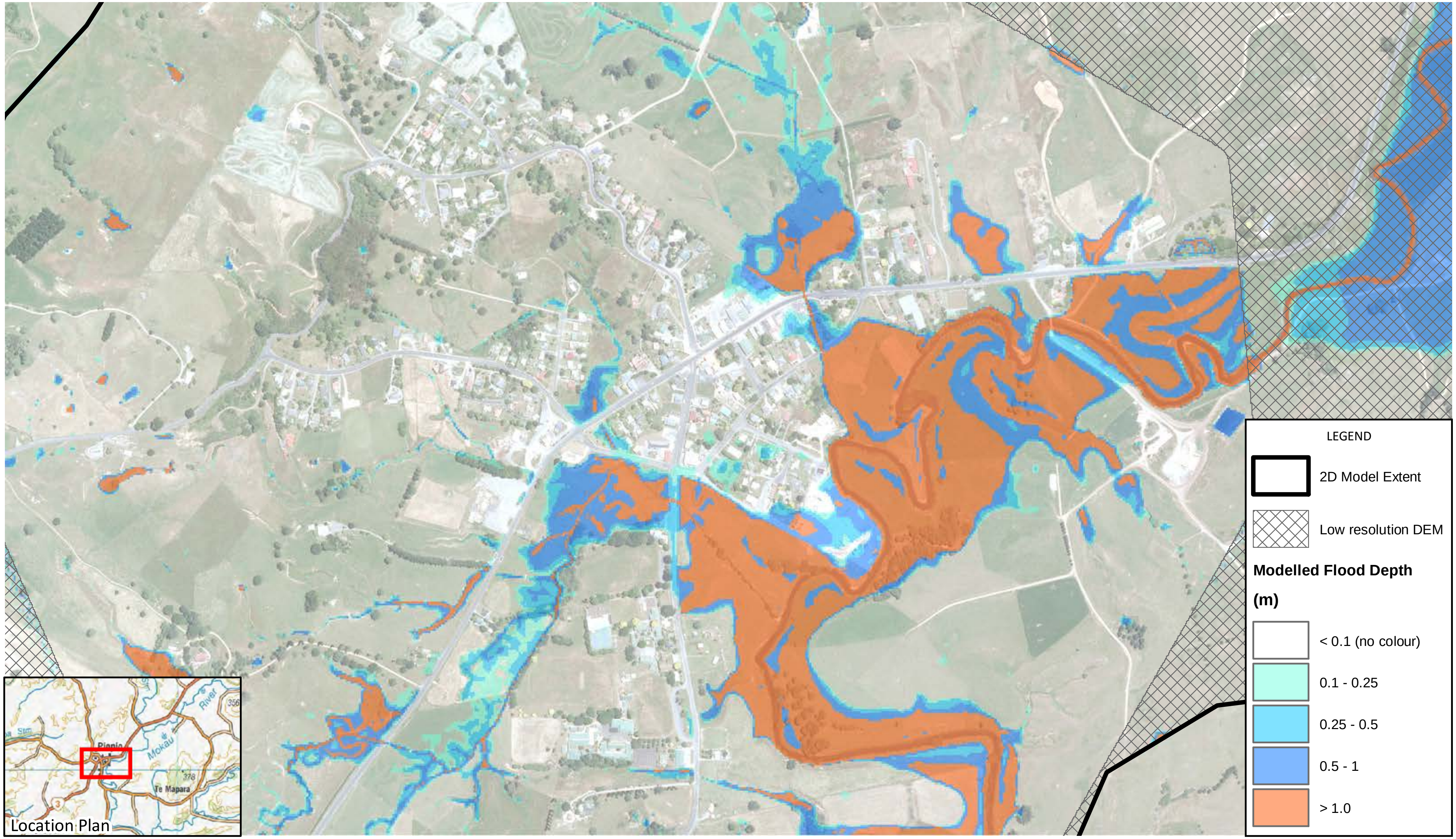
## Te Kuiti Flood Hazard Assessment
## Preliminary Modelled Flood Depths
## 100 year ARI rainfall event + RCP8.5 climate change scenario

FIGURE No. Figure 05

Rev. 0

Path: T:\Hamilton\Projects\1004962\1004962.0020\WorkingMaterial\GIS\Figures\20190503_PrelimResults\F05_TeKuiti_100y85_01.mxd Date: 3/09/2019 Time: 12:06:31 PM

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Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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F06_Piopio_020y_01.mxd

SCALE (AT A4 SIZE)
1:10,000

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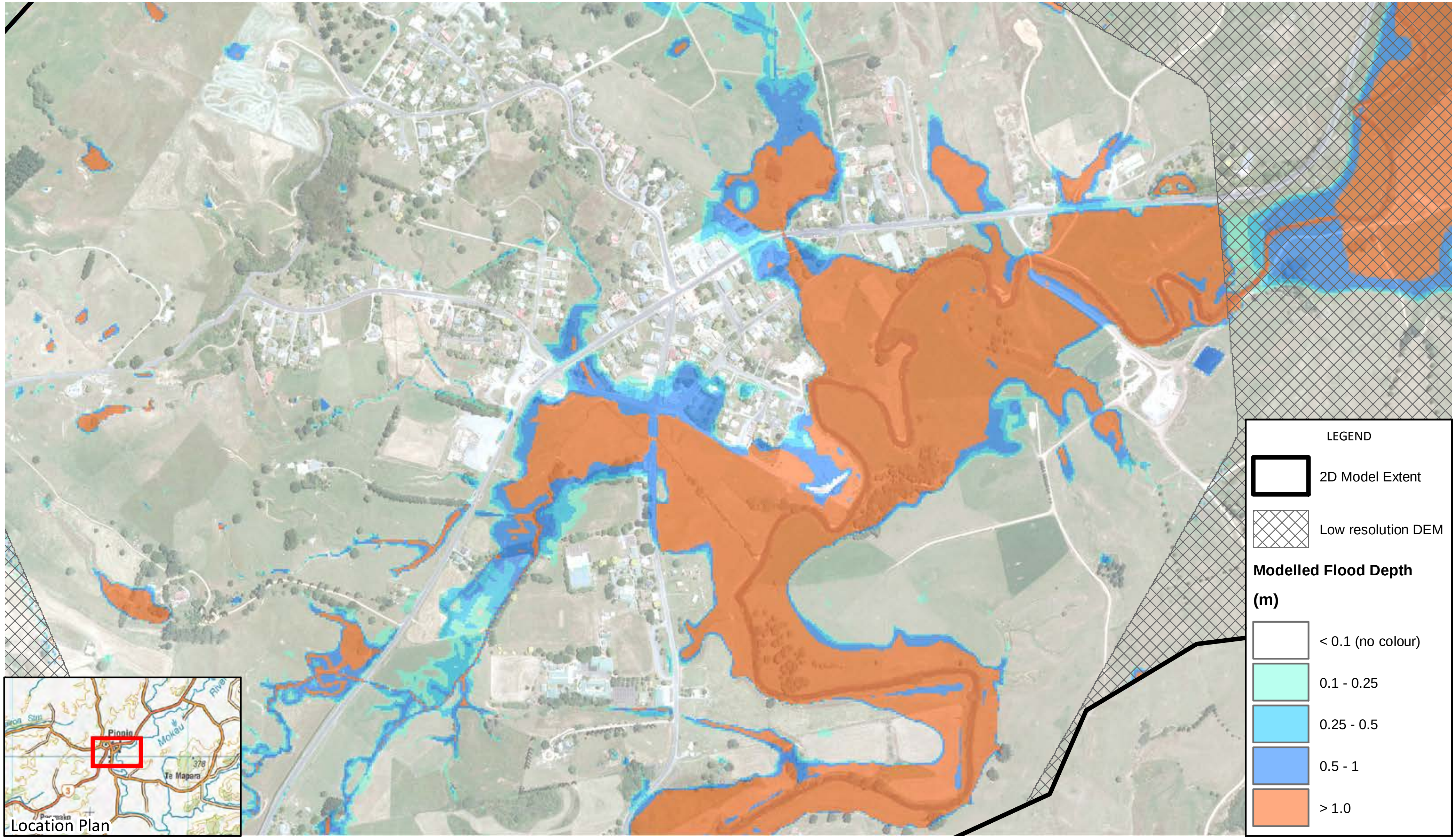
# Waitomo District Council
## Piopio Flood Hazard Assessment
## Modelled Flood Depths
## 20 year ARI rainfall event

FIGURE No. Figure 06

Rev. 0




Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE
F07_Piopio_100y_01.mxd

SCALE (AT A4 SIZE)
1:10,000

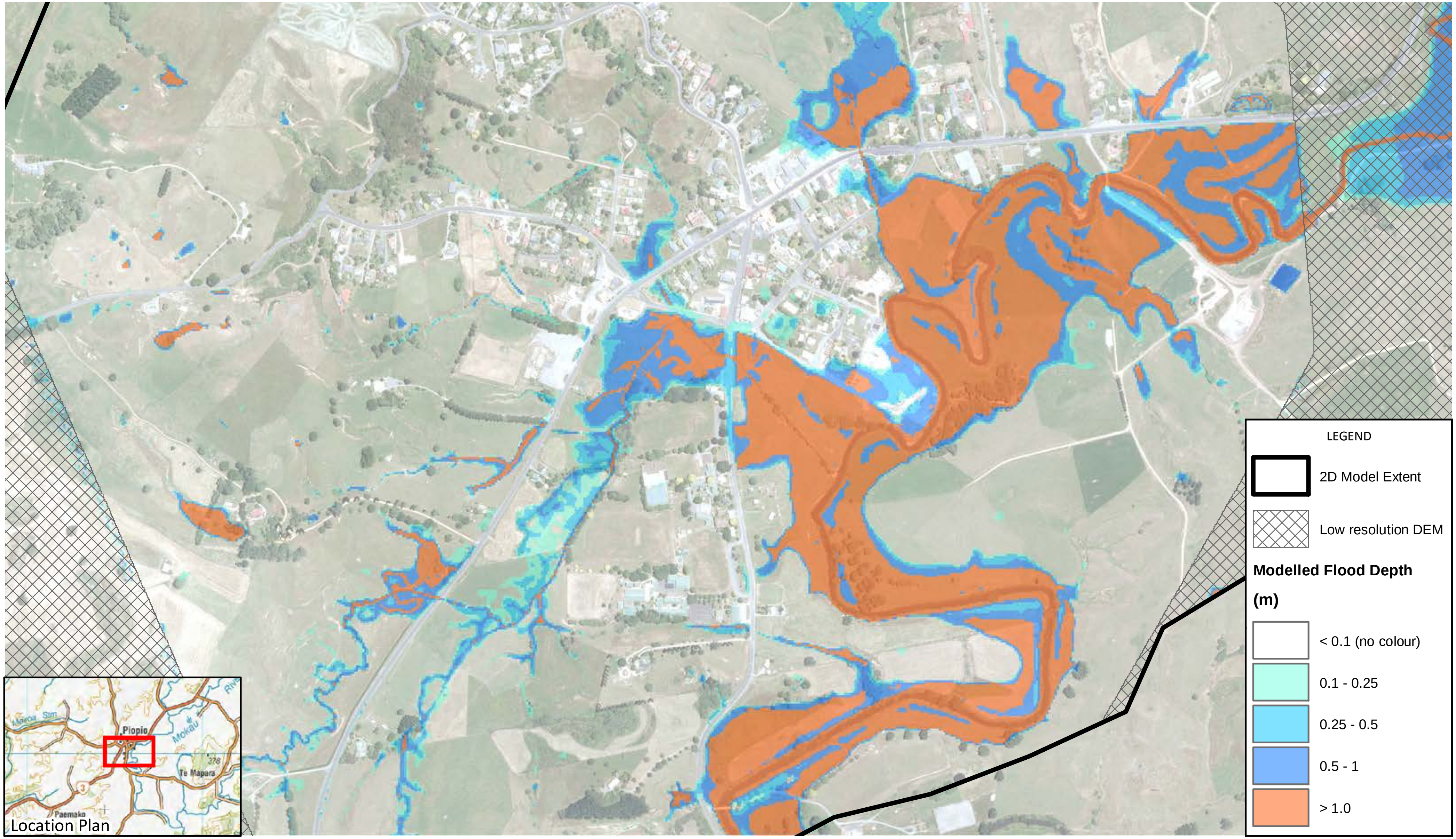
PROJECT No.
1004962.0020

# Waitomo District Council

## Piopio Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI rainfall event

FIGURE No. Figure 07

Rev. 0

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Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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SCALE (AT A4 SIZE) 1:10,000

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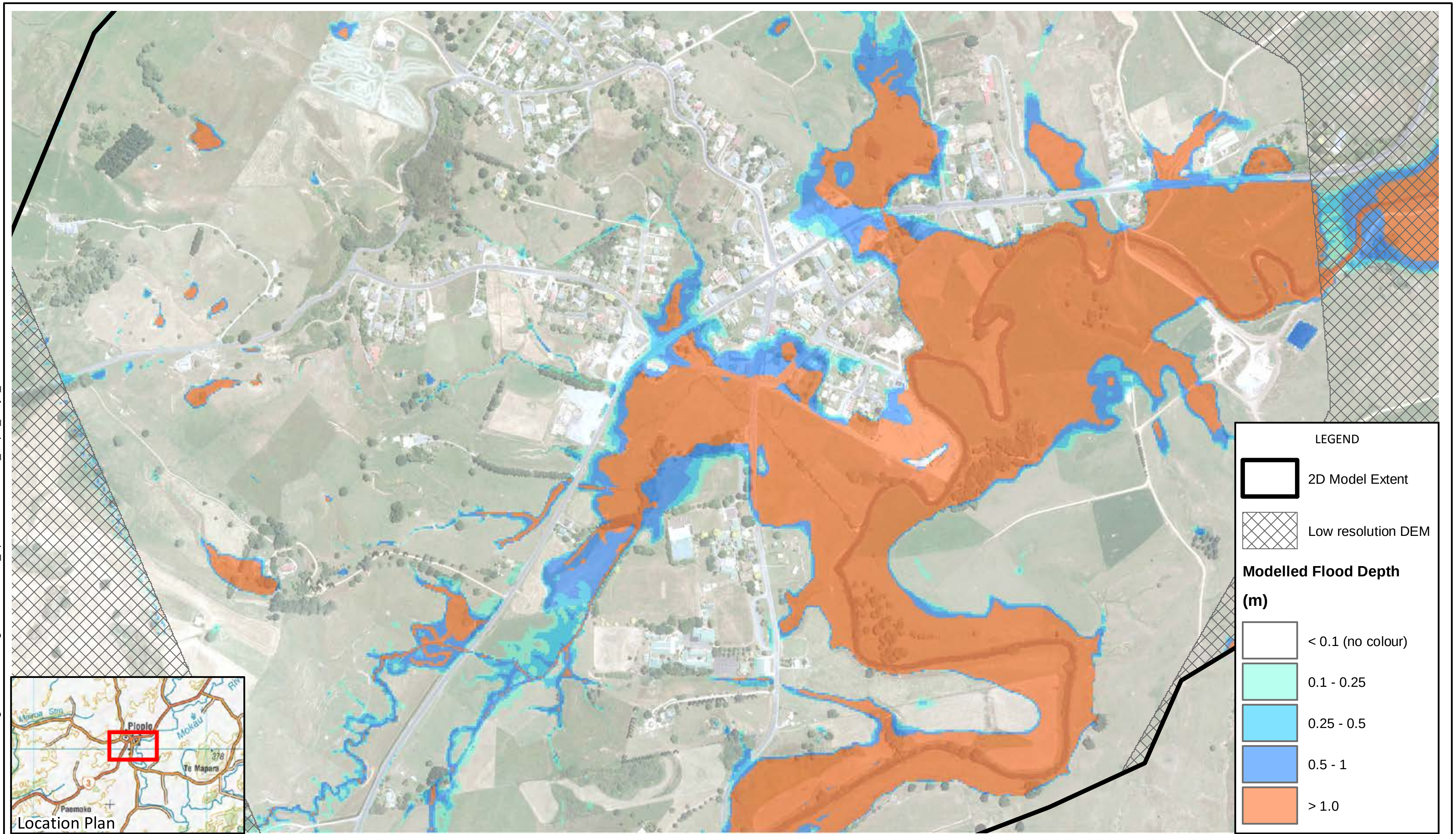
## Piopio Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI rainfall event

FIGURE No. Figure 08

Rev. 0

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Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE F09_Piopio_100y6_01.mxd

SCALE (AT A4 SIZE) 1:10,000

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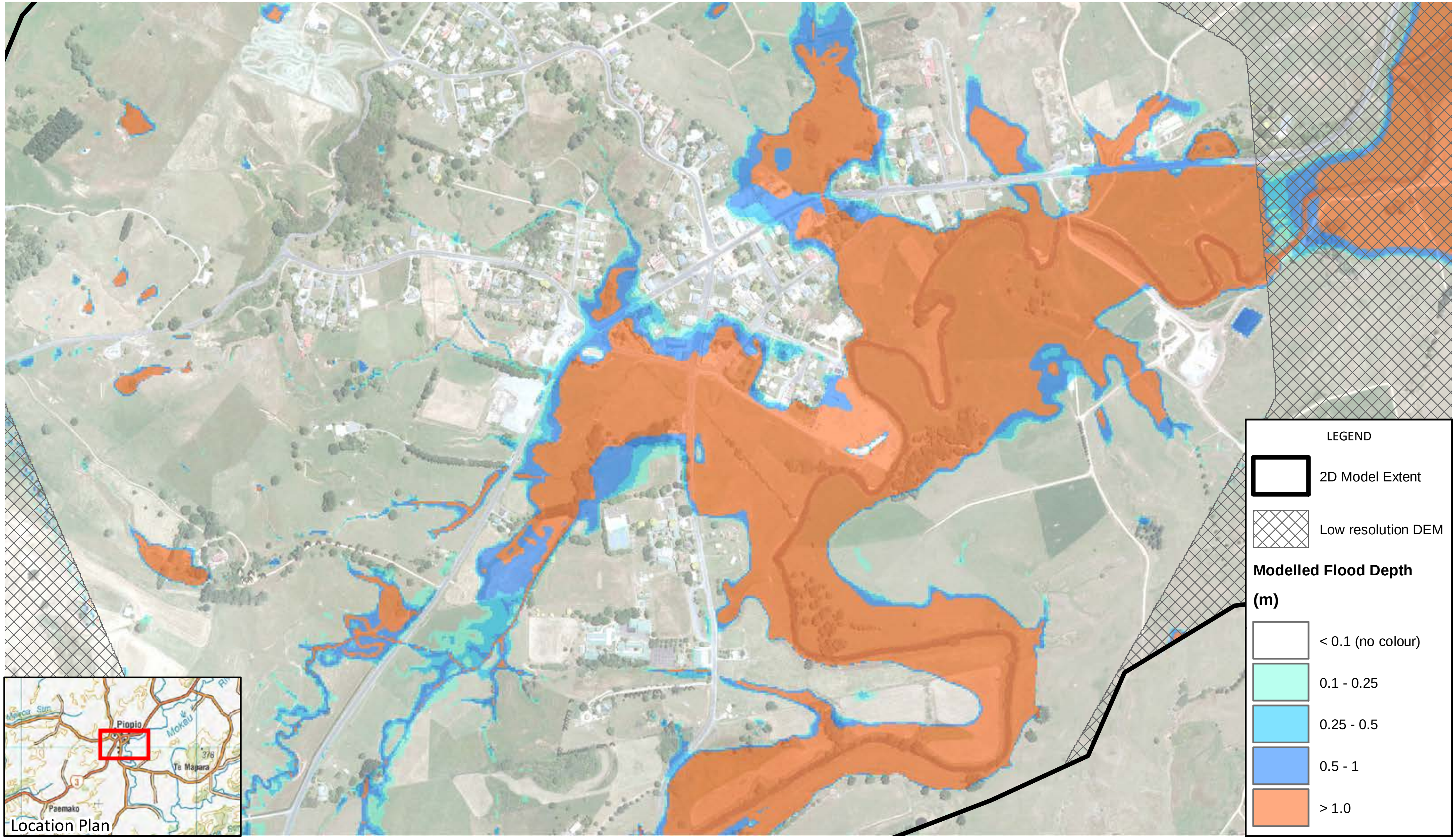
# Waitomo District Council
## Piopio Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI rainfall event + RCP6.0 climate change scenario

FIGURE No. Figure 09

Rev. 0

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Notes: Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE
F10_Piopio_100y85_01.mxd

SCALE (AT A4 SIZE)
1:10,000

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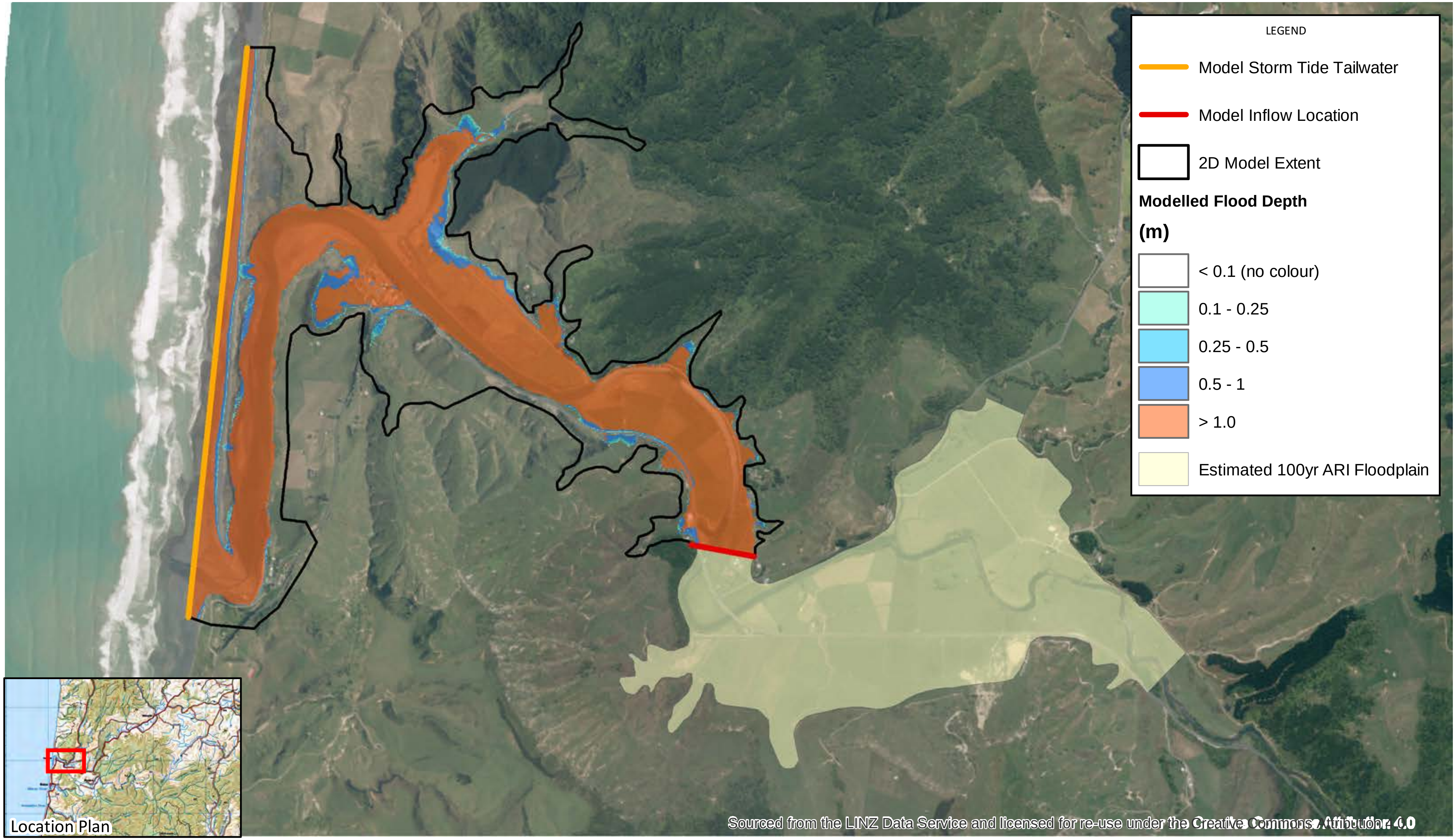
# Waitomo District Council
## Piopio Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI rainfall event + RCP8.5 climate change scenario

FIGURE No. Figure 10

Rev. 0




Path: F:\Te Kuiti & Piopio\Tuflow outputs\Figures\F11_Awakino_100y_01.mxd Date: 27/08/2019 Time: 10:25:47 AM

Notes: - Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).
- Flood depths are derived using NIWA regional peak flow estimates for a present day 100 year ARI event and Waikato Regional Council upper storm tide water level estimate.

A4 SCALE 1:25,000

0 0.25 0.5 0.75 1 1.25 (km)

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ARCFILE F11_Awakino_100y_01.mxd

SCALE (AT A4 SIZE) 1:25,000

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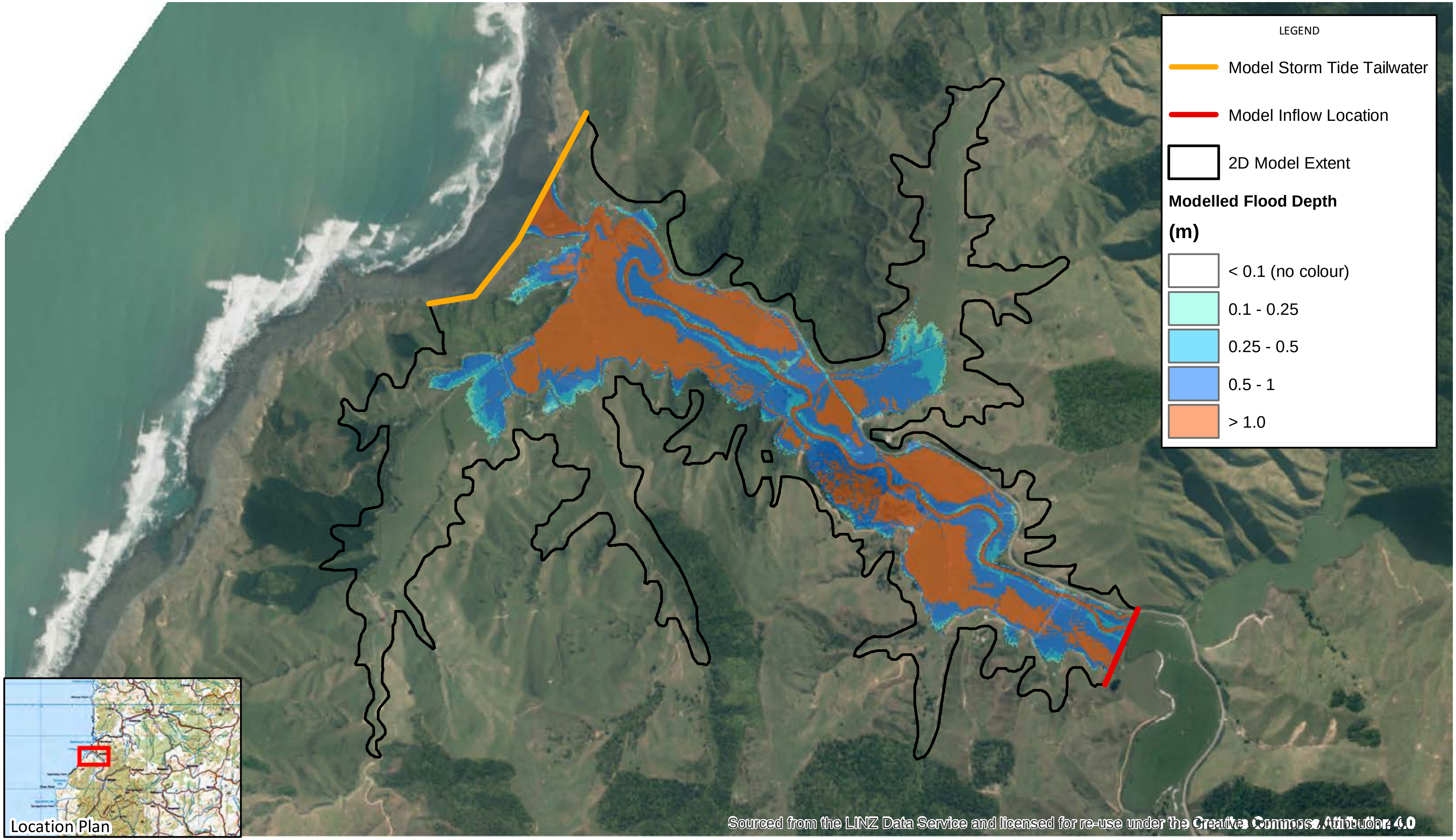
# Waitomo District Council

Awakino Flood Hazard Assessment
Modelled Flood Depths
100 year ARI NIWA Peak Flow Estimate

FIGURE No. Figure 11

Rev. 0




Path: F:\Te Kuiti & Piopio\Tuflow outputs\Figures\F12_Kiritehere100y_01.mxd Date: 27/08/2019 Time: 10:25:18 AM

Notes: - Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).
- Flood depths are derived using NIWA regional peak flow estimates for a present day 100 year ARI event and Waikato Regional Council upper storm tide water level estimate.

A4 SCALE 1:20,000

0 0.2 0.4 0.6 0.8 1 (km)

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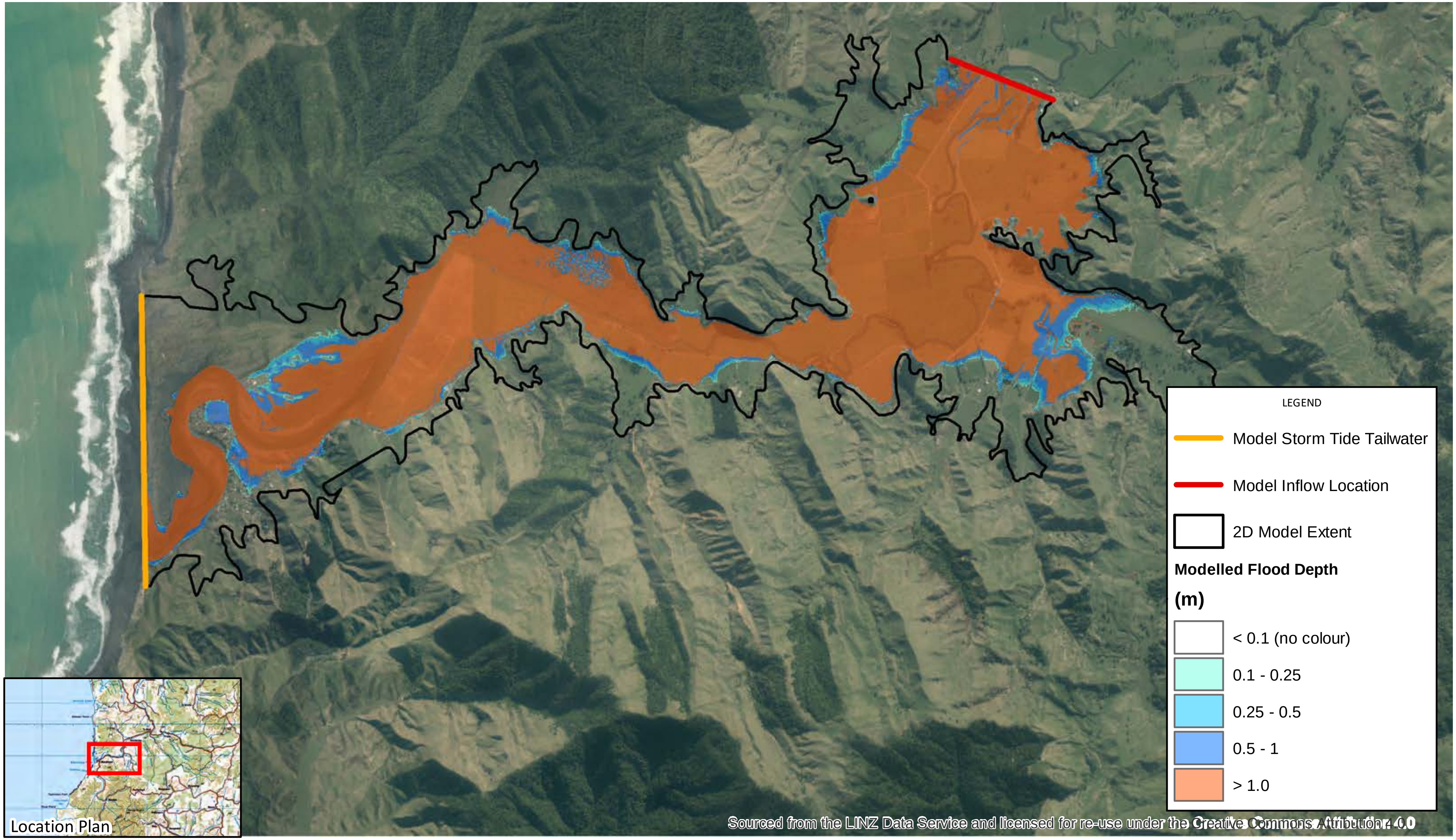
# Waitomo District Council
## Kiritehere Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI NIWA Peak Flow Estimate

FIGURE No. Figure 12

Rev. 0




Notes: - Aerial photography and topographic maps sourced from LINZ Data Service (Crown Copyright Reserved).
- Flood depths are derived using NIWA regional peak flow estimates for a present day 100 year ARI event and Waikato Regional Council upper storm tide water level estimate.

A4 SCALE 1:35,000

0 0.4 0.8 1.2 1.6 2 (km)

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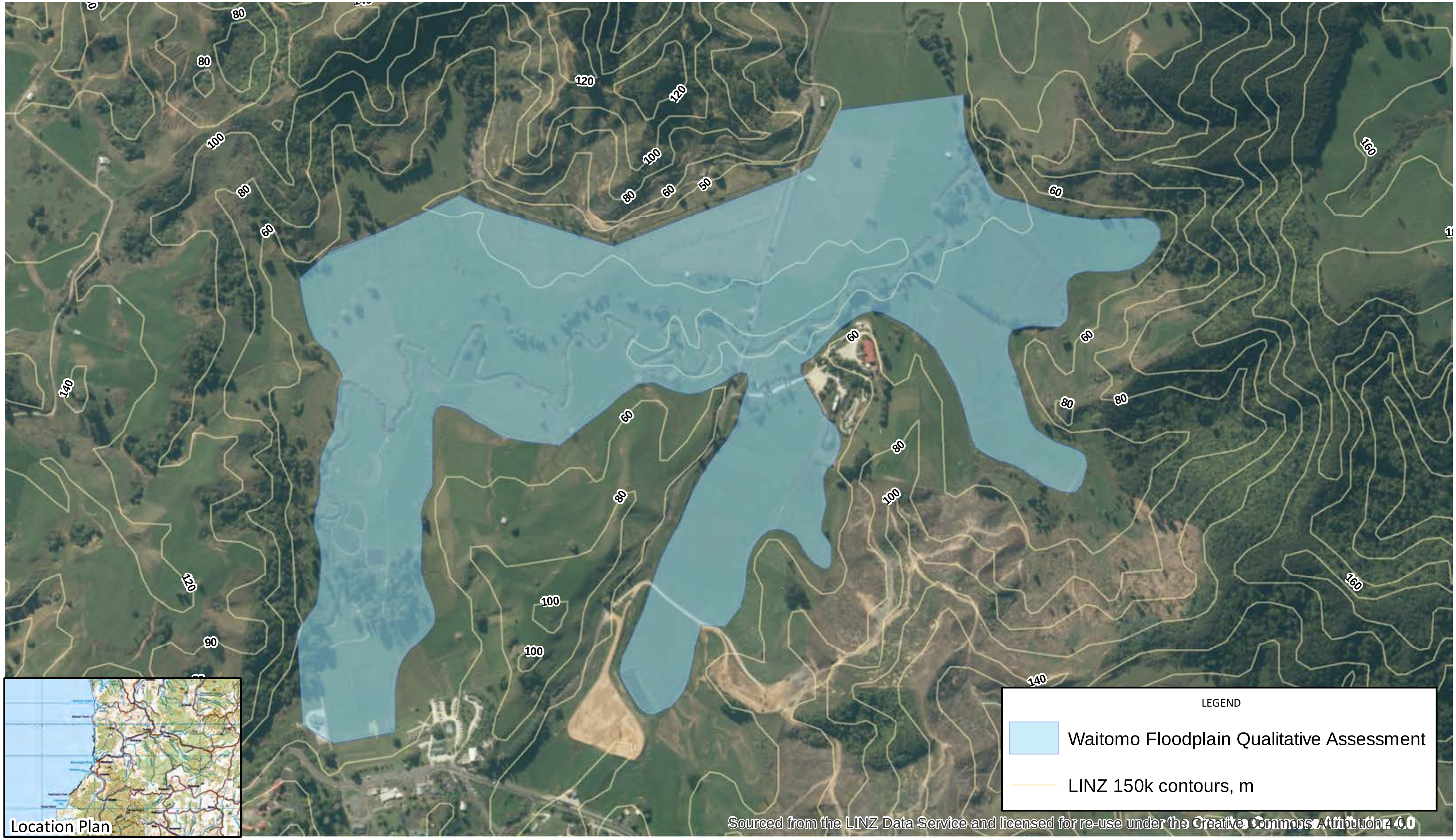
ARCFILE F13_Marakopa_100y_01.mxd
SCALE (AT A4 SIZE) 1:35,000
PROJECT No. 1004962.0020

# Waitomo District Council
## Marokopa Flood Hazard Assessment
## Modelled Flood Depths
## 100 year ARI NIWA Peak Flow Estimate

FIGURE No. Figure 13
Rev. 0

Path: F:\Te Kuiti & Piopio\Tuflow outputs\Figures\F13_Marakopa_100y_01.mxd Date: 27/08/2019 Time: 10:25:41 AM




Notes: - Aerial photography, topographic maps and 20m topographic contours sourced from LINZ Data Service (Crown Copyright Reserved).

A4 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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# Waitomo District Council
## Waitomo Flood Hazard Assessment
## Estimated Floodplain Map

FIGURE No.
Figure 14

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