Greater Wellington Regional Council

Mangatarere Stream Flood Modelling

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Greater Wellington Regional Council

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Contents

Executive Summary

Greater Wellington Regional Council (GWRC) have identified Carterton, Wairarapa, as an area potentially at risk of flooding from the Mangatarere Stream. GWRC are interested in exploring the possible extents of flooding from a 1% Annual Exceedance Probability (AEP) event.

A hydrology assessment was undertaken to estimate the design flows using the gauging station ‘Mangatarere @ Gorge’ at the upper extent of the model. Inflows were determined for the 1%AEP flow and the 1%AEP flow with an allowance for climate change flow for the Mangatarere Stream for various points along the stream.

An integrated 1-dimensional/2-dimensional (1-D/2-D) hydraulic model of the Mangatarere Stream and surrounding area was constructed using the modelling software package TUFLOW. The hydraulic model combines the 1-D stream channel and bridge structures with the 2-D grid created from LiDAR representing the flood plains.

Two scenarios, 1%AEP, 1%AEP plus climate change, were simulated. Additionally design flows for the Mangatarere Stream taken from the GWRC Waiohine Modelling study were also simulated in the model, as they are higher flows than were estimated in this study. This was used as a sensitivity exercise.

The results of the simulations predict that during a 1%AEP event, flood water from the Mangatarere Stream will reach Carterton, causing significant flooding. The results of the climate change scenario, and the higher flow runs show the extent of the flooding throughout Carterton could be even more significant.

The results indicate that flood water from the Mangatarere Stream reaches Carterton via two major flow paths originating at Smith’s cow shed. One along Anderson’s Line reaches the north of the town, and another splits and reaches the north west of the town. Therefore this study has concluded that Carterton is currently at risk of flooding from the Mangatarere Stream in a 1%AEP event.

1 Introduction

1.1 Context

Greater Wellington Regional Council (GWRC) has identified Carterton as being potentially at risk of flooding from the Mangatarere Stream, and the purpose of this report is to review the potential extent of this flooding.

The report details the development of an integrated 1-D/2-D model of the Mangatarere Stream; including determination design flows for the stream, inputs to the integrated 1-D/2-D hydraulic model, and presentation of the results.

The report provides flood extents for the 1% Annual Exceedance Probability (AEP) which is a 1 in 100 year Average Recurrence Interval (ARI); and the 1% AEP with an allowance for climate change to 2090 to determine the potential future impacts.

1.2 Location Information

The Mangatarere Stream flows from the Tararua Range to the North and West of Carterton, around the north and west of the town and down to the confluence with the Waiohine River to the South West of Carterton.

The area of interest to GWRC the area to the true left bank of the Mangatarere Stream downstream of Smith's Cow Shed, as flooding on this bank has the potential to reach Carterton.

A location plan showing the Mangatarere Stream (in blue) and its proximity to Carterton is presented in Figure 1-1.

GWRC considers this approach to be a 'rapid' flood hazard assessment. Therefore the flood extents provided in this report are 'initial' and are intended to inform the need a scope for a more detailed assessment working with Councils and the community to develop agreed flood maps.

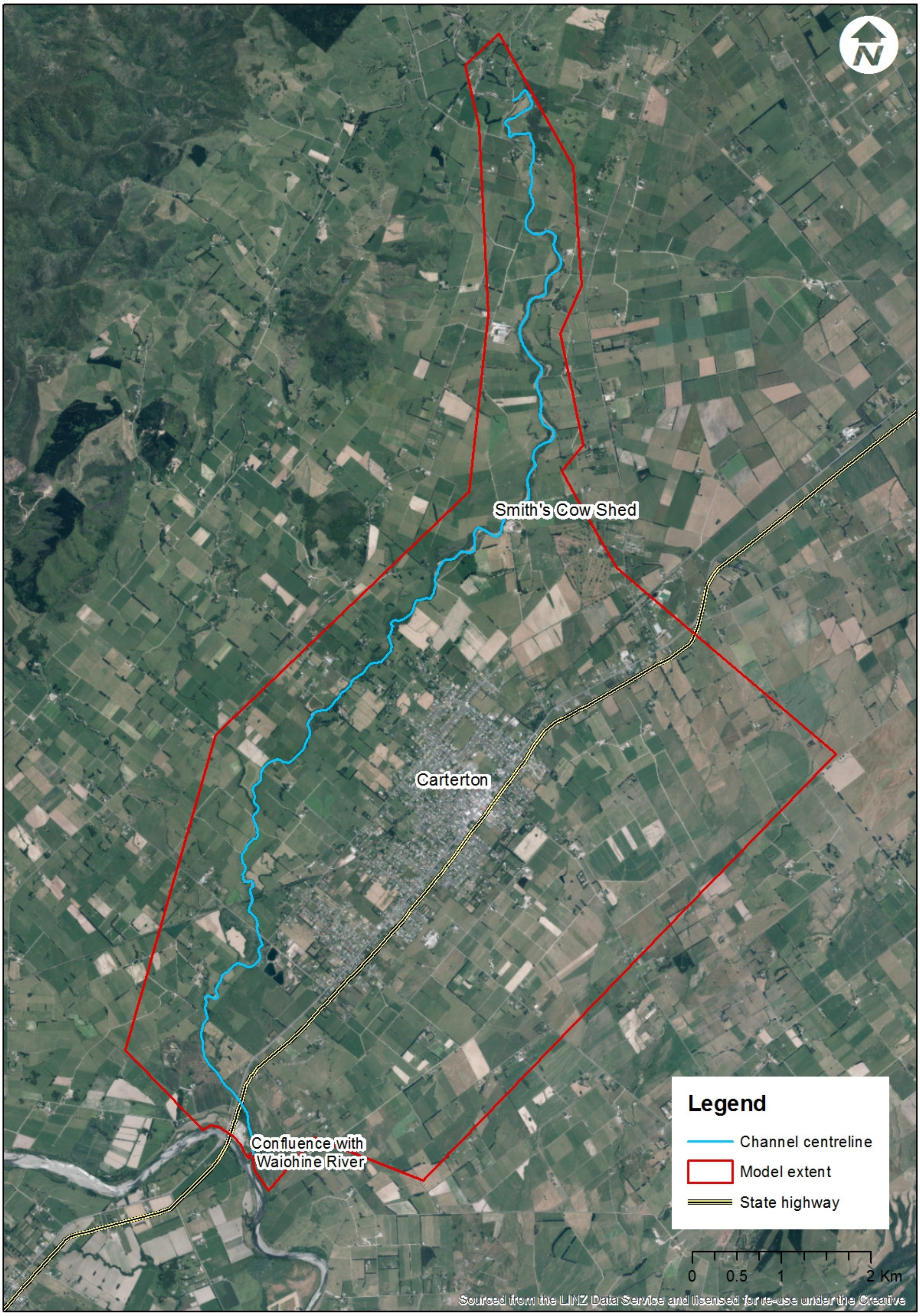


Figure 1-1: Location plan of the Mangatarere Stream, Carterton and surrounding area

2 Available Data

2.1 Hydrological data

A review of the hydrological data determined that there are 3 flow monitoring sites available for the Mangatarere Stream within the Waiohine catchment.

- Mangatarere at Gorge
- Mangatarere at Belvedere Bridge
- Mangatarere at SH2 Bridge

Suitability of these sites have been reviewed in the Opus Hydrology report (Opus, 2014) attached in Appendix A. Details of the estimates of design flows are also included in this report.

2.2 Hydraulic modelling report of the Waiohine River

GWRC provided a hydrology report for the Waiohine catchment that included an estimate of design flow for a 1% AEP flow for the Mangatarere Stream (Wallace, 2011).

This flow is significantly different to the design flows calculated by Opus. This is due to the longer flow record available at the time of the Opus hydrology study which allowed a more appropriate distribution to be fitted to the annual maxima points. This is discussed in detail in **Section 3** of this report.

2.2.1 Existing Waiohine River Model

GWRC hold an existing model of the Waiohine River. The confluence of the Mangatarere Stream and the Waiohine River is at the downstream end of the study reach. Modelled water levels in the Waiohine at the confluence for the relevant design events have been obtained and reviewed for use as a downstream boundary for the simulations.

This existing model of the Waiohine River also includes a section of the Mangatarere Stream stretching to approximately 500m upstream of the railway bridge. This includes 3 bridges; SH2, Dalefield Road and the railway bridge, for which water level and cross section information has also been provided to determine the channel geometry.

2.3 Historical flooding information

Photographs of the Mangatarere Stream flooding in 1994 have been provided by GWRC. The photographs are of the area around and upstream of Smith's cowshed. They show extensive flooding on both banks, however the left bank is of greater concern as Carterton lies this side of the stream.

Although the magnitude of the flood is not known, the photographs provide us with a good understanding of flow paths and potential flooding sites for a 1%AEP flow in this area. The results of the 2-D modelling simulations has been validated to some extent using this information, see Section 5.3.

2.4 LiDAR

Processed 1m resolution point elevation data obtained from LiDAR is available to create the DEM. This LiDAR data has not been classified and therefore additional efforts to 'smooth' the data to a bare earth surface have been required.

This data is in Mean Sea Level datum (MSL). It has been necessary to adjust the level to be consistent with Wairarapa Local datum which is 9.22m higher. The existing model for the Waiohine River is in Wairarapa Local datum.

2.5 Survey Data

There are 47 cross sections available which include sections at each of the 9 bridges within the study reach. This data has been provided in Wairarapa Local Datum and will not need to be changed to be used in the model.

2.6 Proposed construction drawings for railway bridge structure

The railway bridge was constructed in early 2014 and proposed construction drawings have been made available to Opus by GWRC. It is our understanding that they represent the bridge as built on site. These drawings have provided us with the geometry of the rail bridge.

2.7 Site visit

Opus conducted a site visit of the Mangatarere Stream on 11 June 2014 with GWRC. A number of sites along the stream to the confluence with the Waiohine River were visited. This provided a general overview of the stream and surrounding floodplains to allow estimation of the channel roughness.

This site visit included observation and measurement of approximate dimensions of all of the 9 bridges along the study reach. This data has been used to estimate deck heights and to check lengths. Photographs were also taken of the sites visited. The key bridge levels determined from cross sections and the site visit are shown in Table 5-1, along with results from the modelling of the 1% AEP event.

3 Hydrology

3.1 Design flows

A hydrology assessment of the Mangatarere Stream has been undertaken (Opus 2014) and this is included in Appendix A. This report details the analysis undertaken to determine the 1%AEP and the 1%AEP plus climate change to 2090 flow estimates for the 'Mangatarere @ Gorge' site. The analysis concluded that the estimates for design flow of 122m^3/s for a 1%AEP event and 146m^3/s for the 1%AEP plus climate change should be used in the hydraulic modelling analysis.

In addition, the modelling report for the GWRC Waiohine model provided an estimate of 163m^3/s and 196m^3/s respectively for the same location. These differences are shown in Table 3-1.

Table 3-1: Differences in estimated design flows for 'Mangatarere @ Gorge'

AEP	Design Flow (m3/s)	GWRC Design Flow (m3/s)	Difference (%)
1%	122	163	34
1% plus climate change to 2090	146	196	34

The estimates in the GWRC Waiohine modelling report are significantly larger than the estimates from the hydrology assessment undertaken for this study.

The design flow profiles are derived from a relatively short record therefore confidence in extrapolating out to obtain values for rare events such as 1% AEP events is lower than for longer records.

The GWRC flow estimate for a 1%AEP event was increased by 20% to obtain an estimate for the 1%AEP plus climate change event. The Opus hydrology study had access to 5 additional years of records for the analysis and although still a small flow record, the additional data allowed a more appropriate distribution to be fitted to the annual maxima points. Because of this, there is greater confidence in the design flows estimated for this study than for the Waiohine modelling study, and, these flows will be used in the hydraulic model. The higher flows have also been considered as a form of sensitivity analysis.

The hydrology analysis also estimated the flow at four specific inflow locations for contributing tributary flow, shown on the location plan in Figure 3-1. The design inflows used are summarised in Section 4.2.1.

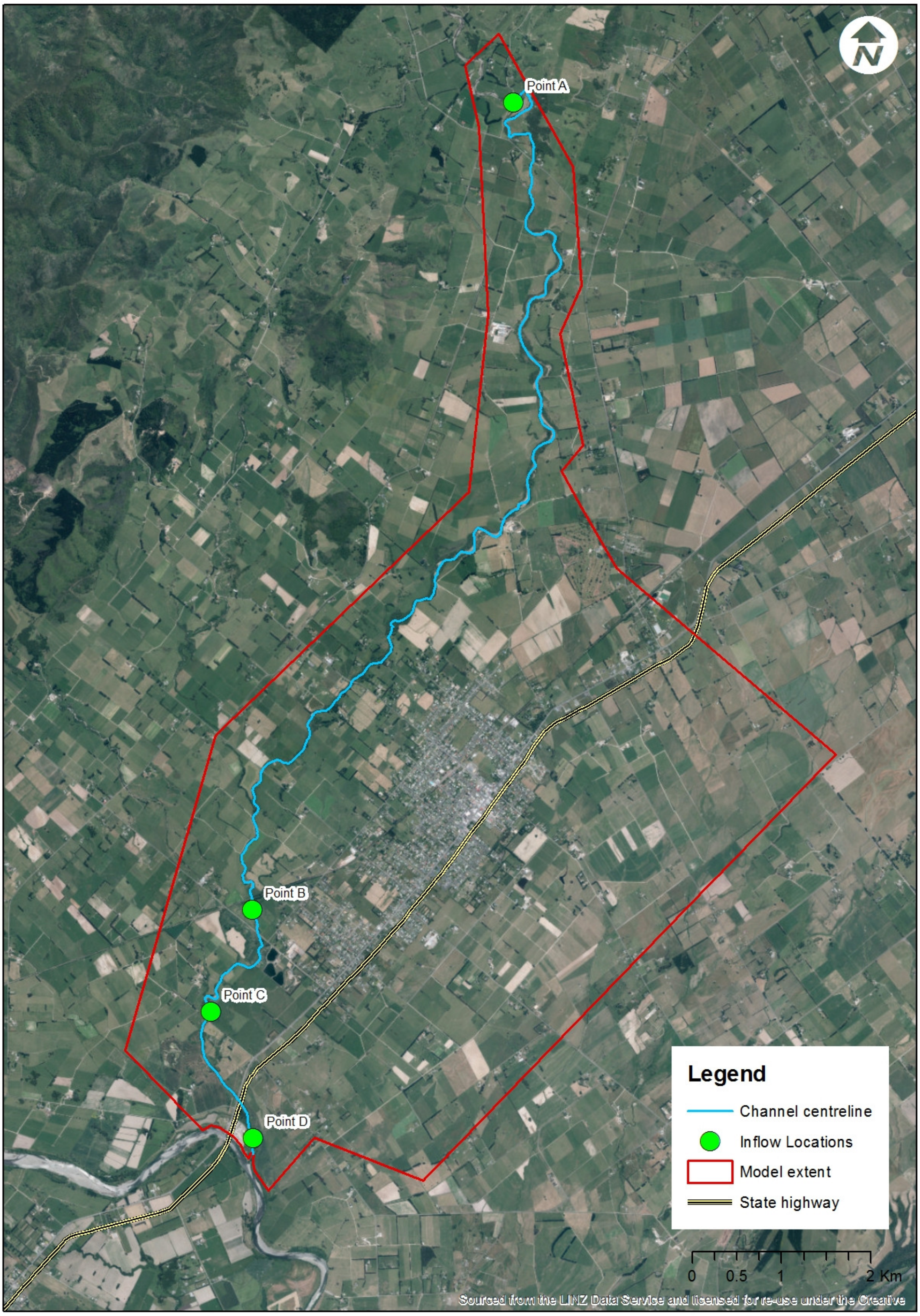


Figure 3-1: Model inflow locations

4 Model Build

The integrated 1-D/2-D hydraulic model of the Mangatarere Stream has been constructed using the modelling software package TUFLOW. It incorporates the stream channel and bridges as a 1D element and the surrounding areas and flood plains in the 2-D domain.

4.1 Model build

4.1.1 Extent

The model extends from the eastern slopes of the Tararua Range to the Waiohine River to the south of Carterton, Wairarapa. The model extent, along with inflow locations detailed in Section 3 is shown in Figure 4-1

4.1.2 Digital Elevation Model (DEM) development

The terrain is represented in the model as a 5m grid in a Digital Elevation Model (DEM). The DEM was constructed from the available 1m grid LiDAR data. The LiDAR information was provided in Mean Sea Level Datum (MSL) and was adjusted to be in Wairarapa Local Datum.

The LiDAR data provided was not classified or filtered, and hence wasn't a 'bare earth' model, which led to issues with the hydraulic modelling. The simulations encountered difficulties with the standard 2-D grid created from the raw LiDAR. This was due to large changes in grid elevation as a result of the LiDAR data not being representative of the ground elevation in some locations where vegetation was present, in particular at the 1-D/2-D boundary.

Because of this, a different approach to creating the underlying DEM grid was adopted. The data required a process of 'smoothing' which included interpolation of elevation points to give an estimated bare-earth elevation value for the grid square.

Additionally, areas sensitive to the large changes in elevation caused by vegetation were identified using the aerial photography and reviewing any large unrealistic changes in terrain, and given an elevation appropriate to the ground level based on the surrounding elevation point data.

4.1.3 Flood plain roughness

The land surrounding the Mangatarere is predominantly farmland and therefore a roughness value of 0.035 has been specified for the flood plain, as being reasonably representative. This value is considered an average across the catchment and no variation for Carterton or other farm buildings, or thicker vegetation have been taken into account at this preliminary stage.

4.1.4 Stream channel

The stream centreline was digitised and the cross sections provided by GWRC were used for the channel geometry definition. Additional cross sections were interpolated and added to the hydraulic model to allow the model calculations to perform more effectively and to reduce the potential for instabilities. The locations of the cross sections are shown in Figure 4-1

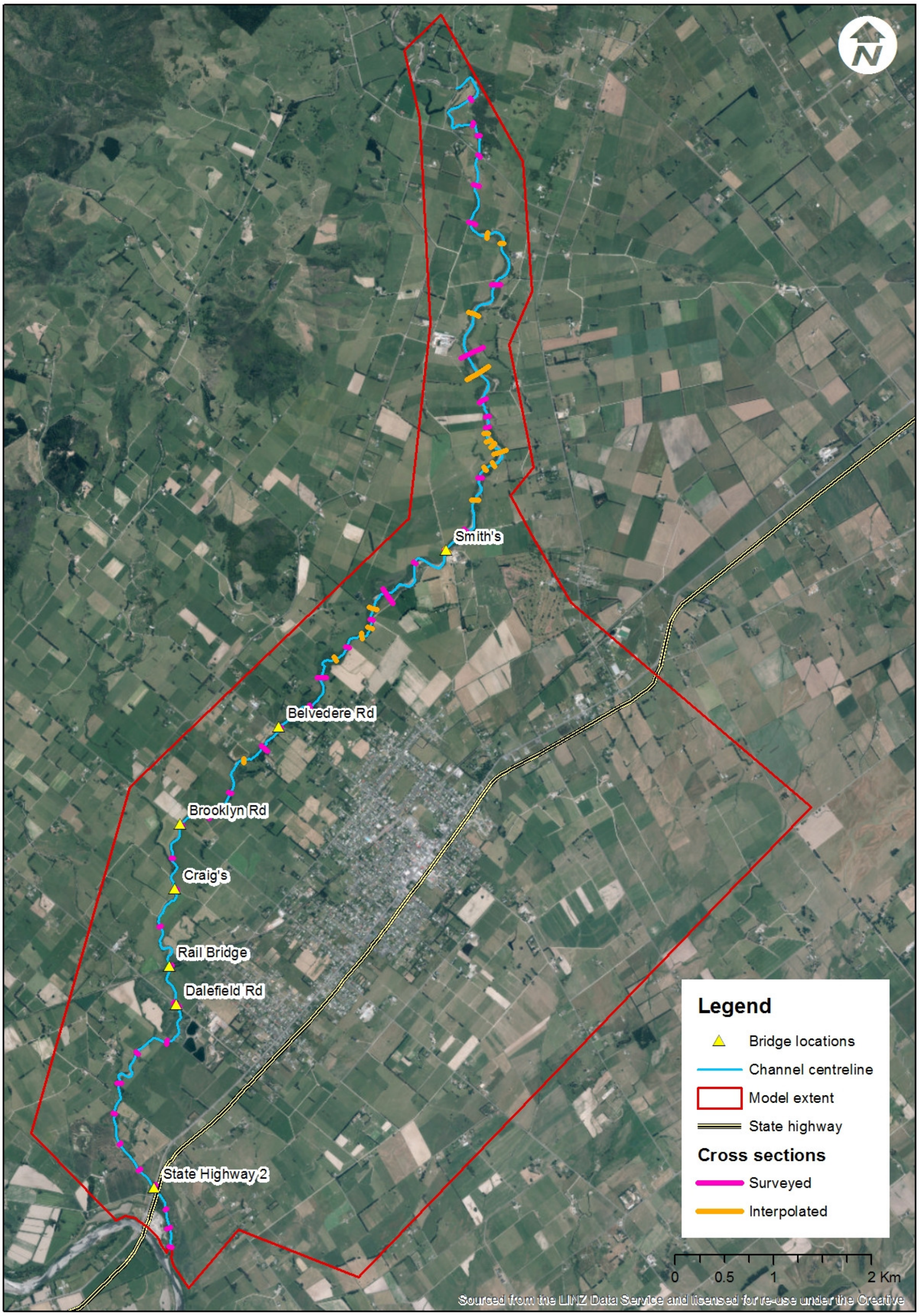


Figure 4-1: Cross section and bridge locations on Mangatarere Stream

4.1.5 Hydraulic structures

Along the Mangatarere Stream there are 9 bridges upstream of the confluence with the Waiohine River. The 2 most upstream bridges have been omitted; Tea Creek Road is the upstream extent of the model and Mangatarere Valley Road bridge was assumed that the flow would be contained locally within the channel. This was confirmed in the modelling analysis and detailed in Table 5-1.

The 7 bridges included in the model have been added to the model with the information for the dimensions taken from the surveyed cross section at that location. The height of the soffit of the bridge has been determined from analysis of the LiDAR, the cross section data and the measured levels on the site visit. The modelled bridge locations are also shown on Figure 4-1.

4.1.6 Materials and Roughness

The site visit provided an opportunity to assess the roughness of the stream channel in some locations. The bed comprised mainly of small rocks and pebbles which were present throughout the reach of the stream.

Crack Willow is present on the banks along almost the entire length of the study area. It is reducing the amount of erosion on the banks, however it is likely to significantly increase the channel's resistance to flows in the higher range.

The roughness of the channel appropriate to high flows has therefore been estimated as a Manning's n value of 0.06 for the entire length of the reach. In some places and for low flow events, an appropriate roughness value may be lower than that applied. However this conservative approach has been adopted for this study as the channel has not been reviewed in every location, and it concerns 1%AEP where the flood flows would utilise this part of the channel.

4.2 Boundary Conditions

4.2.1 Inflows

Design flows have been calculated for 4 of the larger tributaries along the Mangatarere Stream as detailed in **Section 3**. These locations (Points A, B, C and D) have been used as inflows into the 1-D element of the model.

The inflow at Point A was used as the most upstream inflow. The 3 downstream inflows have been calculated by subtracting the flow at the point immediate upstream. For simplicity it has therefore been assumed that all flow between points enters at the downstream point and that it doesn't reach the Mangatarere Stream via overland flow. Peak inflows for each point are listed in Table 4-1.

Table 4-1: Estimated design flows at each inflow location for all scenarios

	1% AEP (m^3/s)	1% AEP + Climate change (m^3/s)	GWRC 1% AEP (m^3/s)	GWRC 1% AEP + Climate change (m^3/s)
Point A	144	173	194	233
Point B	114	137	154	185
Point C	76	91	102	122
Point D	74	89	100	120

The flood extents considered for this report are based on the flow assessment derived for this study (the columns shown in blue in Table 4-1), with flood extents from the earlier GWRC assessment shown as additional assessments in the appendices (flows shown in Table 4-1 as yellow columns).

The largest flood hydrograph within the data record was 12 February 2004. The inflow hydrographs for each of the design flows have been created using the profile from this flood hydrograph and scaled to the peak flow.

4.2.2 Downstream boundary

The downstream boundary for each event has been set as the water level in the Waiohine River for the 1%AEP. These water levels have been extracted from the results of the simulations of the GWRC hydraulic model of the Waiohine River.

The 1% AEP design flow in the Mangatarere Stream has been assumed to coincide with the 1% flood event in the Waiohine River. This may not always be the case, and may result in a higher joint probability. However the modelling undertaken by GWRC for the Waiohine River indicates that the water levels at this location only differ by 25mm at the peak in a 2% AEP event when compared to a 1% AEP event.

5 Results

The results of the simulations predict that some north-west areas of Carterton are at risk of flooding from the Mangatarere Stream. In all scenarios simulated, the flood water reaches Carterton and flows into the town to varying extents.

The extent of flooding for the 4 scenarios are discussed in this section with the preliminary flood maps included in the Appendix. These flood maps show water level and depth.

5.1 Design flows

5.1.1 1%AEP

The preliminary flood map presented in Figure 5-1 shows the predicted flooding depths throughout the model extent and in the vicinity of Carterton as a result of a 1%AEP event.

Flood water from the Mangatarere Stream reaches Carterton via 2 major flow paths originating at Smith's cow shed; one along Anderson's Line reaches the north of the town, and another splits and reaches the north west of the town.

The water level results from the 1% AEP event for each of the bridge locations is shown in Table 5-1. The key dimensions obtained from the survey information and site visit are also detailed.

Table 5-1: Water level results for 1% AEP event

Bridge	Channel invert m	Soffit level m	Deck level m	Water level (1% AEP) m	Comments
Tea Creek Road	Upstream extent of model and therefore this bridge has not been included.				
Mangatarere Valley Road	141.05	147.18	146.33	144.34	Not included in model. Difference between predicted water level and soffit level is 2.84m.
Smith's	102.91	106.21	106.68	106.73	Water level predicted to reach the bridge soffit and deck level.
Belvedere	83.35	87.3	87.73	86.87	Water level not predicted to reach soffit.
Brooklyn Road	74.75	77.7	79.16	78.08	Water level predicted to reach soffit level.
Craig's	71.8	75.12	76.14	74.22	Water level not predicted to reach soffit.
Rail bridge	67.98	70.98	71.98	70.77	Information from construction drawings is unclear and therefore soffit and deck levels assumed from site visit.
Dalefield Road	65.71	71.40	71.85	69.01	Water level not predicted to reach soffit.
State Highway 2	57.58	62.28	63.3	61.67	State Highway 2 Bridge.

The 1% AEP water levels are not predicted to reach the bridge in the upstream two bridges. Tea Creek Bridge is the upper extent of the model and Mangatarere Valley Road Bridge is at an elevation 2.84m higher than the predicted water level.

In the 1% AEP event, the water levels are not predicted to overtop the State Highway Bridge; and are predicted to rise to approximately 0.2m below the soffit of the Rail Bridge.

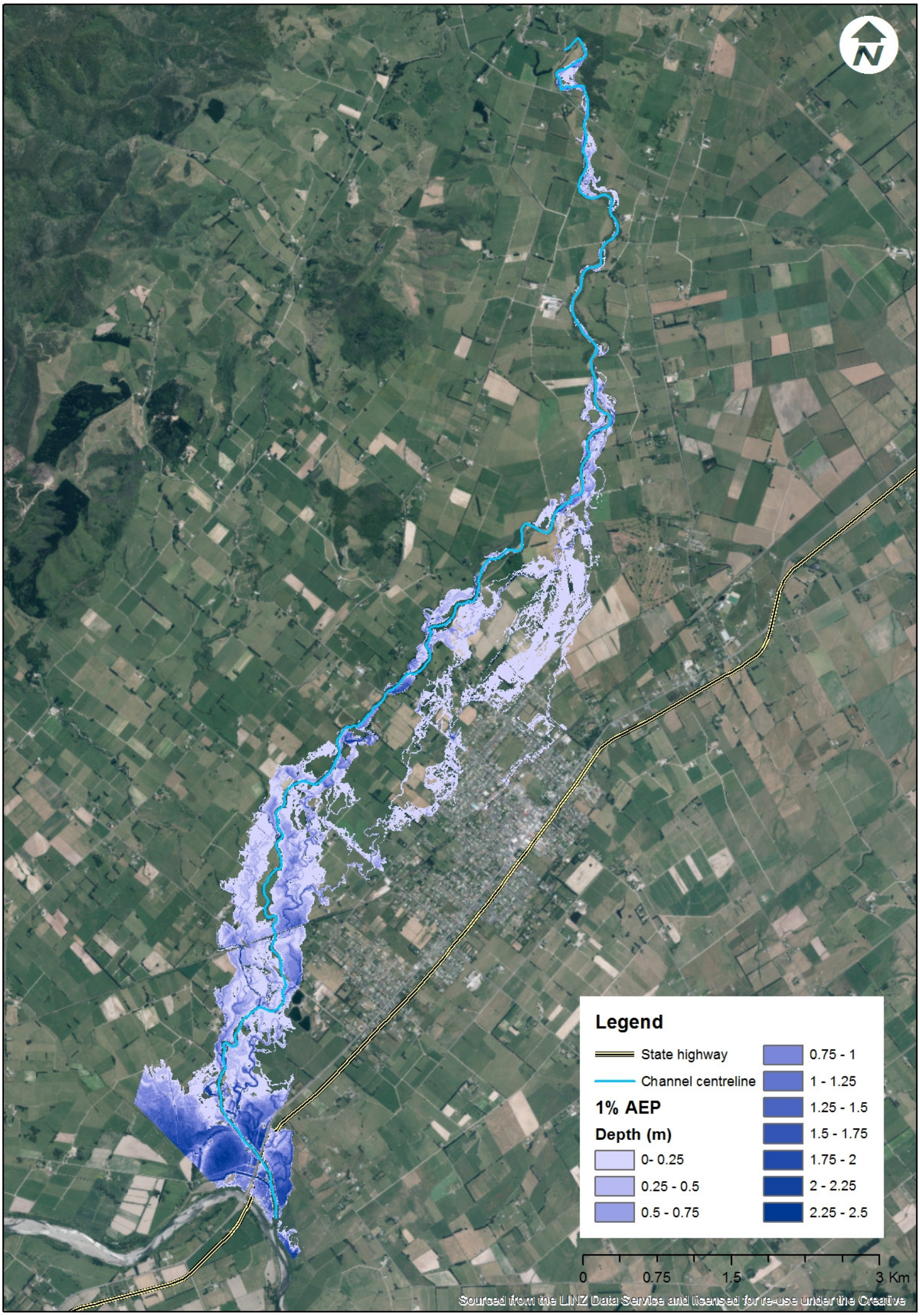


Figure 5-1: Preliminary flood extent through Carterton for 1% AEP

5.1.2 Climate change scenario (to 2090)

The results of the 1%AEP event with an allowance for climate change to 2090 show that the extent of flooding in Carterton could impact a larger part of the town. Figure 5-2 shows the differences between the predicted extents in the 1% AEP, and 1% AEP plus climate change flooding events.

The impact on climate change on the flood extent may be important for Carterton as additional flowpaths are present and the flooding is predicted to reach further into the town.

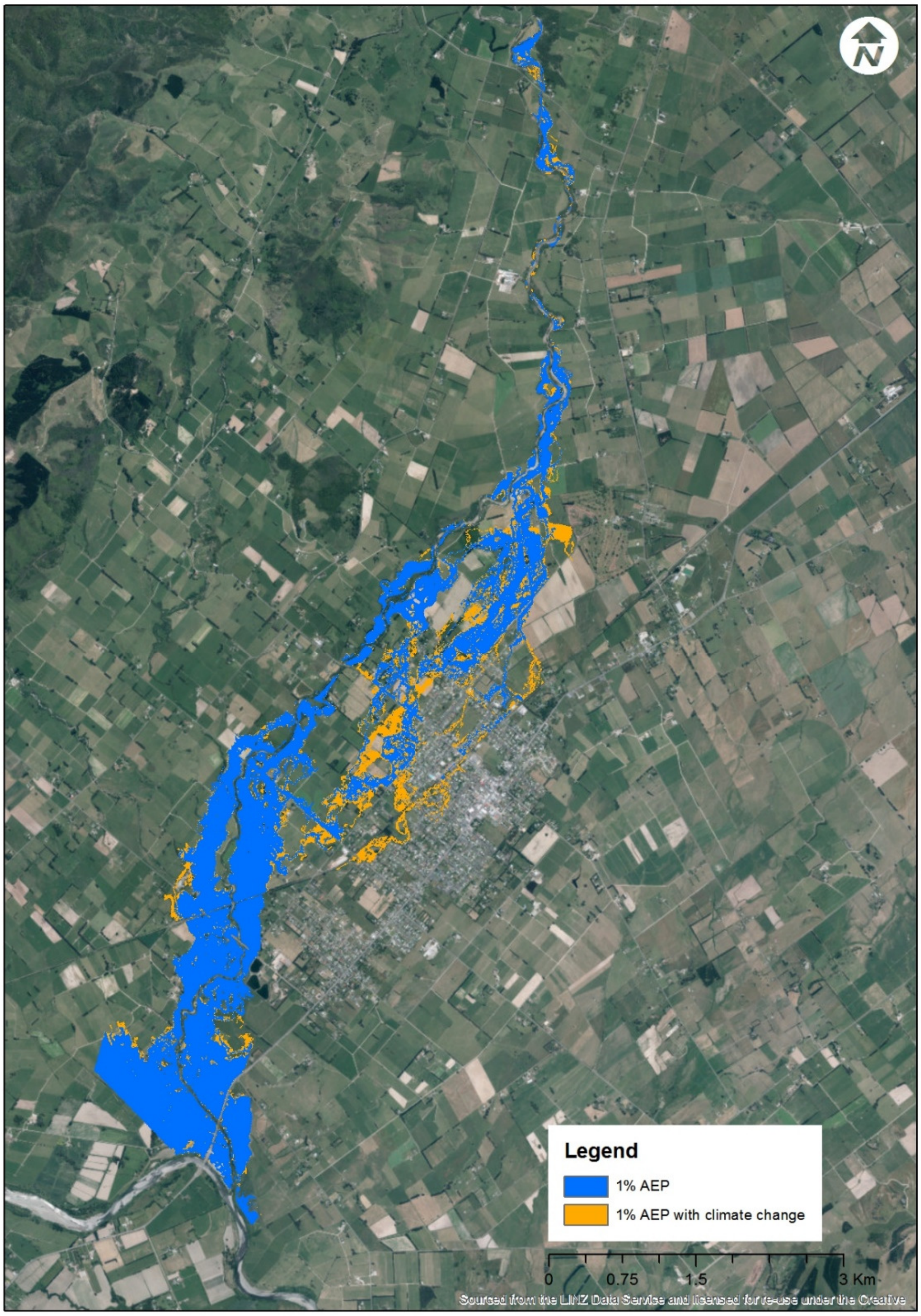


Figure 5-2: Differences between modelled flood extents predicted as a result of 1% AEP flow and a 1% AEP flow with an allowance for climate change

5.2 Sensitivity analysis

The design flows estimated for the Mangatarere Stream in the GWRC Waiohine Modelling study are 33% higher than the design flows estimated for this study.

Although there is greater confidence in the flows determined for this study (as explained in **Section 3)** the higher flows were also simulated in the model to determine the potential impact on Carterton. This is a form of sensitivity run.

The results of the additional scenarios show the extent of the flooding throughout Carterton could be even more considerable. They indicate additional flowpaths triggered in more significant events, and provide greater understanding of the flood risk within bounds of uncertainty.

These results, for water level and depth, are shown on the flood maps in Appendix D and may be useful for consideration of the uncertainty associated with the shorter flow records.

5.3 Calibration/Validation

The model has not been calibrated as no flood level data was available. However, the photographs of the flooding from the Mangatarere Stream in the vicinity of Smith's cowshed from November 1994 allow a form of validation of the model in this area.

The photographs in Figure 5-3 below show the flooding in 1994 in the vicinity of Smith's Cowshed; and the results from the modelled 1% AEP flooding event are shown in Figure 5-4. The model predicts flooding and flowpaths in similar locations.

Figure 5-3: Historical flooding photographs, Mangaratere Stream, 1994

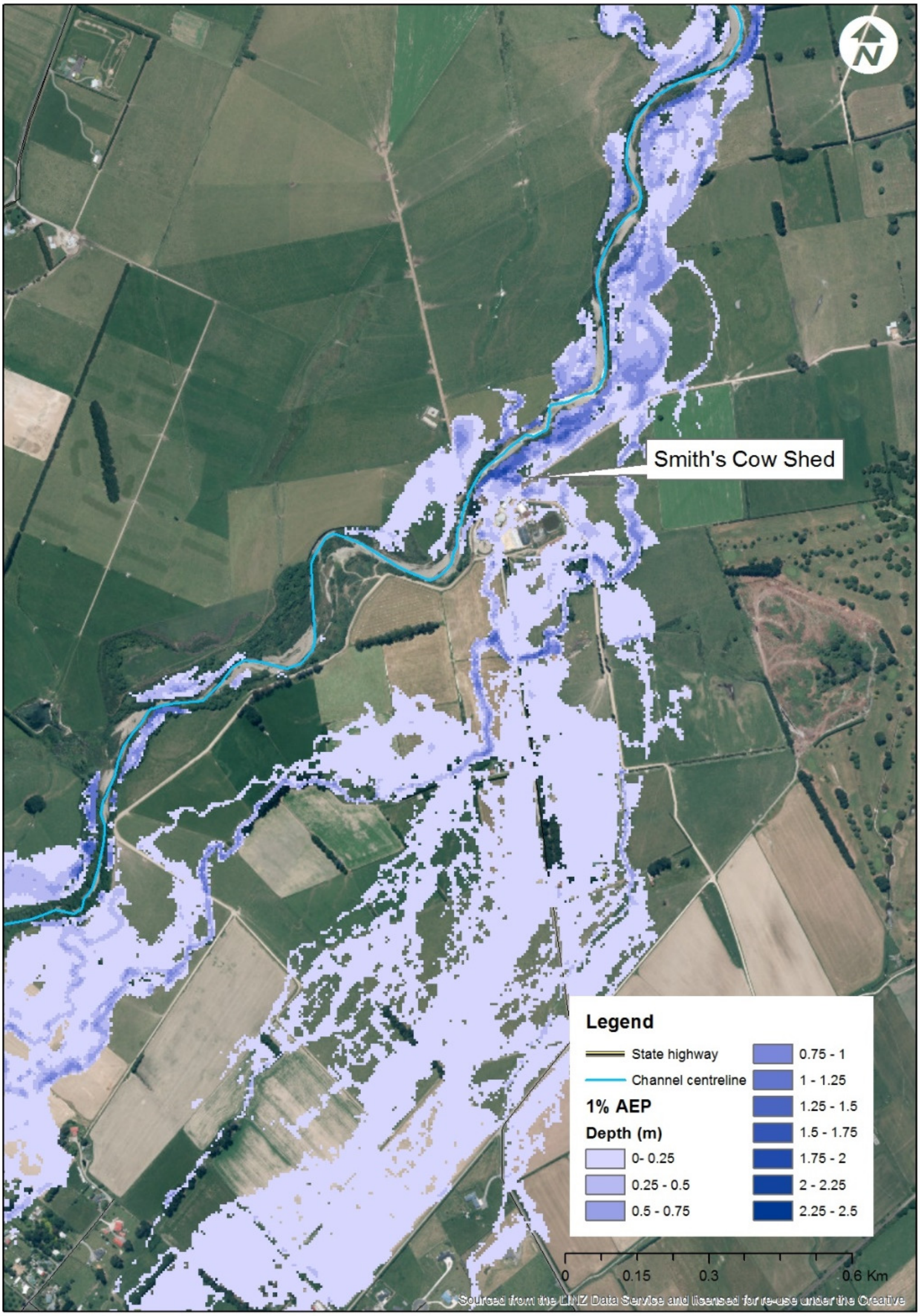


Figure 5-4: Modelled 1% AEP flood event in vicinity of Smith's Cow Shed

5.4 Model Limitations

5.4.1 Simplifications and assumptions

The 1-D/2-D hydraulic model is a simplification of reality and therefore the results are subject to a number of assumptions which are discussed in this section. Simplifications have been made to be able to represent key features when information is not available, reduce computational runtimes and file sizes, and to enable stable model performance.

Key simplifications and assumptions and their impact on the results of this study include:

- The DEM grid size was 5m which although will allow much of the floodplain to be represented appropriately, local flood depths and levels will be averaged.
- The DEM was post-processed from the original format provided. This was to ensure that true ground was represented as far as possible and not vegetation as captured by the LiDAR. The need for this is explained in **Section 4.1.2**, however the ground levels have been assumed and may differ in reality.
- The design flow profiles are derived from a relatively short record therefore confidence in extrapolating out to obtain values for rare events such as 1% AEP events is lower than for longer records. The results of the sensitivity analysis highlight the impact higher flows.
- It has been assumed that the flow profile for the 1%AEP event would be similar to the highest flow on record and the profile for each of the scenarios was derived from this event. The actual flow profile experienced in an event may differ from this due to spatial and temporal variability of rainfall in the catchment.
- All of the inflows assume that all water from their corresponding sub-catchment arrives at that point only and not via overland flow. Although this is not likely to be typical of the catchment, because the majority of the sub-catchment area for each inflow point falls on the true right bank, we can be confident that the flooding on the true left bank and to Carterton is generally representative of flooding from the Mangatarere Stream.
- It has been assumed that the 1%AEP event on the Mangatarere Stream coincides with the 1%AEP event in the Waiohine River. This may not always be the case, however the modelling undertaken by GWRC for the Waiohine River indicates that the water levels at this location only differ by 25mm at the peak in a 2% AEP event when compared to a 1% AEP event and therefore is reasonable.

5.4.2 Limitations

These assumptions and simplifications are reasonable for this preliminary rapid flood hazard assessment and the results of this modelling study should be used to review the potential flood hazard to Carterton. They are suitable for identifying areas potentially at risk, defining potential flow paths, and understanding the impacts of climate change on the catchment.

However, given the implications of some of the assumptions and the opportunity to refine this modelling, the water levels produced are not intended for use in the design of any flood defences or development minimum floor levels.

6 Summary

This study has concluded that Carterton is at risk of flooding from the Mangatarere Stream in a 1% AEP event. The results of the climate change scenario, and the sensitivity runs also show the flood hazard to Carterton is already significant and may become increasingly so over time with climate change impacts.

GWRC considers this approach to be a ‘rapid’ flood hazard assessment. Therefore the flood extents provided in this report are ‘initial’ and are intended to inform the need a scope for a more detailed assessment working with Councils and the community to develop agreed flood maps.

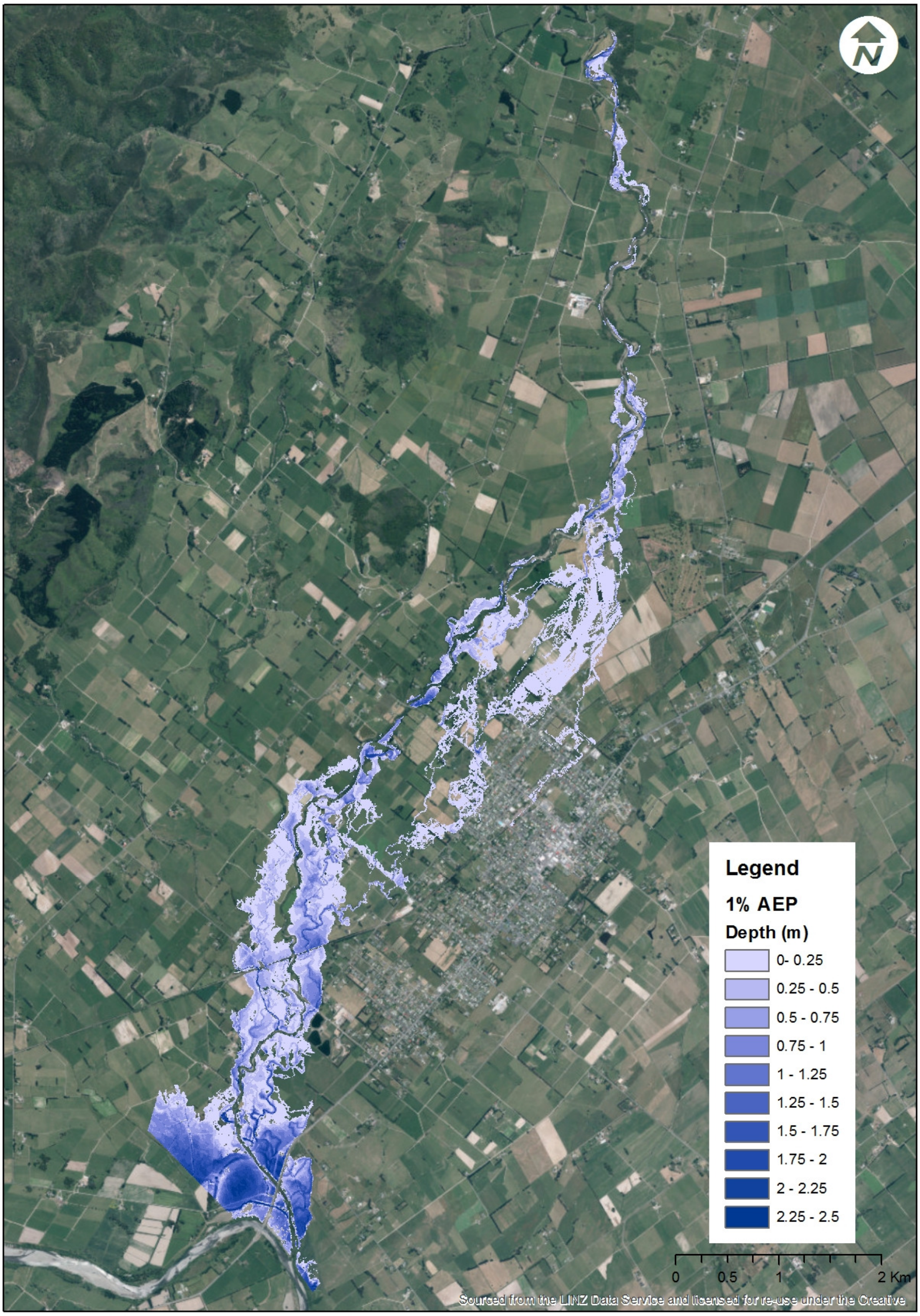
The modelling results could be further refined with classified and filtered LiDAR data, increased detail in the DEM with smaller grid sizes, and further information on geometry and flow profiles for the tributaries feeding into the right bank. However, these preliminary flood maps give a good representation of the potential extent of the impact of a 1% AEP flood event in the Mangatarere Stream.

The actual flood extent in Carterton itself could be better defined through further a detailed topographic survey of road and ground levels within the town, and also the incorporation of surface water drainage features, particularly culverts beneath the roads.

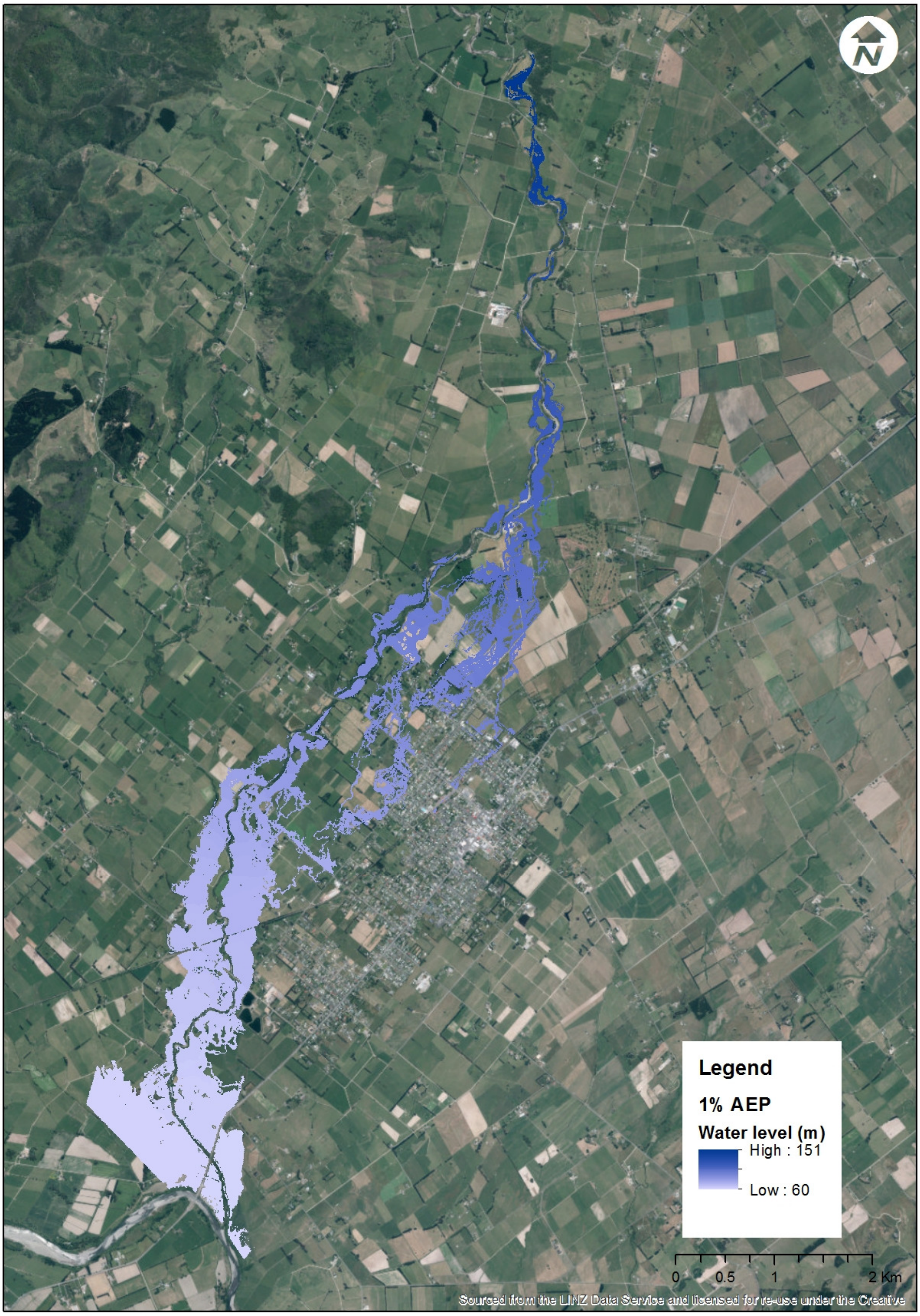
Appendix A – Hydrology report

Appendix B - 1% AEP preliminary food maps

Modelled Depth for 1% AEP

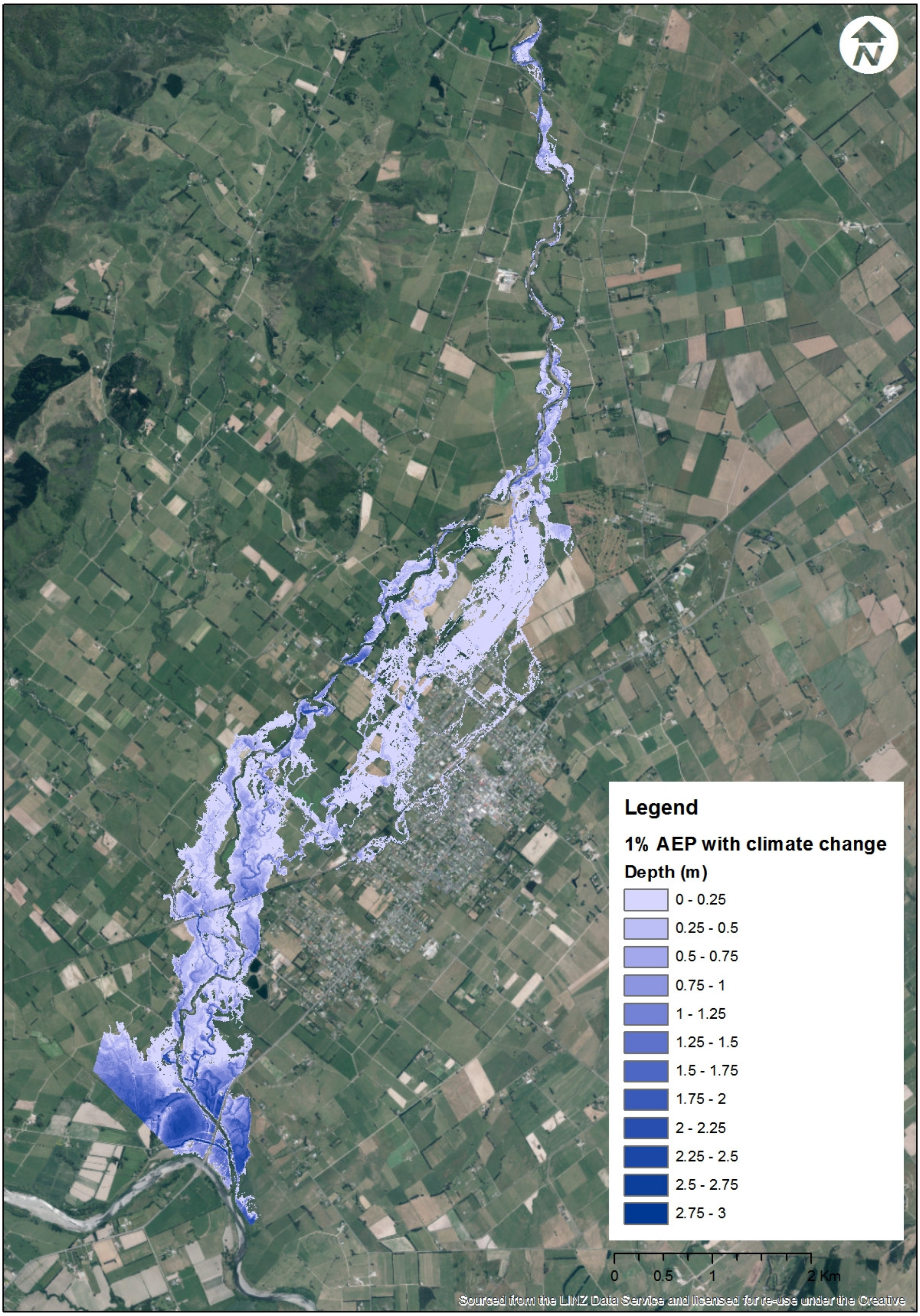


Modelled water level for 1% AEP

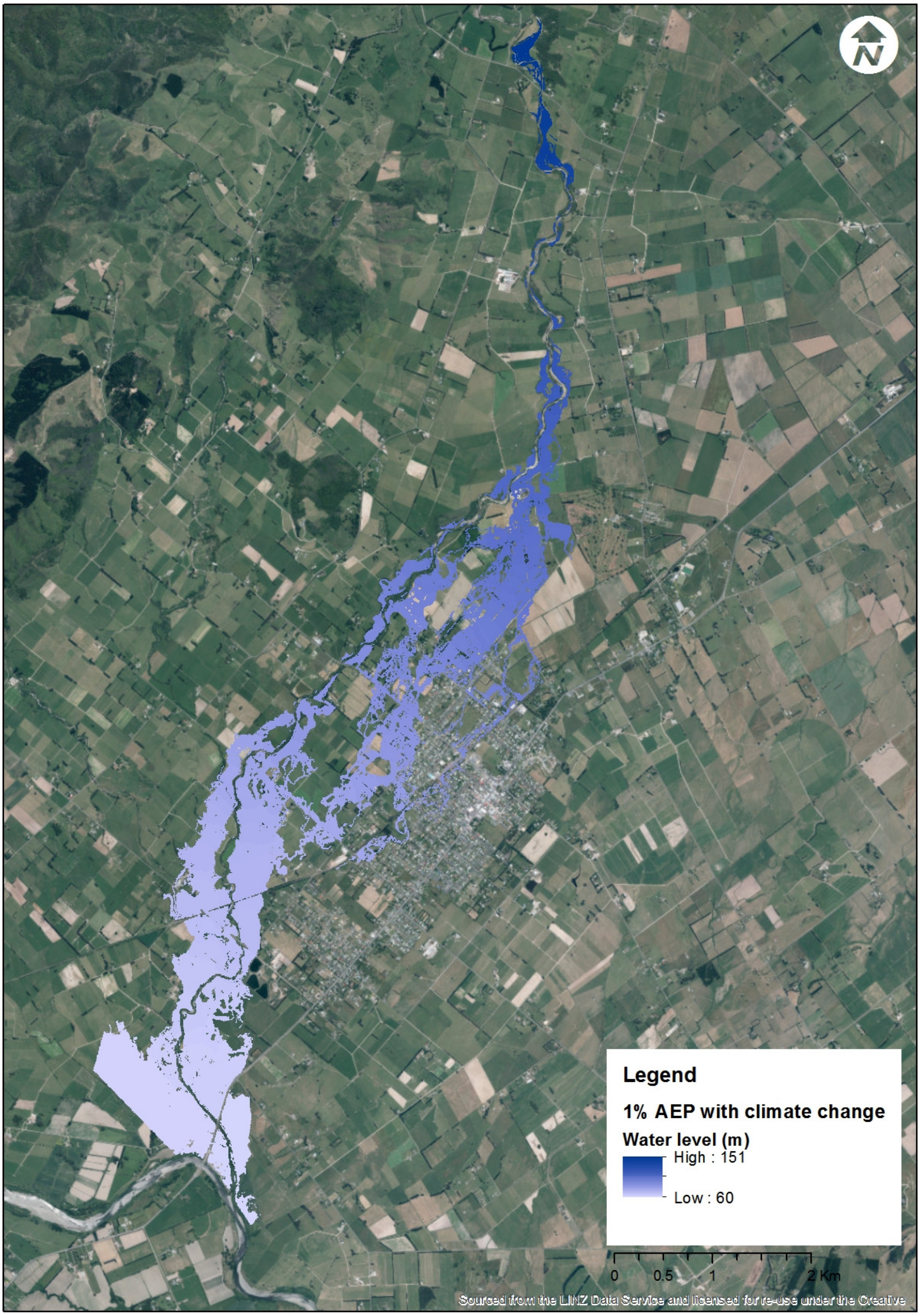


Appendix C - 1% AEP plus climate change preliminary food maps

Modelled water depth for 1% AEP plus climate change

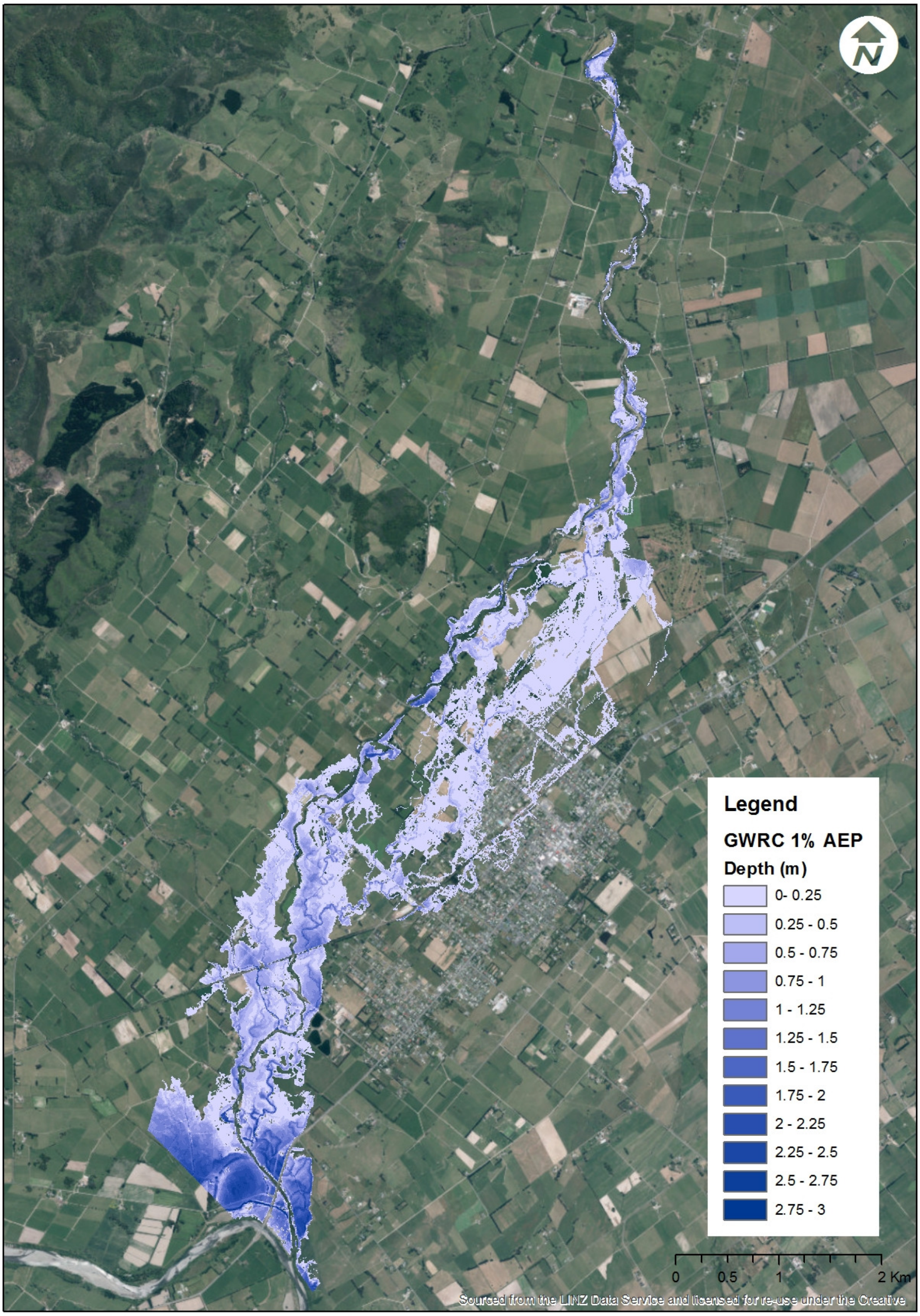


Modelled water level for 1% AEP plus climate change

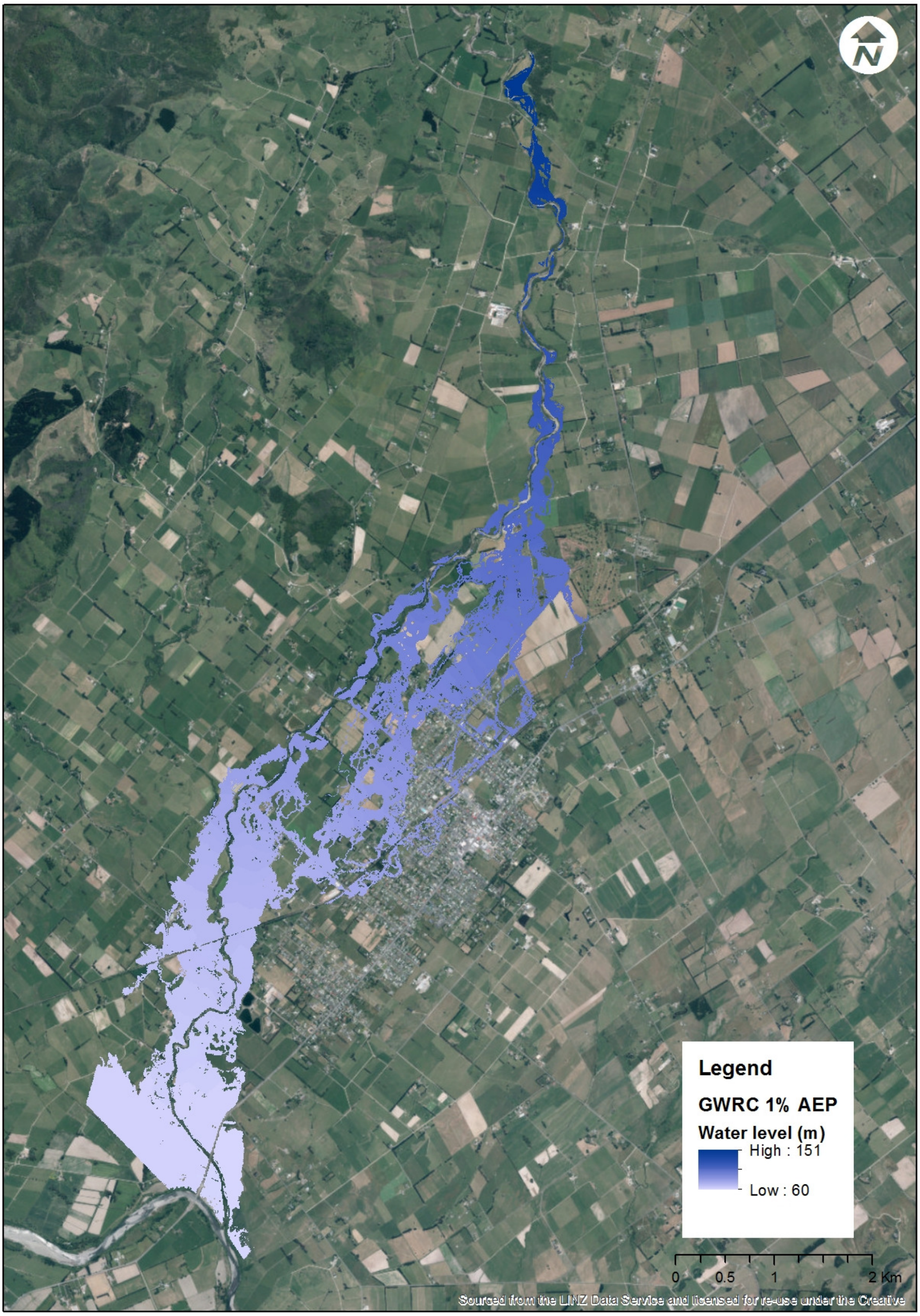


Appendix D – Sensitivity testing

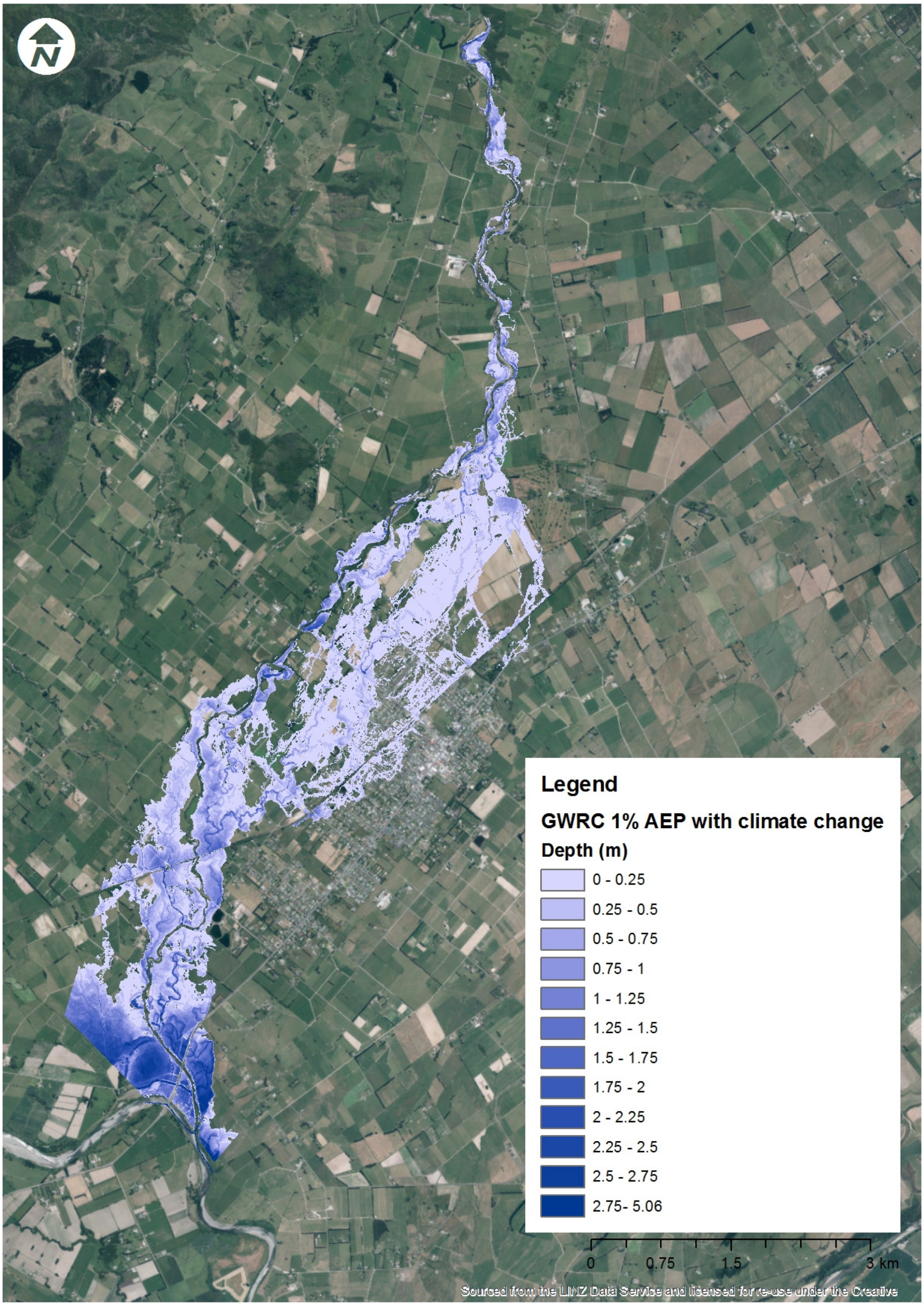
Modelled water depth for 1% AEP (GWRC design flows)



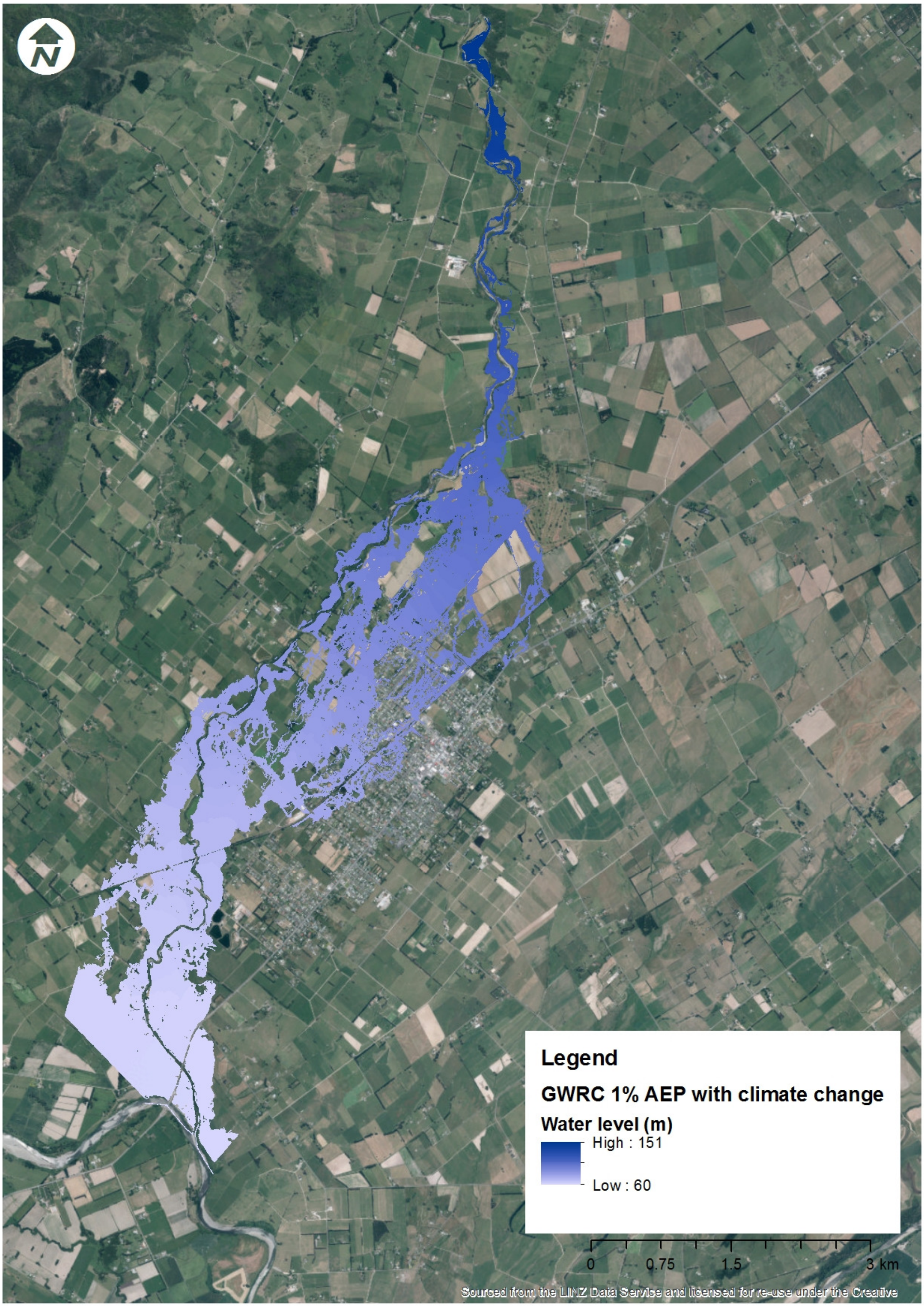
Modelled water level for 1% AEP (GWRC design flows)



Modelled water depth for 1% AEP plus climate change (GWRC design flows)



Modelled water level for 1% AEP plus climate change (GWRC design flows)



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