Utuhina - Phases 2 and 3

Numerical Modelling

Bay of Plenty Regional Council

Report

August 2021

The expert in **WATER ENVIRONMENTS**

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Utuhina - Phases 2 and 3

Numerical Modelling – Title 2

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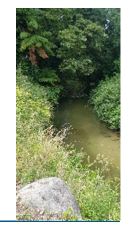

Utuhina Stream,
downstream of Malfroy Rd

Project manager	Philip Wallace

Project number	44800902-01
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Classification	Restricted

CONTENTS

FIGURES

TABLES

1 Previous modelling

A summary of previous hydraulic modelling is given in DHI (2017). A brief outline of the model studies is given below.

2 Introduction

The Utuhina Stream drains a south-western catchment of Lake Rotorua, of around 60 km^2 (Figure 2-1). The stream and its major tributaries (in particular, the Mangakakahi and Otamatea Streams (Figure 2-2)) flow through residential and industrial areas within Rotorua City before discharging to the lake and have a long history of flooding and erosion.

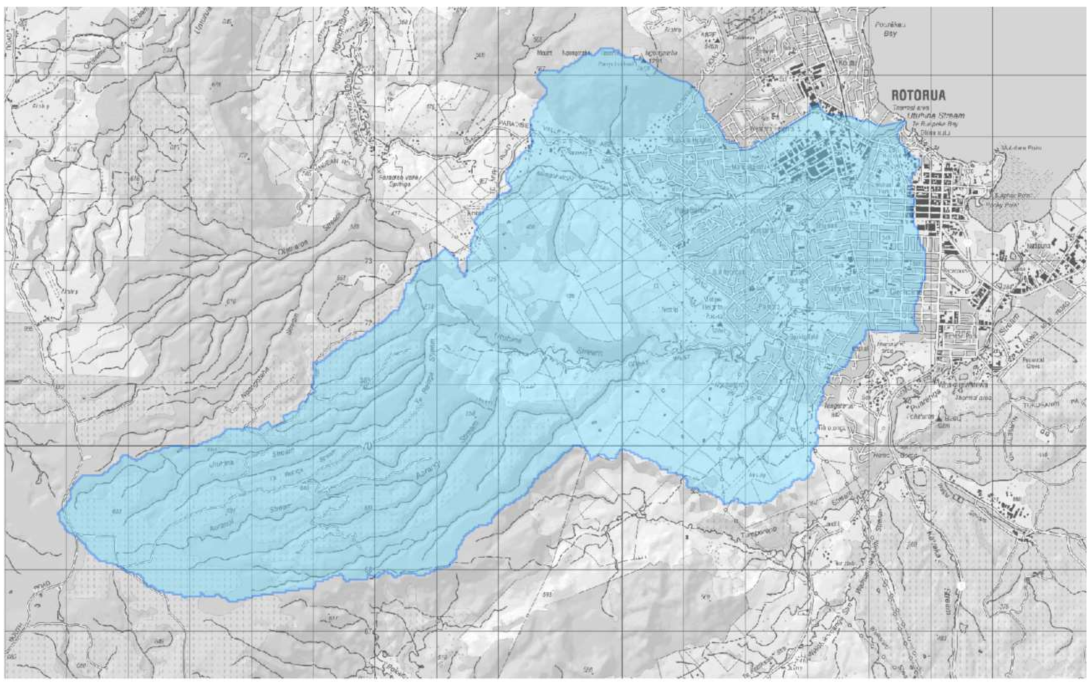


Figure 2-1 Utuhina catchment

BOPRC has responsibility for stream management, flood protection and erosion control in lower Utuhina catchment, as part of the Kaituna Catchment Control Scheme. The Regional Council's Rivers and Drainage Asset Management Plan 2018-2068 (BOPRC, 2018) specifies protection against a 1% AEP (annual exceedance probability) flood event, downstream of Old Taupo Road.

In 2017 BOPRC initiated a new project to determine the flood and erosion risk to properties adjacent the Utuhina Stream and then develop appropriate mitigation options. The study area includes the entire Utuhina Stream Catchment.

The project has been divided into four phases:

- Phase 1: Gap analysis and preparation of the project scope
- Phase 2: Data collection and model build
- Phase 3: Calibration, design simulations, mapping and reporting
- Phase 4: Mitigation options

Phase 1 was completed in 2017 (DHI, 2017).

This current report describes the modelling and results from Phases 2 and 3. Phase 2 was largely completed in 2018/19, while most of Phase 3 was carried out in 2019/20.

The completion of Phase 3 was delayed in 2020 due to a need to model the effects of Plan Change 2 (Pukehangi Heights) pursued by Rotorua Lakes Council (RLC) under a fast-track process. Modelling for the Pukehangi Plan Change has been outlined in evidence presented at the hearing for the Plan Change[1] (Wallace, 2020), but it drew upon the modelling work described in this current report.

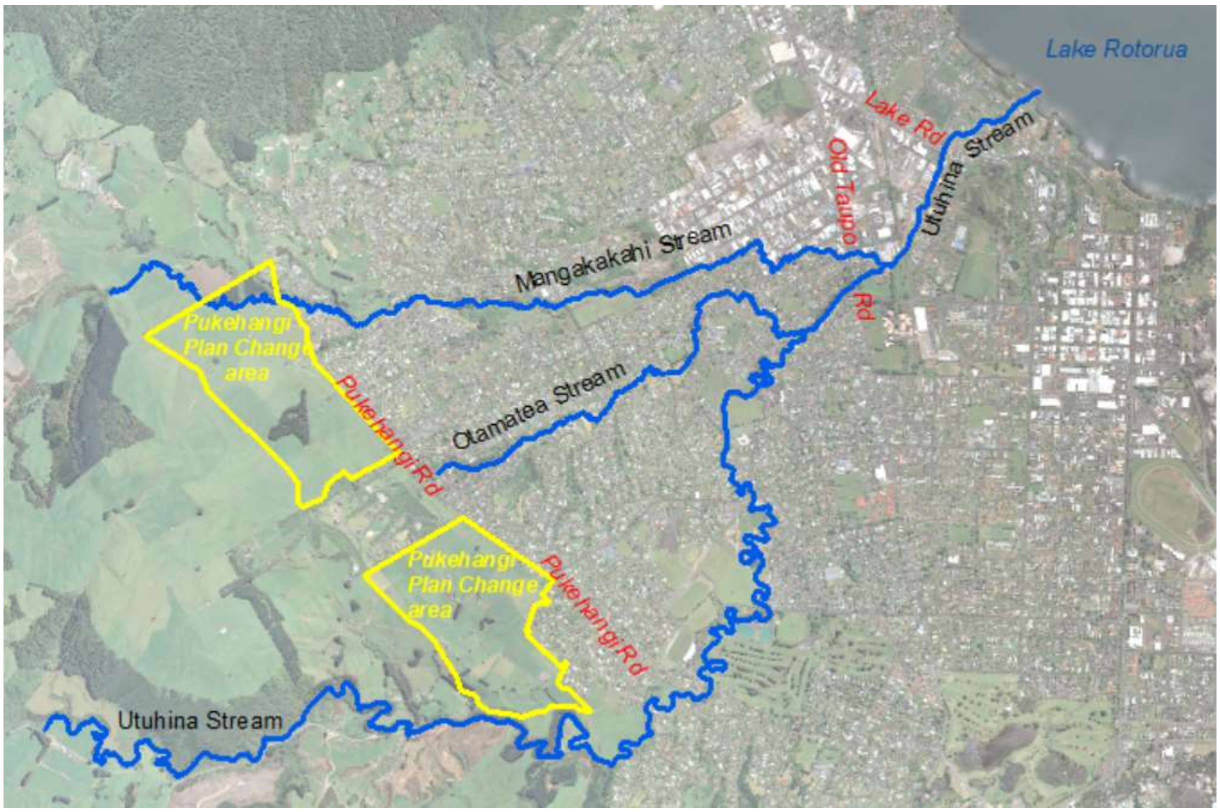


Figure 2-2 Major tributaries and features of interest

[1] https://letstalk.rotorualakescouncil.nz/District-Plan-Plan-Change-2-Pukehangi-Heights/news_feed/executive-summaries-presented-at-the-hearing

2.1 Utuhina Stream

The first computational hydraulic model study was carried out in 2003 by Riley Consultants (2003) for BOPRC. The 1D model, built with MIKE 11 software, represented the Utuhina Stream between Old Taupo Road and the lake. Over the next ten years the model was revised and updated with additional calibration data (Wallace, 2006 and 2011).

In 2013, the model was reconfigured into a combined 1D-2D model, using MIKE FLOOD software (Wallace, 2014). The model extended 300-350m upstream of Old Taupo Road in both the Mangakakahi and Utuhina branches.

2.2 Mangakakahi Stream

Barnett and McMurray (2009) built a 1D model that covered the main branch of the Mangakakahi Stream from Pukehangi Road (i.e. the upstream extent of the urban area) to the Utuhina confluence. The model was built using Aulos software.

3 MIKE FLOOD model

3.1 Model software

The model software used for this current study is MIKE FLOOD 2017 (SP2). This software simulates both channel flow and overland flow, dynamically linking them during a simulation. Channel flow is represented with a 1-dimensional (1-D) MIKE 11 model, while overland flow is represented with a 2-dimensional (2-D) MIKE 21 FM model.

Figure 3-1 shows the model extent.

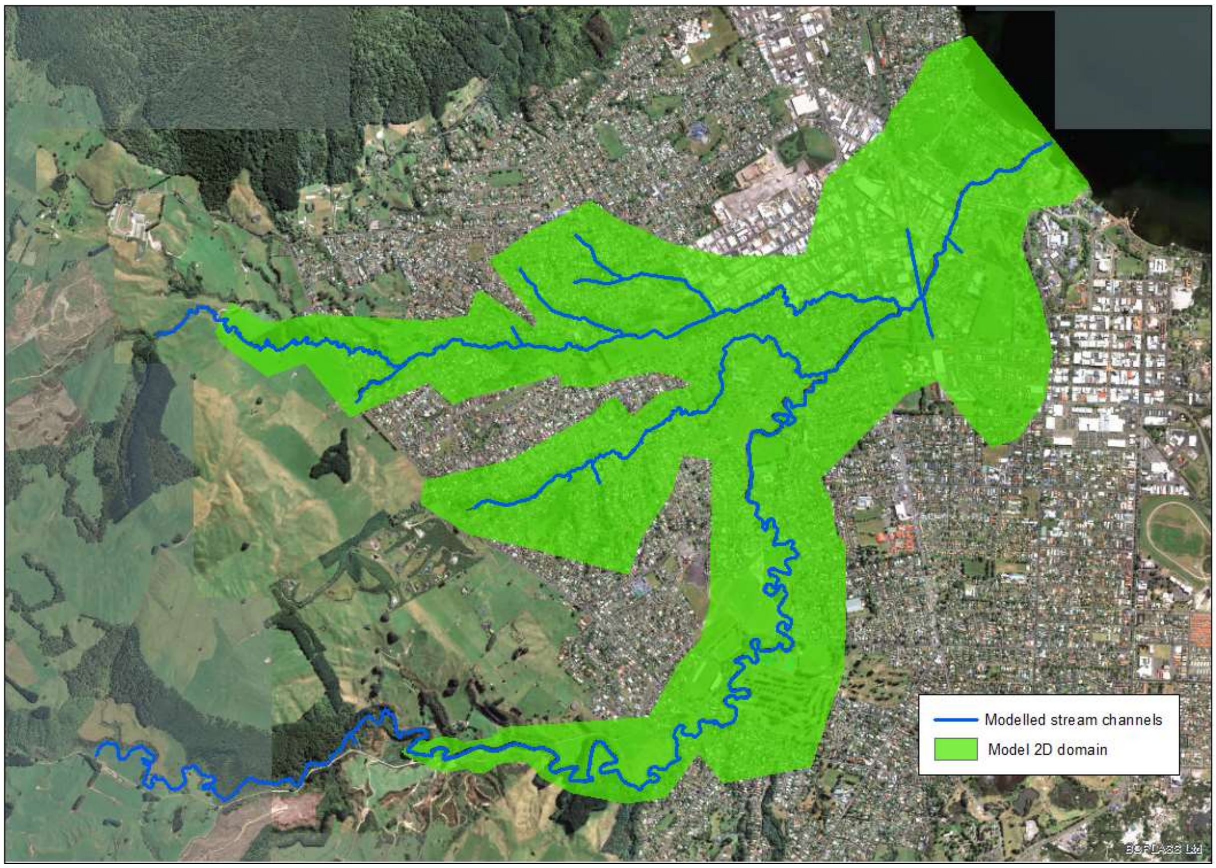


Figure 3-1 Model layout

3.2 MIKE 11

3.2.1 Model branches

The MIKE 11 model consists of branches representing the three main stream channels (Utuhina, Otamatea and Mangakakahi) as well as short lengths of tributary channels and culverts (Figure 3-1).

Some small lengths of additional 1-D channel (dotted line in Figure 3-2) were added for the 2017 and 2018 event calibration simulations and the design scenarios, to reflect physical works and development in the Amohau St area. Most of the additional branches are closed culverts.

Figure 3-2 Additional model branches in Amohau St commercial development for design simulations and later calibration events

3.2.2 Cross-sections

Survey cross sections from a 2018 survey by Beca (2018) were used for most of the lengths of the three main streams. The location of the sections is given in Appendix D.

In addition, cross-sections surveyed for Rotorua Lakes Council in the early 2000s were used for the Mangakakahi tributaries as well as to supplement the 2018 cross-sections for the Mangakakahi Stream itself where there were large gaps between those 2018 cross-sections. In a few locations in tributary channels, the survey data were supplemented with approximate sections derived from LiDAR.

For the 2011 calibration events however, from Old Taupo Road to the lake, 2018 cross-sections were replaced by sections dating from 2007 and 2010. Those earlier sections were considered to better represent the stream geometry than post-flood sections from 2011 (as explained in Wallace (2014)) or 2018 sections.

3.2.3 Structures

Bridges and culverts were inserted into the model where appropriate. Information for the structures has come from the various surveys noted above. In addition, 360° photos taken by Beca for each cross-section and bridge, along with information gleaned during site visits, have assisted in setting up the structures in the model.

The Old Taupo Road bridge over the Utuhina is hydraulically inefficient and in previous modelling (Wallace, 2006) the pier ratio was increased and the soffit lowered to allow for debris blockage, for calibration to the May 1999 flood and for design simulations. That assumption was maintained in the 2013 modelling work and has again been kept for the current study, both for calibration and design simulations.

In this current study, other than one design simulation being carried out with debris blockage of the Old Taupo Road bridge over the Mangakakahi and of the Lake Road bridge, all other bridges are assumed not to have debris blockage.

3.2.4 Channel resistance

After model calibration, the adopted channel resistance profiles for the Utuhina Stream are as shown in Figure 3-3. (Upstream of chainage 3000 m, the Manning's n value remains at 0.100).

Values downstream of Old Taupo Road are largely based on the values adopted in previous modelling (calibration to the January2011 events), described in Wallace (2014). However they have been increased by 10% for around 600 m downstream of Old Taupo Road in this current exercise to improve the calibration. Values upstream of Old Taupo Road were derived from fitting model predictions to the 2017 debris levels (Figure 5-33).

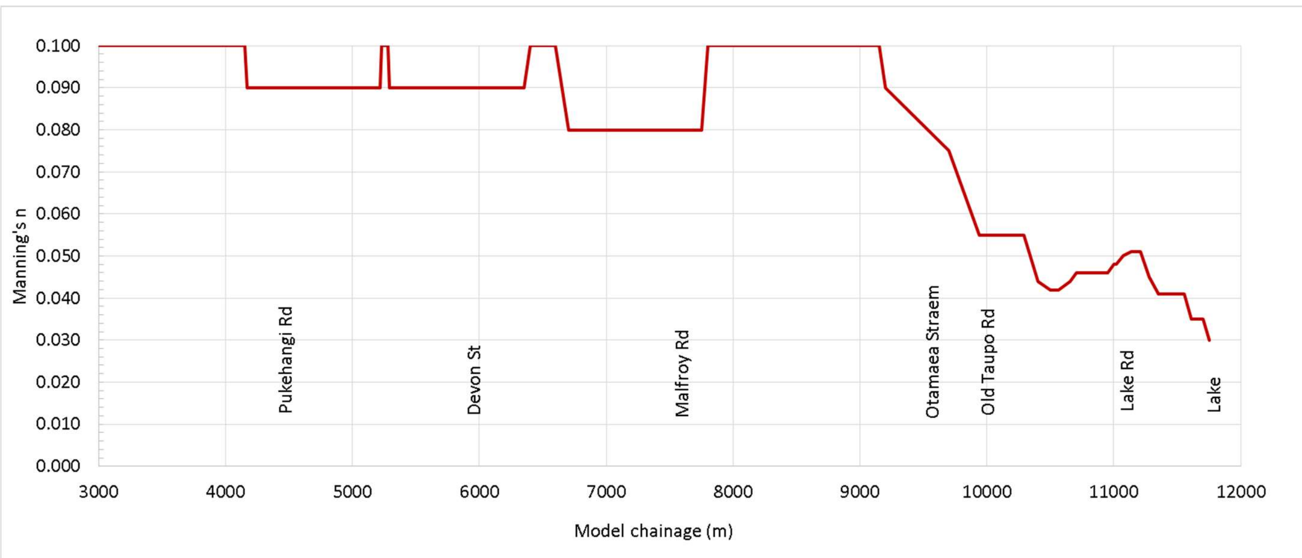


Figure 3-3 Channel resistance, Utuhina Stream

The high Manning's n value for most of the study reach reflects the sinuosity of the stream, as well as the stream being narrow with overhanging vegetation in many places.

There is very little calibration information along the Mangakakahi and Otamatea Streams, so the Utuhina Stream channel resistance values have been taken as a guide for those streams. The Mangakakahi Stream values range from 0.045 to 0.100, while a value of 0.080 is adopted for the Otamatea Stream.

3.3 MIKE 21

3.3.1 Model topography and bathymetry

The model topography for the MIKE 21 flexible mesh (FM) component was in general derived from the 2011 LiDAR survey. However recent 2018 LiDAR data were used to update areas of the model for the design events and relevant calibration events where there have been topographical changes since 2011: around Lake Road, Amohau Street and the Baxendale subdivision (Figure 3-4).

A small step of around 100 mm in the 2011 LiDAR data is apparent along an east-west line, approximately 70 m north of Pukuatua Street and extending at least as far west as Sunset Road and as far east as Ranolf Street. This step is presumably an artefact of the processing of the LiDAR data by the supplier. It has been removed in the MIKE 21 model topography in the vicinity of Amohau Street by the use of the 2018 LiDAR data, but it remains in the model outside of that area. However, the error is within the LiDAR accuracy[2] and in any case the affected floodplain is only inundated in the larger and climate change scenarios.

Lake bathymetry information is less detailed, but sufficient information has been obtained from LINZ data.

Figure 3-4 Area where model updated with 2018 LiDAR for design events and relevant calibration events

Other than three short sections of small tributary open channels which have quadrangular elements, the 2-D model mesh consists of triangular elements, averaging around 5 m^2 in area.

[2] According to the metadata for the 2011 LiDAR (NZAM, 2011), the "*project specified vertical accuracy of +/-0.25m (68% confidence interval) has been met*".

3.3.2 Floodplain roughness

The 2-D roughness was derived from aerial photographs and LCDB version 4.1. The roughness was applied as a *.dfs2* file at 2 x 2 m resolution. The Manning's n values used for each land use type are outlined in Table 3-1.

Table 3-1 MIKE 21 roughness

Landuse type	Manning's n
Bush/dense trees	0.080-0.100
Playing fields	0.033
Water bodies	0.025
Roads	0.020
Industrial area	0.100
Residential area	0.100
Pasture	0.050
Large buildings	0.200

4 Hydrology

4.1 Model inflows

Inflows to the model, for both calibration and design events, are derived from a Non-Linear Reservoir (NLR) model of the Utuhina catchment. A description of the NLR model is given in a report by West (2021). In summary however, the catchment has been broken up into a number of subcatchments and rainstorms applied to each. The rainstorms are spatially varying and are based on rain radar records for the calibration events and HIRDS v4 nested storms for the design events. Calibration of the hydrological model has been an iterative process run in conjunction with the hydraulic model calibration.

The outputs of the NLR model are flow hydrographs that have been applied either as point or distributed inflows to the MIKE 11 1-D component of the hydraulic model. Approximately 75 such hydrographs have been applied to the hydraulic model.

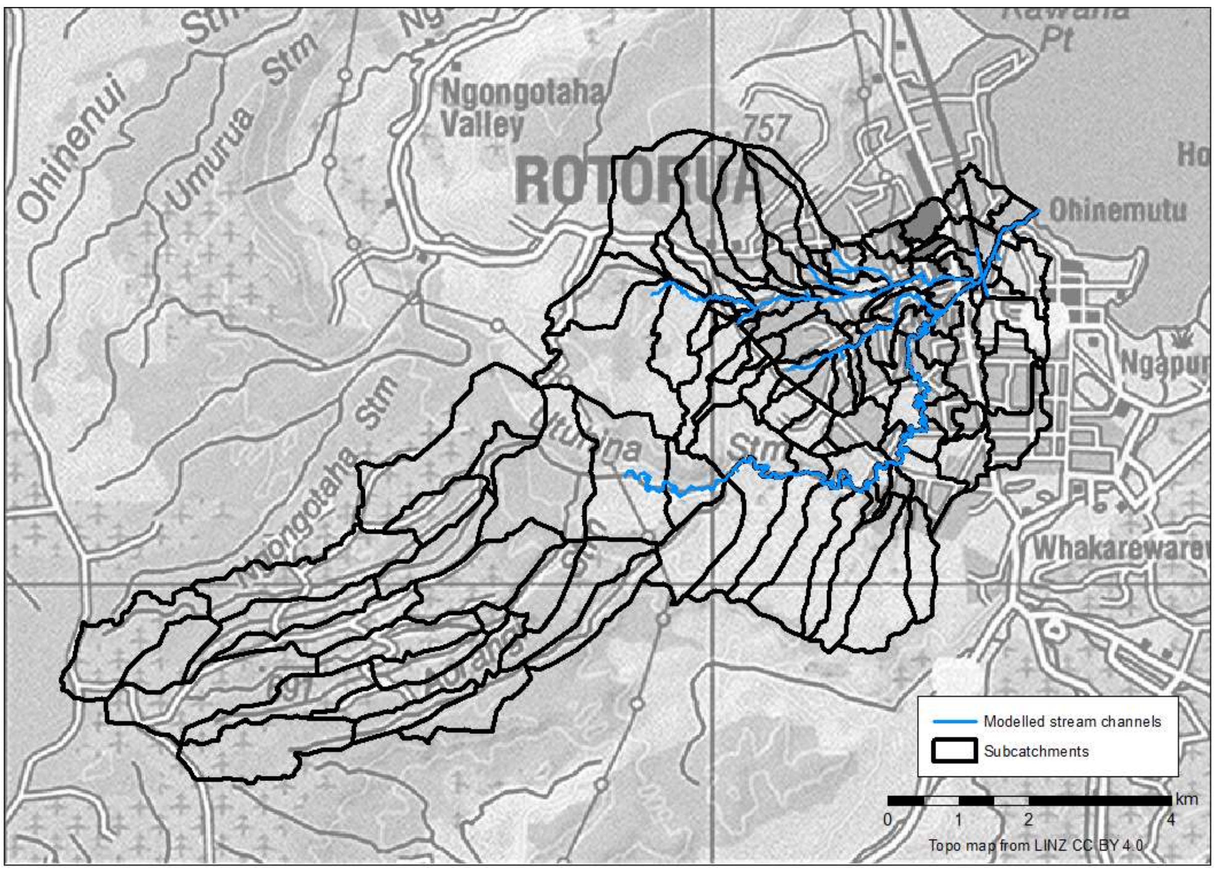


Figure 4-1 Utuhina catchment and subcatchments used in NLR model

4.2 Lake levels

The 2011 and 2014 calibration simulations have used the record from the Town Wharf lake level recorder. That recorder was decommissioned shortly afterwards and the other calibration simulations use records from the Mission Bay site on the opposite side of the lake. The difference in lake levels between the two recorder sites will have little impact on model results in the Utuhina Stream.

Lake levels for design events are assumed constant. The values assumed for each are described in section 6.1

5 Model calibration

Five storms have been modelled:

- 23 January 2011
- 29 January 2011 (Cyclone Wilma)
- 20 August 2014
- 11-13 March 2017
- 29-30 April 2018

As there was not extensive flooding outside the stream channels in these events, initial model simulations were made with just the MIKE 11 component of the model. However, final runs were made with the full MIKE FLOOD model.

Comparisons of model data with recorded or observed data are given in the following sections for each calibration event. For each event, recorded level and flow data (according to rating curves) are available at the three sites shown in Figure 5-1. Peak flood levels were measured (from debris levels) for the two January 2011 floods, the 2017 flood and the 2018 flood, although the measurements do not cover the entire model area. For the 2014 event, two flood photos for the Otamatea Stream have been obtained.

A general commentary on results is provided in section 5.6

Figure 5-1 Recorder sites

5.1 23 January 2011

Calibration results at the recorder sites are given in Figure 5-2 to Figure 5-7. Note there were gaugings at the Utuhina @ Depot St site just before the peak and on the recession. The gauging results actually fit slightly better to the rated curve that BOPRC had adopted in 2013 than to the more recent revision shown in Figure 5-2 (refer to the email correspondence in Appendix C.1)

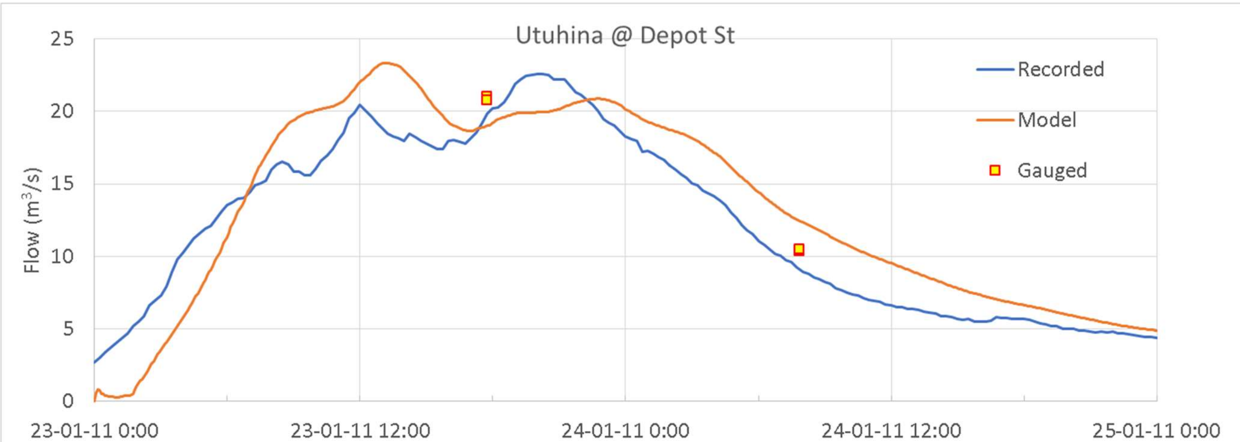


Figure 5-2 Utuhina @ Depot St recorder, 23 January 2011 event, recorded and model flows

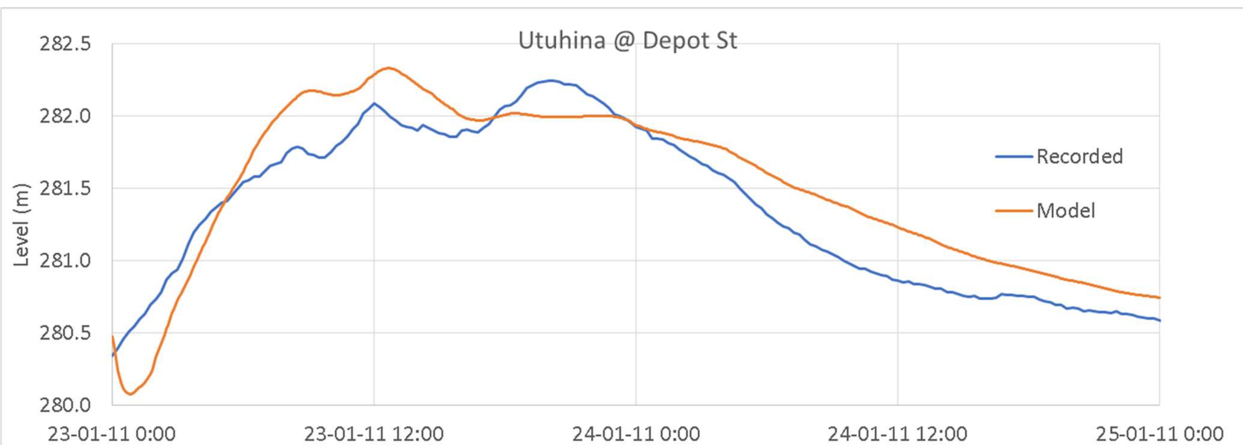


Figure 5-3 Utuhina @ Depot St recorder, 23 January 2011 event, recorded and model levels

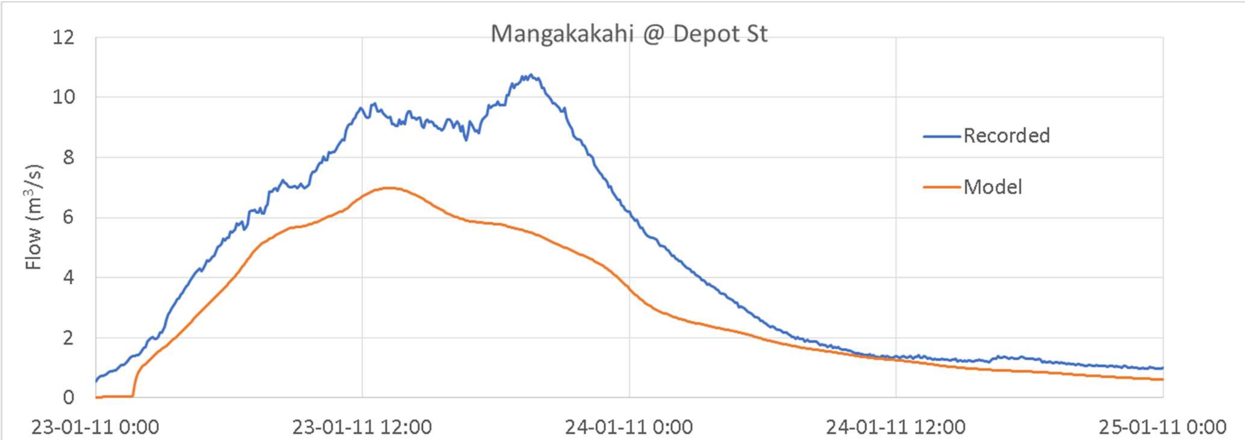


Figure 5-4 Mangakakahi @ Depot St recorder, 23 January 2011 event, recorded and model flows

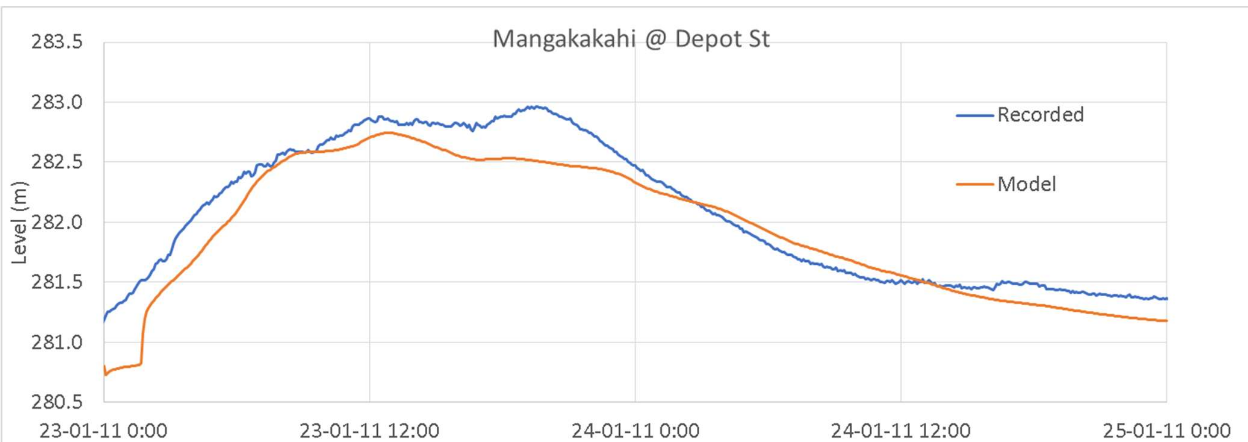


Figure 5-5 Mangakakahi @ Depot St recorder, 23 January 2011 event, recorded and model levels

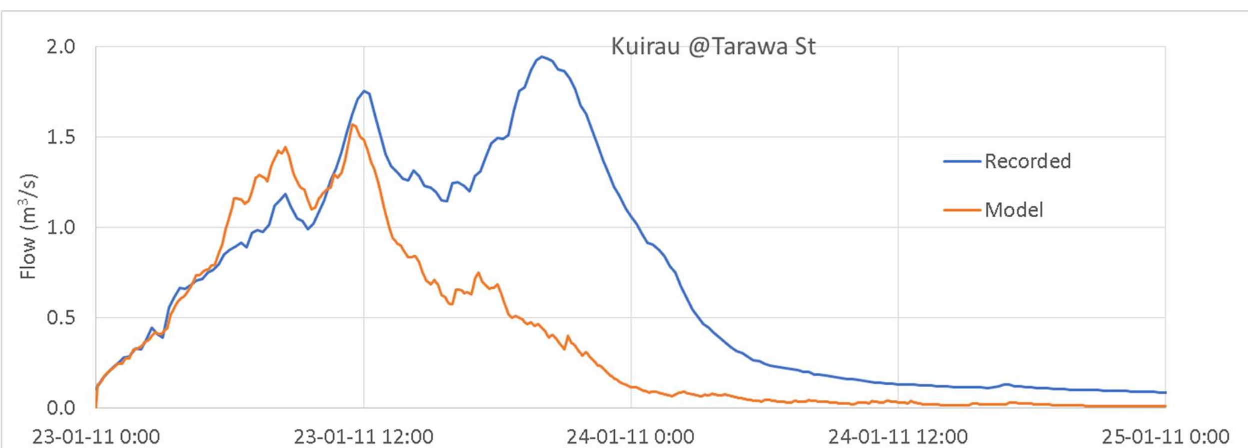


Figure 5-6 Kuirau @ Tarawa Rd recorder, 23 January 2011 event, recorded and model flows

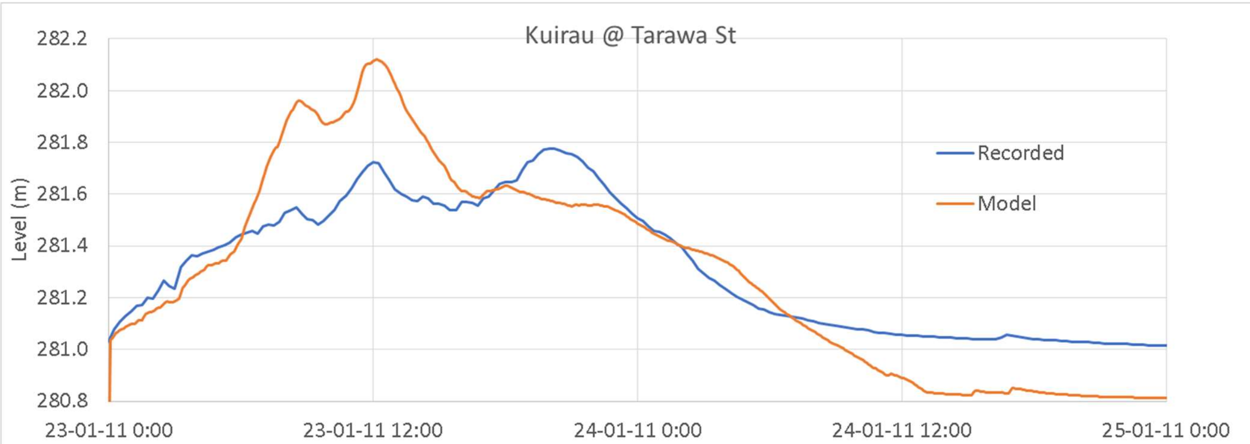


Figure 5-7 Kuirau @ Tarawa Rd recorder, 23 January 2011 event, recorded and model levels

The model underpredicts the discharge at the Mangakakahi recorder (Figure 5-5), but the discrepancy is less marked for the water level hydrograph (Figure 5-4). This is a pattern noted for the other calibration events also, and in part may be related to rating uncertainties mentioned in section 5.6.

BOPRC measured peak flood levels downstream of Old Taupo Road for the event, while the then RDC (now RLC) measured them downstream of Lake Road. Model predictions are compared to the measurements in Figure 5-8. The RDC measurements seem to be too low (as previously reported in Wallace (2014)), but the model gives a reasonable match to the BOPRC levels. The average difference between the model and the BOPRC debris levels is 73 mm, with the average absolute difference being 153 mm.

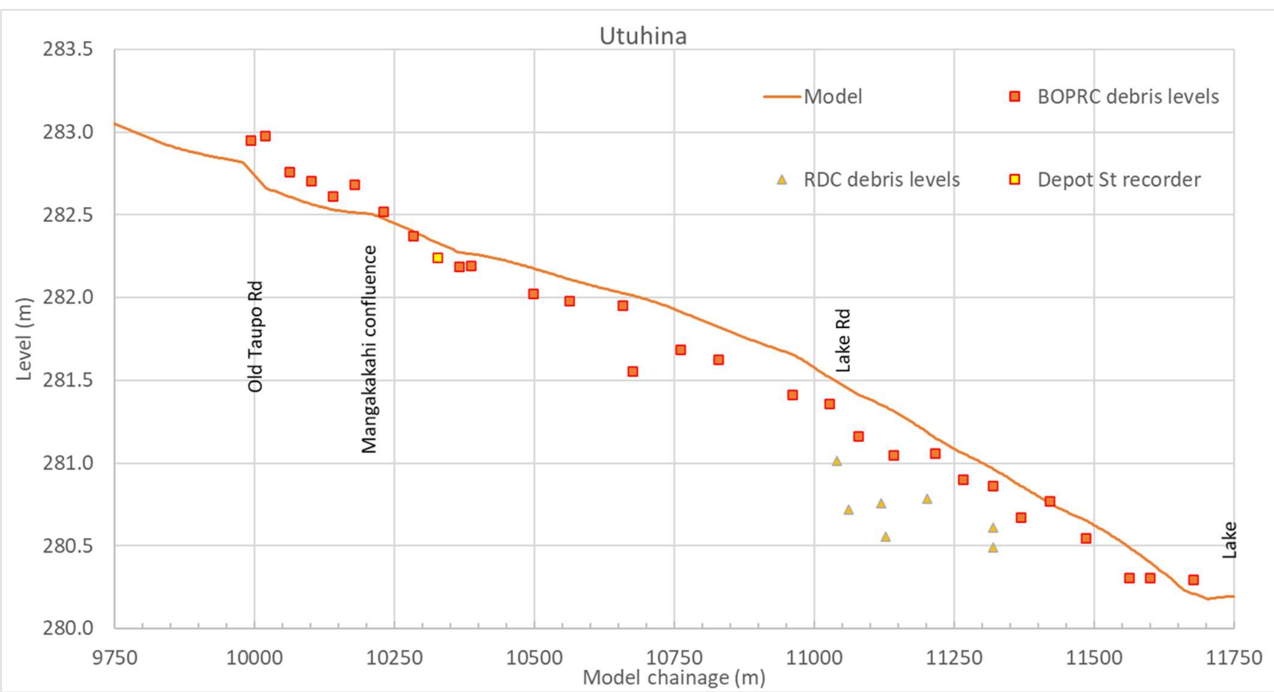


Figure 5-8 Peak flood levels, Utuhina Stream, 23 January 2011 event

5.2 29 January 2011

Calibration results at the recorder sites are given in Figure 5-9 to Figure 5-14.

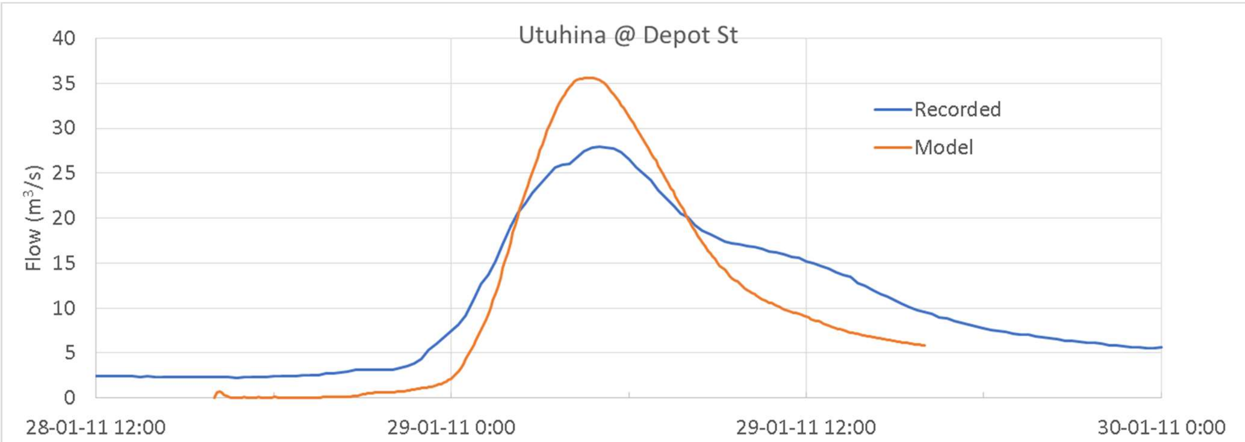


Figure 5-9 Utuhina @ Depot St recorder, 29 January 2011 event, recorded and model flows

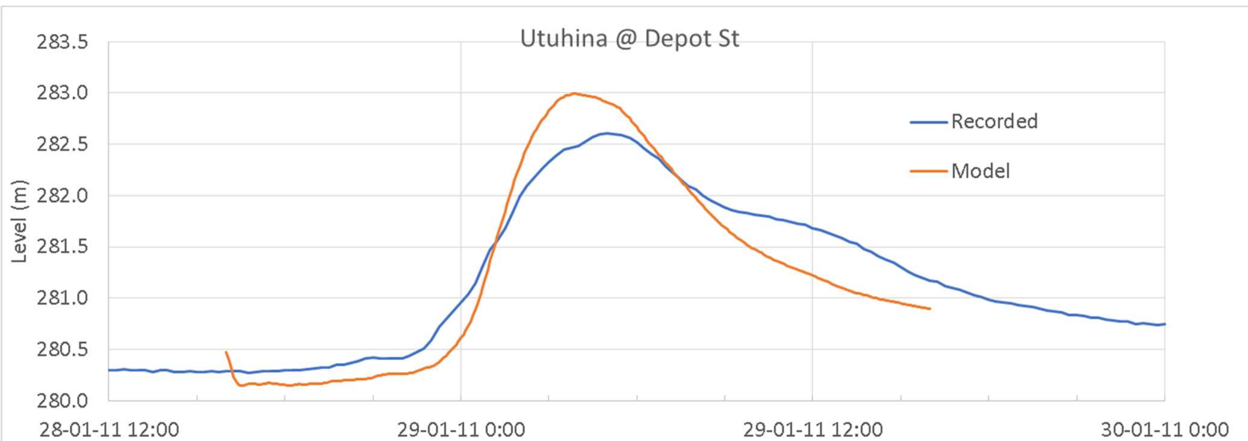


Figure 5-10 Utuhina @ Depot St recorder, 29 January 2011 event, recorded and model levels

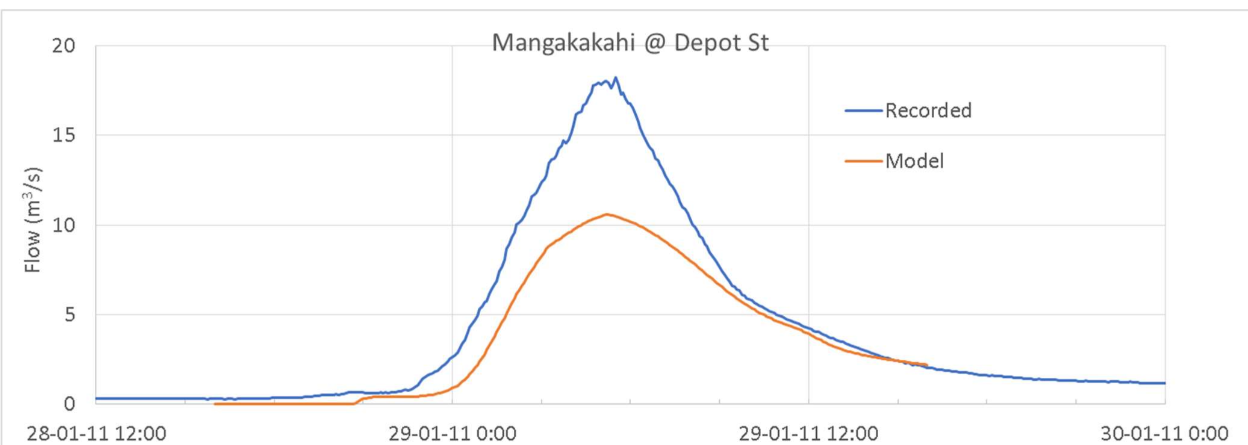


Figure 5-11 Mangakakahi @ Depot St recorder, 29 January 2011 event, recorded and model flows

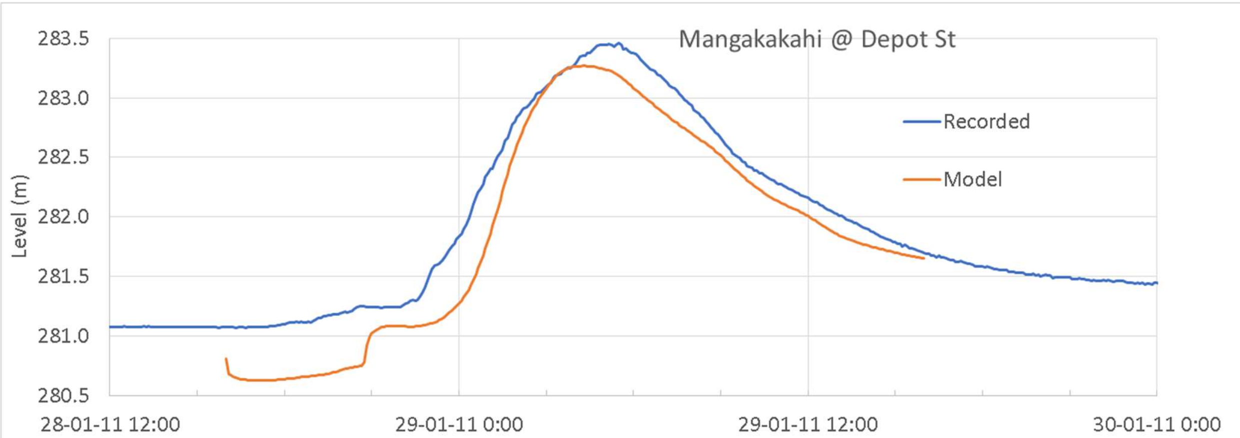


Figure 5-12 Mangakakahi @ Depot St recorder, 29 January 2011 event, recorded and model levels

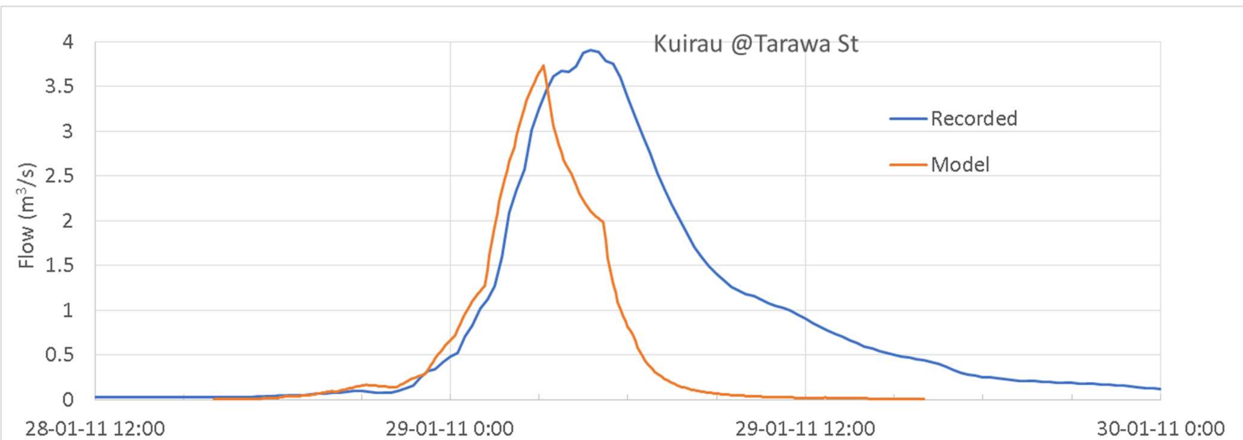


Figure 5-13 Kuirau @ Tarawa Rd recorder, 29 January 2011 event, recorded and model flows

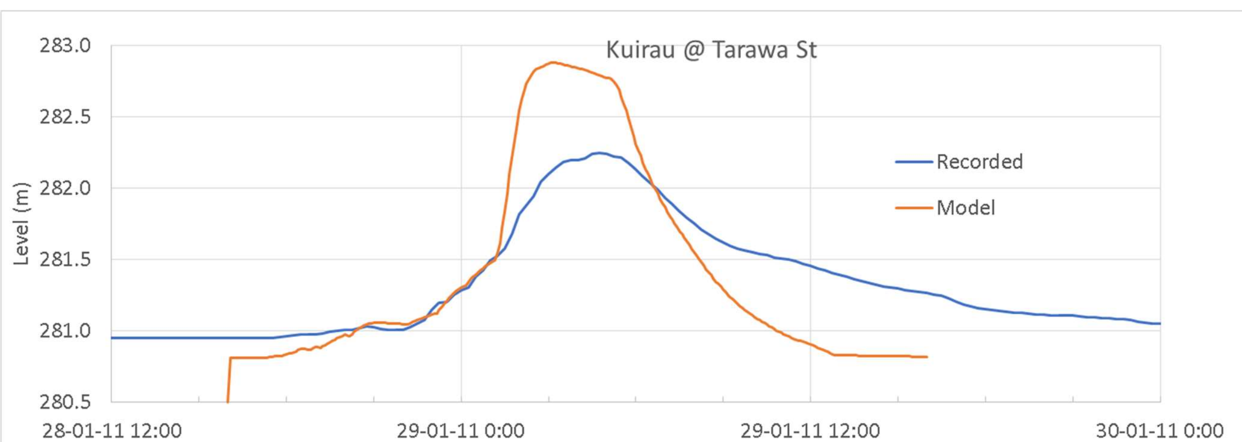


Figure 5-14 Kuirau @ Tarawa Rd recorder, 29 January 2011 event, recorded and model levels

Figure 5-15 compares model predictions of peak flood level in the Utuhina Stream with debris levels measured by BOPRC and RDC. From Devon St to around chainage 8300 m, the model predicts lower levels than were recorded by RLC. However, downstream of Old Taupo Road the model overpredicts measured levels by an average of 376 mm (Figure 5-15). As for the 23rd January event, the RDC levels downstream of Old Taupo Road appear low.

Note also that BOPRC classified its measurements according to the degree of confidence it had in the debris levels (measuring debris levels is subject to a degree of interpretation). Figure 5-15 shows the low confidence values separately to the other points (high or medium confidence). The low confidence points perhaps sit a little below the others, but the difference is not significant.

Given that Figure 5-9 shows the model significantly overpredicting flows for the Utuhina @ Depot St site, an alternative simulation has been carried out with the model stripped to the area below that recorder and run with recorded inflows. Only the 1-D component of the model has been used (that some floodplain areas are shown as flooded in the full model simulation is largely due to model overpredictions). The Utuhina @ Depot St inflows were taken from the rating as of 2013 (with a peak of 31.1 m^3/s, slightly higher for the current rating of 27.9 m^3/s shown in Figure 5-9). Inflows for the Kuirau @ Tarawa Rd site are also based on the 2013 rating, with a peak of 2.7 m^3/s; even though that rating had issues, the current rating likely overestimates flows (see Appendix C.1).

The alternative simulation gives a much better fit to the BOPRC recorded levels (Figure 5-16), with an average error of only 30 mm (underprediction) and thus gives confidence in the Manning's n values adopted for the lower reaches of the Utuhina Stream.

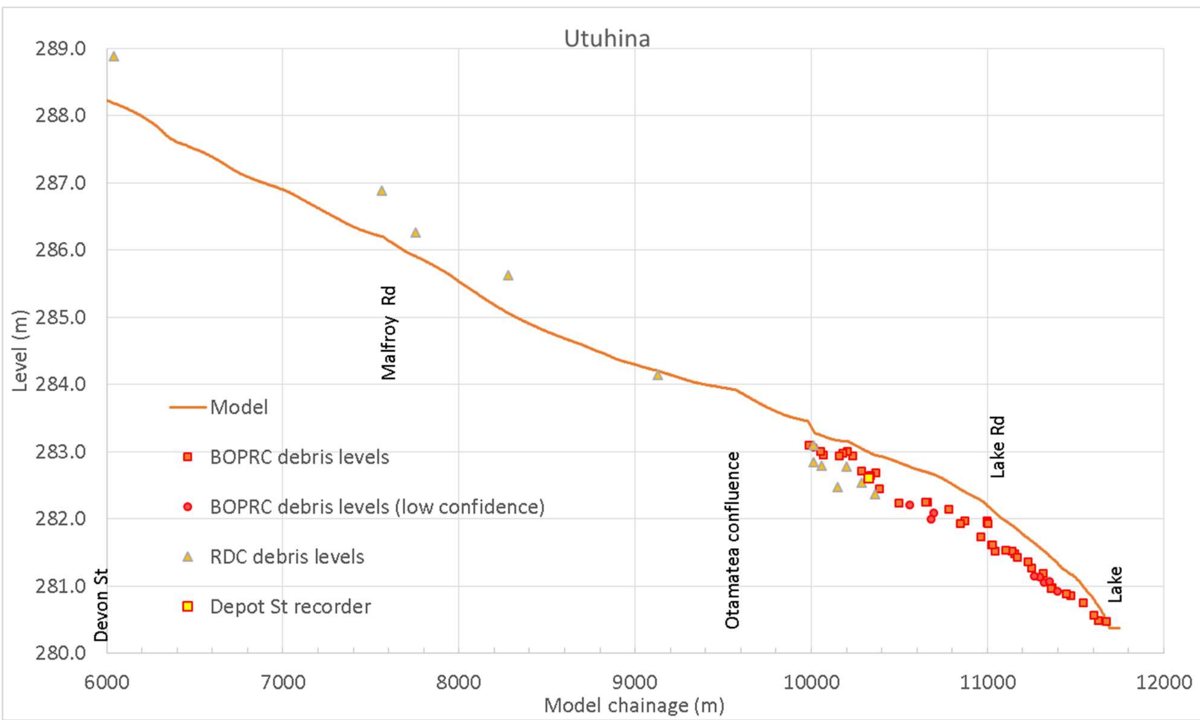


Figure 5-15 Peak flood levels, Utuhina Stream (Devon St to Lake), 29 January 2011 event

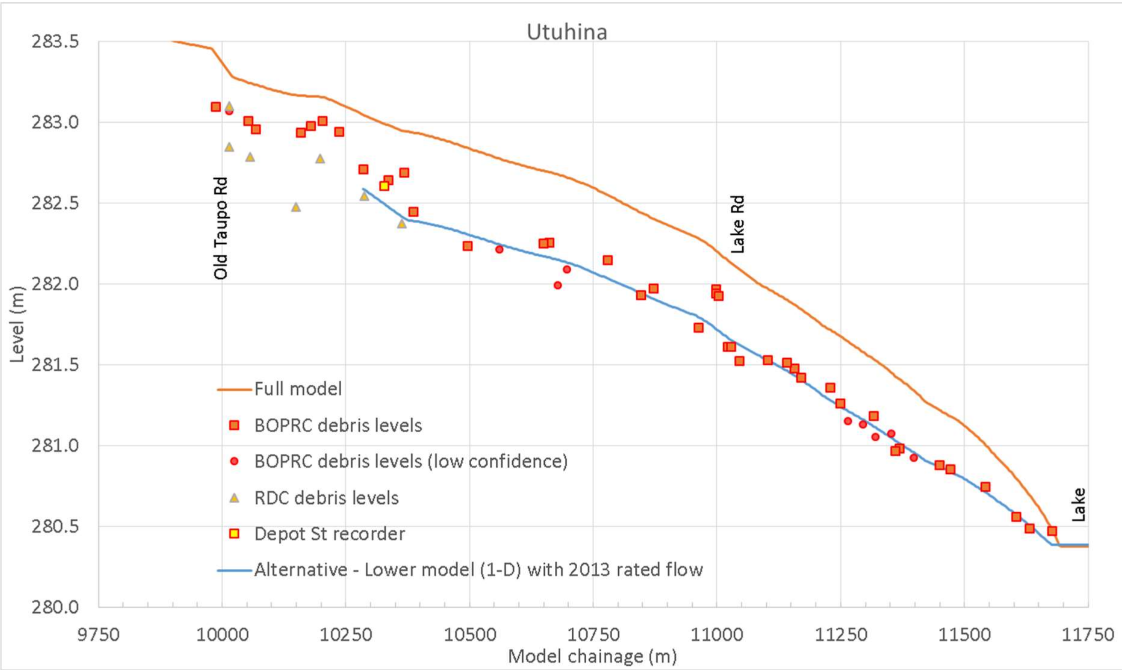


Figure 5-16 Peak flood levels, Utuhina Stream downstream of Old Taupo Road, 29 January 2011 event

5.3 20 August 2014

Calibration results at the recorder sites are given in Figure 5-17 to Figure 5-22.

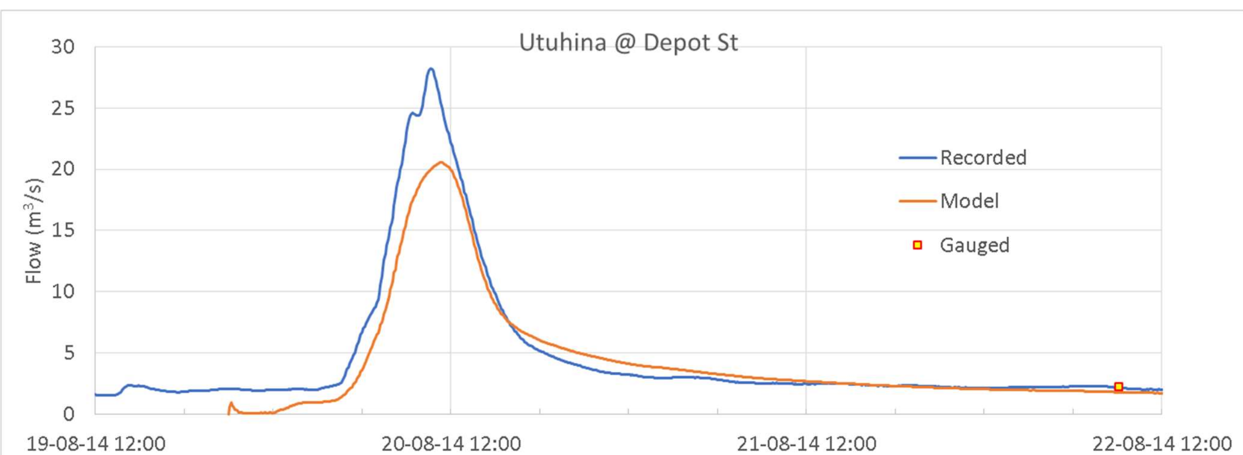


Figure 5-17 Utuhina @ Depot St recorder, 20 August 2014 event, recorded and model flows

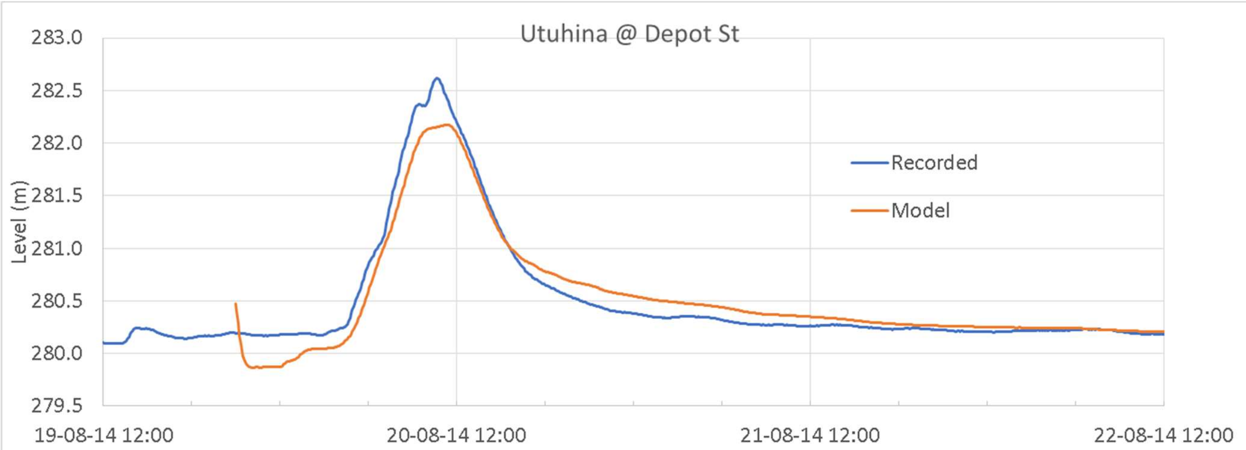


Figure 5-18 Utuhina @ Depot St recorder, 20 August 2014 event, recorded and model levels

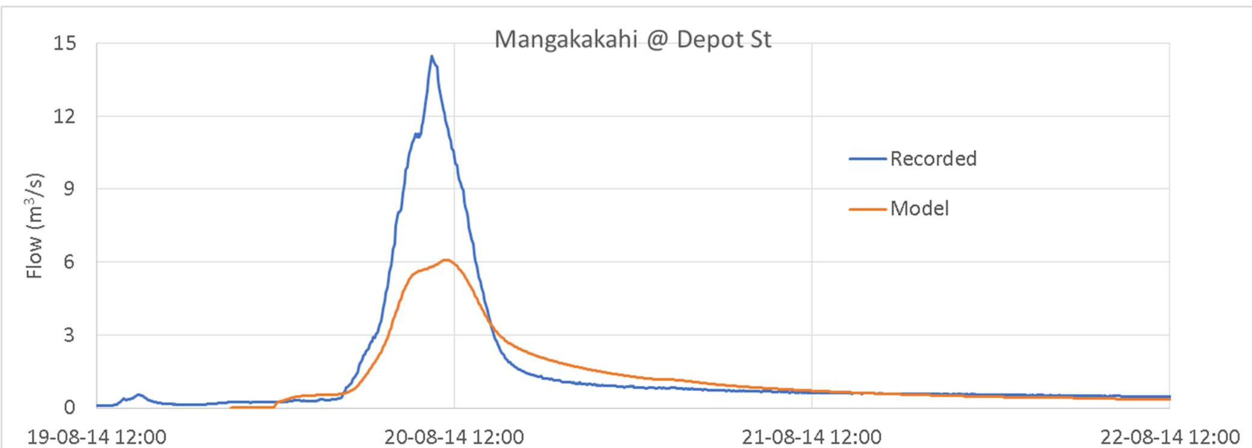


Figure 5-19 Mangakakahi @ Depot St recorder, 20 August 2014 event, recorded and model flows

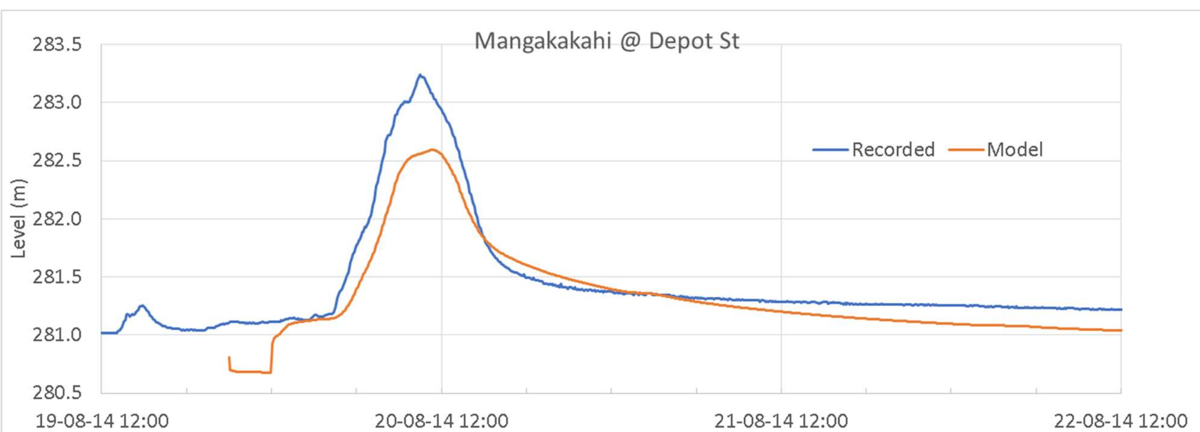


Figure 5-20 Mangakakahi @ Depot St recorder, 20 August 2014 event, recorded and model levels

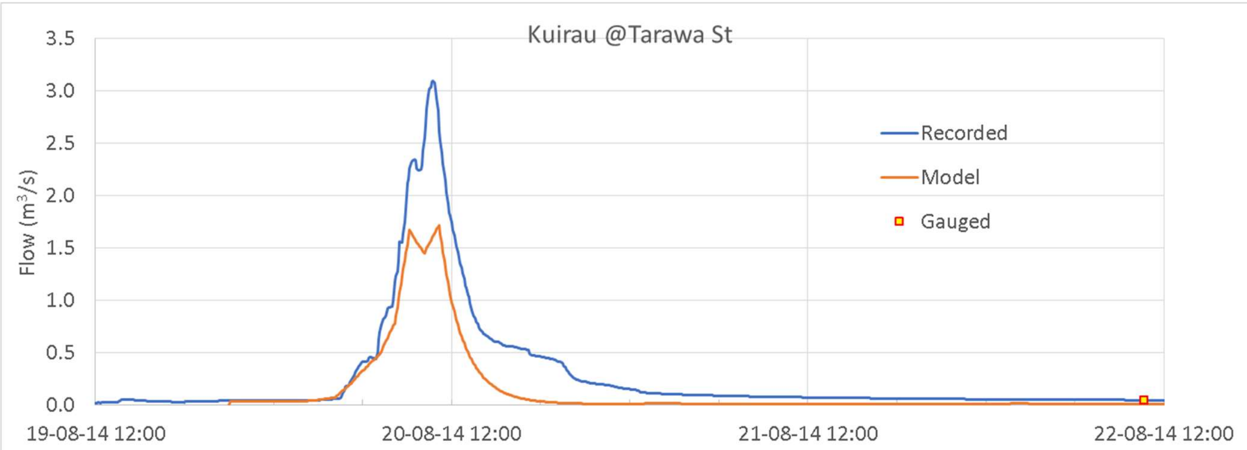


Figure 5-21 Kuirau @ Tarawa Rd recorder, 20 August 2014 event, recorded and model flows

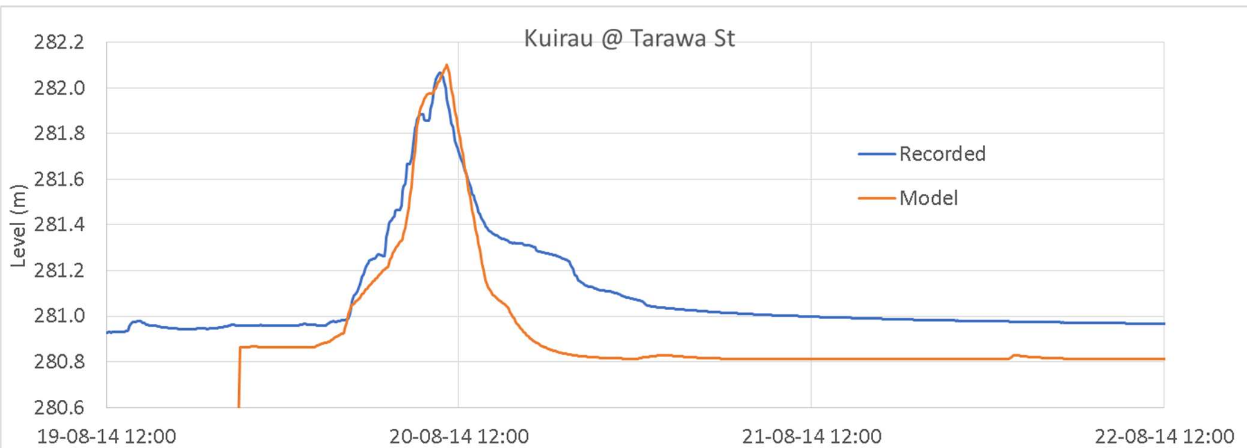


Figure 5-22 Kuirau @ Tarawa Rd recorder, 20 August 2014 event, recorded and model levels

Photographs of floodwaters from the Otamatea Stream during the event were provided in WSP-Opus (2018) and have been reproduced in Figure 5-23 (Sunset Road, upstream culvert[3]) and Figure 5-24 (Ford Road). Model predictions of flood depths at the same sites are shown in Figure 5-25 and Figure 5-26 respectively (red arrows show the direction of the photographs).

The predictions show a general agreement with the photographs but a more refined comparison indicates an underprediction. Comparing the water depths and extents in the photographs with the actual ground levels according to LiDAR data suggests that the flood is approximately 286 m RL level at the Sunset Road culvert and approximately 286.1-286.2 m RL at the Ford Road culvert. Model predictions are around 200mm lower at each location.

[3] The Otamatea Stream passes through two culverts under Sunset Road, at chainage 3300 m and chainage 3630 m. The former is shown in the flood photographs. Ford Road is further upstream, at chainage 2880 m.

Figure 5-23 Photographs of flooding at Sunset Road, Otamatea Stream (upstream culvert), August 2014

Figure 5-24 Photograph of flooding at Ford Road, Otamatea Stream, August 2014

Figure 5-25 Flood depths (model prediction), Sunset Road, Otamatea Stream (upstream culvert), August 2014

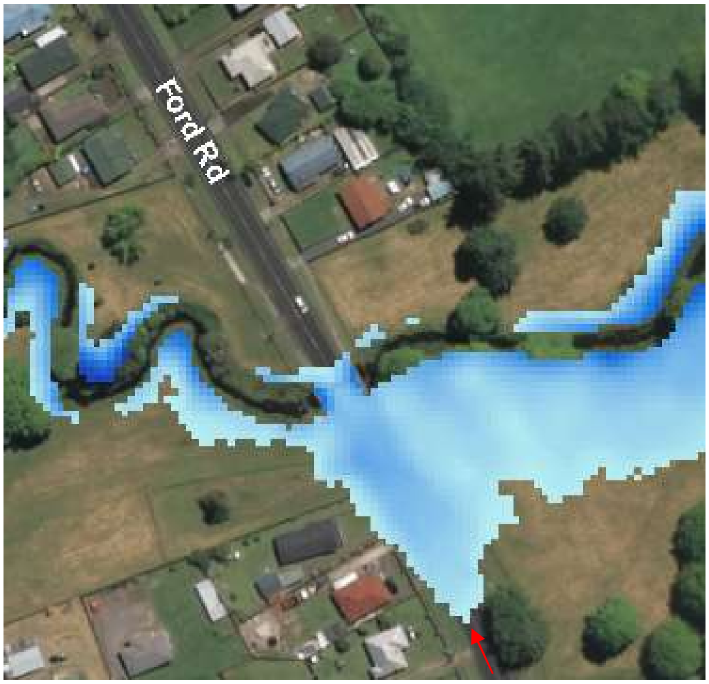


Figure 5-26 Flood depths (model prediction), Ford Road, Otamatea Stream August 2014

5.4 11-13 March 2017

Calibration results at the recorder sites are given in Figure 5-27 to Figure 5-32. Results for the revised NLR (ultimately used for the design scenarios as outlined in section 6.1.1) are shown by a grey dotted line in the figures.

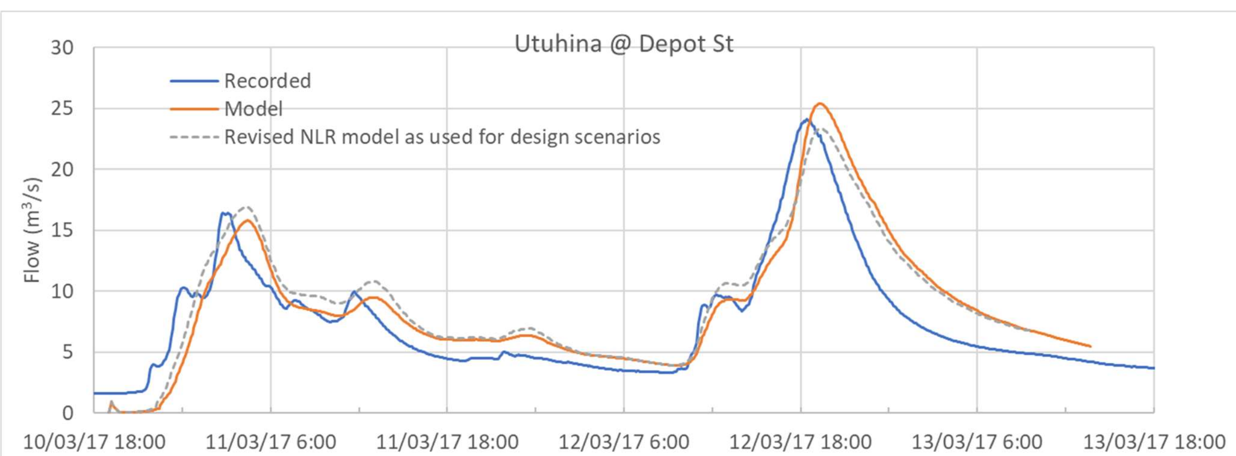


Figure 5-27 Utuhina @ Depot St recorder, 11-13 March 2017 event, recorded and model flows

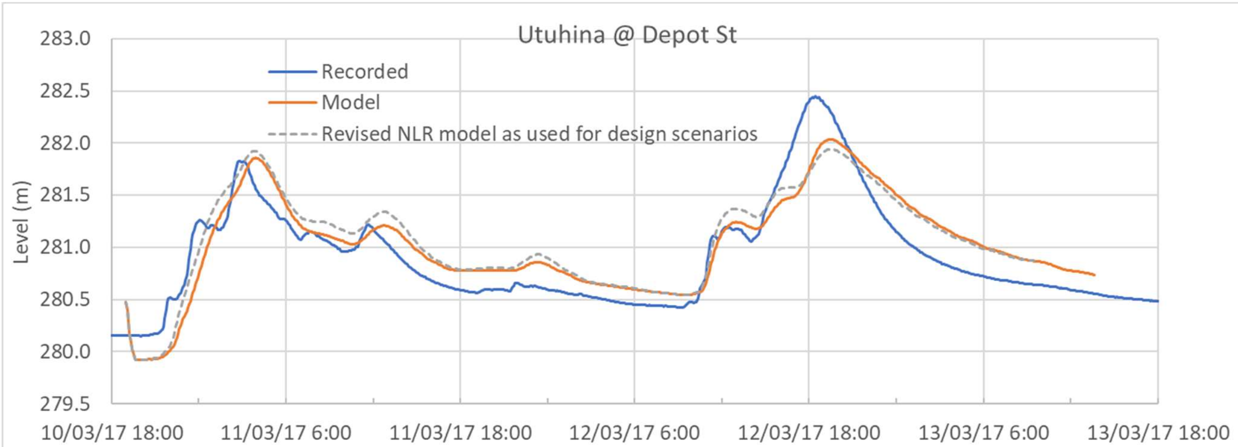


Figure 5-28 Utuhina @ Depot St recorder, 11-13 March 2017 event, recorded and model levels

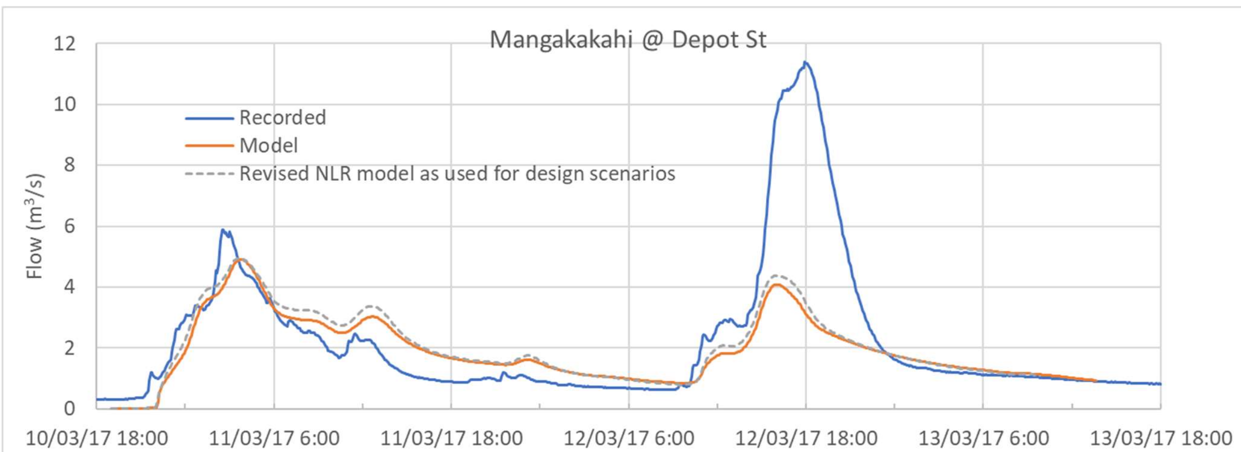


Figure 5-29 Mangakakahi @ Depot St recorder, 11-13 March 2017 event, recorded and model flows

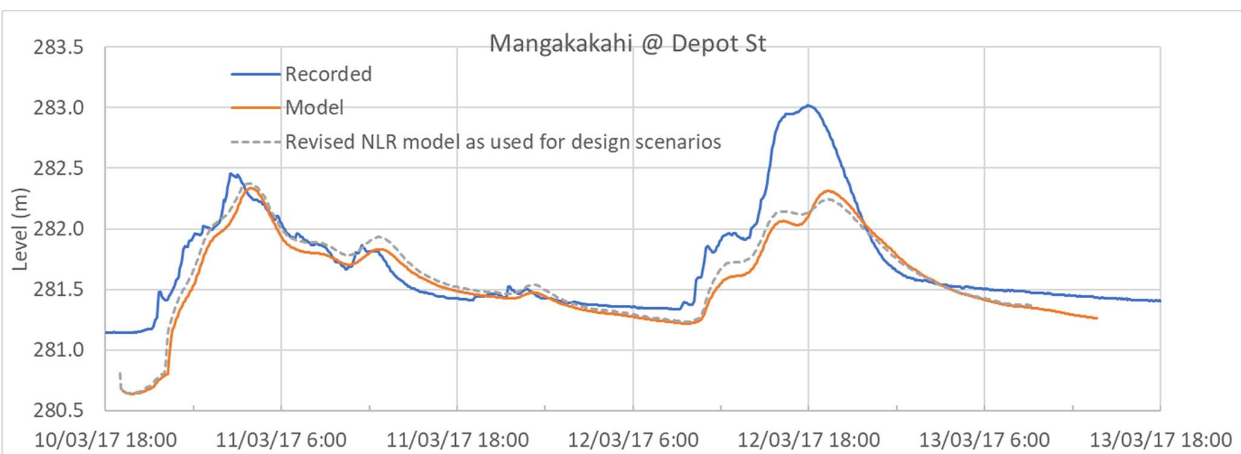


Figure 5-30 Mangakakahi @ Depot St recorder, 11-13 March 2017 event, recorded and model levels

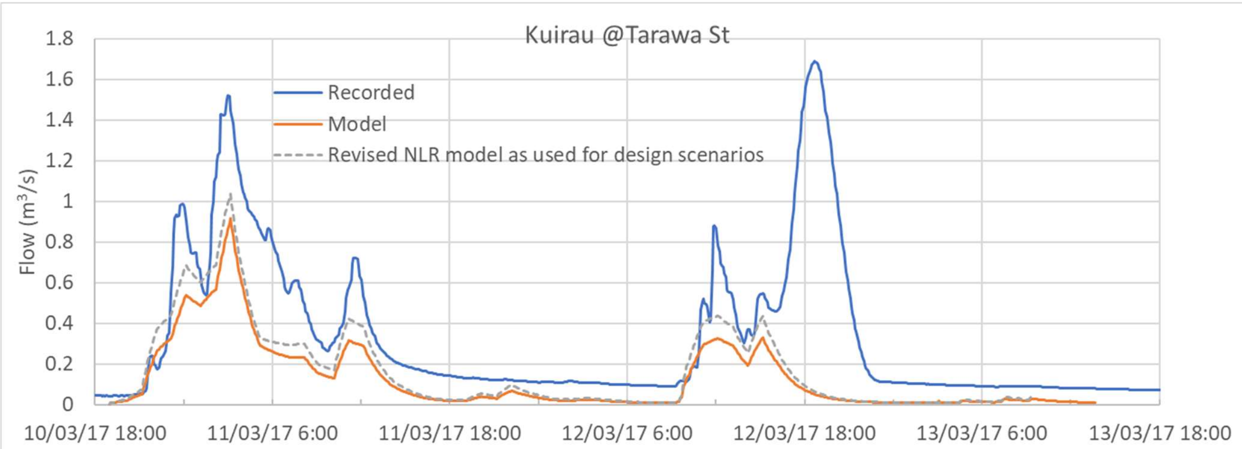


Figure 5-31 Kuirau @ Tarawa Rd recorder, 11-13 March 2017 event, recorded and model flows

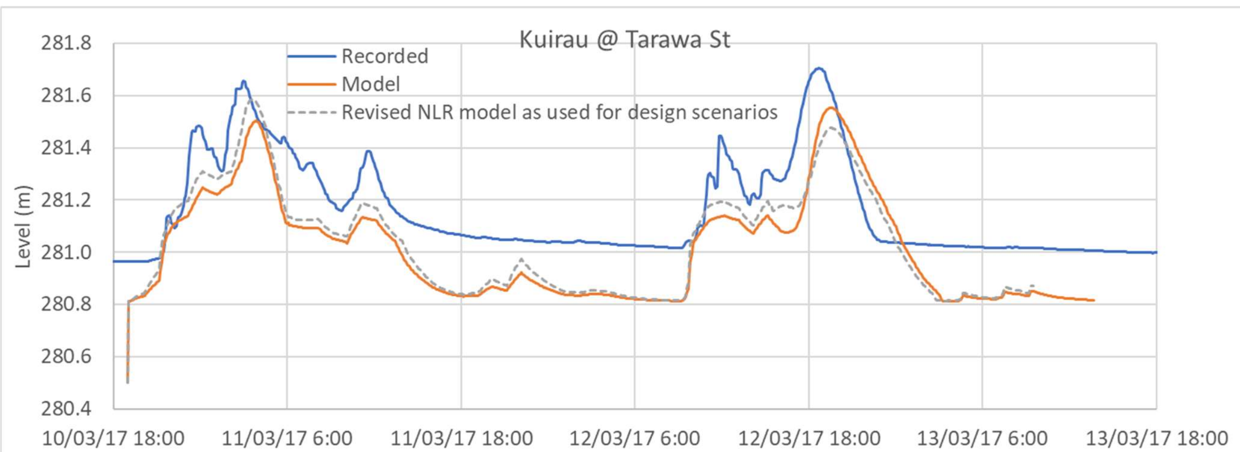


Figure 5-32 Kuirau @ Tarawa Rd recorder, 11-13 March 2017 event, recorded and model levels

Figure 5-33 and Figure 5-34 compare predicted peak levels with measured debris levels for the Utuhina and Otamatea Streams, respectively. A full listing of the debris points and model predictions is provided in Appendix E. The average difference between the predicted and measured levels for the Utuhina Stream is around -66 mm (i.e. net underprediction), while for the Otamatea it is 137 mm (net overprediction). (Note that there is some interpretation and judgement as to the correlation of each debris point with model centreline chainage, given the rather sinuous nature of the stream channel.)

Results for the revised NLR are again shown by a grey dotted line in the figures. The average difference between the measured debris levels and the predicted peak levels for the Utuhina Stream is 204 mm, while it is almost unchanged for the Otamatea Stream.

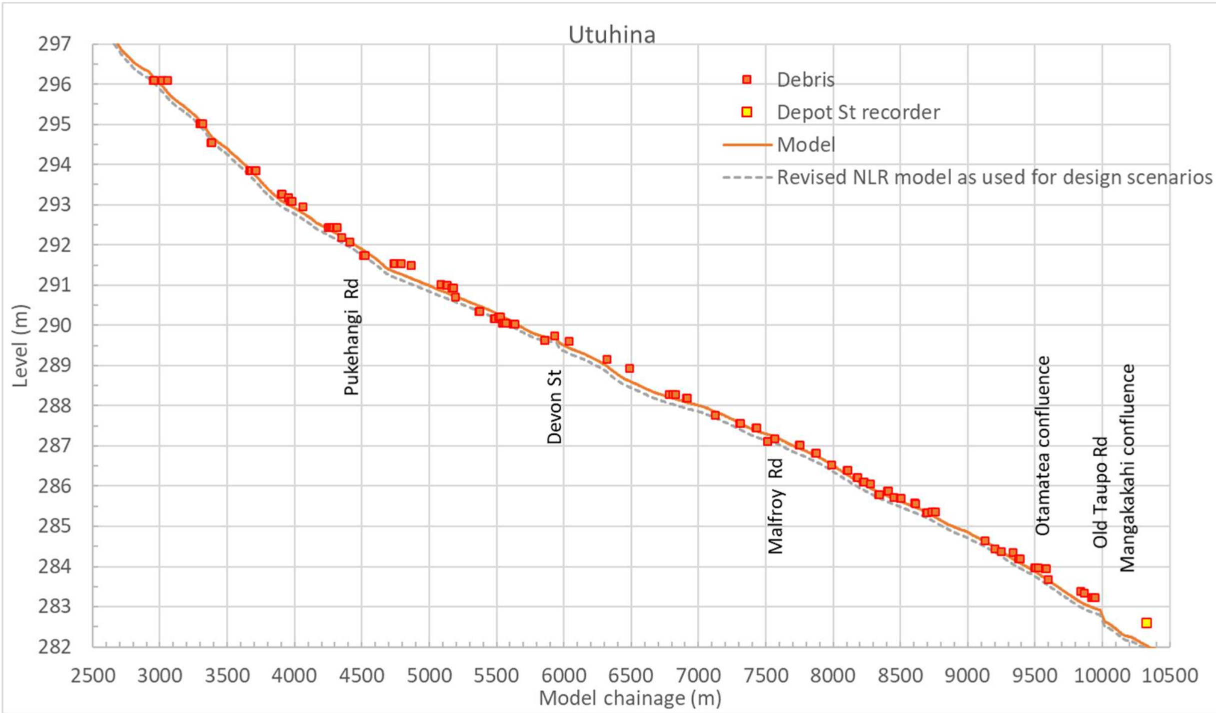


Figure 5-33 Peak flood levels, Utuhina Stream, 11-13 March 2017 event

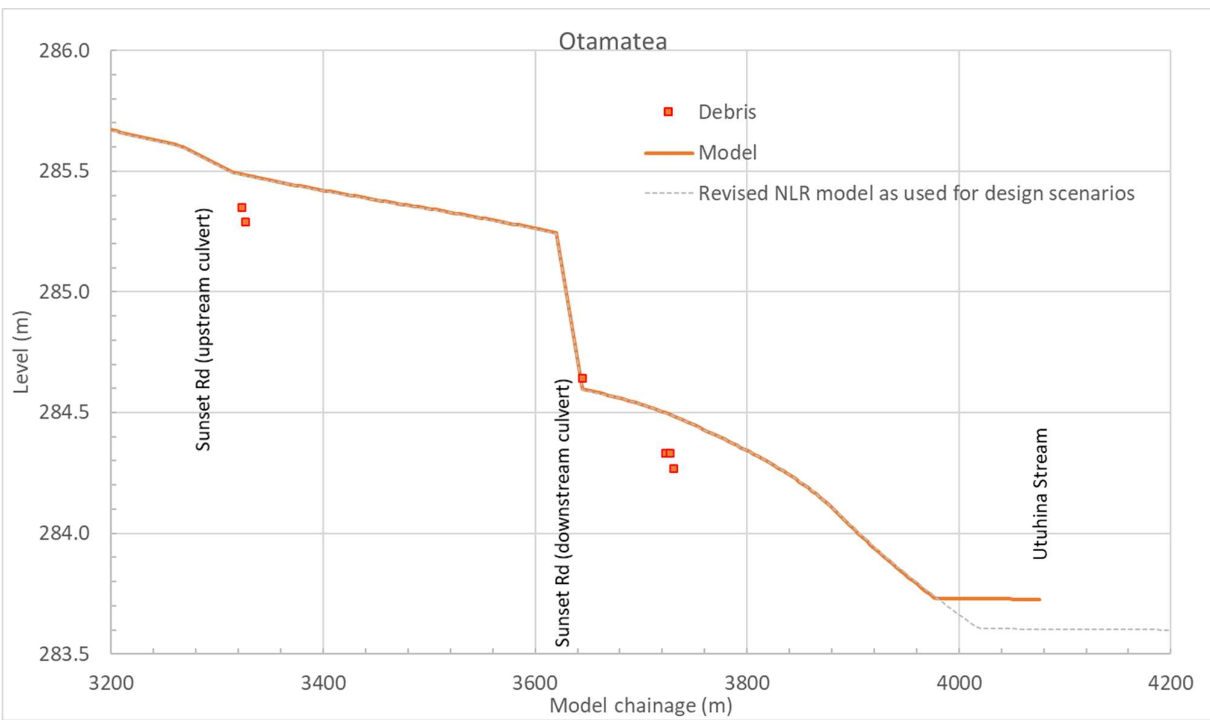


Figure 5-34 Peak flood levels, Otamatea Stream, 11-13 March 2017 event

5.5 29 April 2018

Calibration results at the recorder sites are given in Figure 5-35 to Figure 5-40.

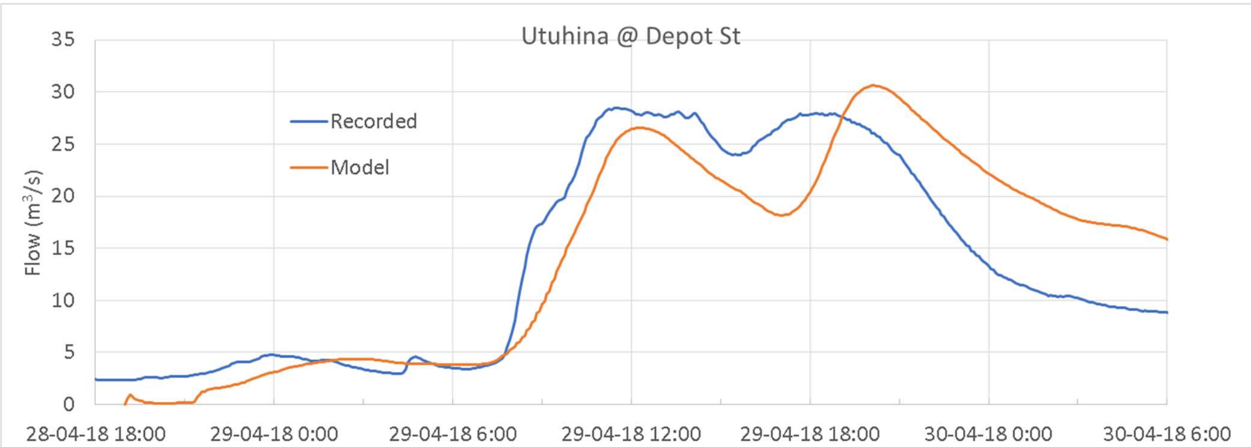


Figure 5-35 Utuhina @ Depot St recorder, 29 April 2018 event, recorded and model flows

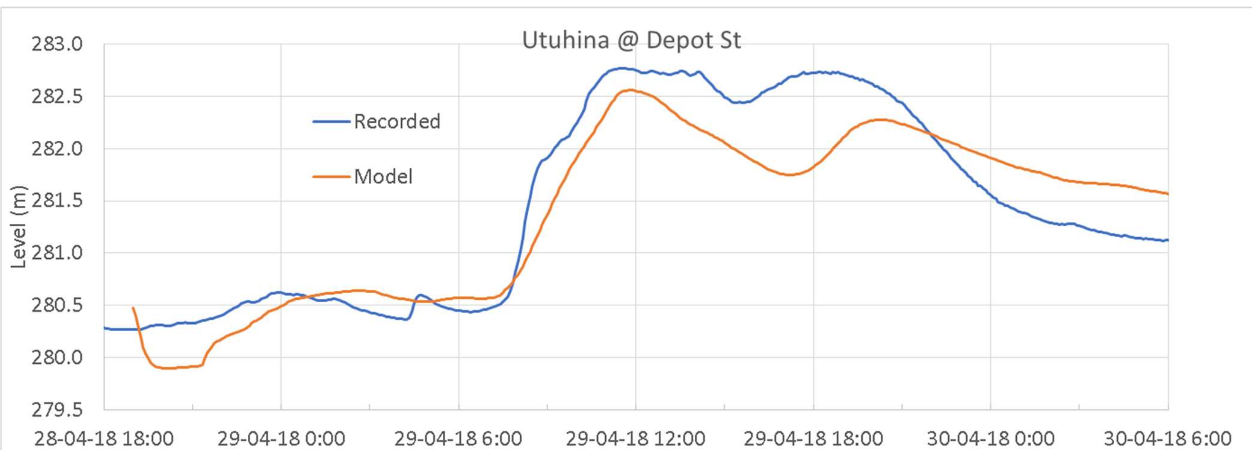


Figure 5-36 Utuhina @ Depot St recorder, 29 April 2018 event, recorded and model levels

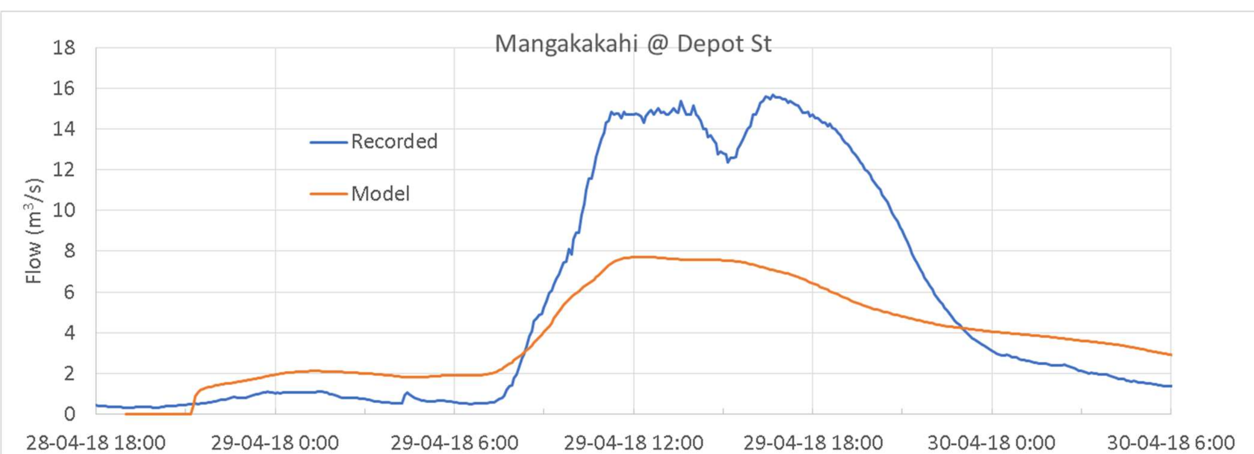


Figure 5-37 Mangakakahi @ Depot St recorder, 29 April 2018 event, recorded and model flows

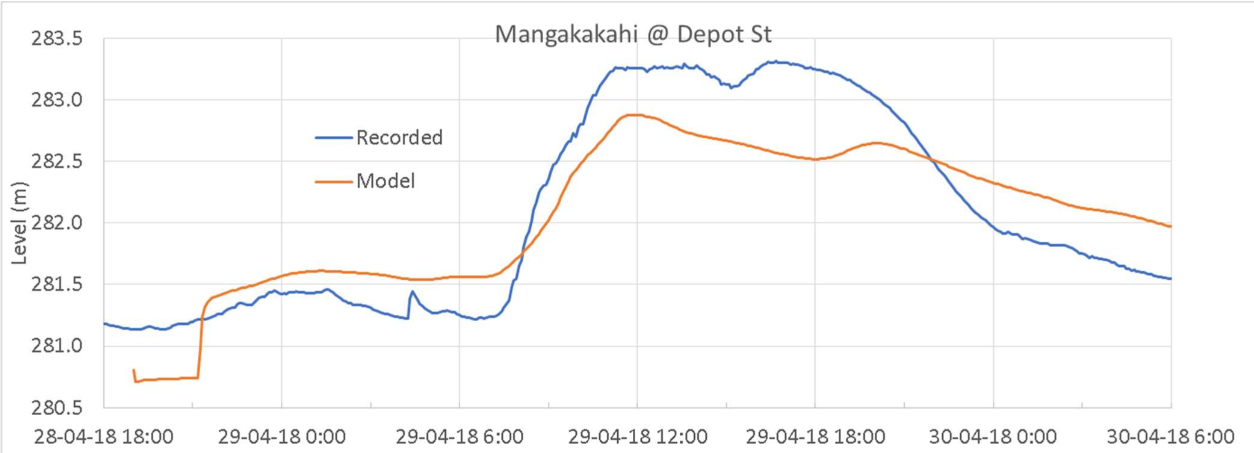


Figure 5-38 Mangakakahi @ Depot St recorder, 29 April 2018 event, recorded and model levels

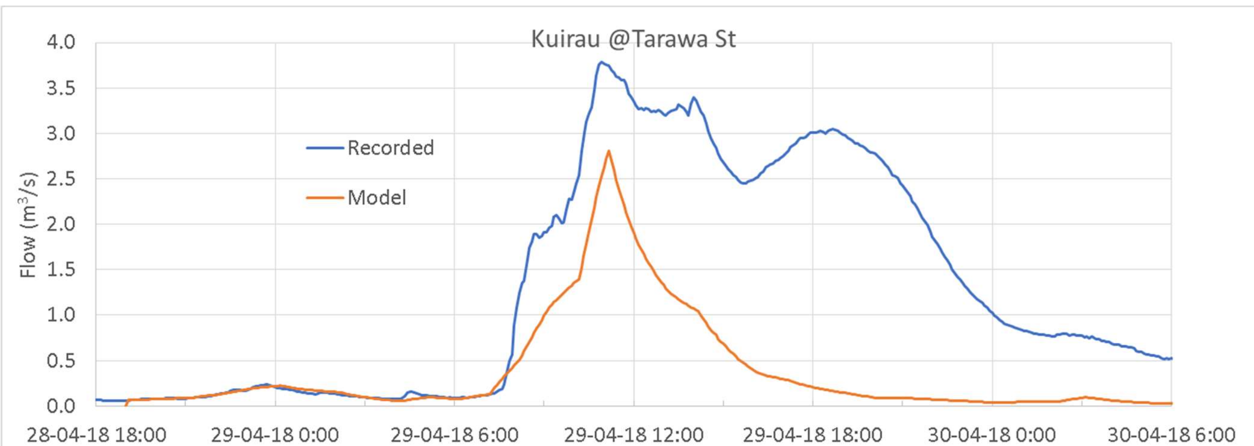


Figure 5-39 Kuirau @ Tarawa Rd recorder, 29 April 2018 event, recorded and model flows

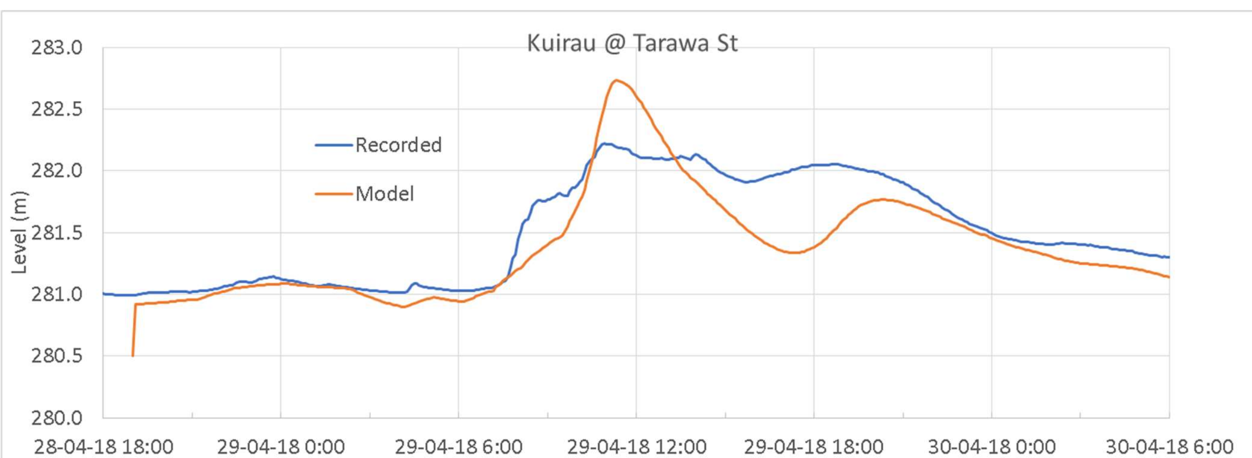


Figure 5-40 Kuirau @ Tarawa Rd recorder, 29 April 2018 event, recorded and model levels

RLC also recorded a number of flood levels on the floodplain, in areas where the stormwater network to the south of State Highway 30A was overwhelmed (Figure 5-41). However the model does not include the stormwater network and the model does not reproduce that flooding.

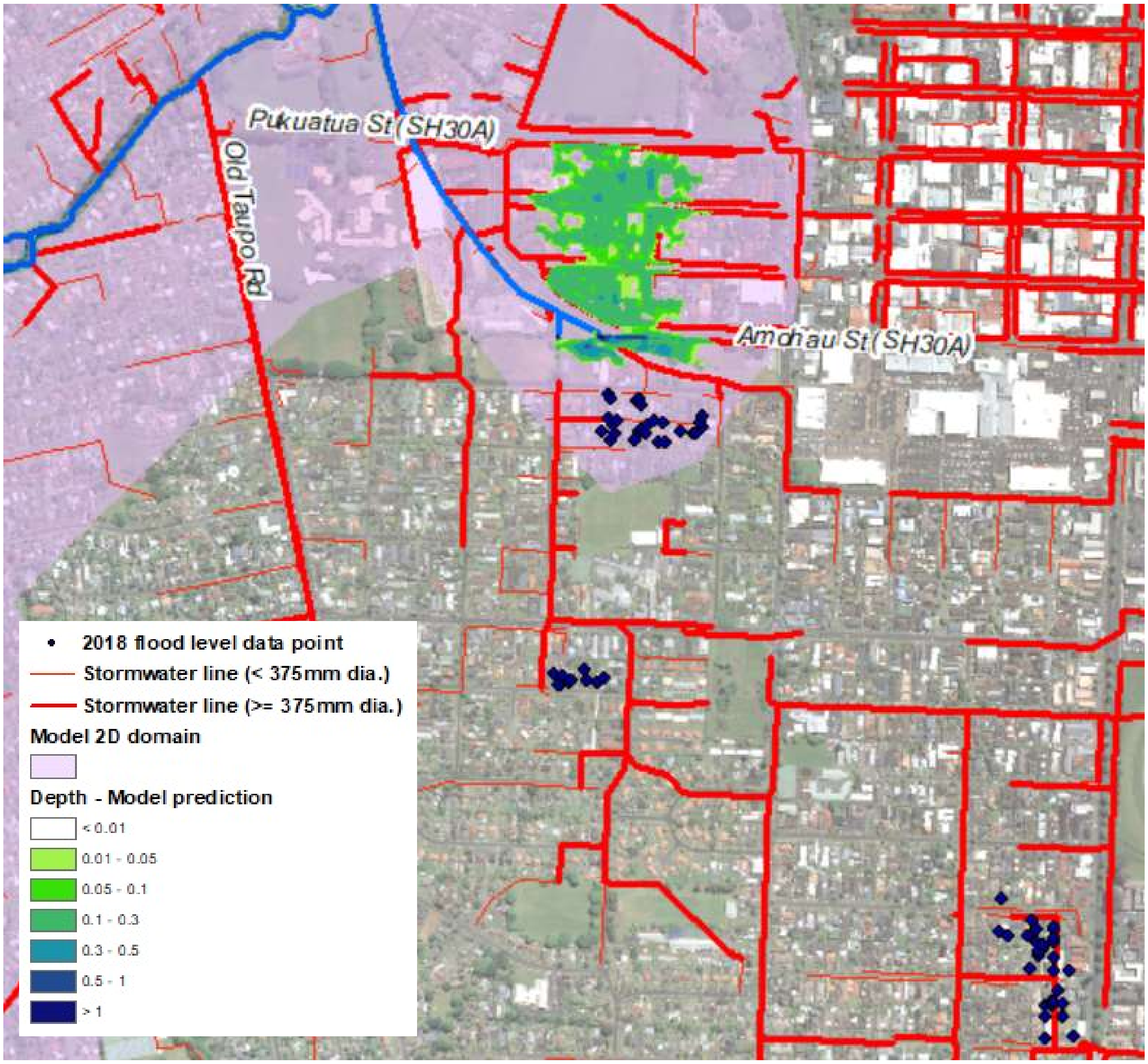


Figure 5-41 Recorded flood levels south of SH30A, April 2018 event

5.6 Discussion

Considerable effort has gone into the model calibration and a number of iterations of the hydrological model and hydraulic model were tested. By adjusting hydrological model parameters and Manning's n values, ultimately a satisfactory calibration has been achieved, even if there are variations in how well the model reproduces individual calibration events.

In the case of the January 2011 events, the rain radar data of the time had a coarse resolution with some gaps in the data (temporal and spatial). Thus, it is not surprising that the model did not predict results particularly well for the 29 January event, although results for the 23 January event appear reasonable. However, by stripping the model down to channels downstream of the known flows at the Utuhina and Kuirau recorders (rating uncertainties notwithstanding), the model was able to give a good prediction of the 29 January event.

Results for the 2014 event show some underprediction in levels at the Utuhina and Mangakakahi recorder sites, but this may be due to the underprediction of flows at the Utuhina recorder. The final iteration of the hydrological model included adjustments to give more flow in the Otamatea and Utuhina Streams to address a greater underprediction in early results for this event, but any further adjustments would have compromised results for other events. The 200 mm underprediction at the two Otamatea locations for which photos were available is acceptable in this context.

The 2017 "event" actually consisted of two separate floods, but the hydrological model appears to have reproduced the shape of each (Figure 5-27). Debris levels for the event provided the basis for setting Manning's n values for the Utuhina Stream. Eventually, in tandem with hydrological model adjustments, a good fit to the debris levels was obtained. Results gave a good match to the peak levels at the Utuhina @ Depot St site for the first flood but were underestimated for the second.

The revised hydrological model used for the design simulations gave peak Utuhina Stream levels slightly lower (on average, 204 mm lower) than the debris levels. After discussion with BOPRC, it was agreed that for reasons of expediency, the calibration would not be further refined. Instead, it was agreed that the 500 mm freeboard for design levels (BOPRC, 2018) be increased by 200 mm.

For the 2018 event, which had a twin peak to the flood, the model provided a reasonable fit to the Utuhina @ Depot St recordings, although there is a discrepancy in the relative size of each of the peaks; the model results show a larger flow but lower level for the second peak.

This last point highlights the inconsistent patterns of the model Q-H curves at the recorder sites. Figure 5-42 and Figure 5-43 show the Q-H curves from model results for the Utuhina and Mangakakahi recorder sites, respectively, and compare them to the adopted rating curves at the site (derived from level and flow data provided). Clearly there is a large range in flood level for any given flow.

For the Utuhina recorder site, the backwater effect of the two side drains entering the channel just downstream will have a significant effect on levels at the site (Figure 5-44). In the 2018 event, for example, the model predicts a total of around 14 m^3/s coming from those two drains for the first peak (compared to around 26 m^3/s predicted in the main Utuhina channel), whereas almost no flow is predicted from them in the second peak (Figure 5-45).

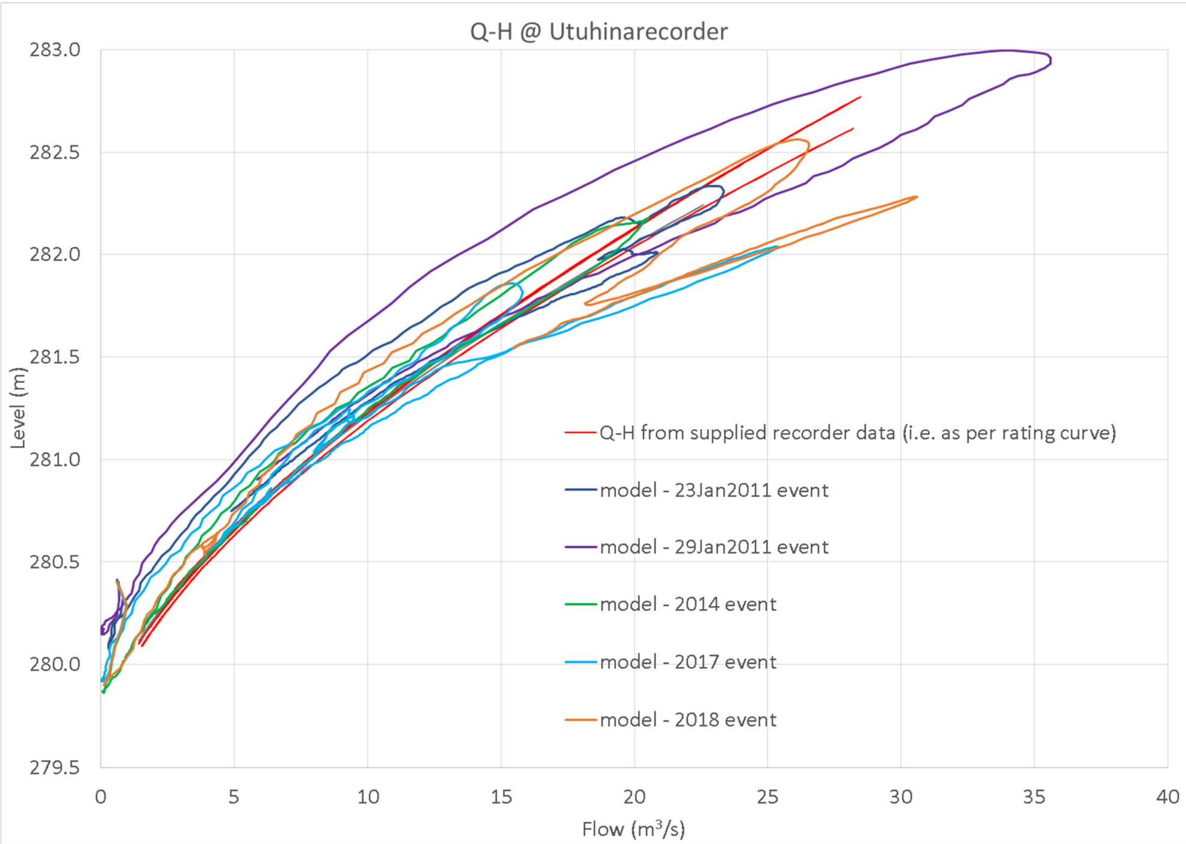


Figure 5-42 Q-H curve for Utuhina @ Depot St

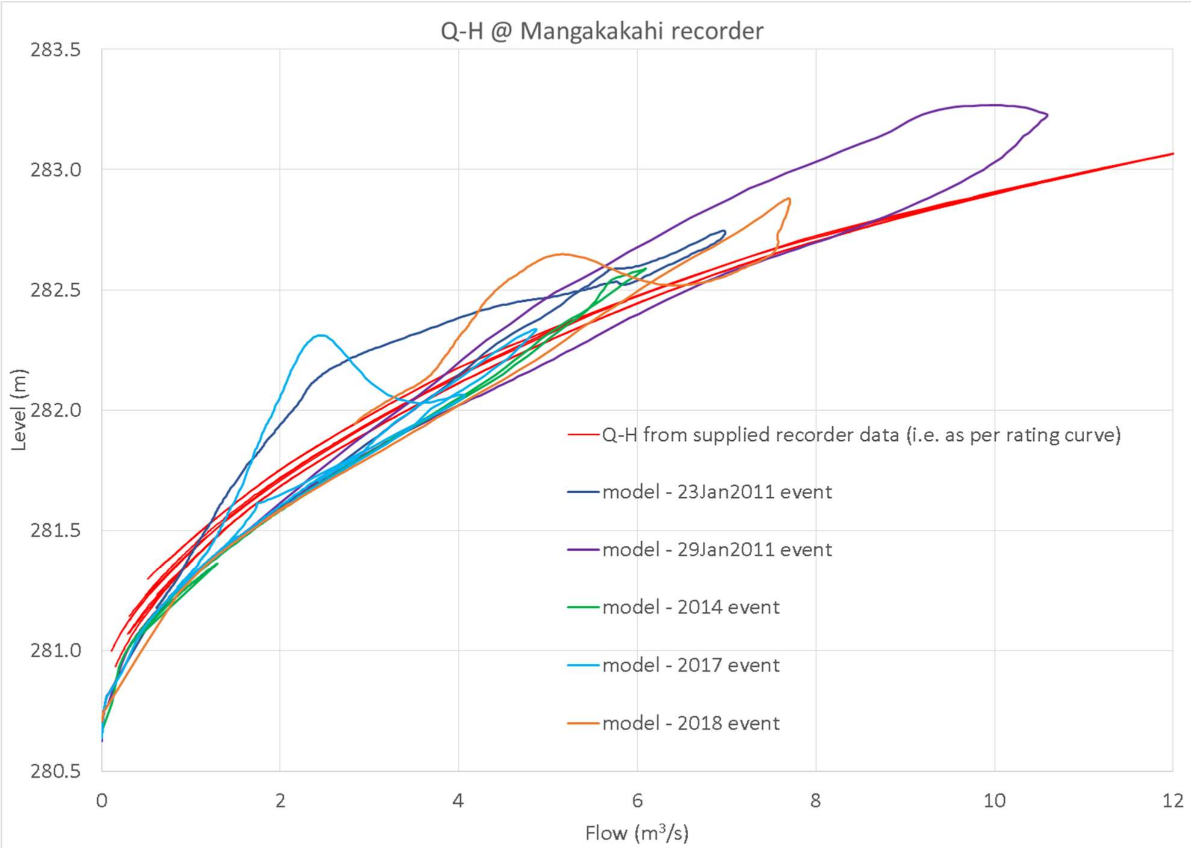


Figure 5-43 Q-H curve for Mangakakahi @ Depot St

Figure 5-44 Side drains entering Utuhina Stream downstream of recorder site

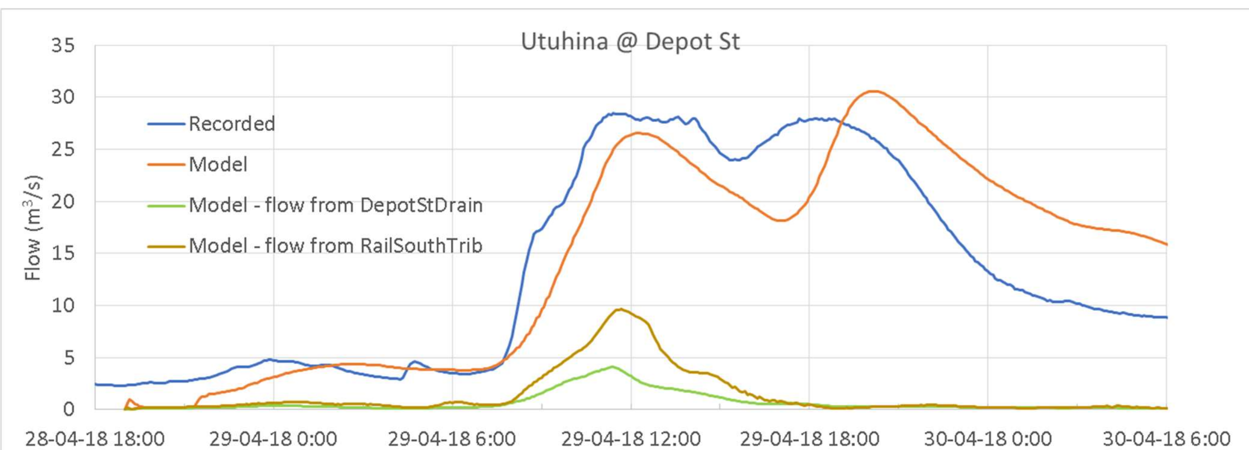


Figure 5-45 Flows at Utuhina @ Depot St recorder and model flows from side drains, April 2018 event

Likewise, water levels at the Mangakakahi recorder site will be strongly influenced by the backwater effect of the Utuhina Stream. Any underprediction of water levels at the Utuhina recorder site will likely manifest themselves in underpredictions at the Mangakakahi recorder site. The Mangakakahi recorder site is maintained by NIWA and it is unclear how well the site is rated or what gaugings have been carried out.

The Kuirau recorder site has only ever been gauged at low flow gaugings, and even that only with difficulty, so the rating has high uncertainty at flood flows. (Refer Appendix C.1). However, the contribution of the Kuirau Stream to Utuhina flows is minor.

6 Design scenarios

The following design storm scenarios have been modelled:

- 2% AEP (50-year return period)
- 1% AEP (100-year return period)
- 0.2% AEP (500-year return period)

For each, two storm centres have been modelled: one on the upper Utuhina catchment and one on the urban area. The former gives more flow in the Utuhina Stream than the latter, while the latter gives more flow in the Mangakakahi and Otamatea Streams than the former.

Each return period and storm centre scenario was modelled with current climate conditions and with 3.68°C of warming (RCP 8.5 to 2130).

In addition, a 1% AEP storm (current climate and centred on the urban area) was modelled with debris blockage on selected bridges. (Refer section 3.2.3)

Thus, a total of 13 design simulations have been performed.

6.1 Design model assumptions

6.1.1 Design hydrology

As has been indicated in sections 4.1, 5.4 and 5.6, the NLR model used for calibration was slightly modified for design simulations. During work for the Pukehangi Plan Change, design simulations for climate change scenarios gave what were considered excessive flows in the Utuhina Stream[4]. The NLR was subsequently modified to increase losses in the upper catchment (West, 2021).

According to flood frequency analysis of the Utuhina @ Depot St flow record, the accepted 1% AEP flow there is 55 m^3/s (Blackwood, 2020). The hydraulic model can reproduce that flow (Figure 6-1) by running outputs from the design NLR model with the following assumptions:

- 1% AEP storm, moving at a bearing of 070° and with a travel speed of 0.55 m/s, centred on the upper Utuhina catchment (at the time of maximum intensity)
- 1% AEP storm, moving at a bearing of 070° and with a travel speed of 0.55 m/s, centred on the urban catchment

The same direction and speed, and the same two storm centres, have then been used for the other AEP and climate change scenarios.

[4] Email from Philip Wallace to Peter West, 10 August 2020, and email reply from Peter West to Philip Wallace and Kathy Thiel-Lardon, 11 August 2020

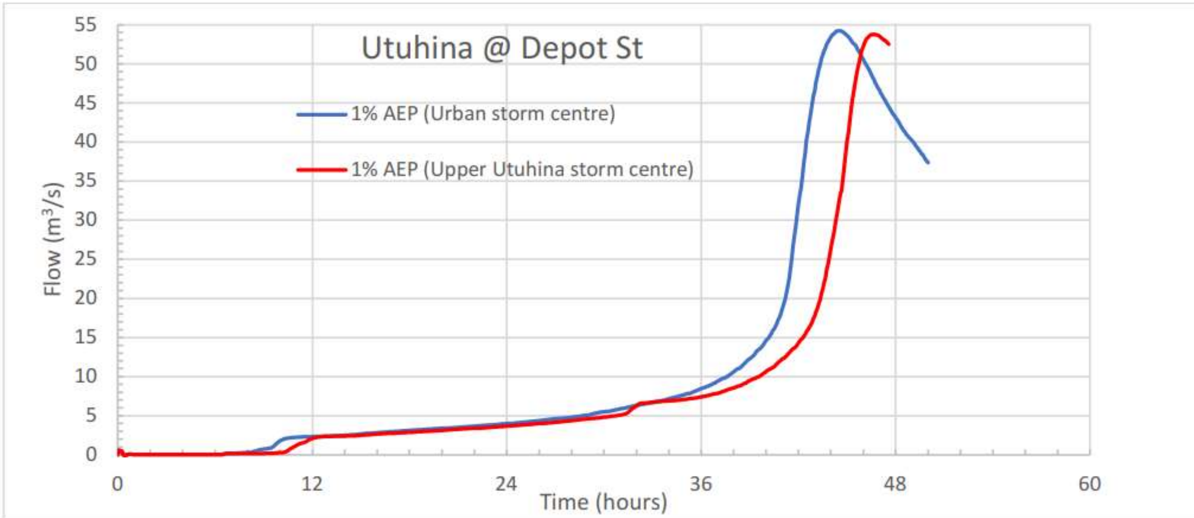


Figure 6-1 Predicted 1% AEP hydrographs for Depot Street recorder site in Utuhina Stream: urban and upper Utuhina storm centres

6.1.2 Lake levels

As lake levels respond only very slowly to rainfall events, constant lake levels are assumed for design scenarios. Furthermore, only minor changes in design lake levels are expected with climate change since the lake levels are controlled artificially by stoplogs at the outlet (to the Ohau Channel on the north-eastern side of the lake). Table 6-1 gives the assumed combinations of design storms and lake levels.

Table 6-1 Design storm and lake level combinations

Climate	Design storm	Lake level
Current climate	2% AEP	5% AEP = 280.28
Current climate	1% AEP	5% AEP = 280.28
Current climate	0.2% AEP	1% AEP = 280.34
2130 climate	2% AEP	5% AEP = 280.38
2130 climate	1% AEP	5% AEP = 280.38
2130 climate	0.2% AEP	1% AEP = 280.44

6.1.3 Bridge debris blockage

For all scenarios, the Old Taupo Road bridge has an assumed pier ratio of 0.355 (0.3 above the “no-debris” situation and a soffit 0.5 m lower than the nominal soffit, to allow for likely debris blockage on what is an inefficient waterway (see section 3.2.3).

For the specific additional debris blockage scenario, the soffits of the Old Taupo Road culvert in the Mangakakahi Stream and of the Lake Road bridge over the Utuhina Stream have been lowered by 0.5 m. The pier ratio of the Lake Road bridge is increased by 0.1 to 0.1335[5].

[5] A subsequent check of the final "no-debris" model files showed that the piers option was inadvertently unticked for Lake Road, but the effect is expected to be insignificant as the no-debris pier ratio is small at only 3%.

6.2 Results

6.2.1 Stream levels

Peak stream water levels are given in Figure 6-2 to Figure 6-9. Figure 6-9 also shows design water levels (with 700 mm freeboard), existing stopbank and floodwall levels and indicative top of bank levels for the lower Utuhina Stream. Levels are also tabulated in Appendix F.

Note that the effect of bridge debris in the 1% AEP scenario increases levels by around 150 mm immediately upstream of the affected bridges (Mangakakahi at Old Taupo Road and Utuhina at Lake Road), but slightly reduces levels downstream of Lake Road (Figure 6-6 and Figure 6-9).

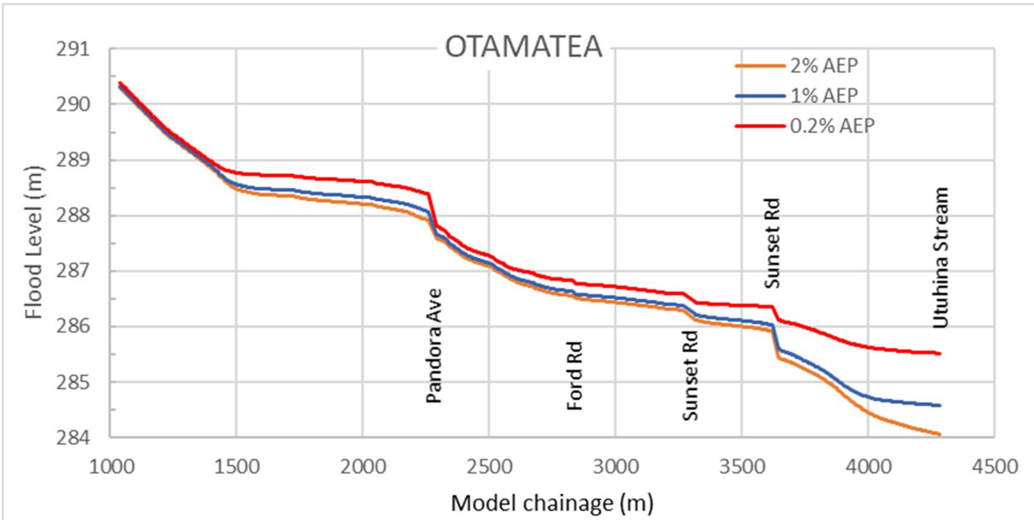


Figure 6-2 Peak flood levels (current climate design scenarios), Otamatea Stream

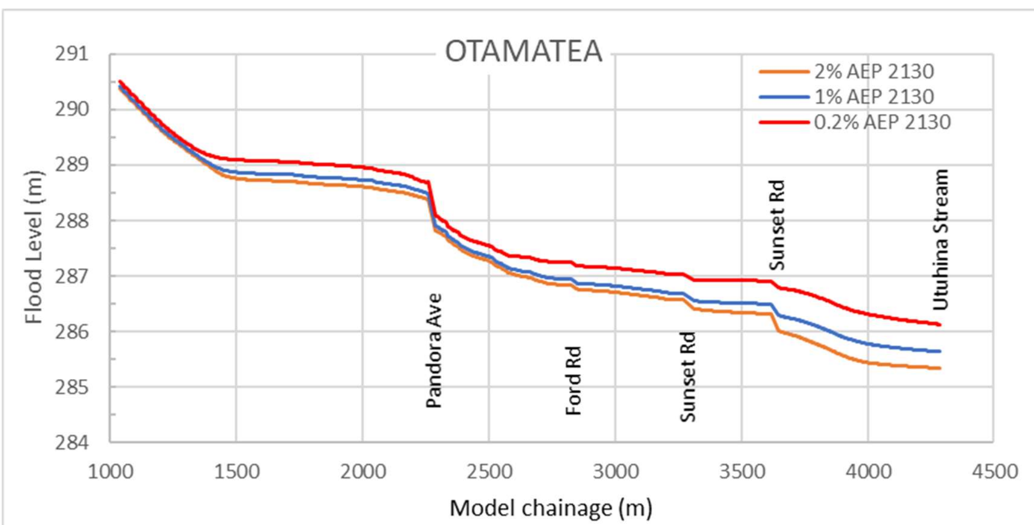


Figure 6-3 Peak flood levels (2130 climate design scenarios), Otamatea Stream

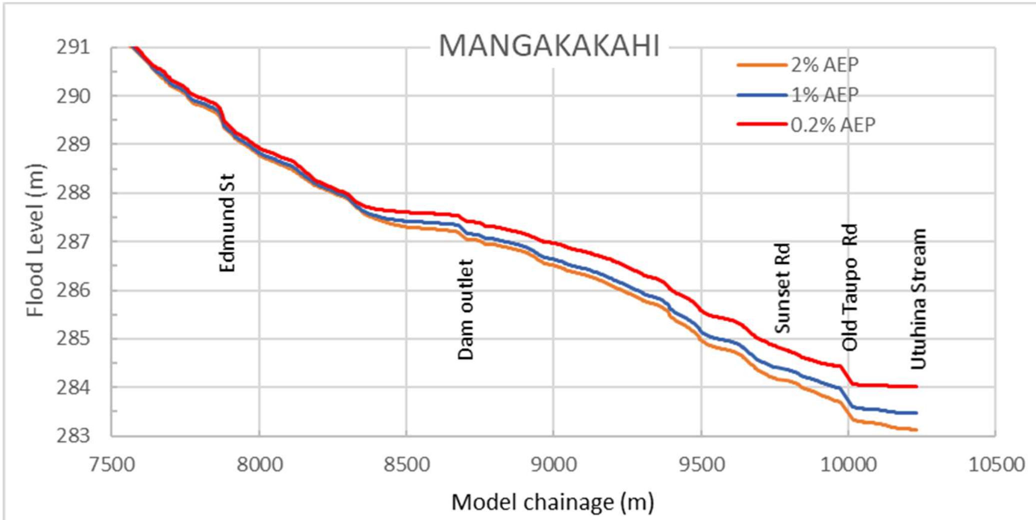


Figure 6-4 Peak flood levels (current climate design scenarios), Mangakakahi Stream

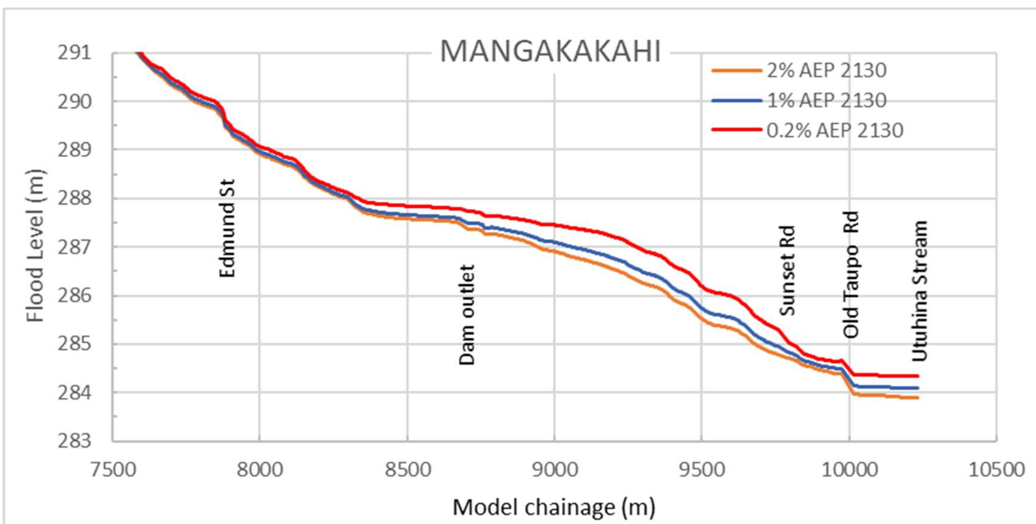


Figure 6-5 Peak flood levels (2130 climate design scenarios), Mangakakahi Stream

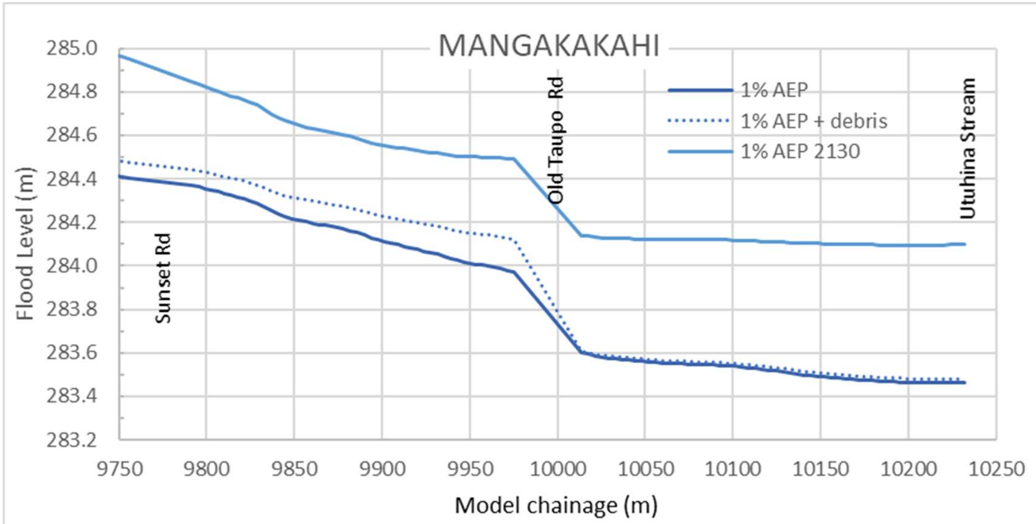


Figure 6-6 Peak flood levels (1% AEP design scenarios), lower Mangakakahi Stream

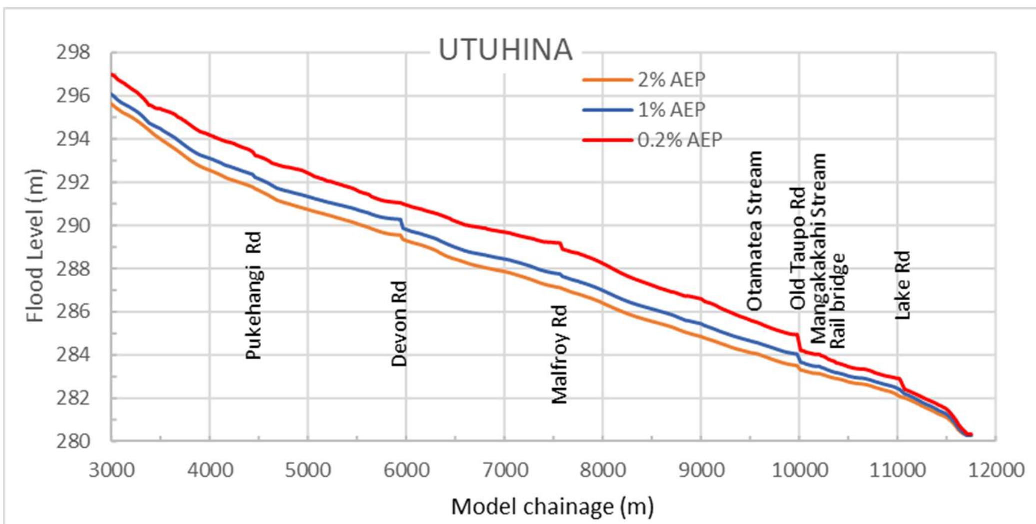


Figure 6-7 Peak flood levels (2130 climate design scenarios), Utuhina Stream

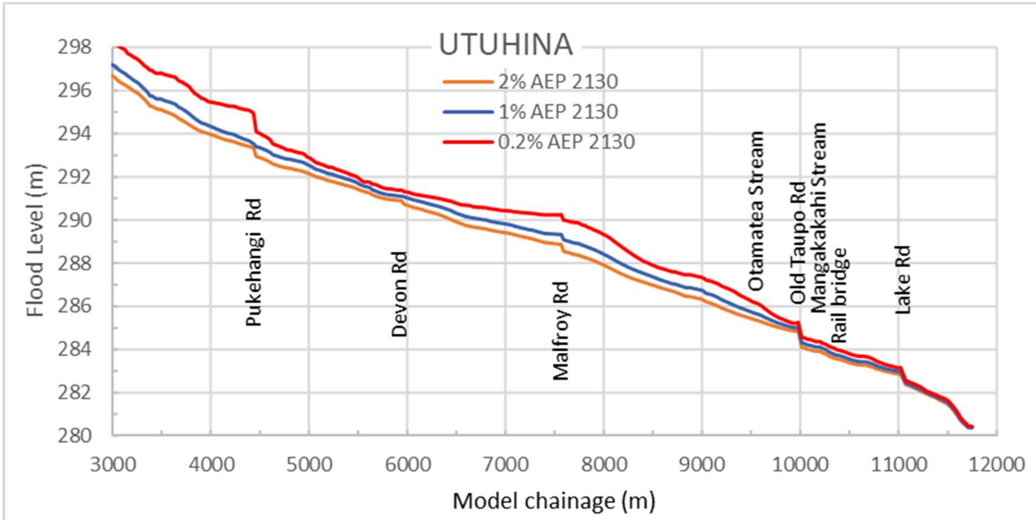


Figure 6-8 Peak flood levels (current climate design scenarios), Utuhina Stream

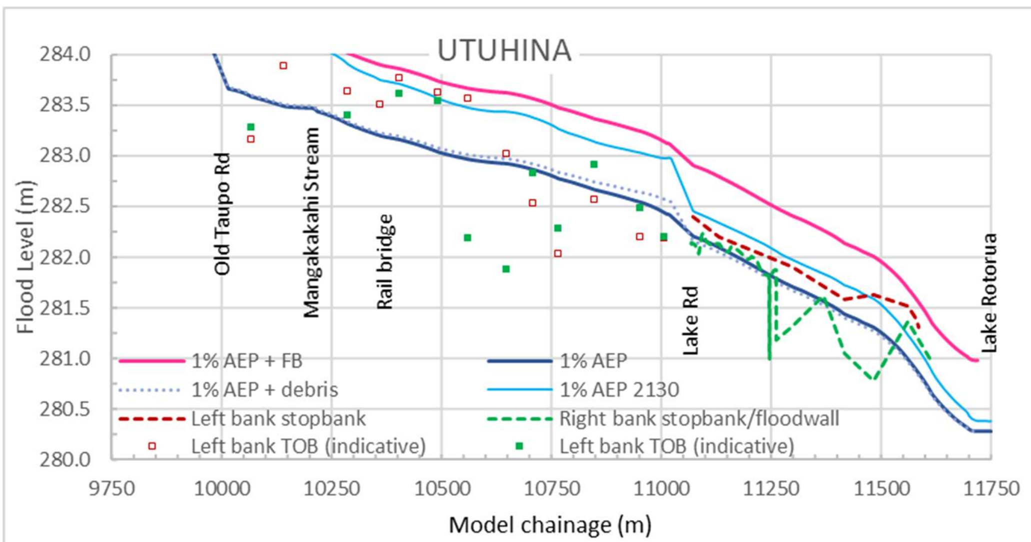


Figure 6-9 Peak flood levels (1% AEP design scenarios), lower Utuhina Stream

6.2.2 Stream flows

Flow hydrographs from selected scenarios and for selected sites are shown in Figure 6-10 to Figure 6-16.

Figure 6-10 and Figure 6-11 show flows at Depot St for the urban storm centre and the upper Utuhina storm centre respectively; the former peak earlier than the latter, while actual peaks for each of the two storm centres are generally similar.

Figure 6-12 and Figure 6-13 show in-stream flow hydrographs at Old Taupo Road. For the Utuhina Stream, the upper Utuhina storm centre generally gives slightly higher flows than the urban storm centre, so results for the former are given in Figure 6-12. In the case of the Mangakakahi Stream the urban storm centre flows gives slightly higher flows and so results from that are shown in Figure 6-13.

Figure 6-13 also shows a twin peak for the larger storm scenarios, which can be explained by the effect of the detention dam 1.3 km upstream (Figure 6-14).

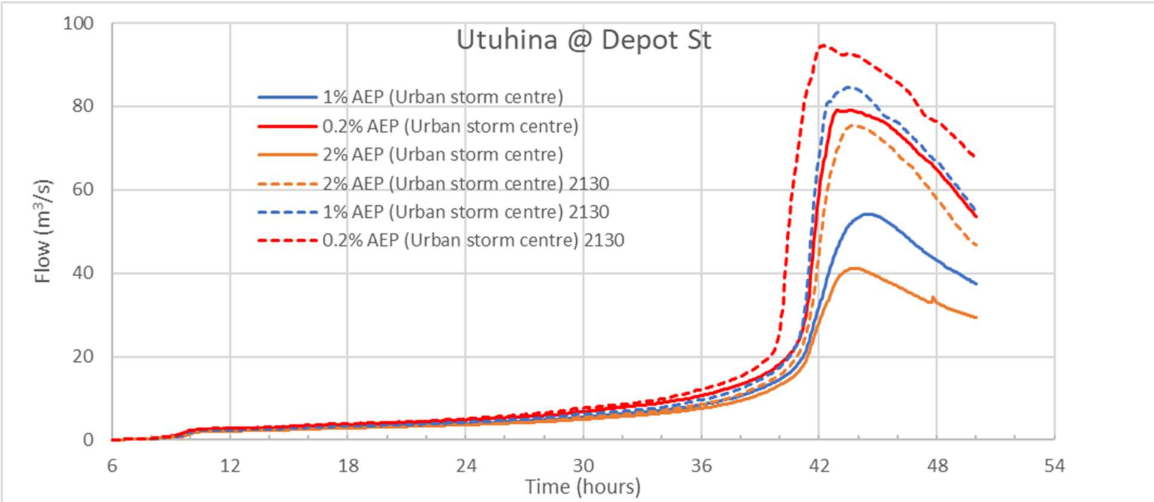


Figure 6-10 Flow hydrographs for Utuhina Stream at Depot St recorder site (urban storm centre)

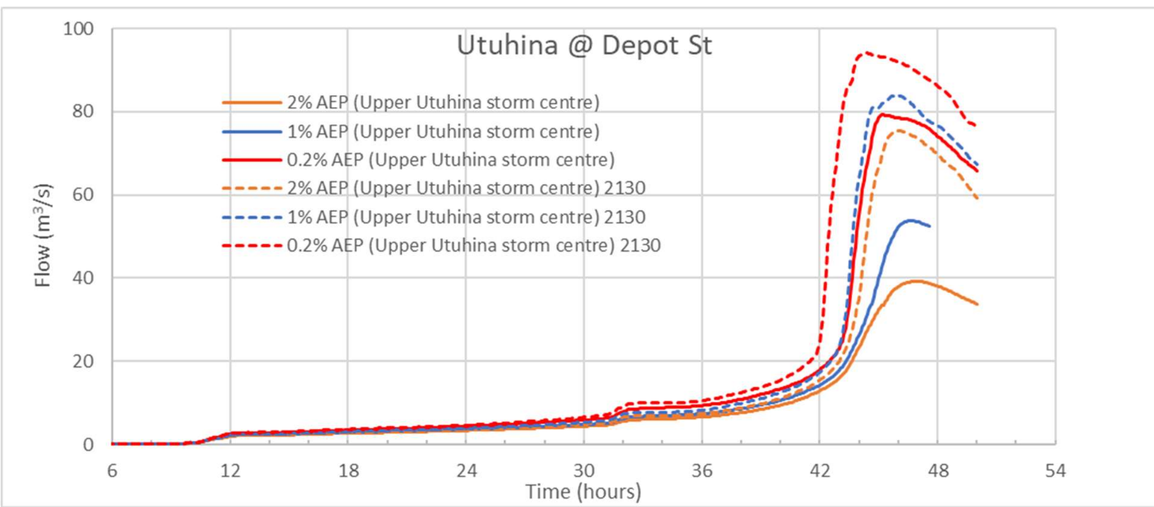


Figure 6-11 Flow hydrographs for Utuhina Stream at Depot St recorder site (upper Utuhina storm centre)

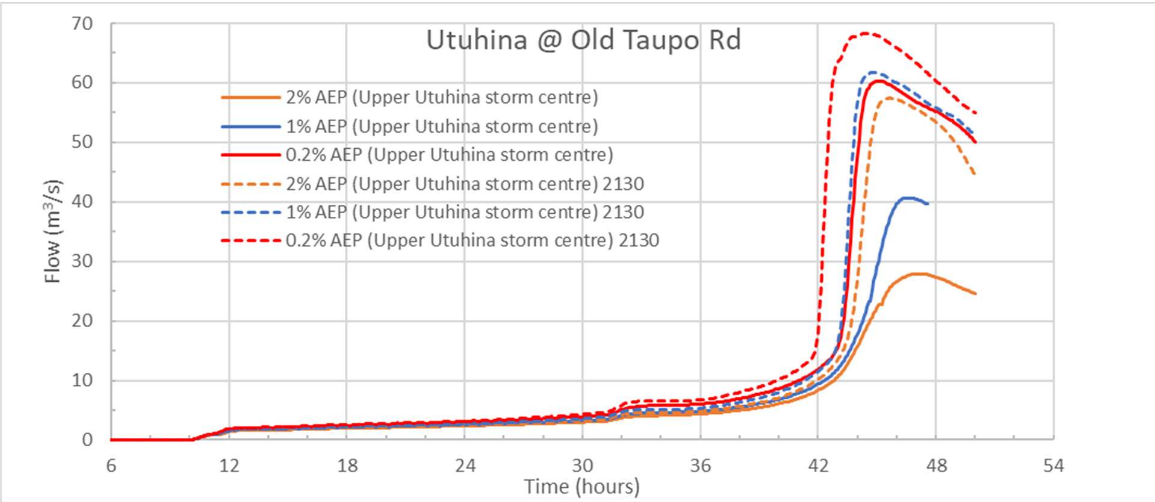


Figure 6-12 Flow hydrographs for Utuhina Stream at Old Taupo Rd (upper Utuhina storm centre)

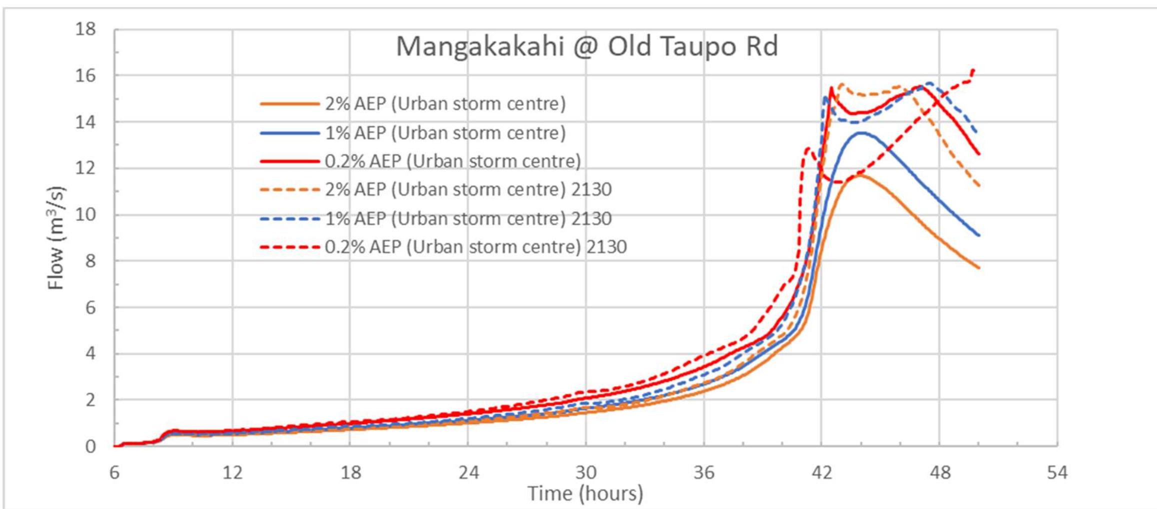


Figure 6-13 Flow hydrographs for Mangakakahi Stream at Old Taupo Rd (urban storm centre)

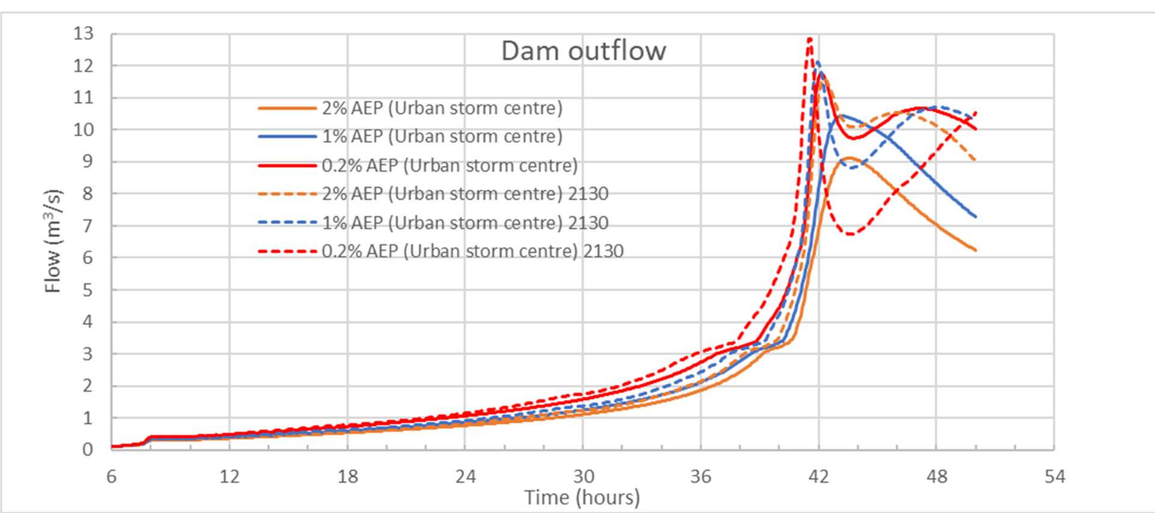


Figure 6-14 Flow hydrographs for Mangakakahi Stream, detention dam outlet (urban storm centre)

Figure 6-15 and Figure 6-16 compare flows at Old Taupo Road and Depot Street, for the 1% AEP urban storm centre, for current climate and 2130 climate.

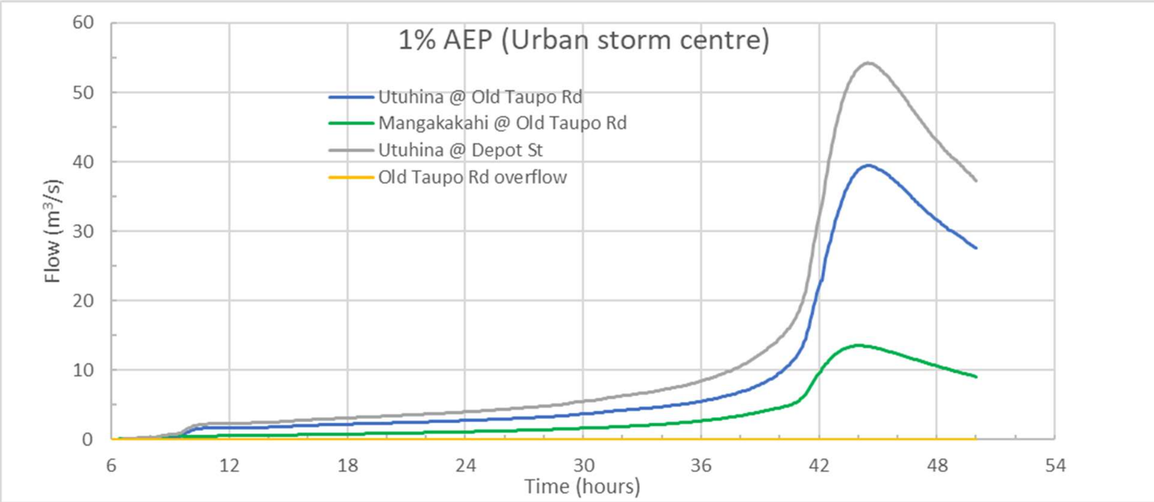


Figure 6-15 Flow hydrographs for 1% AEP storm, current climate, urban storm centre

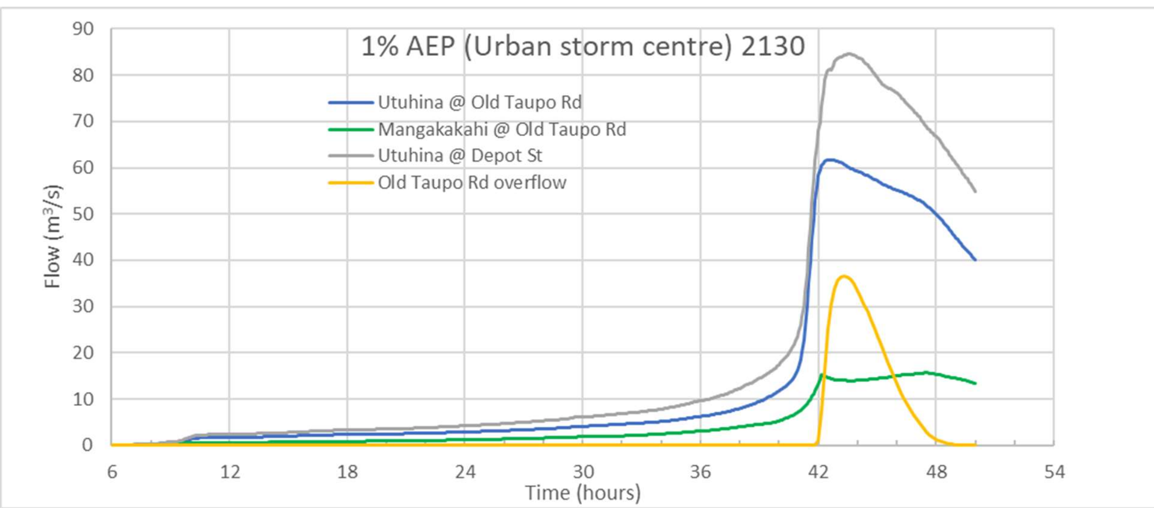


Figure 6-16 Flow hydrographs for 1% AEP storm, 2130 climate, urban storm centre

6.2.3 Old Taupo Road overflow

In larger storms, the model predicts that Old Taupo Road will be overtopped. Figure 6-17 shows the overtopping flows. (The urban storm centre scenarios give slightly higher overflows than the upper Utuhina storm centre scenarios.)

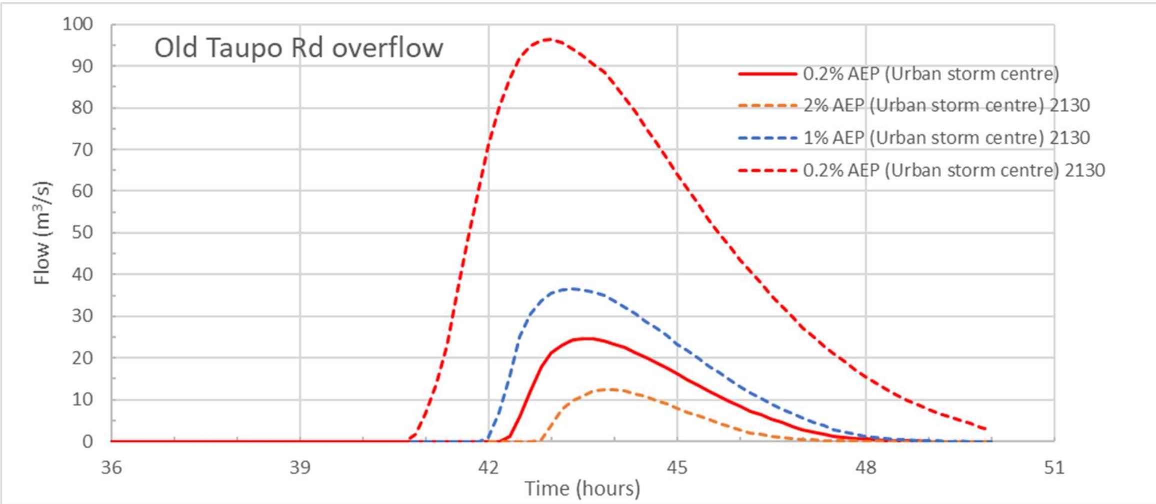


Figure 6-17 Flow overtopping Old Taupo Rd, urban storm centre

6.2.4 Flood maps

Figure 6-18 and Figure 6-19 show flood extents (for non-zero depths) for current climate and 2130 climate design scenarios, respectively. Each design scenario shown is a maximum of maximum of the urban- and upper Utuhina-centred storms for the particular return period. The maps are drawn such that the 2% AEP flood overlays the 1% AEP flood, which in turn overlays the 0.2% AEP.

More detailed maps showing flood depths are shown in Figure 6-20 to Figure 6-25. Again, each scenario shown represents the maximum of the urban- and upper Utuhina-centred storms

The floodmaps have been supplied to BOPRC in raster format. Raster values have been interpolated from the FM elements. The raster resolution is 2 m x 2 m resolution, very close to the original mesh and model output resolution of just over 5 m^2 (triangular elements), so any differences between the raster and actual model outputs will be insignificant.

Freeboard has not been applied to the levels and depths shown in the floodmaps. However, a minimum of 300 mm freeboard is recommended if flood level advice is to be supplied to external parties. Any such advice should also be qualified with a note that the floodmaps show flooding from the streams but do not explicitly show flooding from direct localised rainfall or from pipe surcharges.

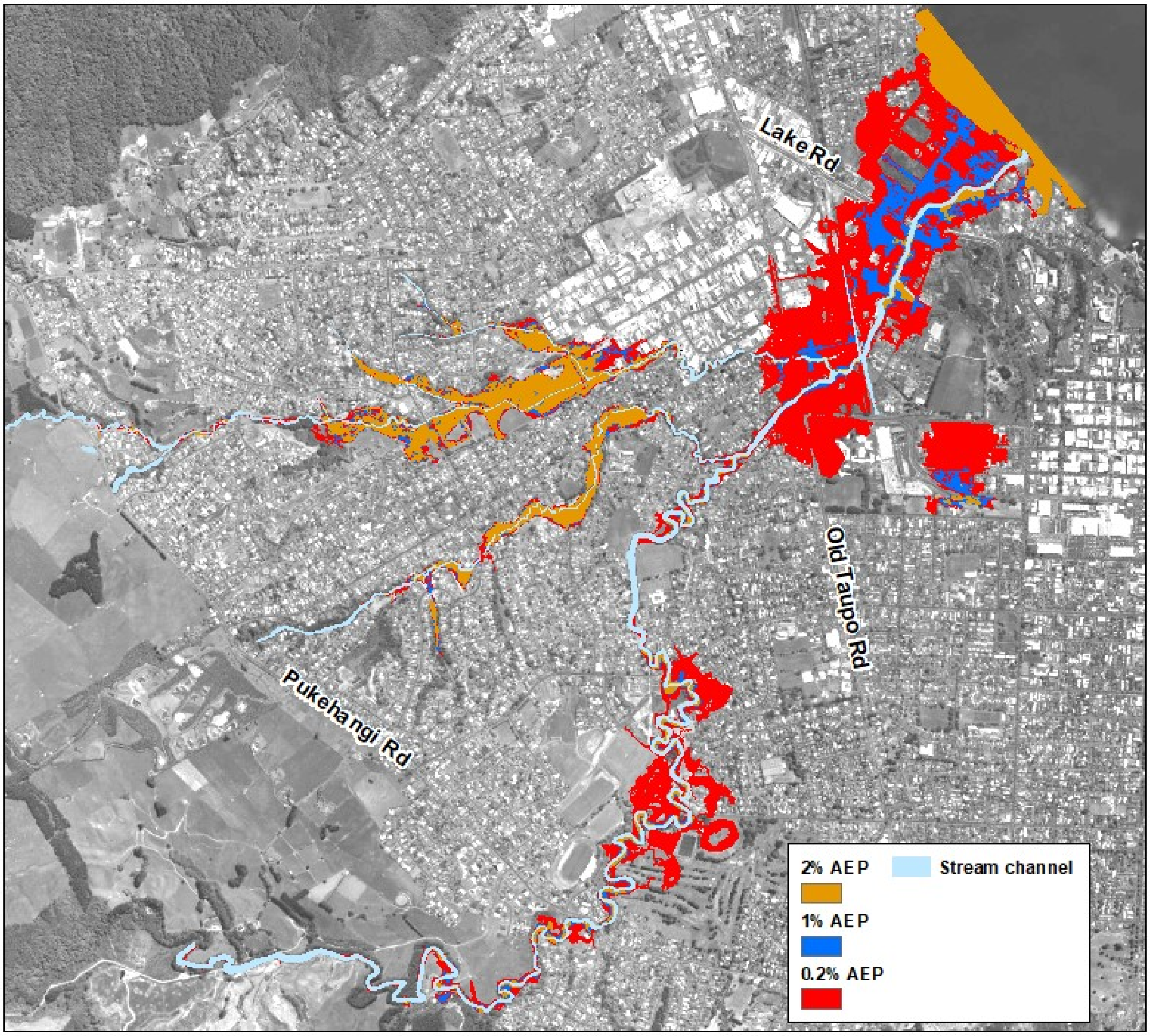


Figure 6-18 Flood extent, current climate design scenarios

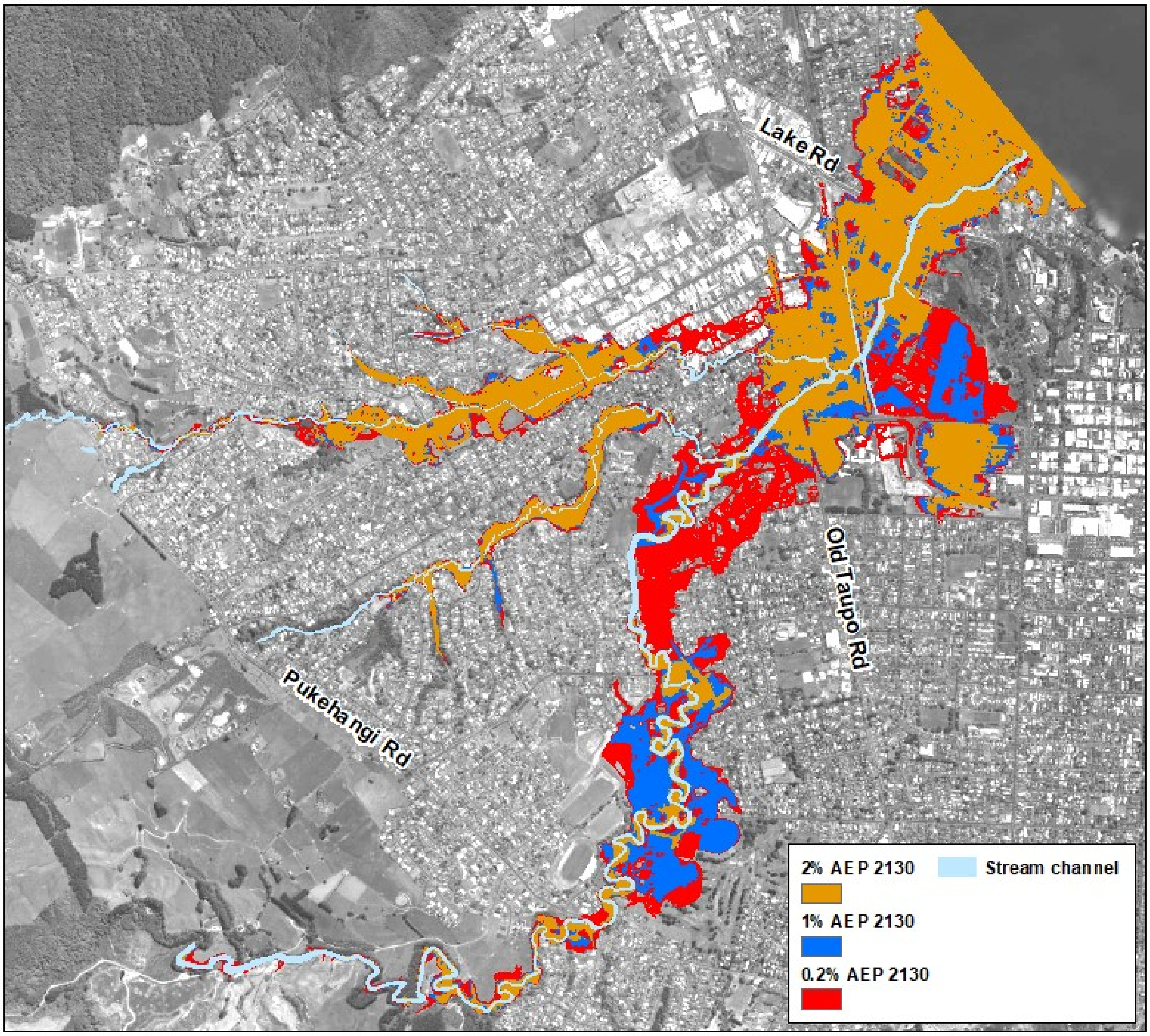


Figure 6-19 Flood extent, 2130 climate design scenarios

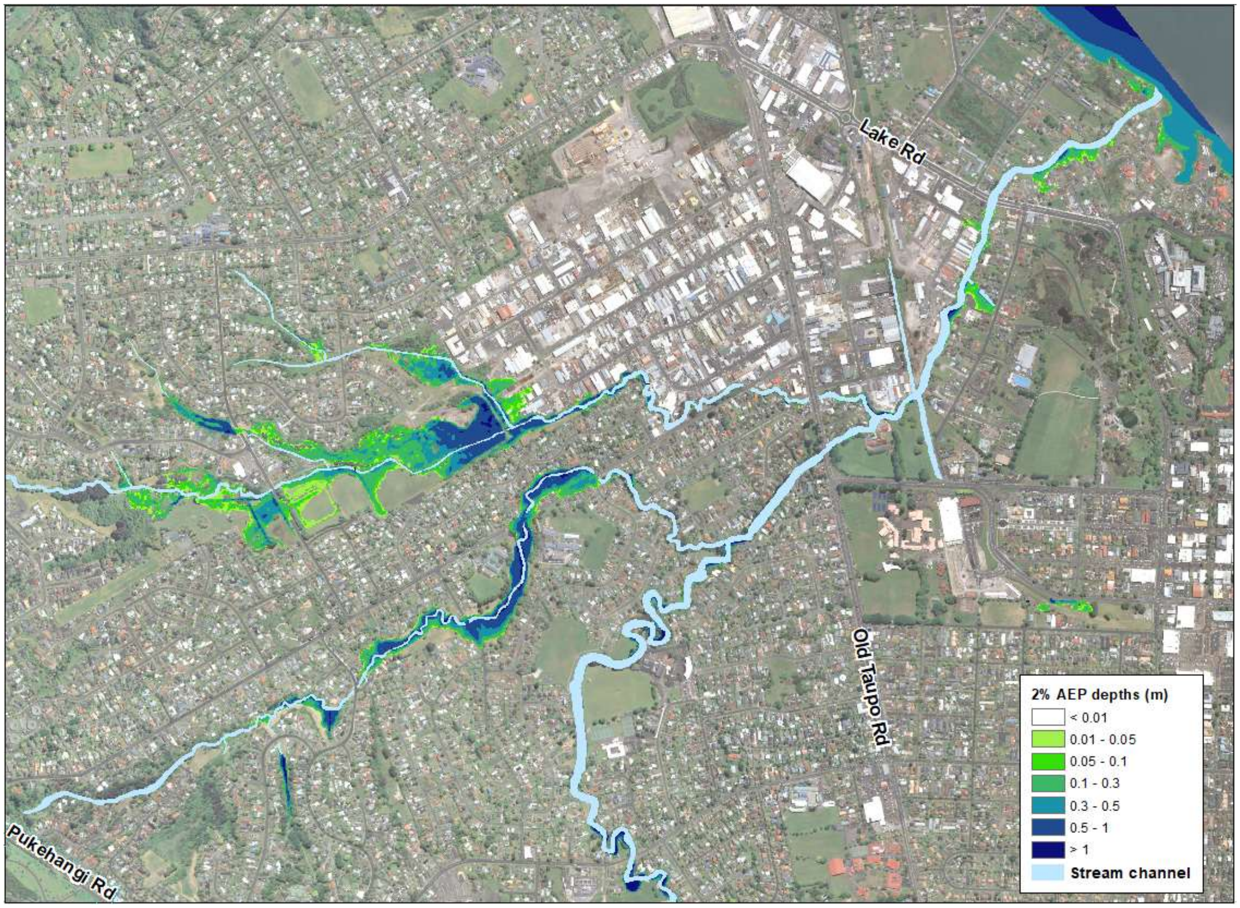


Figure 6-20 Flood map, 2% AEP current climate

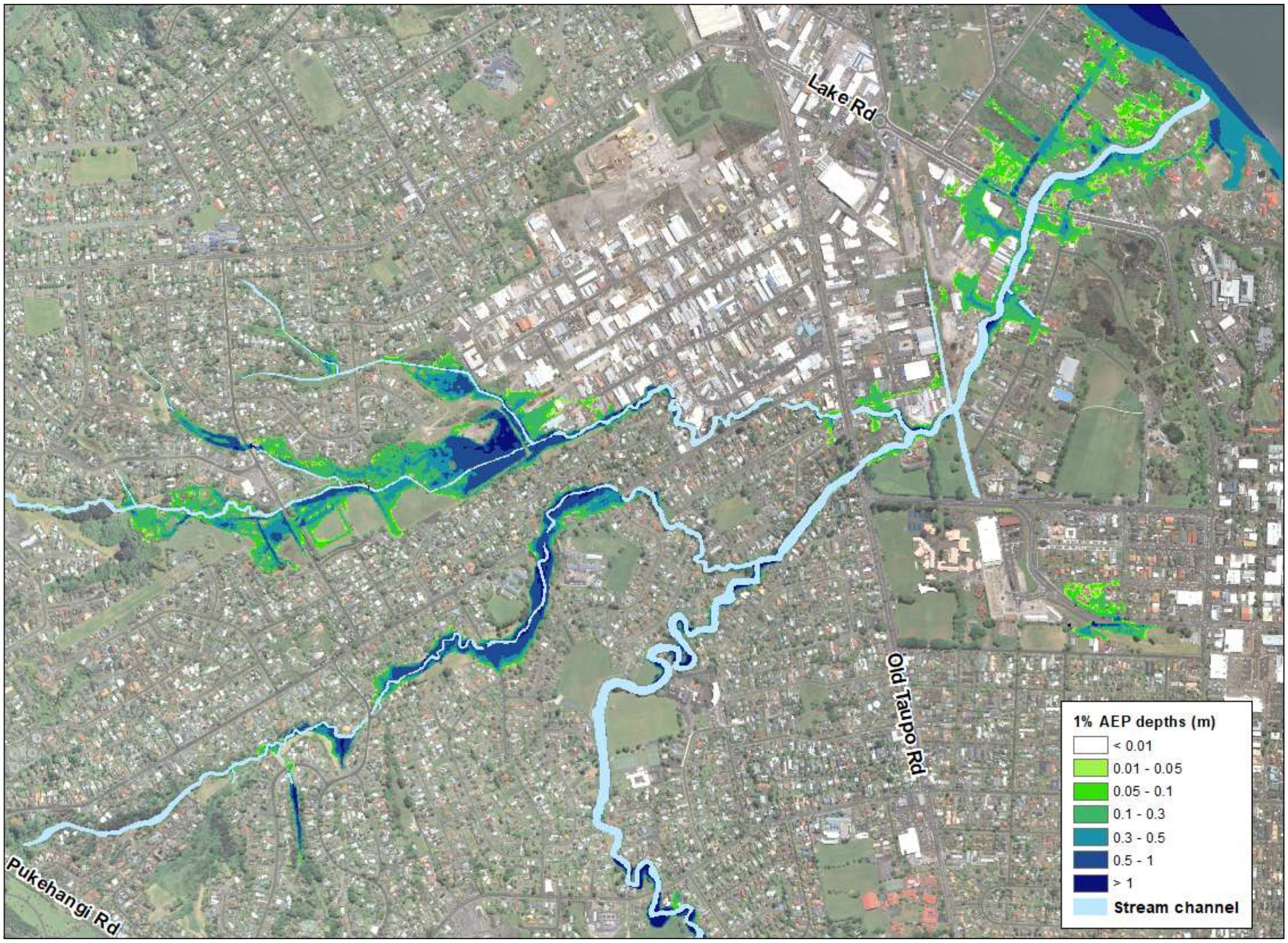


Figure 6-21 Flood map, 1% AEP current climate

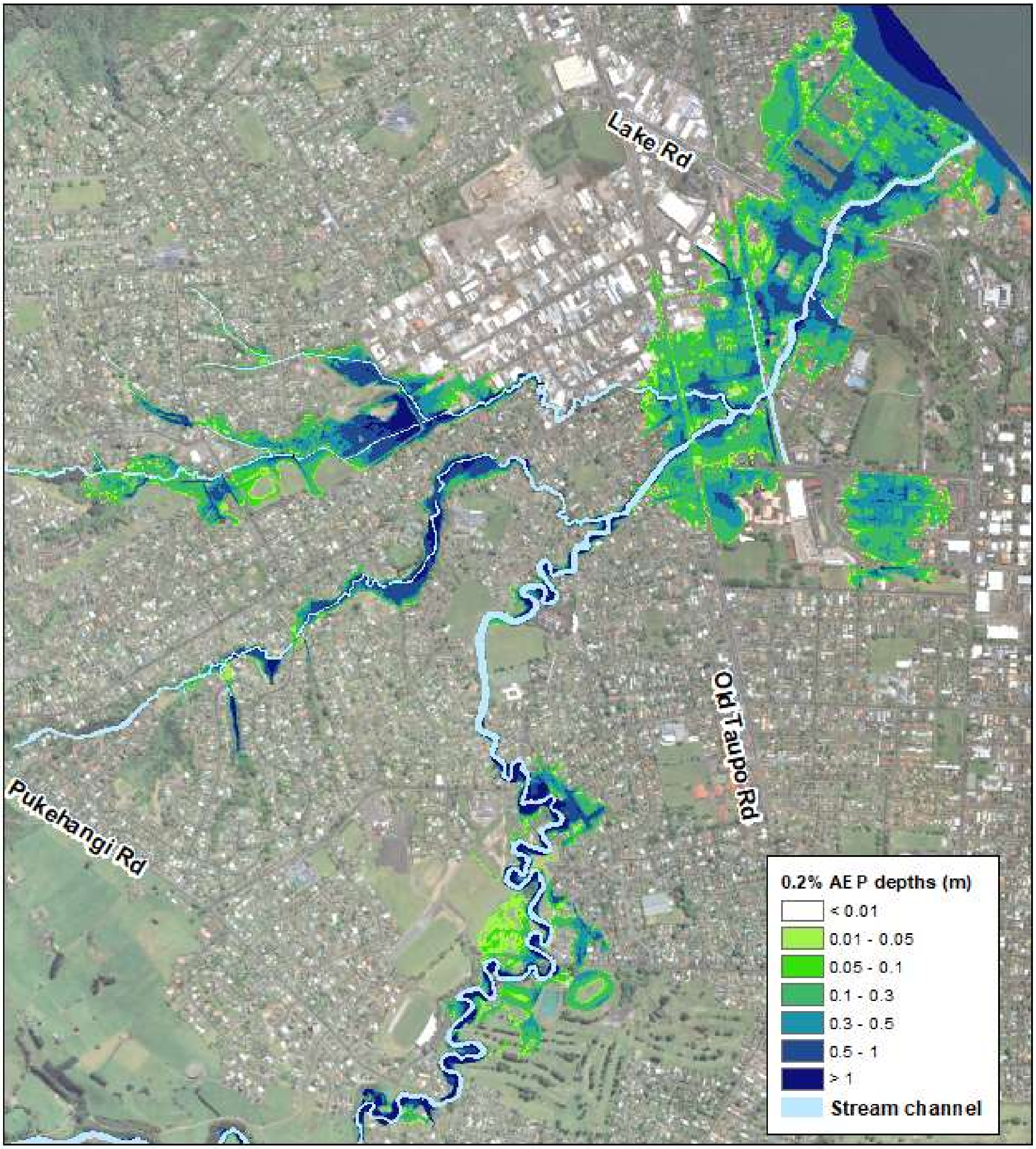


Figure 6-22 Flood map, 0.2% AEP current climate

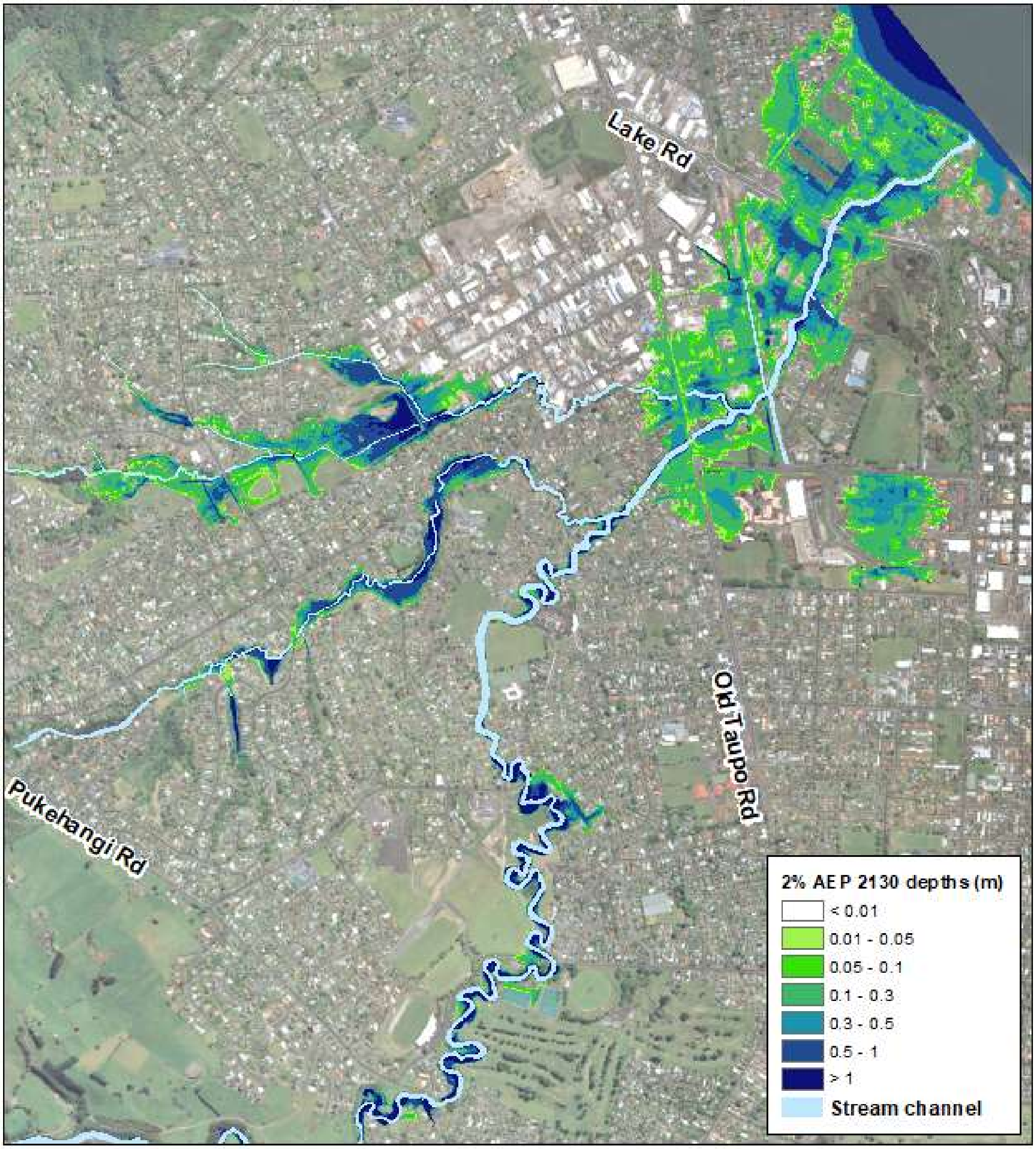


Figure 6-23 Flood map, 2% AEP 2130 climate

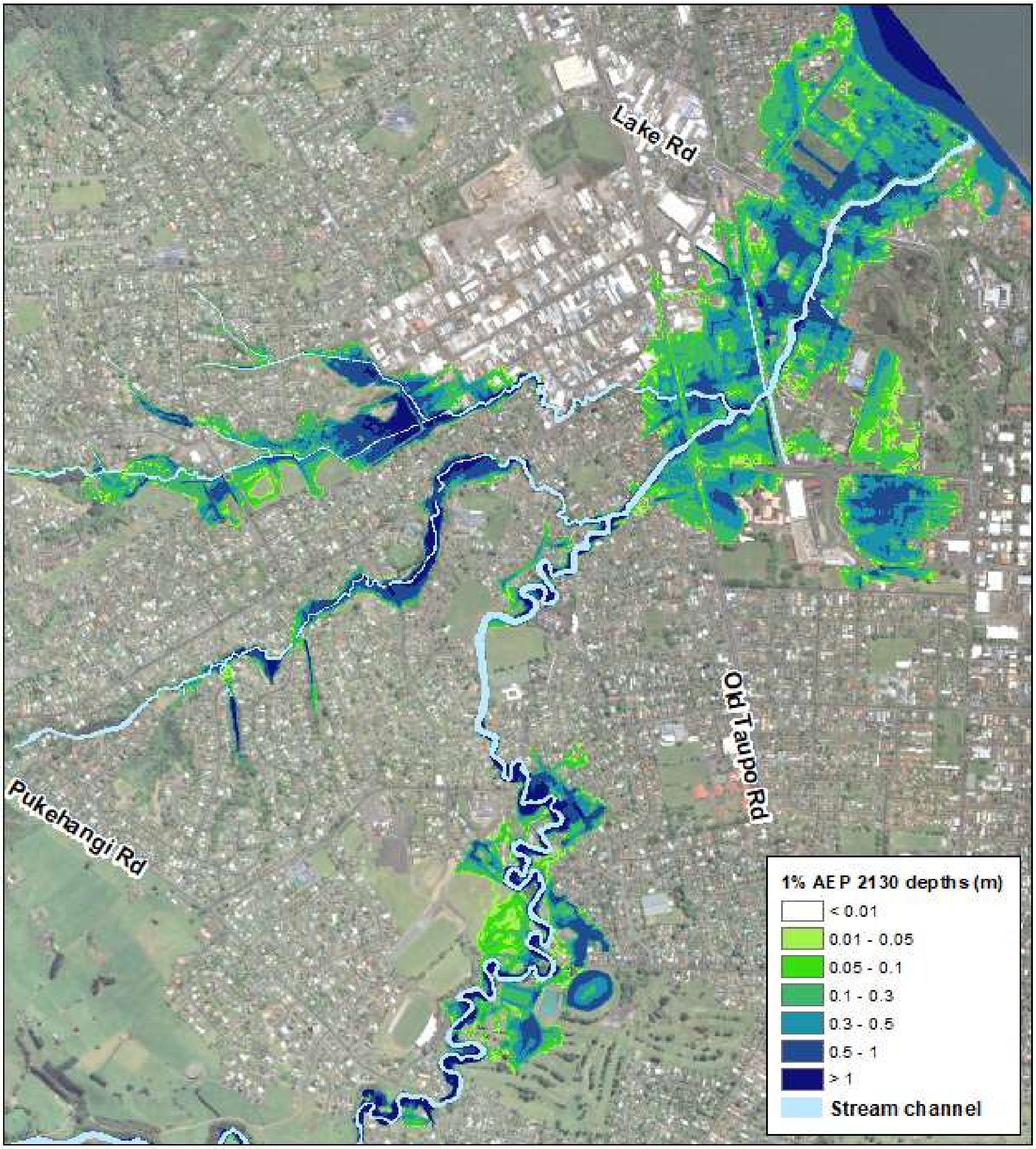


Figure 6-24 Flood map, 1% AEP 2130 climate

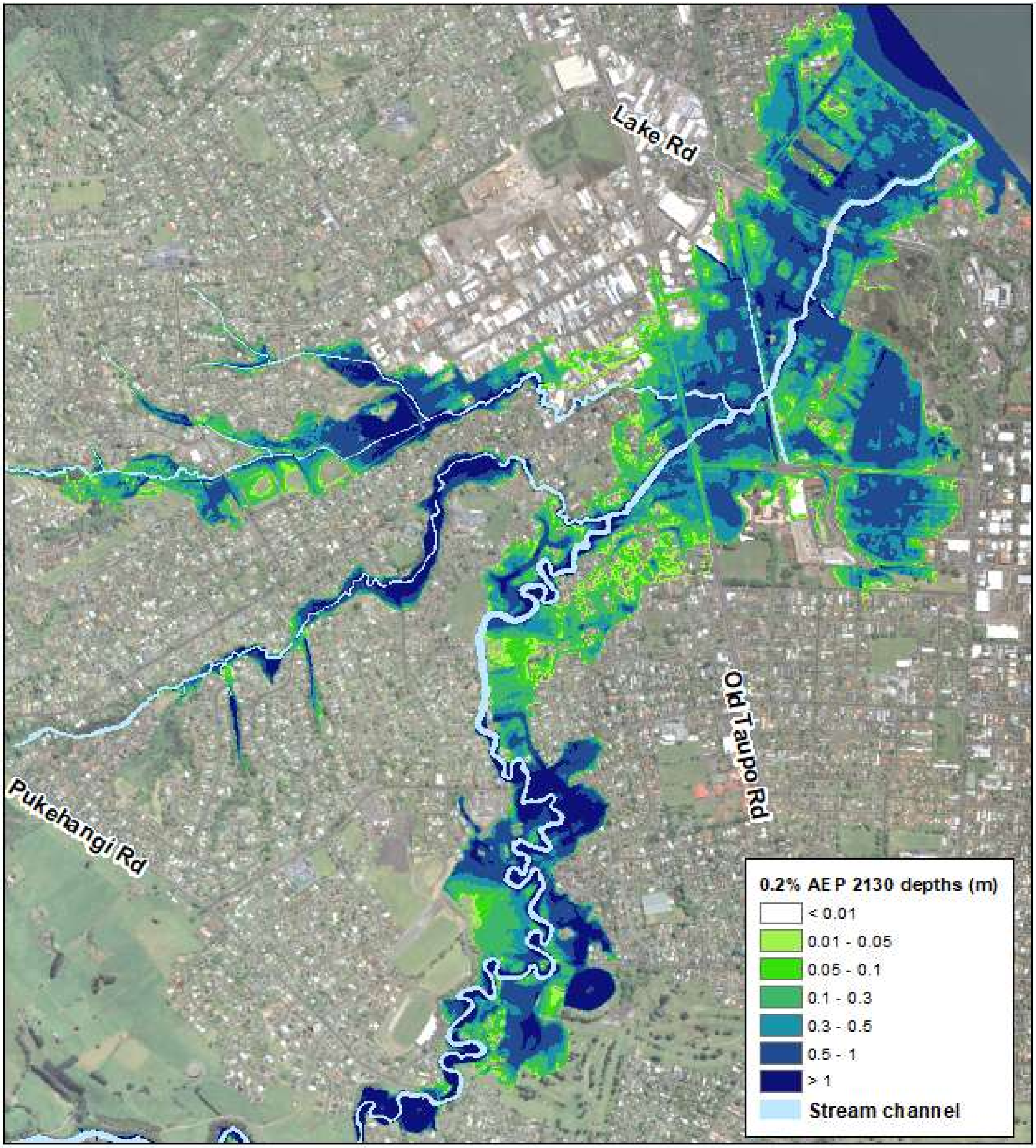


Figure 6-25 Flood map, 0.2% AEP 2130 climate

7 Conclusions and recommendations

A coupled 1-D and 2-D hydraulic model of the Utuhina Stream and floodplain has been built, calibrated and used to predict flood levels and extents for design storms. The model covers the urban area subject to possible flooding from the Utuhina Stream and its tributaries (Otamatea and Mangakakahi Streams) plus stream reaches upstream of Pukehangi Road. As the project scope did not allow for the urban stormwater pipe network to be modelled, overland flow from direct rainfall to the streams has not been explicitly modelled, nor has pipe surcharging been considered.

By adjusting hydrological model parameters and Manning's n values, ultimately a satisfactory calibration has been achieved, even if there are variations in how well the model reproduces individual calibration events.

However, extrapolating the calibration NLR hydrological model led to excessive flows in larger design scenarios, and the NLR model was subsequently adjusted to reduce runoff in the upper catchment. A rerun of the hydraulic model for the March 2017 flood event with the outputs of the revised NLR model gave peak stream levels 200 mm lower than observed debris levels from that event, on average. Nonetheless, it was agreed with BOPRC that the revised NLR model would stand for design scenarios.

In tandem with the NLR model, the hydraulic model is considered fit for the purpose of predicting flood levels and depths for the design scenarios assessed in this study (2% to 0.2% AEP), with the proviso that freeboard be increased to 700 mm when specifying design levels in the stream channels.

Nonetheless, the NLR hydrological model, and ultimately the hydraulic model, would benefit from additional flow and water level recorders upstream of the current recorders. While the existing sites provide useful water level records, flows are affected by backwater from the urban side drains (for the Utuhina @ Depot St site) and the Utuhina Stream (for the Mangakakahi @ Depot St). Having extra recorders further upstream would also reduce the uncertainty of the longitudinal flow profiles and subcatchment inputs along the lengths of the stream.

It is also recommended that flood debris levels be continued to be collected along the Utuhina Stream following flood events and that such levels also be collected along the Mangakakahi and Otamatea Streams. Little or no calibration information was available for these latter two streams in the current modelling exercise.

The adopted design standard for the lower Utuhina Stream downstream of Old Taupo Road calls for protection from a 1% AEP event, with 500 mm freeboard. Model results show that this standard is not being reached; the floodwaters spill in a 2% AEP event on the right bank downstream of Lake Road, through a gap in the floodwall. In a 1% AEP event, floodwaters spill from both banks downstream of the old railway in particular and also overtop Lake Road. In both events, there is also some inundation predicted for a limited number of industrial and residential properties further upstream alongside the three main streams.

In a 0.2% AEP event, flooding is more widespread, with around 25 m^3/s overtopping Old Taupo Road, and flooding of residential properties between Malfroy Road and Devon Street.

With climate change to 2130 under RCP 8.5 (3.68°C warming), flood depths and extents for the 2% AEP event approach those of the current climate 0.2% AEP event. The 2130 1% AEP and 2130 0.2% AEP events are successively bigger and results from the latter show extensive areas under water.

8 References

/1/ Barnett and McMurray (2009); *Rotorua District Council Western Heights Stormwater Model Report*. January 2009

/2/ Bay of Plenty Regional Council (2018); *Rivers and Drainage Asset Management Plan 2018-2068*

/3/ Beca Ltd. (2018); *Utuhina River – Catchment Field Surveys for Stormwater Hydraulic Modelling.*

/4/ Blackwood, P. (2020); *In the matter of The Resource Management Act 1991(RMA) and in the matter of Proposed Plan Change 2: Pukehangi Heights to the Rotorua District Plan under Part 5, Sub-Part 5 –Streamlined Planning Process and Schedule 1 Part 5 of the RMA. Summary of Evidence of Peter Blackwood on Behalf of Bay of Plenty Regional Council –Utuhina Flood Frequency & Rainfall Temporal Variation*. 21 September 2020. https://letstalk.rotorualakescouncil.nz/42068/widgets/274340/documents/181969/download

/5/ DHI (2017); *Utuhina: Phase 1: Numerical Modelling – Scoping*. Prepared for Bay of Plenty Regional Council, October 2017.

/6/ Environment Bay of Plenty (2007); *Environmental Data Summary.* Environmental Publication 2007/06.

/7/ New Zealand Aerial Mapping (2011); *Data Supply Metadata LiDAR 1k supply 2*

/8/ Rotorua District Council (2010); *Stormwater Urban Catchment 15: Linton Park Detention Basin - Upgrading Report*. Rotorua District Council Works Division, June 2010

/9/ Wallace, P. (2006); *Utuhina MIKE 11 Model.* 31 August 2006

/10/ Wallace, P. (2011); *Utuhina Stream Model Update*. Report prepared for Bay of Plenty Regional Council. River Edge Consulting Limited, July 2011

/11/ Wallace, P. (2014); *Utuhina Stream Flood Modelling and Mapping*. Report prepared for Bay of Plenty Regional Council. River Edge Consulting Limited, February 2014

/12/ Wallace, P. (2020); *In the matter of The Resource Management Act 1991(RMA) and in the matter of Proposed Plan Change 2: Pukehangi Heights to the Rotorua District Plan under Part 5, Sub-Part 5 –Streamlined Planning Process and Schedule 1 Part 5 of the RMA. Summary of Evidence of Philip Wallace on Behalf of Bay of Plenty Regional Council –Hydraulic Modelling and Flood Impacts*. 21 September 2020. https://letstalk.rotorualakescouncil.nz/42068/widgets/274340/documents/181971/download

/13/ West, P. (2020); *In the matter of The Resource Management Act 1991(RMA) and in the matter of Proposed Plan Change 2: Pukehangi Heights to the Rotorua District Plan under Part 5, Sub-Part 5 –Streamlined Planning Process and Schedule 1 Part 5 of the RMA. Summary Statement of Evidence of Peter Morley West on Behalf of Bay of Plenty Regional Council –Hydrological Basis for Analysis*. 21 September 2020. https://letstalk.rotorualakescouncil.nz/42068/widgets/274340/documents/182481/download

/14/ West, P. (2021); *BOPRC Flood Forecasting Systems: Utuhina Hydrological Model Establishment*. Blue Duck Design Ltd., 15 March 2021.

/15/ WSP Opus (2018); *Catchment 14: Stormwater Model Build and System Performance Report.* Report to Rotorua Lakes Council, May 2018.

APPENDICES

APPENDIX A – Project Brief

A Project Brief

Project Briefing Sheet

This Project Brief is issued pursuant to the agreed terms and conditions of the Contract for Engineering Services Panel Suppliers contract number 2016 0161-12 between Bay of Plenty Regional Council and DHI Water and Environment Limited for the period 1/09/2018 – 30/06/19.			
Project Name:	Utuhina Stream Capacity Review and Flood Risk Assessment		
Engineering Manager:	Mark Townsend		
Project Manager:	Kathy Thiel-Lardon		
Engineering Job Number:	FRP	**Contract Number:**	2016 0161-12
Job Tracker Number:	-	**Purchase Order Number:**	
Client Name/Contact Person:	Bay of Plenty Regional Council Contact: Kathy Thiel-Lardon **M:** 027 503 8242 **W:** 0800 884 881 x 8144		
Consultant Name/ Contact Person:	DHI Water and Environment Limited Contact: Philip Wallace **M:** 021 238 7515 **W:** 04 974 5543		
Purpose/Objective:	The Utuhina Stream has a long history of flooding and erosion. Recent discussions with Rotorua Lakes Council identified the need of an updated model to assess the impacts of flood flows, set boundary conditions for the stormwater systems and optimise any potential mitigation options used to mitigate flood and erosive risks. This project seeks to determine the flood and erosion risk to properties adjacent the Utuhina Stream and then develop appropriate mitigation options.		
Scope of Work:	The study area includes the entire Utuhina Stream Catchment. Hydrological input generation will be required for the entire catchment area. Hydraulic modelling will be required for the lower and middle catchment and need to extend into the floodplain areas. This project is to be split into three phases, Phase 1: Gap analysis and preparation of the project scope. **Phase 2: Data collection and model build** **Phase 3: Calibration, design simulations, mapping and reporting.** Phase 4 (Provisional): Flood Risk Assessment and Mitigation Options. The attached table shows the tasks to be undertaken. These need to be further refined by the Consultant.		
Methodology:	The methodology shall be refined by the Consultant.		
Detailed Methodology Attached	None		
Input Requirements:	The project will involve a number of stakeholders (e.g. BOPRC Engineering, Data Services, Land Management and RLC) with different levels of engagement required.		

	The individual project tasks will require different amounts of inputs from each party and iterative processes between tasks and staff. There is a range of information that can be referenced for this study including: • Previous modelling and capacity assessment reports. • Historical flood event assessments.
Detailed Inputs Attached	None
Deliverables:	The deliverables for the project includes: • A project scope. • A survey database. • A calibration database. • A calibrated hydrological model of the entire catchment. • A calibrated hydraulic model for the middle and lower catchment areas. • A boundary condition analysis. • A Capacity Review Report. • A Flood Risk Assessment Report.
Detailed Deliverables Attached	None
Resources:	This project will require various people to interact and iterate findings between tasks.
Detailed Resources Attached	None

APPENDIX B–Model Files

MIKE FLOOD Files

B MIKE FLOOD Files

Input and output files for selected final model simulations can be tracked via the *.couple* files noted in Table B-1.

Unless otherwise noted, the models were run with MIKE 2017 (SP2) on DHI computers.

All simulations used the "low order" solution technique within MIKE 21 FM. Ideally, the "higher order" option would have been used, but this would have led to long simulation times. From past experience with other projects, the high order results are typically not significantly different from low order results.

Note also that the design simulations and the March 2017 calibration simulation with the design NLR model have adjustments to the exponential smoothing factor[6] for lateral links in the Utuhina, Mangakakahi and Otamatea to remove instabilities along those links in large flows (the 0.2 % AEP event and the climate change scenarios). The mid-reaches of the Utuhina in particular showed some instabilities without the adjustments. Tests with the March 2017 event showed that the adjustments had negligible effect for that event, and it was not considered necessary to rerun the other calibration events.

Table B-1 MIKE FLOOD *.couple* files

Scenario	.couple file
23 January 2011 flood	Utuhina_23Jan11.couple
29 January 2011 flood	Utuhina_29Jan11
August 2014 flood	Utuhina_Aug14.couple
March 2017 flood	Utuhina_Mar17.couple
March 2017 flood (design hydrology NLR model)	Utuhina_Mar17-ESF.couple
April 2018 flood	Apr18.couple
2% AEP, current climate, urban-centred storm	UtuhinaQ50 Storm070_0pt55_UrbanCentre.couple
2% AEP, current climate, upper Utuhina-centred storm	UtuhinaQ50 Storm070_0pt55_UtuhinaCentre.couple
1% AEP, current climate, urban-centred storm	UtuhinaQ100 Storm070_0pt55_Urban.couple
1% AEP, current climate, upper Utuhina-centred storm	UtuhinaQ100 Storm070_0pt55_UtuhinaCentre.couple
0.2% AEP, current climate, urban-centred storm	UtuhinaQ500 Storm070_0pt55_UrbanCentre.couple
0.2% AEP, current climate, upper Utuhina-centred storm	UtuhinaQ500 Storm070_0pt55_UtuhinaCentre.couple
1% AEP, current climate, urban-centred storm, debris	UtuhinaQ100 Storm070_0pt55_Urban_D1.couple

[6] Refer to http://doc.mikepoweredbydhi.help/webhelp/2020/mikeflood_help/#%3Cid=1206

2% AEP, 2130 climate, urban-centred storm	Utuhina_Q50_2130_Storm070_0pt55(UrbanCentre).couple
2% AEP, 2130 climate, upper Utuhina-centred storm	Utuhina_Q50_2130_Storm070_0pt55(UtuhinaCentre).couple
1% AEP, 2130 climate, urban-centred storm	Utuhina_Q100_2130_Storm070_0pt55(UrbanCentre).couple
1% AEP, 2130 climate, upper Utuhina-centred storm	Utuhina_Q100_2130_Storm070_0pt55(UtuhinaCentre).couple
0.2% AEP, 2130 climate, urban-centred storm	Utuhina_Q500_2130_Storm070_0pt55(UrbanCentre).couple
0.2% AEP, 2130 climate, upper Utuhina-centred storm	Utuhina_Q500_2130_Storm070_0pt55(UtuhinaCentre).couple

In addition, the 29 January 2011 event was also simulated with an alternative set-up, where only the reach downstream of the Utuhina Stream Depot Street recorder was modelled (refer 5.2). Only a 1-D model was used for that simulation, as defined in the set-up of *Utuhina_29Jan11(M11onlyLOWER).sim11*

APPENDIX C–Hydrology

Email correspondence

C Hydrology

Email correspondence regarding the hydrological assumptions is provided below.

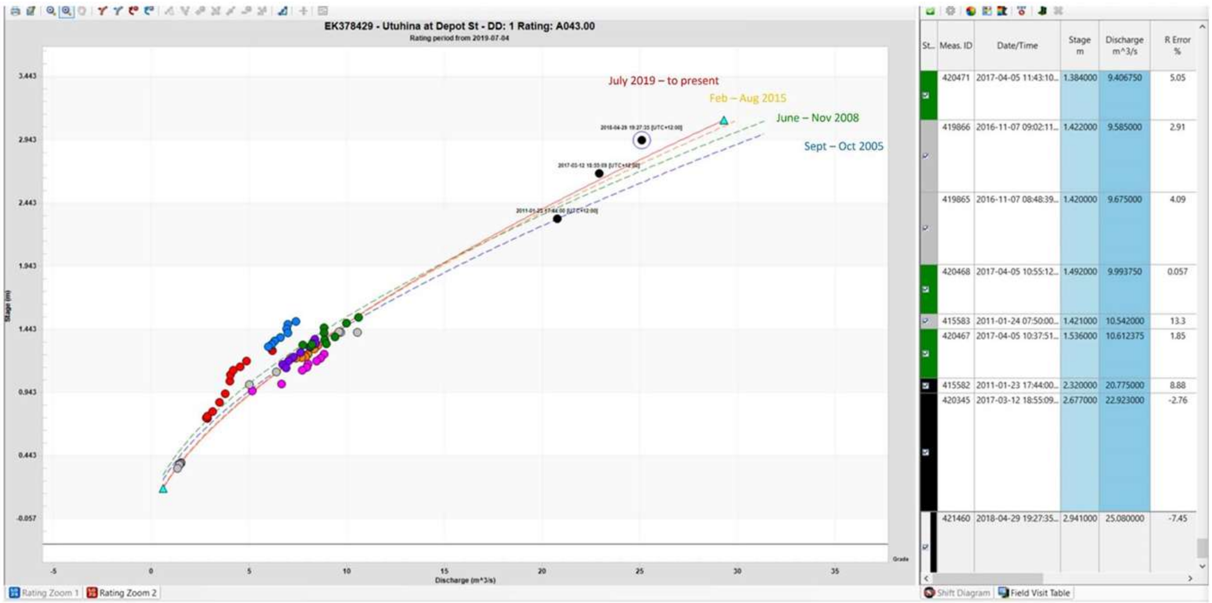
C.1 Utuhina and Kuirau recorder ratings

From: Craig Putt <Craig.Putt@boprc.govt.nz>
Sent: Friday, April 24, 2020 3:07 PM
To: Philip Wallace
Subject: RE: Issue [EDS-611735] has been assigned to you by Angela Perks
Attachments: RE: Gap Analysis & Scoping Exercise For Utuhina Stream Flood Hazard; Kuirau at Tarewa Road 20090423 (3).jpg; Kuirau at Tarewa Road 20170601 - Radar Installed (5).JPG; Utuhina at Depot Street 20170405 1045 (9).JPG; Utuhina at Depot Street 20170312 2000 (4).jpg; Utuhina at Depot Street 20190802 - ADCP Stationary Gauging Workshop (1) 1.52m3-sec.jpg

Hi Phil,

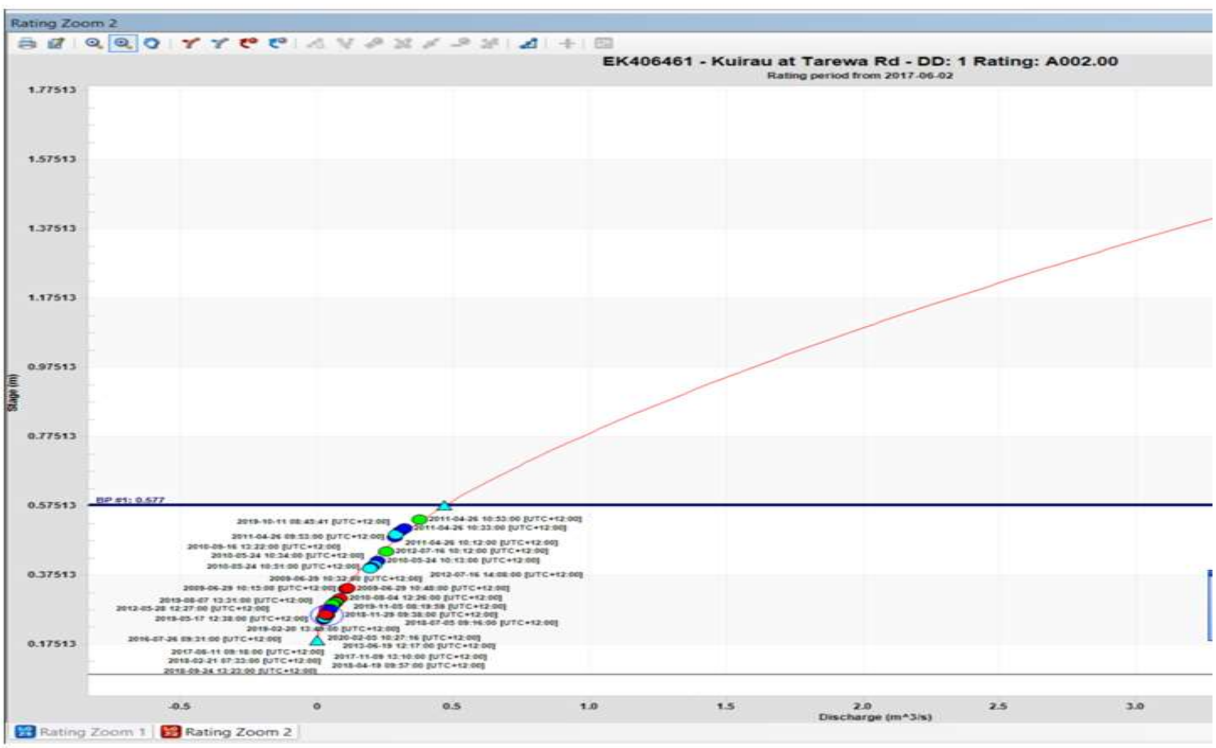
Good to hear from you. Hope you guys are keeping well in your bubble!

Yes, we still have some issues with these two sites. The ratings drawn for Utuhina at Depot St in 2011 and 2013 were done in TIDEDA and were largely based on 'best fit' and the limited data we had at the time. When we migrated to Aquarius software, we were then able to draw rating curves in both log-log and linear space, with the advantage of using a mathematical formula to validate each segment of a curve (and more data). The formula has some hydrological constraints which discourage users from creating unrealistic shapes and I used this as the basis to review the Utuhina ratings, after our highest recorded gauging on 29 April 2018 (25.08m3/s at 2.941m stage). However, there is still an ongoing issue with gauging scatter between events, which is not driven by hysteresis. The plot below is an update of the one that I sent you 26/06/2017 (attached), showing gaugings colour coded by storm events. Note that the 3 black gaugings which are the highest on record, are from different events. The light grey gaugings at the lower end of the curve are also from different events. As you can see, there is a lot of variability! My theory is that the top end of the rating has been retreating as the banks have (1) collapsed; (2) been stabilised with gabion baskets; and (3) become vegetated with 1m high weeds, over time (see plot below and photos attached). The erosion at the gauging cross section and water level recorder is a little worse than at the Engineers cross section, 30m upstream.



St..	Meas. ID	Date/Time	Stage m	Discharge m^3/s	R Error %
	420471	2017-04-05 11:43:10...	1.384000	9.406750	5.05
	419866	2016-11-07 09:02:11...	1.422000	9.585000	2.91
	419865	2016-11-07 08:48:39...	1.420000	9.675000	4.09
	420468	2017-04-05 10:55:12...	1.492000	9.993750	0.057
	415583	2011-01-24 07:50:00...	1.421000	10.542000	13.3
	420467	2017-04-05 10:37:51...	1.536000	10.612375	1.85
	415582	2011-01-23 17:44:00...	2.320000	20.775000	8.88
	420345	2017-03-12 18:55:09...	2.677000	22.923000	-2.76
	421460	2018-04-29 19:27:35...	2.941000	25.080000	-7.45

Kuirau at Tarewa Rd ratings were revised when we moved to Aquarius, because the original rating was not hydraulically correct. The top end is entirely theoretical, based on channel width and form. However, the formula does not allow for the fact that Kuirau Stream flow backs up when the Utuhina Stream rises. So, the rated flow is the likely maximum flow, above 0.577m of stage (which is the top of the weir – rated at 475L/sec). In reality, it's probably a lot less. I've attempted to gauge the site a couple of times when the weir was drowned out (at around 0.7m stage, from memory), but the velocities were too low to record anything useful. Photos attached, showing normal flow conditions at the weir, staff gauge and upstream culvert (coming from Kuirau Park). Stage-discharge rating shown below:



Hope that helps. Let me know if you have any further questions relating to these sites.

Regards,

Craig Putt
Senior Environmental Data Officer
Bay of Plenty Regional Council Toi Moana

P: 0800 884 880 DD: 0800 884 881 x7579
E: Craig.Putt@boprc.govt.nz
M: 029 368 7579 W: www.boprc.govt.nz
A: PO Box 364, Whakatāne 3158, New Zealand

Thriving together – mō te taiao, mō ngā tāngata

From: JobTracker No-Reply <jobtracker@boprc.govt.nz>
Sent: Thursday, 16 April 2020 19:51
To: Craig Putt <Craig.Putt@boprc.govt.nz>
Subject: Issue [EDS-611735] has been assigned to you by Angela Perks

The following issue has been assigned to you:

Title:	2011 floods, Utuhina Stream and Kuirau Stream
Area:	Environmental Data Services
Created By:	Administrator at 2020-04-16 03:40 PM
Reporter:	External Consultants
Category:	External
Priority:	High
Type:	Data Query
Due Date:	2020-04-24 11:00 AM
Description:	

The following issue has been added via the Mailbox Reader.

Mailbox:	JobsForEds@boprc.govt.nz
From:	plw@dhigroup.com
To:	jobsforeds@boprc.govt.nz
Delivered On:	2020-04-16 03:35 PM

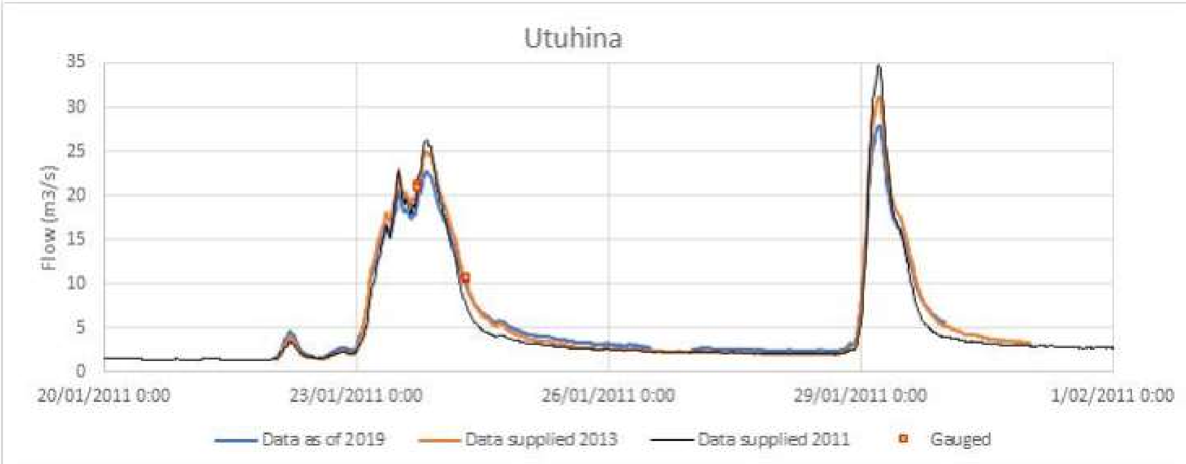
Hi,

I am interested in the ratings that have been applied to the Utuhina and Kuirau Streams.

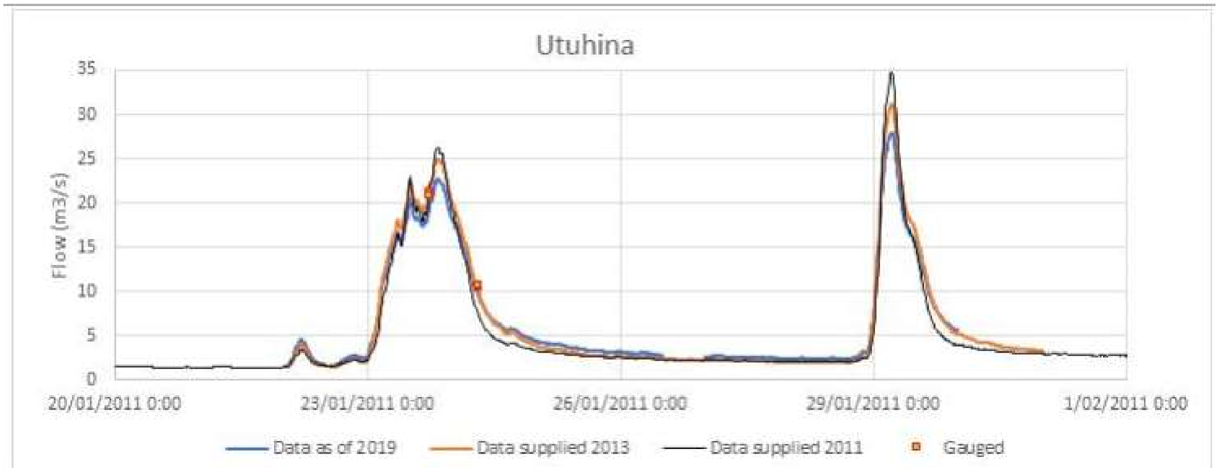
I can understand that over time the ratings change as more gaugings are obtained, but I am wondering about the what seems to be retrospective changes to the flow estimates for particular floods.

In particular, I am remodelling the 2011 floods for the Utuhina Stream. I had previously modelled these in 2013.

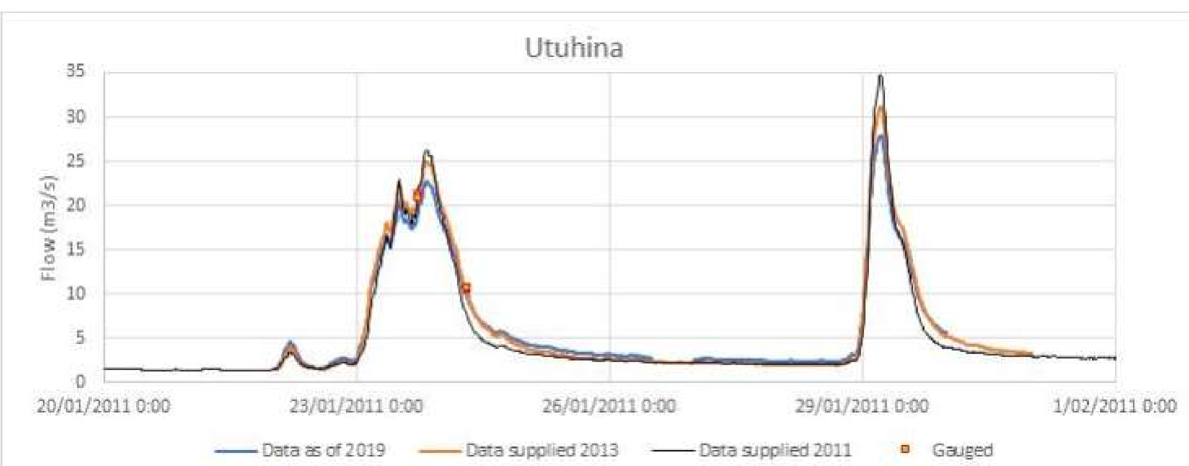
Below is a plot of the Utuhina flows, for data supplied at three different times (current/2019 has been taken from the data portal https://envdata.boprc.govt.nz/ . For 2011 and 2013 the data were supplied by BOPRC (from Craig Putt I seem to recall).



Looking more closely at the 1st flood ie 23rd Jan, when there were some gaugings, the gaugings seem to fit better to the flows as supplied as of 2013.



In the case of the Kuirau, the flow estimates seem to have gone up quite a lot to what was supplied in 2013.



However, from the gaugings I have been given (thanks Ange), the highest gauging was only 0.376 m3/s (in April 2011), so we can assume that the reliability at high flows is very low.

(Peter W, - Interestingly, your NLR model predicts a peak flow of 2.5m/s, pretty close to the 2013 rating of 2.7m3/s for that 2011 event)

I'd be interested in any comments that you may have. I am thinking that for my modelling, I will use the 2013 ratings for both the Utuhina @ Depot St and Kuirau @ Tarawa Rd flows. For the Utuhina, this is because the gaugings from the 23rd Jan 2011 event seem to match the 2013 rating best. Perhap the changes to the rating more recently reflect actual changes to the bed since 2011/2013.

(Although at xs about 30m u/s, the most recent xs in 2018 seems to have bigger flow area at peak levels of 2011 event than those of c2007-2013, which is perhaps doesn't support what I am arguing).

Thanks for any comments you may have

Regards

Phil

C.2 Hydrology inputs to hydraulic model

From: Peter West
Sent: Thursday, 23 April 2020 6:20 p.m.
To: plw@dhigroup.com
Cc: Peter Blackwood; Peter West (Blue Duck); Kathy Thiel-Lardon
Subject: Utuhina Hydrologic modelling; Calibration refinement; Hydraulic model input files

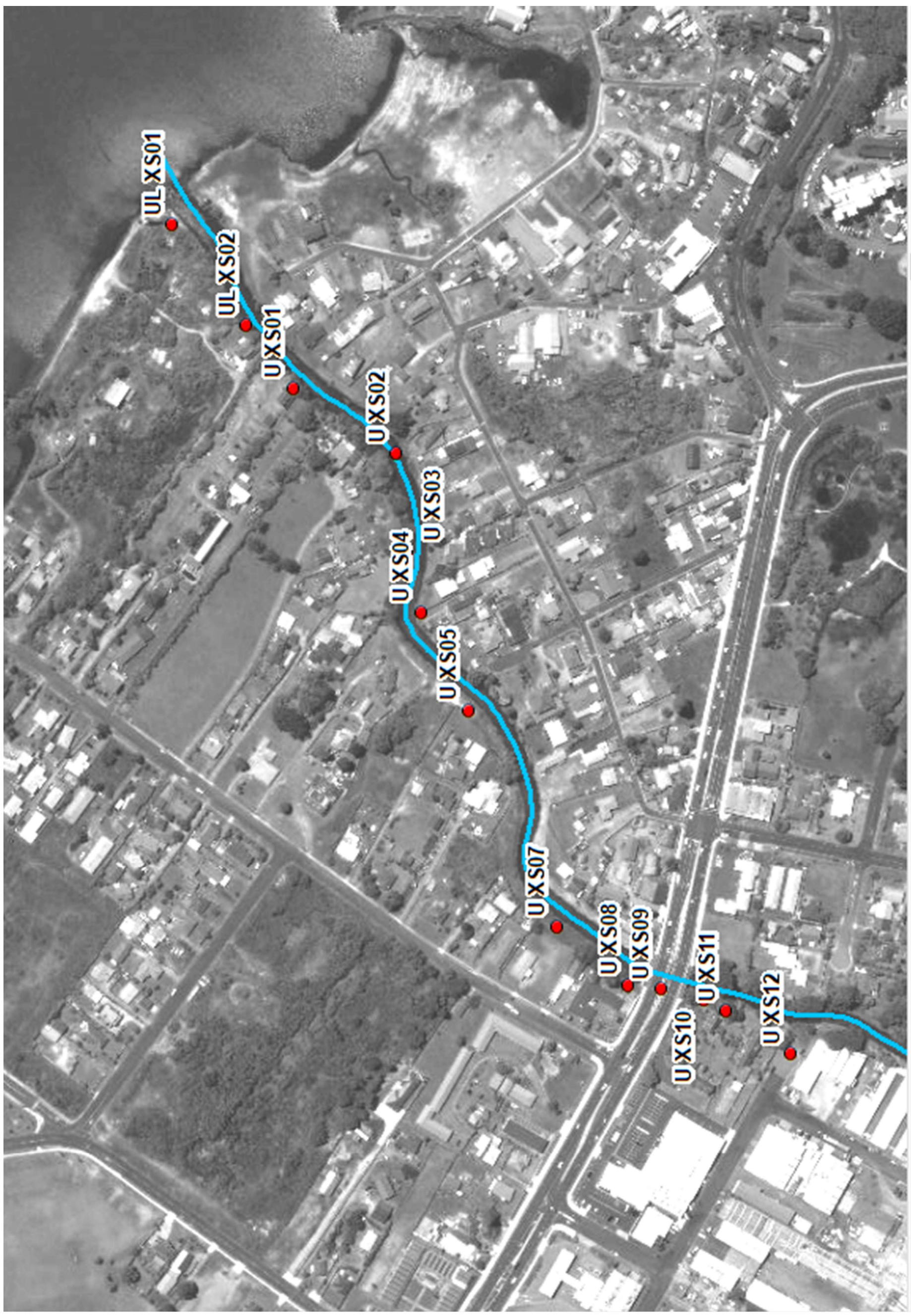
Hi Phil,
I've completed a refinement of the Utuhina hydrologic model calibration following your hydraulic simulations with our first attempt.
Your hydraulic model results have made it possible to gain a lot of understandings.
Although there is only one actually functioning flow gauge in the system, it is possible to see the characteristic response from each of the main contributing subcatchments in the gauge record now.
I've been able to re-define soil-response characteristics for the upper catchment, and the urban area.
However I've been unable to model the additional discharge photographed in the Otamatea catchment in the 2014 storm. I have to conclude that we are not observing the full rainfall intensities for that event.
You will see that for several of the calibration flood peaks, I'm asking you to model flows higher than the rated flows at Utuhina at Depot street. This is because I've found the rating there to be impacted by the large inflowing urban drains immediately downstream to up to 8m3/s. Although difficult without several more iterations, I hope that this set of inputs will enable us to calibrate closely to the levels observed at the gauge.
Please find attached two sets of boundary conditions for the hydraulic model: Calibration inputs; and Design inputs.
Let me know how it goes.
Thanks
Peter

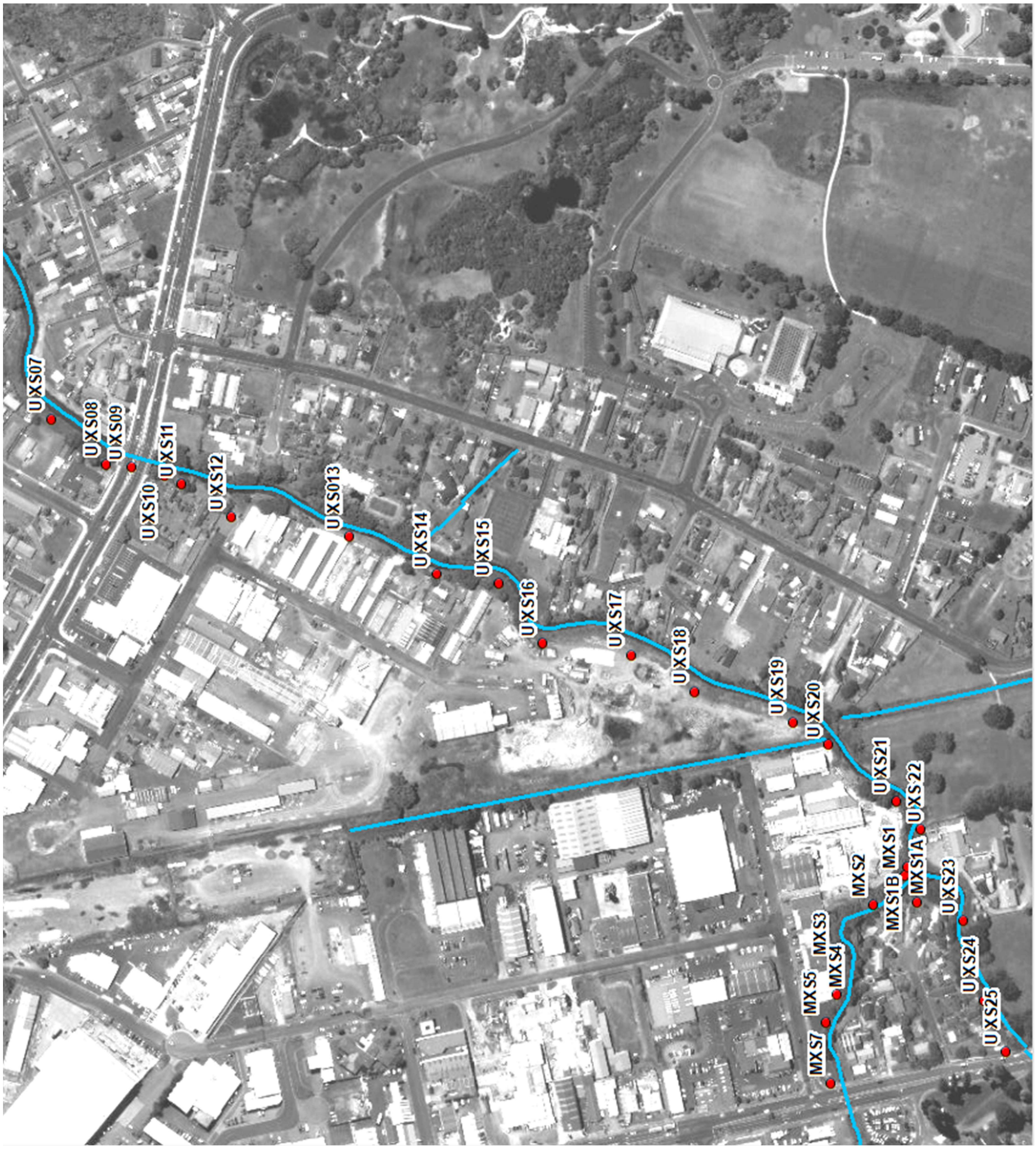
APPENDIX D–Cross-section locations

2018 survey

D Cross-section Locations

The following diagrams show the location of 2018 cross-sections for the three main streams. The numbering of the sections generally proceeds in an upstream direction. Beca supplied the raw data in *.csv* format, which has also been converted to a point shape file *2018survey.shp*.





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UXS21
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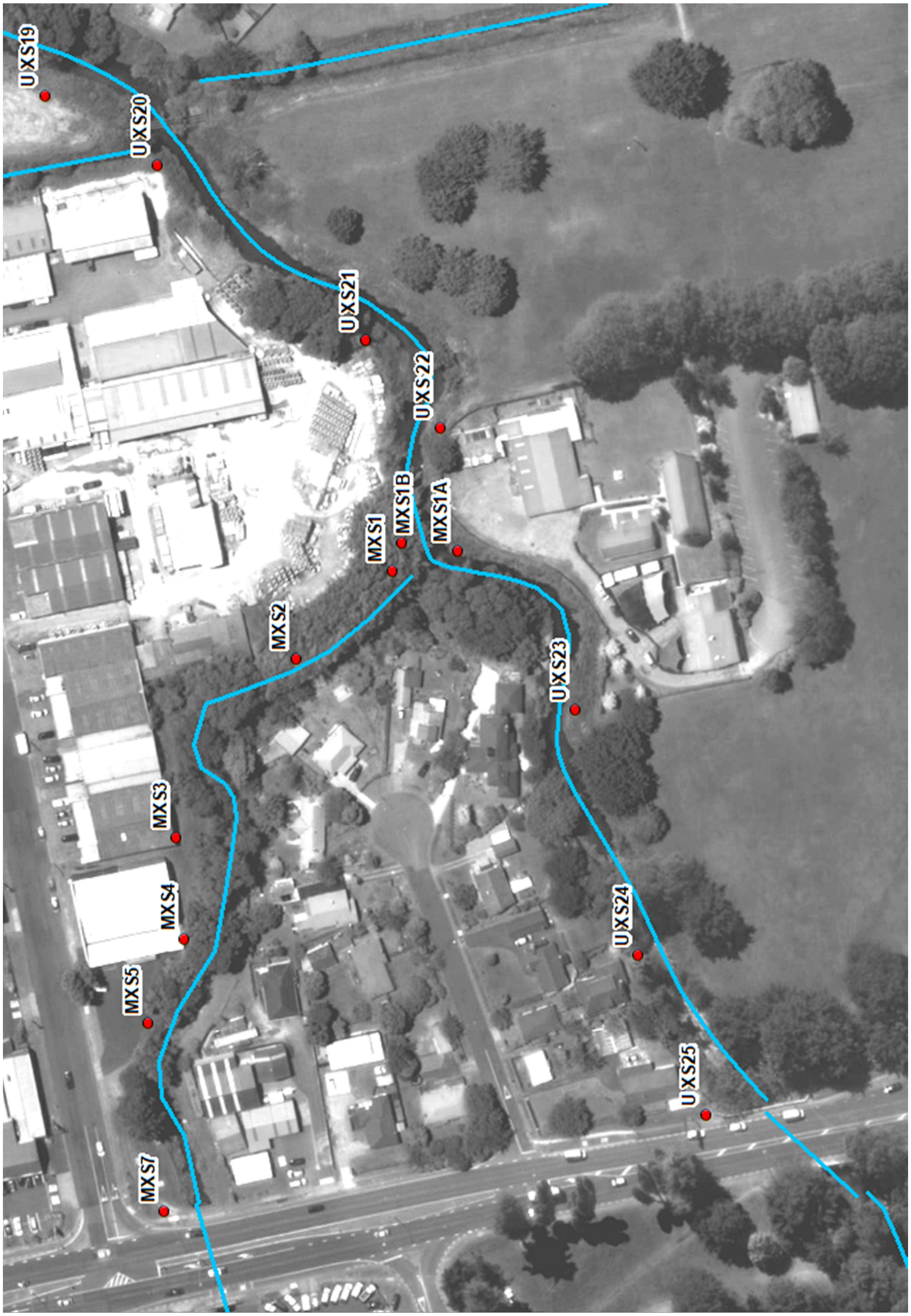
UXS25
MXS7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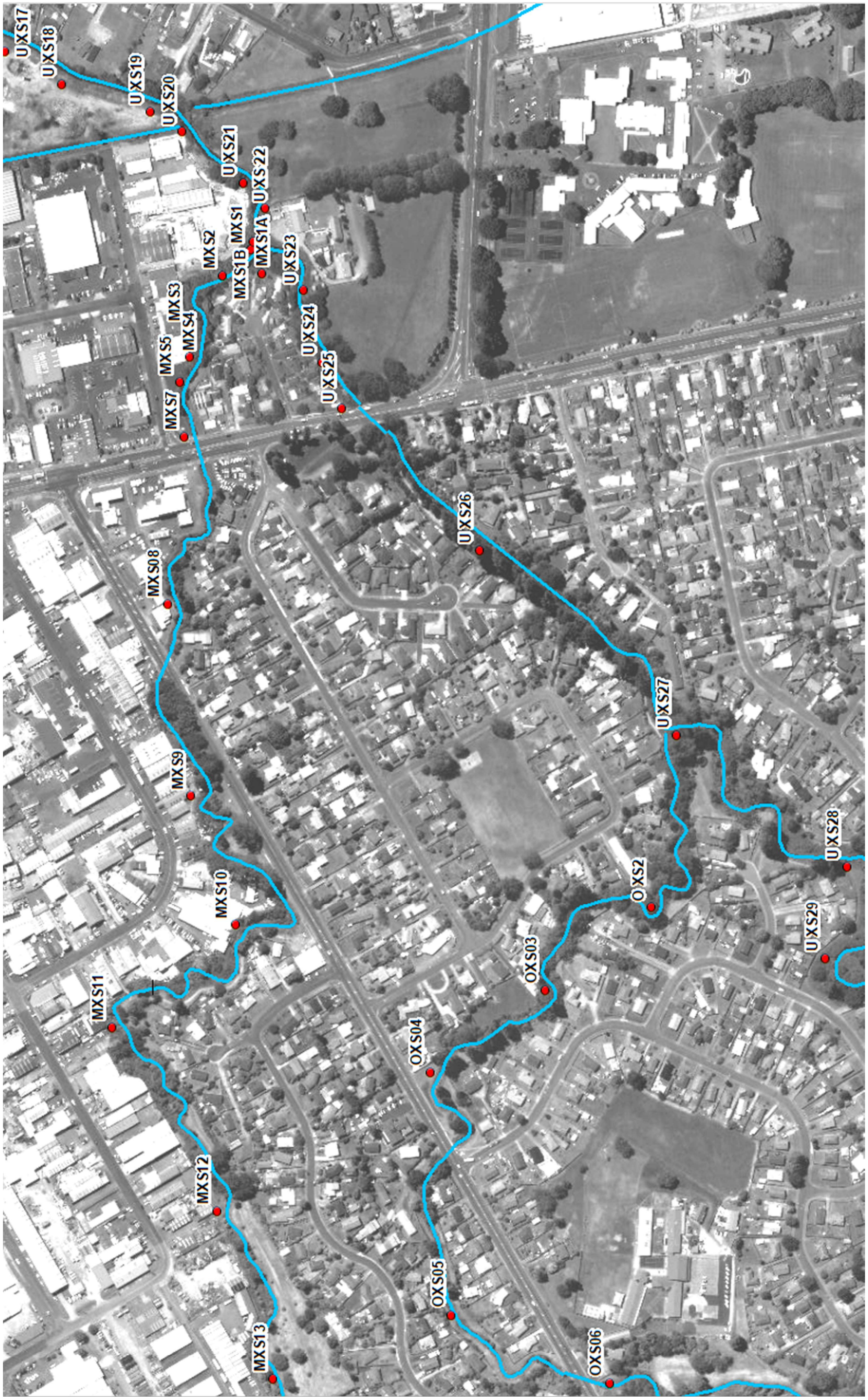
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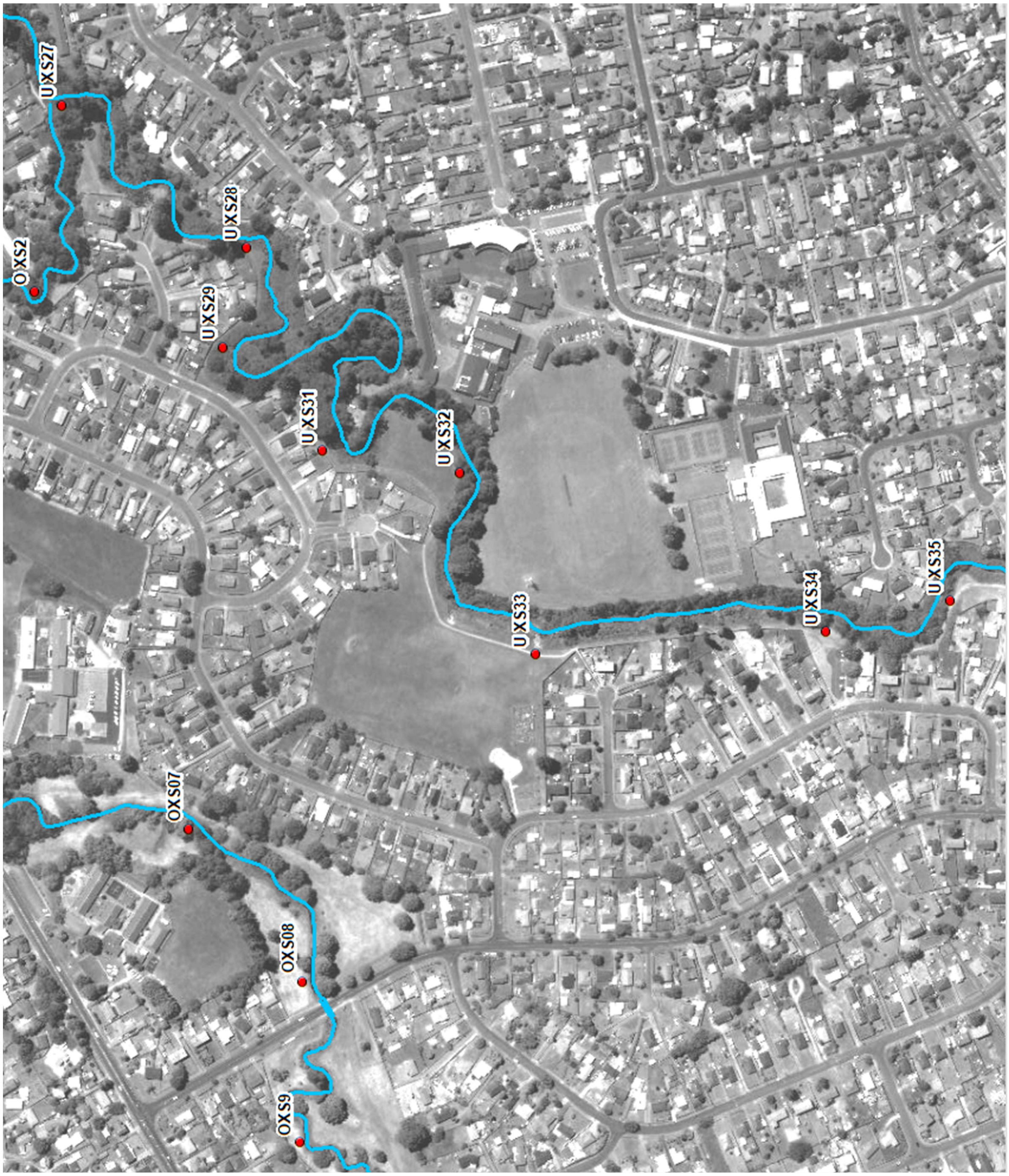
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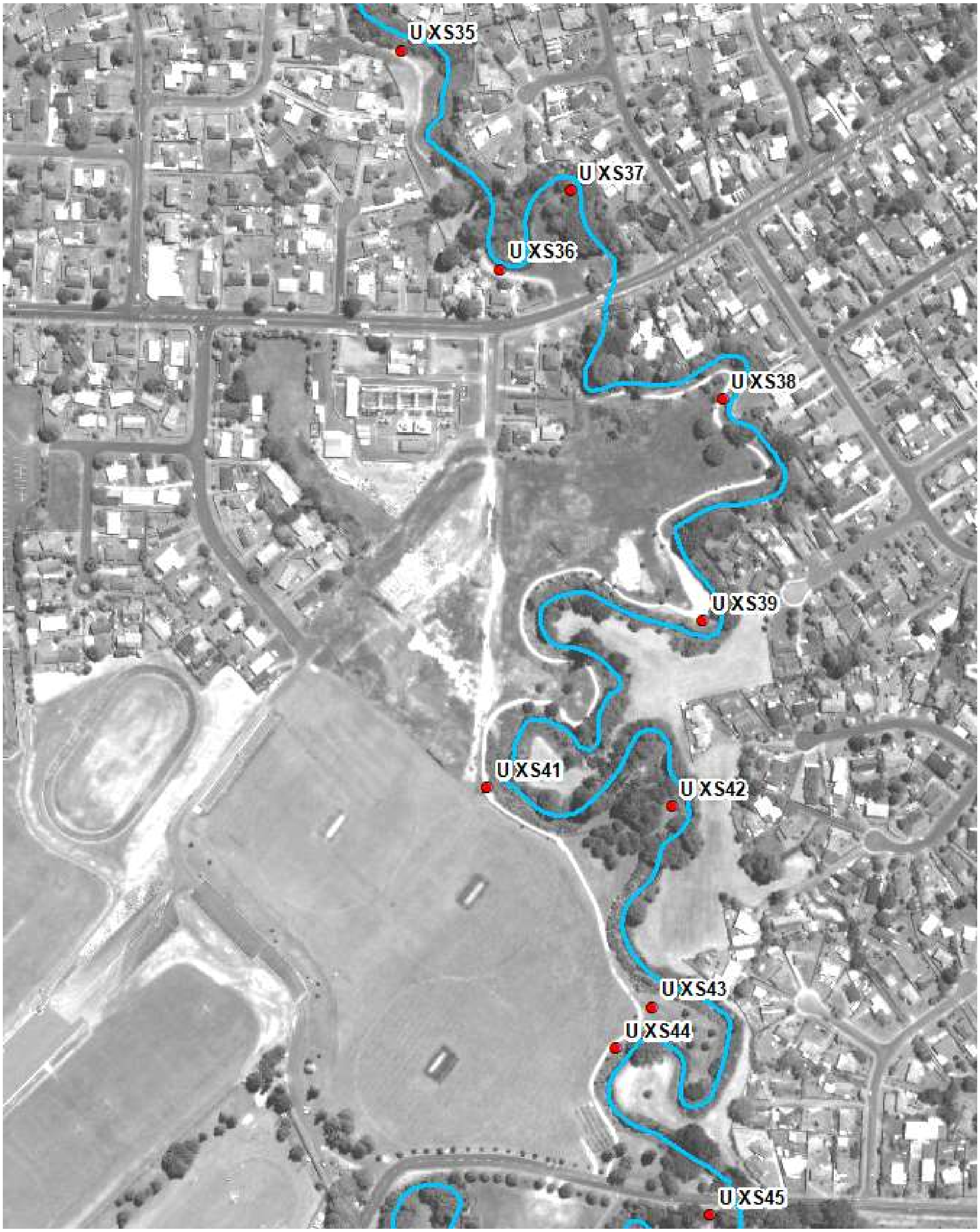
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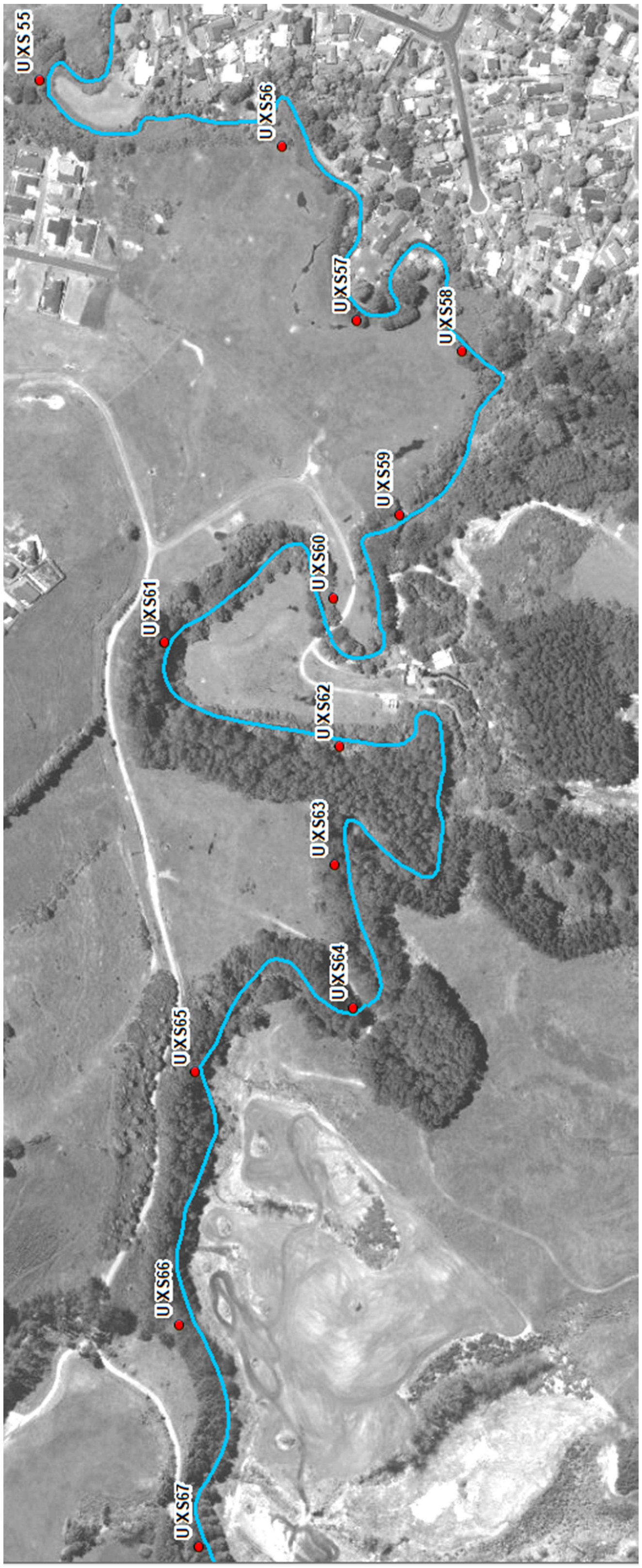
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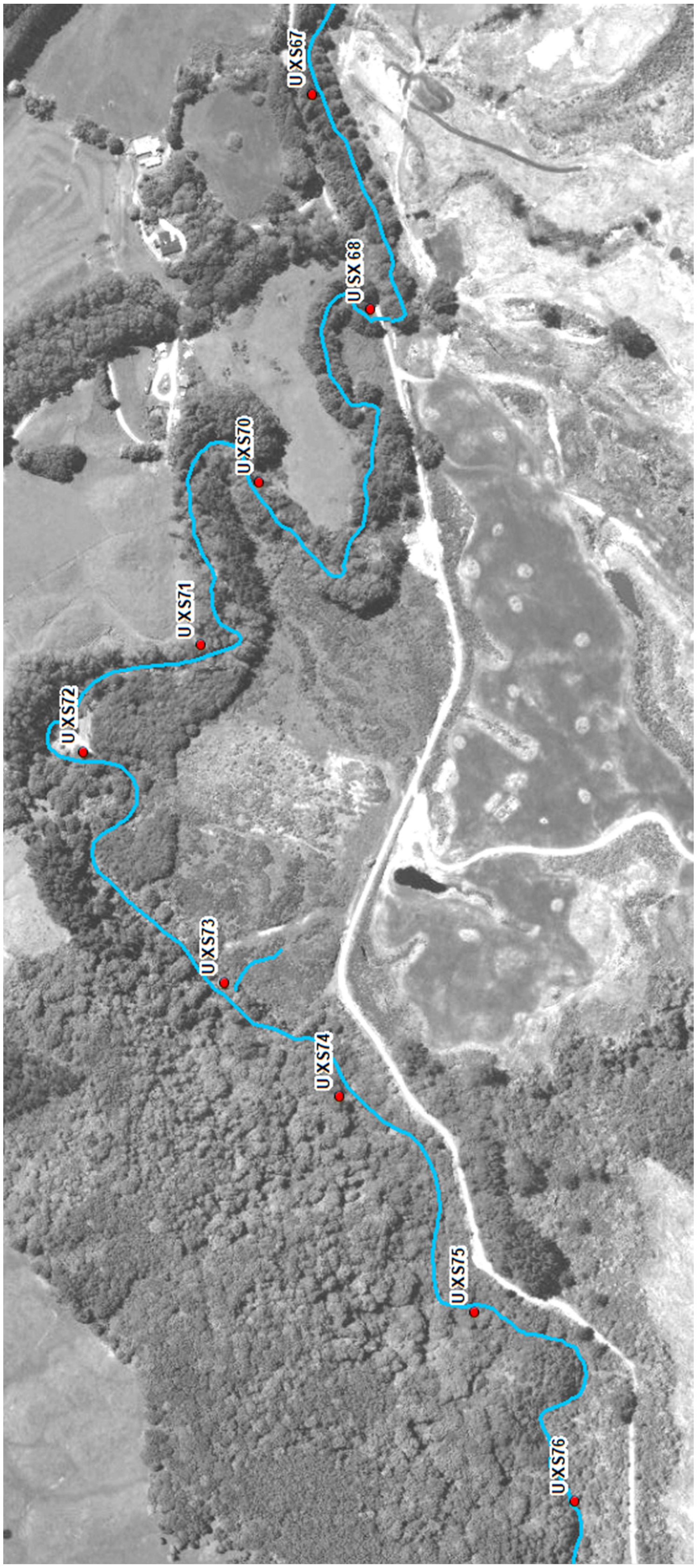
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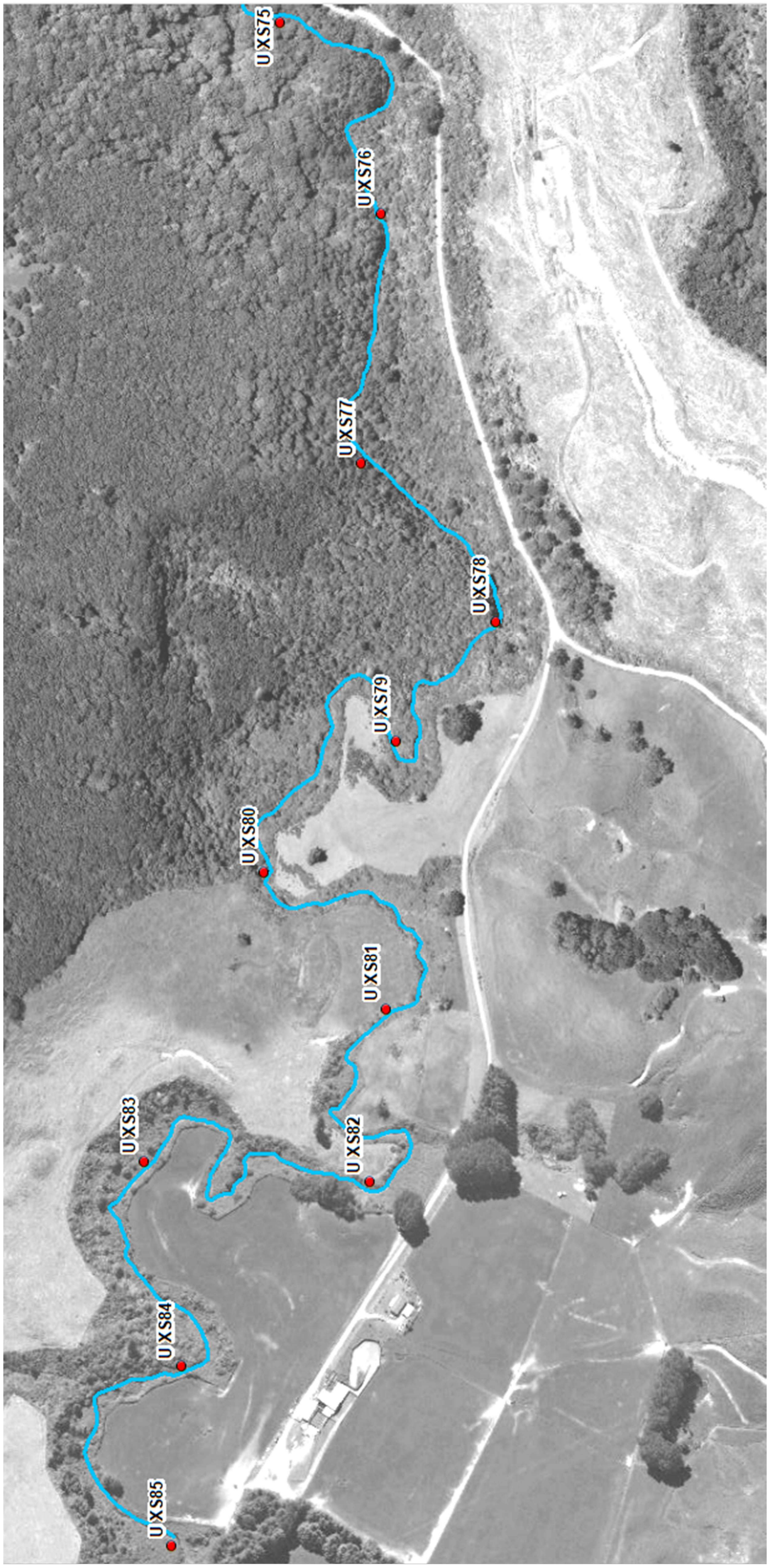
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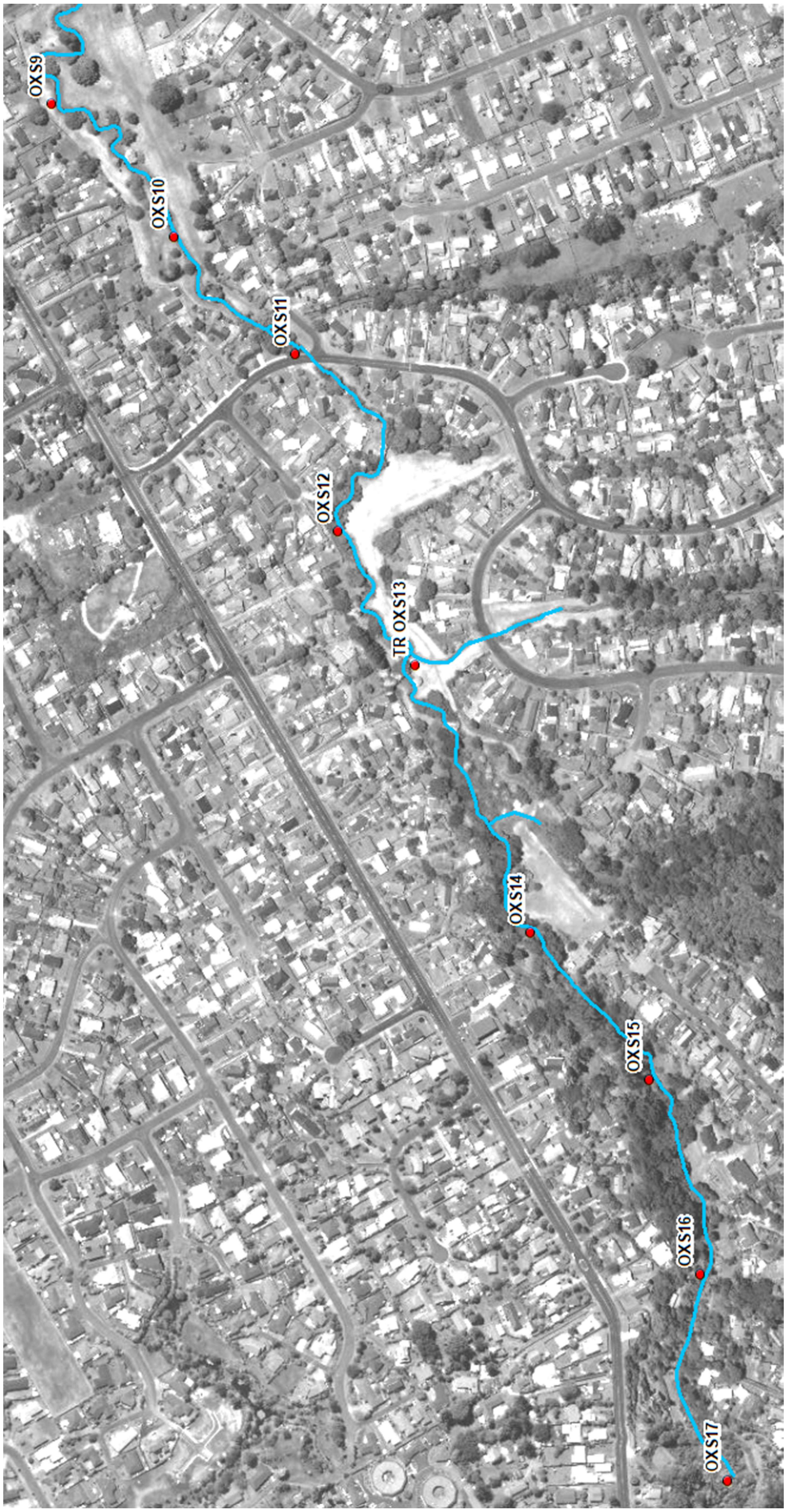
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OXS10
OXS11
OXS12
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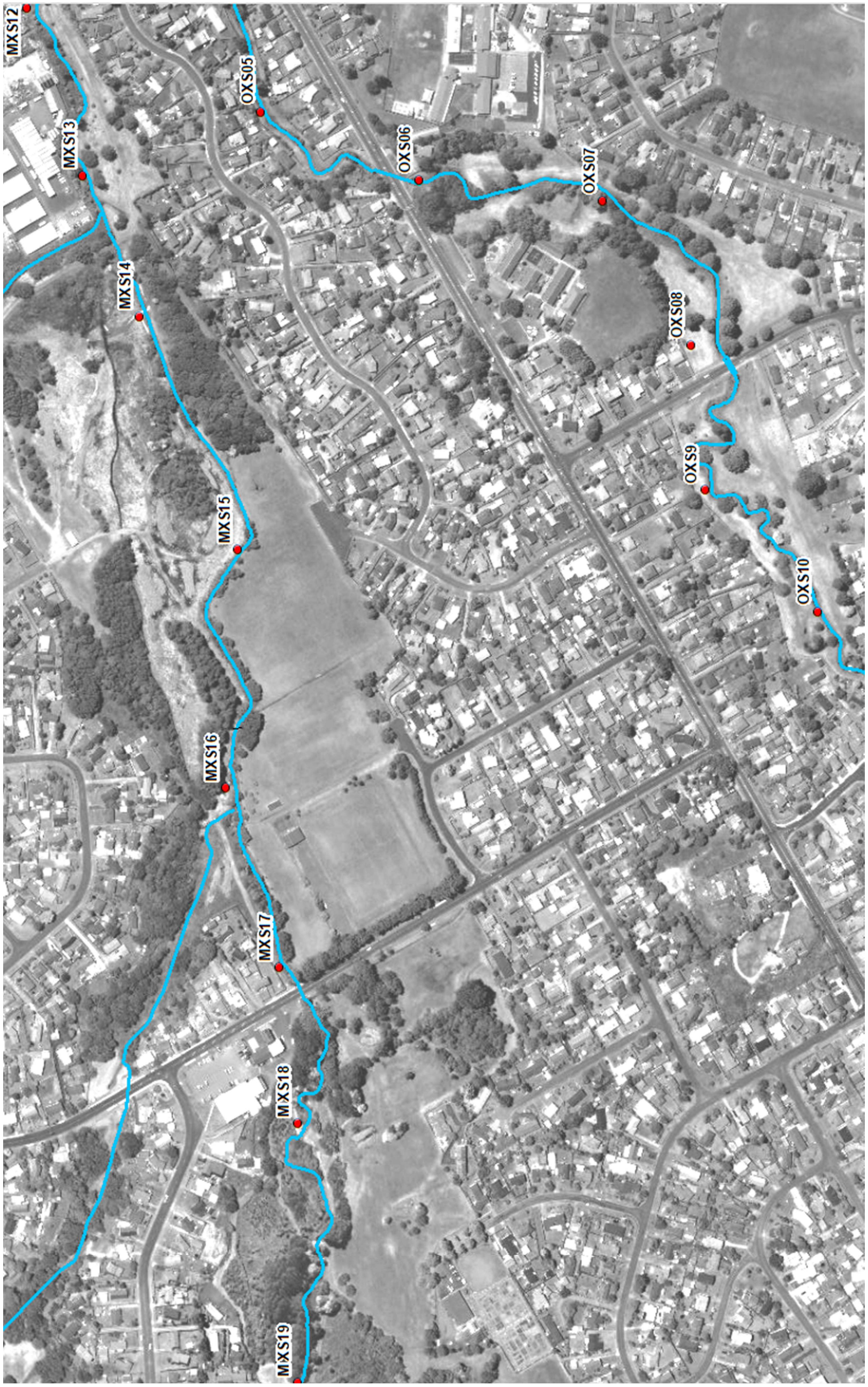
OXS17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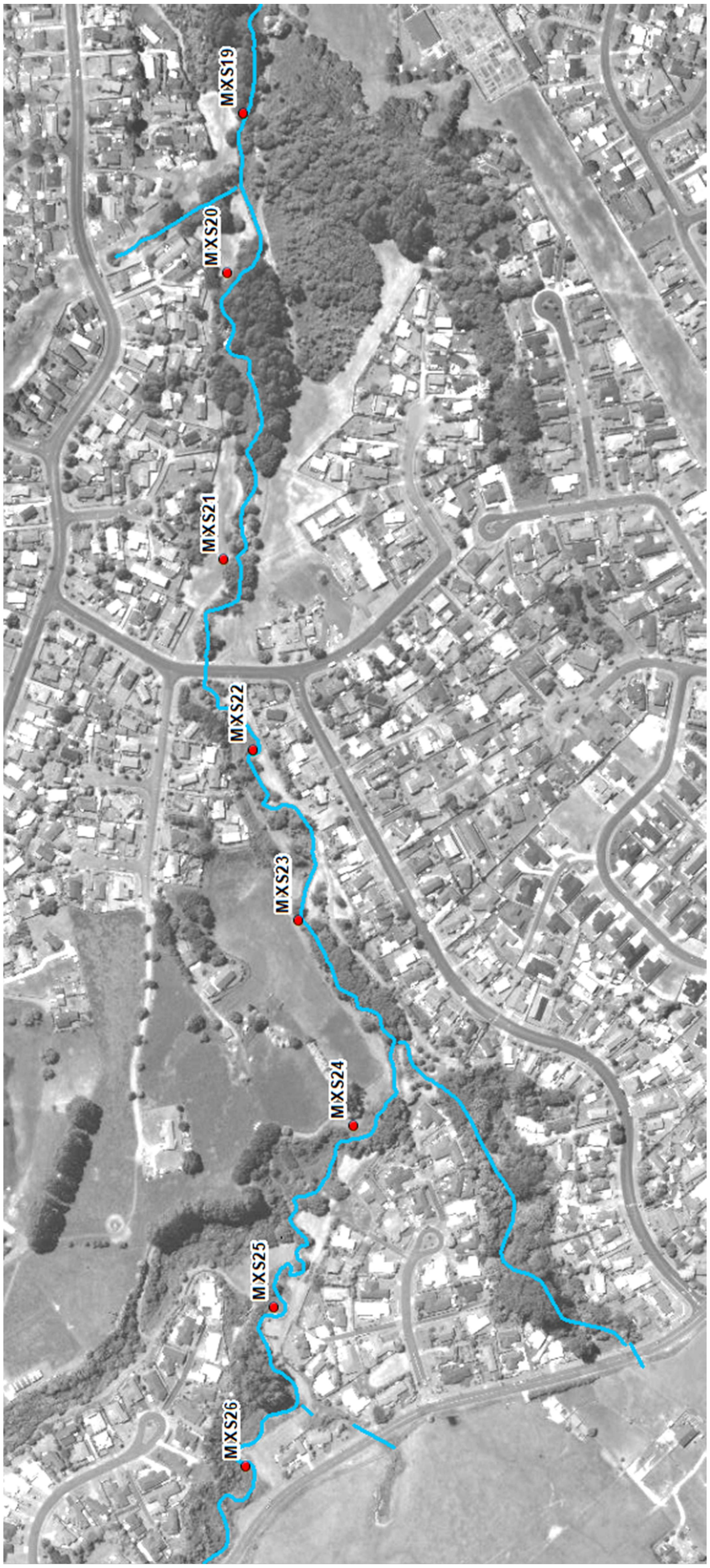
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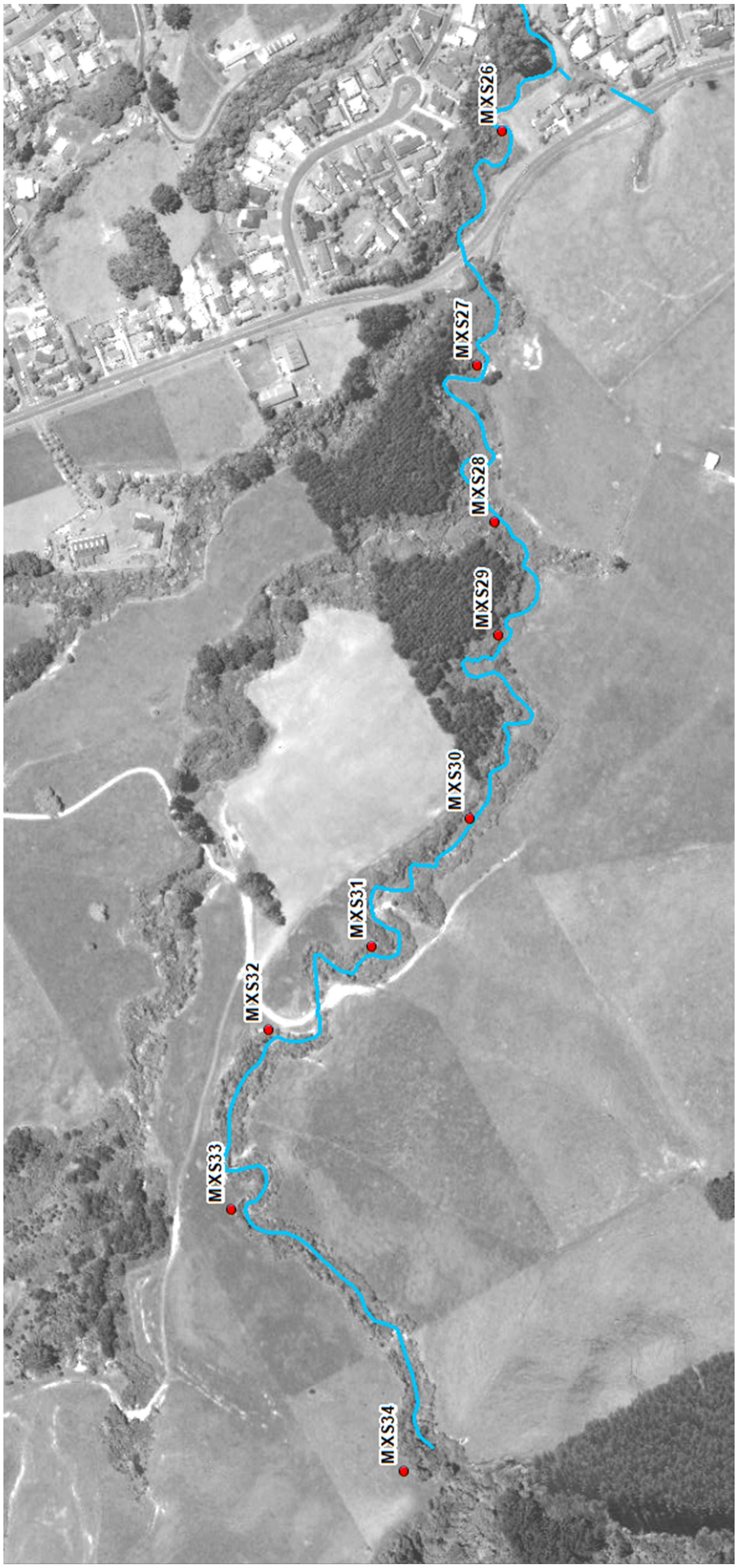
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APPENDIX E–Calibration Results

Peak flood levels

E Calibration Results

Model results are compared to recorded debris levels for the March 2017 flood event. “Debris MC” indicates the survey team had medium confidence in the debris level and “Debris HC” indicates high confidence.

						Model prediction			Model prediction		
	Recorded debris					NLR calibration model			revised NLR model (design runs)		
Branch	Easting	Northing	Elevation	Feature_Co	Chainage	Model	Error	absolute	Model	Error	absolute
OTAMATEA	1882616.404	5773967.358	285.351	Debris MC	3323	285.4881	0.137	0.1371	285.4857	0.135	0.1347
OTAMATEA	1882617.965	5773969.408	285.291	Debris MC	3327	285.4844	0.193	0.1934	285.482	0.191	0.191
OTAMATEA	1882832.195	5774061.067	284.644	Debris MC	3645	284.5959	-0.048	0.0481	284.595	-0.049	0.049
OTAMATEA	1882888.900	5774082.097	284.333	Debris MC	3723	284.4988	0.166	0.1658	284.4982	0.165	0.1652
OTAMATEA	1882888.900	5774082.097	284.333	Debris MC	3727	284.4918	0.159	0.1588	284.4913	0.158	0.1583
OTAMATEA	1882894.388	5774080.897	284.267	Debris MC	3731	284.4845	0.218	0.2175	284.484	0.217	0.217
AVERAGE							**0.137**	**0.153**		**0.136**	**0.153**

						Model prediction			Model prediction		
	Recorded debris					NLR calibration model			revised NLR model (design runs)		
Branch	Easting	Northing	Elevation	Feature_Co	Chainage	Model	Error	absolute	Model	Error	absolute
UTUHINA	1881888.456	5771439.954	296.102	Debris HC	2953	296.1781	0.0761	0.0761	296.0415	-0.0605	0.0605
UTUHINA	1881888.456	5771439.954	296.102	Debris HC	2957	296.1653	0.0633	0.0633	296.0277	-0.0743	0.0743
UTUHINA	1881888.456	5771439.954	296.102	Debris HC	3016	295.9638	-0.1382	0.1382	295.8195	-0.2825	0.2825
UTUHINA	1881918.613	5771433.546	296.087	Debris HC	3059	295.7872	-0.2998	0.2998	295.6536	-0.4334	0.4334
UTUHINA	1882096.613	5771342.996	295.004	Debris HC	3296	295.0887	0.0847	0.0847	294.9626	-0.0414	0.0414
UTUHINA	1882096.613	5771342.996	295.004	Debris HC	3300	295.0730	0.0690	0.0690	294.9473	-0.0567	0.0567
UTUHINA	1882096.613	5771342.996	295.004	Debris HC	3308	295.0402	0.0362	0.0362	294.9162	-0.0878	0.0878
UTUHINA	1882096.613	5771342.996	295.004	Debris HC	3316	295.0061	0.0021	0.0021	294.8844	-0.1196	0.1196
UTUHINA	1882162.969	5771375.846	294.533	Debris HC	3380	294.7106	0.1776	0.1776	294.6158	0.0828	0.0828
UTUHINA	1882162.969	5771375.846	294.533	Debris HC	3388	294.6775	0.1445	0.1445	294.5837	0.0507	0.0507
UTUHINA	1882252.635	5771458.632	293.837	Debris HC	3666	293.8811	0.0441	0.0441	293.7297	-0.1073	0.1073
UTUHINA	1882252.635	5771458.632	293.837	Debris HC	3670	293.8672	0.0302	0.0302	293.7160	-0.1210	0.1210
UTUHINA	1882252.635	5771458.632	293.837	Debris HC	3678	293.8393	0.0023	0.0023	293.6885	-0.1485	0.1485
UTUHINA	1882278.621	5771485.451	293.844	Debris HC	3706	293.7401	-0.1039	0.1039	293.5902	-0.2538	0.2538
UTUHINA	1882278.621	5771485.451	293.844	Debris HC	3710	293.7256	-0.1184	0.1184	293.5759	-0.2681	0.2681
UTUHINA	1882278.621	5771485.451	293.844	Debris HC	3714	293.7112	-0.1328	0.1328	293.5616	-0.2824	0.2824
UTUHINA	1882326.964	5771629.189	293.253	Debris HC	3901	293.1037	-0.1493	0.1493	292.9589	-0.2941	0.2941
UTUHINA	1882326.964	5771629.189	293.253	Debris HC	3905	293.0941	-0.1589	0.1589	292.9492	-0.3038	0.3038
UTUHINA	1882329.818	5771663.561	293.182	Debris HC	3953	293.0032	-0.1788	0.1788	292.8546	-0.3274	0.3274
UTUHINA	1882329.818	5771663.561	293.182	Debris HC	3957	292.9957	-0.1863	0.1863	292.8470	-0.3350	0.3350
UTUHINA	1882332.740	5771673.869	293.094	Debris HC	3969	292.9735	-0.1205	0.1205	292.8244	-0.2696	0.2696
UTUHINA	1882332.740	5771673.869	293.094	Debris HC	3973	292.9662	-0.1278	0.1278	292.8169	-0.2771	0.2771
UTUHINA	1882332.740	5771673.869	293.094	Debris HC	3981	292.9515	-0.1425	0.1425	292.8021	-0.2919	0.2919
UTUHINA	1882340.236	5771677.633	292.951	Debris HC	4060	292.7964	-0.1546	0.1546	292.6483	-0.3027	0.3027
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4250	292.4011	-0.0259	0.0259	292.2480	-0.1790	0.1790
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4262	292.3761	-0.0509	0.0509	292.2252	-0.2018	0.2018
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4274	292.3546	-0.0724	0.0724	292.2043	-0.2227	0.2227
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4290	292.3249	-0.1021	0.1021	292.1754	-0.2516	0.2516
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4310	292.2846	-0.1424	0.1424	292.1368	-0.2902	0.2902
UTUHINA	1882481.285	5771704.968	292.427	Debris HC	4314	292.2772	-0.1498	0.1498	292.1297	-0.2973	0.2973
UTUHINA	1882537.549	5771717.025	292.178	Debris HC	4348	292.2118	0.0338	0.0338	292.0658	-0.1122	0.1122
UTUHINA	1882569.623	5771693.541	292.080	Debris HC	4410	292.0953	0.0153	0.0153	291.9496	-0.1304	0.1304
UTUHINA	1882662.607	5771746.561	291.731	debris hc	4511	291.8703	0.1393	0.1393	291.7269	-0.0041	0.0041
UTUHINA	1882662.607	5771746.561	291.731	debris hc	4526	291.8353	0.1043	0.1043	291.6913	-0.0397	0.0397
UTUHINA	1882662.494	5771855.377	291.533	debris mc	4736	291.3405	-0.1925	0.1925	291.1991	-0.3339	0.3339
UTUHINA	1882662.494	5771855.377	291.533	debris mc	4740	291.3347	-0.1983	0.1983	291.1931	-0.3399	0.3399
UTUHINA	1882662.494	5771855.377	291.533	debris mc	4748	291.3234	-0.2096	0.2096	291.1816	-0.3514	0.3514
UTUHINA	1882712.930	5771854.898	291.537	debris hc	4788	291.2739	-0.2631	0.2631	291.1309	-0.4061	0.4061
UTUHINA	1882712.930	5771854.898	291.537	debris hc	4796	291.2650	-0.2720	0.2720	291.1216	-0.4154	0.4154
UTUHINA	1882780.798	5771889.329	291.491	debris mc	4864	291.1721	-0.3189	0.3189	291.0274	-0.4636	0.4636

						Model prediction			Model prediction		
	Recorded debris					NLR calibration model			revised NLR model (design runs)		
Branch	Easting	Northing	Elevation	Feature_Co	Chainage	Model	Error	absolute	Model	Error	absolute
UTUHINA	1882780.798	5771889.329	291.491	debris mc	4868	291.1671	-0.3239	0.3239	291.0220	-0.4690	0.4690
UTUHINA	1882675.117	5771978.086	291.009	debris hc	5085	290.8662	-0.1428	0.1428	290.7262	-0.2828	0.2828
UTUHINA	1882711.733	5772008.301	290.988	debris hc	5125	290.8165	-0.1715	0.1715	290.6779	-0.3101	0.3101
UTUHINA	1882711.733	5772008.301	290.988	debris hc	5132	290.8064	-0.1816	0.1816	290.6682	-0.3198	0.3198
UTUHINA	1882743.989	5772040.271	290.938	debris hc	5168	290.7563	-0.1817	0.1817	290.6207	-0.3173	0.3173
UTUHINA	1882743.989	5772040.271	290.938	debris hc	5180	290.7395	-0.1985	0.1985	290.6048	-0.3332	0.3332
UTUHINA	1882736.822	5772079.157	290.712	debris hc	5196	290.7173	0.0053	0.0053	290.5837	-0.1283	0.1283
UTUHINA	1882768.428	5772096.169	290.345	debris hc	5366	290.4873	0.1423	0.1423	290.3555	0.0105	0.0105
UTUHINA	1882768.428	5772096.169	290.345	debris hc	5374	290.4753	0.1303	0.1303	290.3441	-0.0009	0.0009
UTUHINA	1882807.636	5772165.544	290.165	debris mc	5484	290.3178	0.1528	0.1528	290.1866	0.0216	0.0216
UTUHINA	1882807.636	5772165.544	290.165	debris mc	5492	290.3035	0.1385	0.1385	290.1727	0.0077	0.0077
UTUHINA	1882800.767	5772191.420	290.208	debris hc	5516	290.2565	0.0485	0.0485	290.1284	-0.0796	0.0796
UTUHINA	1882800.767	5772191.420	290.208	debris hc	5528	290.2350	0.0270	0.0270	290.1086	-0.0994	0.0994
UTUHINA	1882801.550	5772209.289	290.047	debris mc	5544	290.2131	0.1661	0.1661	290.0871	0.0401	0.0401
UTUHINA	1882801.550	5772209.289	290.047	debris mc	5555	290.1945	0.1475	0.1475	290.0694	0.0224	0.0224
UTUHINA	1882801.550	5772209.289	290.047	debris mc	5571	290.1693	0.1223	0.1223	290.0453	-0.0017	0.0017
UTUHINA	1882808.547	5772200.477	290.039	debris hc	5627	290.0754	0.0364	0.0364	289.9558	-0.0832	0.0832
UTUHINA	1882808.547	5772200.477	290.039	debris hc	5631	290.0668	0.0278	0.0278	289.9471	-0.0919	0.0919
UTUHINA	1882808.547	5772200.477	290.039	debris hc	5635	290.0539	0.0149	0.0149	289.9370	-0.1020	0.1020
UTUHINA	1882972.766	5772163.075	289.617	debris mc	5856	289.7161	0.0991	0.0991	289.6235	0.0065	0.0065
UTUHINA	1882972.766	5772163.075	289.617	debris mc	5860	289.7133	0.0963	0.0963	289.6210	0.0040	0.0040
UTUHINA	1883046.920	5772189.712	289.742	debris mc	5931	289.6751	-0.0669	0.0669	289.5868	-0.1552	0.1552
UTUHINA	1882957.142	5772259.594	289.605	Debris HC	6040	289.4382	-0.1668	0.1668	289.2982	-0.3068	0.3068
UTUHINA	1882977.887	5772361.150	289.163	Debris HC	6321	288.9862	-0.1768	0.1768	288.8351	-0.3279	0.3279
UTUHINA	1882979.240	5772504.577	288.922	Debris HC	6486	288.6157	-0.3063	0.3063	288.4637	-0.4583	0.4583
UTUHINA	1882912.597	5772577.292	288.275	Debris HC	6781	288.2135	-0.0615	0.0615	288.0634	-0.2116	0.2116
UTUHINA	1882912.597	5772577.292	288.275	Debris HC	6809	288.1868	-0.0882	0.0882	288.0357	-0.2393	0.2393
UTUHINA	1882912.597	5772577.292	288.275	Debris HC	6833	288.1628	-0.1122	0.1122	288.0119	-0.2631	0.2631
UTUHINA	1882902.916	5772609.548	288.192	Debris HC	6913	288.0818	-0.1102	0.1102	287.9306	-0.2614	0.2614
UTUHINA	1882902.916	5772609.548	288.192	Debris HC	6917	288.0783	-0.1137	0.1137	287.9269	-0.2651	0.2651
UTUHINA	1883001.195	5772658.699	287.759	Debris HC	7128	287.8469	0.0879	0.0879	287.6898	-0.0692	0.0692
UTUHINA	1883034.566	5772762.284	287.570	Debris HC	7304	287.5766	0.0066	0.0066	287.4203	-0.1497	0.1497
UTUHINA	1883034.566	5772762.284	287.570	Debris HC	7312	287.5623	-0.0077	0.0077	287.4064	-0.1636	0.1636
UTUHINA	1883005.359	5772805.522	287.447	Debris HC	7428	287.3770	-0.0700	0.0700	287.2246	-0.2224	0.2224
UTUHINA	1883005.359	5772805.522	287.447	Debris HC	7432	287.3716	-0.0754	0.0754	287.2193	-0.2277	0.2277
UTUHINA	1882910.014	5772820.700	287.114	Debris HC	7512	287.2870	0.1730	0.1730	287.1333	0.0193	0.0193
UTUHINA	1882910.014	5772820.700	287.114	Debris HC	7516	287.2834	0.1694	0.1694	287.1295	0.0155	0.0155
UTUHINA-BRIDGES	1882926.144	5772869.733	287.181	Debris HC	7568	287.2401	0.0591	0.0591	287.0856	-0.0954	0.0954
UTUHINA	1882893.848	5772900.938	287.024	Debris HC	7751	286.9426	-0.0814	0.0814	286.7937	-0.2303	0.2303
UTUHINA	1882893.848	5772900.938	287.024	Debris HC	7755	286.9374	-0.0866	0.0866	286.7882	-0.2358	0.2358
UTUHINA	1882807.796	5772970.344	286.819	Debris HC	7866	286.7630	-0.0560	0.0560	286.6150	-0.2040	0.2040
UTUHINA	1882807.796	5772970.344	286.819	Debris HC	7874	286.7504	-0.0686	0.0686	286.6024	-0.2166	0.2166
UTUHINA	1882785.050	5773059.783	286.524	Debris HC	7990	286.5336	0.0096	0.0096	286.3851	-0.1389	0.1389
UTUHINA	1882767.326	5773165.409	286.396	Debris HC	8105	286.2857	-0.1103	0.1103	286.1402	-0.2558	0.2558
UTUHINA	1882767.326	5773165.409	286.396	Debris HC	8113	286.2693	-0.1267	0.1267	286.1242	-0.2718	0.2718
UTUHINA	1882773.182	5773234.077	286.223	Debris HC	8177	286.1404	-0.0826	0.0826	285.9982	-0.2248	0.2248
UTUHINA	1882773.182	5773234.077	286.223	Debris HC	8180	286.1326	-0.0904	0.0904	285.9905	-0.2325	0.2325
UTUHINA	1882766.817	5773281.286	286.093	Debris HC	8224	286.0482	-0.0448	0.0448	285.9072	-0.1858	0.1858
UTUHINA	1882766.817	5773281.286	286.093	Debris HC	8232	286.0333	-0.0597	0.0597	285.8924	-0.2006	0.2006
UTUHINA	1882762.338	5773327.432	286.053	Debris HC	8276	285.9542	-0.0988	0.0988	285.8137	-0.2393	0.2393
UTUHINA	1882753.425	5773392.649	285.781	Debris HC	8339	285.8491	0.0681	0.0681	285.7089	-0.0721	0.0721
UTUHINA	1882753.425	5773392.649	285.781	Debris HC	8347	285.8370	0.0560	0.0560	285.6967	-0.0843	0.0843
UTUHINA	1882762.048	5773452.008	285.867	Debris HC	8403	285.7565	-0.1105	0.1105	285.6158	-0.2512	0.2512
UTUHINA	1882762.048	5773452.008	285.867	Debris HC	8407	285.7509	-0.1161	0.1161	285.6102	-0.2568	0.2568
UTUHINA	1882762.048	5773452.008	285.867	Debris HC	8411	285.7453	-0.1217	0.1217	285.6046	-0.2624	0.2624
UTUHINA	1882774.435	5773503.079	285.712	Debris HC	8454	285.6848	-0.0272	0.0272	285.5440	-0.1680	0.1680
UTUHINA	1882829.719	5773515.389	285.700	Debris HC	8501	285.6204	-0.0796	0.0796	285.4800	-0.2200	0.2200

	Recorded debris					Model prediction NLR calibration model			Model prediction revised NLR model (design runs)		
Branch	Easting	Northing	Elevation	Feature_Co	Chainage	Model	Error	absolute	Model	Error	absolute
UTUHINA	1882829.719	5773515.389	285.700	Debris HC	8505	285.6151	-0.0849	0.0849	285.4747	-0.2253	0.2253
UTUHINA	1882916.865	5773503.208	285.581	Debris HC	8608	285.4776	-0.1034	0.1034	285.3401	-0.2409	0.2409
UTUHINA	1882921.851	5773507.762	285.553	Debris HC	8616	285.4665	-0.0865	0.0865	285.3293	-0.2237	0.2237
UTUHINA	1882947.528	5773549.974	285.342	Debris HC	8691	285.3543	0.0123	0.0123	285.2191	-0.1229	0.1229
UTUHINA	1882947.528	5773549.974	285.342	Debris HC	8699	285.3412	-0.0008	0.0008	285.2064	-0.1356	0.1356
UTUHINA	1882925.410	5773563.562	285.364	Debris HC	8731	285.2846	-0.0794	0.0794	285.1516	-0.2124	0.2124
UTUHINA	1882912.177	5773604.567	285.363	Debris HC	8763	285.2206	-0.1424	0.1424	285.0903	-0.2727	0.2727
UTUHINA	1883008.739	5773710.538	284.636	Debris HC	9128	284.6240	-0.0120	0.0120	284.4958	-0.1402	0.1402
UTUHINA	1883044.858	5773669.967	284.435	Debris HC	9200	284.4822	0.0472	0.0472	284.3588	-0.0762	0.0762
UTUHINA	1883090.377	5773675.835	284.372	Debris HC	9248	284.3848	0.0128	0.0128	284.2620	-0.1100	0.1100
UTUHINA	1883102.564	5773743.361	284.347	Debris HC	9340	284.1794	-0.1676	0.1676	284.0522	-0.2948	0.2948
UTUHINA	1883143.627	5773766.455	284.185	Debris HC	9375	284.1095	-0.0755	0.0755	283.9820	-0.2030	0.2030
UTUHINA	1883143.627	5773766.455	284.185	Debris HC	9391	284.0798	-0.1052	0.1052	283.9524	-0.2326	0.2326
UTUHINA	1883217.240	5773818.282	283.963	Debris HC	9498	283.8806	-0.0824	0.0824	283.7576	-0.2054	0.2054
UTUHINA	1883217.240	5773818.282	283.963	Debris HC	9502	283.8723	-0.0907	0.0907	283.7496	-0.2134	0.2134
UTUHINA	1883217.240	5773818.282	283.963	Debris HC	9522	283.8286	-0.1344	0.1344	283.7073	-0.2557	0.2557
UTUHINA	1883240.209	5773877.070	283.949	Debris HC	9578	283.7053	-0.2437	0.2437	283.5791	-0.3699	0.3699
UTUHINA	1883240.209	5773877.070	283.949	Debris HC	9580	283.7009	-0.2481	0.2481	283.5744	-0.3746	0.3746
UTUHINA	1883240.209	5773877.070	283.949	Debris HC	9585	283.6880	-0.2610	0.2610	283.5604	-0.3886	0.3886
UTUHINA	1883261.694	5773882.450	283.674	Debris MC	9597	283.6615	-0.0125	0.0125	283.5324	-0.1416	0.1416
UTUHINA	1883424.553	5774032.153	283.382	Debris HC	9836	283.1208	-0.2613	0.2613	282.9942	-0.3879	0.3879
UTUHINA	1883440.398	5774056.004	283.346	Debris HC	9866	283.0684	-0.2776	0.2776	282.9426	-0.4034	0.4034
UTUHINA	1883476.871	5774114.395	283.234	Debris clear MC	9921	282.9892	-0.2448	0.2448	282.8648	-0.3692	0.3692
UTUHINA	1883476.871	5774114.395	283.234	Debris clear MC	9931	282.9769	-0.2571	0.2571	282.8530	-0.3810	0.3810
UTUHINA	1883476.871	5774114.395	283.234	Debris clear MC	9948	282.9560	-0.2780	0.2780	282.8330	-0.4010	0.4010
AVERAGE					0		**-0.0664**	**0.1168**		**-0.2038**	**0.2084**

APPENDIX F–Design Level Results

Peak flood levels

F Design Level Results

The following tables present design scenario flood levels for the Utuhina, Mangakakahi and Otamatea Streams.

In the lower reaches, downstream of Old Taupo Road, where the Kaituna Catchment Control Scheme specifies a 1% AEP standard of protection, design levels including freeboard are provided. As outlined in section 5.6, an increased freeboard of 700 mm is assumed, in light of calibration results. Existing bank levels are also provided in the following tables for the lower reaches, although in some cases the top of the bank is not well-defined (especially between Old Taupo Road and Lake Road).

Cross-section locations are shown in Appendix D.

All levels are in terms of Moturiki Datum 1953.

F.1 Utuhina Stream

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
uxs85	-2960			338.00	338.42	339.34	338.99	339.58	341.00		
uxs84	-2720			336.89	337.45	338.43	338.07	338.67	340.12		
uxs83	-2483			335.58	336.08	337.34	336.89	337.63	339.21		
uxs82	-2156			334.59	335.06	336.20	335.79	336.47	337.98		
uxs81	-1895			333.60	334.12	335.20	334.86	335.43	336.75		
uxs80	-1638			332.04	332.61	333.60	333.27	333.82	335.11		
uxs79	-1359			330.19	330.71	331.82	331.46	332.06	333.45		
uxs78	-1168			327.82	328.14	329.19	328.76	329.51	331.43		
uxs77	-981			325.83	326.58	328.49	327.82	328.94	331.24		
uxs76	-760			325.56	326.23	327.94	327.34	328.33	330.34		
uxs75	-497			323.12	323.52	324.44	324.12	324.67	325.88		
uxs74	-249			319.69	320.06	320.96	320.63	321.18	322.36		
uxs73	-100			317.39	317.74	318.70	318.34	318.93	320.13		
uxs72	188			313.58	313.96	314.95	314.60	315.18	316.46		
uxs71	395			311.43	311.85	312.90	312.52	313.18	314.64		
uxs70	678			308.56	309.06	310.24	309.84	310.49	311.79		
uxs69	901			307.00	307.48	308.51	308.16	308.74	310.47		
xs68	1102			304.81	305.38	306.59	306.19	306.95	309.86		
ub68down	1140			304.47	305.03	306.36	305.89	306.65	308.33		
uxs67	1363			303.78	304.29	305.50	305.06	305.78	307.29		
uxs66	1569			302.48	302.97	304.24	303.78	304.53	306.10		
uxs65	1793			301.27	301.76	303.14	302.65	303.45	304.99		
uxs64	2002			299.82	300.42	301.85	301.39	302.15	303.62		
ub64down	2012			299.81	300.40	301.80	301.33	302.07	303.44		
uxs63	2146			299.16	299.68	300.95	300.50	301.25	302.73		
uxs62	2520			297.29	297.77	298.85	298.50	299.08	300.05		
uxs61	2718			296.54	296.88	297.66	297.43	297.81	298.65		
uxs60	2916			295.93	296.35	297.21	296.93	297.40	298.38		
ub60up	2933			295.87	296.29	297.16	296.87	297.36	298.40		
ub60down	2949			295.82	296.24	297.09	296.80	297.28	298.25		

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
uxs59	3140			295.17	295.59	296.55	296.23	296.74	297.82		
uxs58	3340			294.57	294.95	295.81	295.53	296.00	297.11		
uxs56	3738			293.24	293.74	294.86	294.54	295.07	296.31		
uxs55	4013			292.53	293.08	294.16	293.95	294.31	295.45		
uxs54	4170			292.20	292.77	293.88	293.69	294.03	295.29		
uxs53	4310			291.98	292.56	293.66	293.51	293.80	295.16		
ub52up	4437			291.78	292.36	293.42	293.34	293.53	294.95		
uxs52	4463			291.70	292.23	293.24	292.95	293.40	294.11		
uxs51	4673			291.20	291.75	292.83	292.54	292.97	293.46		
uxs49	5069			290.64	291.24	292.26	292.02	292.35	292.67		
uxs48	5311			290.34	290.96	291.92	291.69	292.01	292.31		
uxs47	5492			290.09	290.74	291.64	291.44	291.72	291.99		
uxs46	5722			289.73	290.41	291.21	291.05	291.27	291.55		
uxs45	5943			289.55	290.28	291.04	290.89	291.10	291.39		
ub45down	5968			289.35	289.87	291.00	290.73	291.08	291.32		
uxs44	6112			289.14	289.66	290.80	290.53	290.88	291.16		
uxs43	6333			288.76	289.32	290.51	290.24	290.61	290.99		
uxs42	6494			288.44	289.00	290.21	289.92	290.33	290.79		
uxs41	6705			288.15	288.71	289.94	289.65	290.07	290.60		
uxs39	7092			287.75	288.34	289.59	289.32	289.72	290.38		
ub37up	7568			287.12	287.75	289.18	288.87	289.33	290.25		
ub37down	7592			287.07	287.63	288.90	288.55	289.08	289.99		
uxs37	7665			286.94	287.52	288.80	288.45	288.98	289.92		
uxs36	7775			286.79	287.37	288.66	288.32	288.85	289.79		
uxs35	7992			286.42	287.01	288.26	287.93	288.43	289.35		
uxs34	8113			286.17	286.75	287.97	287.66	288.14	288.99		
uxs33	8375			285.72	286.30	287.44	287.16	287.58	288.18		
uxs32	8588			285.45	286.02	287.09	286.85	287.21	287.75		
uxs31	8775			285.17	285.73	286.83	286.58	286.96	287.53		
uxs30	8957			284.91	285.49	286.64	286.37	286.78	287.38		

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
uxs28	9280			284.41	284.96	286.02	285.78	286.15	286.79		
uxs27	9554			284.07	284.59	285.53	285.36	285.66	286.15		
uxs26	9830			283.64	284.18	285.07	284.97	285.15	285.39		
ub25up	9980			283.51	284.04	284.95	284.84	285.02	285.26		
uxs25	10015			283.30	283.66	284.22	284.10	284.30	284.57	284.36	285.00
uxs23	10143	283.88		283.16	283.49	284.05	283.93	284.13	284.40	284.19	284.83
mxs1a	10204			283.14	283.47	284.03	283.91	284.11	284.36	284.17	284.81
mxs1b	10218			283.12	283.44	283.98	283.86	284.06	284.30	284.14	284.76
uxs22	10249			283.08	283.39	283.94	283.81	284.02	284.26	284.09	284.72
uxs21	10288	283.64	283.40	283.02	283.31	283.83	283.71	283.90	284.17	284.01	284.60
uxs20	10363			282.92	283.20	283.70	283.57	283.75	284.01	283.90	284.45
UB20	10375			282.91	283.18	283.64	283.56	283.74	283.99	283.88	284.44
uxs18	10493	283.63	283.55	282.77	283.04	283.47	283.40	283.57	283.81	283.74	284.27
uxs17	10561	283.56	282.19	282.70	282.97	283.39	283.32	283.47	283.72	283.67	284.17
uxs16	10648	283.02	281.88	282.66	282.92	283.35	283.28	283.44	283.68	283.62	284.14
uxs15	10710	282.53	282.82	282.59	282.86	283.29	283.22	283.38	283.62	283.56	284.08
uxs14	10767	282.03	282.28	282.51	282.77	283.19	283.12	283.26	283.49	283.47	283.96
uxs013	10849	282.56	282.91	282.39	282.66	283.07	283.01	283.14	283.33	283.36	283.84
uxs12	10952	282.20	282.48	282.26	282.54	282.97	282.91	283.03	283.21	283.24	283.73
uxs11	11008	282.19	282.19	282.12	282.44	282.91	282.85	282.98	283.15	283.14	283.68
uxs10	11023			282.08	282.40	282.90	282.83	282.97	283.16	283.10	283.67
uxs08	11072	282.40	282.14	282.02	282.21	282.42	282.38	282.46	282.58	282.91	283.16
uxs07	11131	282.20		281.91	282.10	282.31	282.28	282.34	282.45	282.80	283.04
uxs05	11297	281.91		281.54	281.71	281.95	281.92	281.98	282.05	282.41	282.68
uxs03	11417	281.63	281.05	281.27	281.44	281.69	281.66	281.72	281.81	282.14	282.42
uxs02	11483	281.52	280.78	281.15	281.31	281.55	281.52	281.59	281.70	282.01	282.29
uxs01	11561	281.38	281.36	280.87	280.99	281.19	281.16	281.23	281.33	281.69	281.93
ulxs02	11616			280.56	280.65	280.83	280.80	280.87	280.97	281.35	281.57
ulxs01	11704			280.28	280.29	280.37	280.40	280.41	280.48	280.99	281.11

F.2 Mangakakahi Stream

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
mb31up	4711			321.45	321.50	321.61	321.58	321.64	321.80		
mb31down	4723			321.22	321.27	321.38	321.35	321.41	321.57		
mb26up	5766			303.28	303.35	303.56	303.50	303.62	303.93		
mb26down	5784			302.97	303.07	303.32	303.25	303.39	303.72		
mb22up	6869			294.89	295.03	295.31	295.26	295.40	295.69		
mb22down	6894			294.72	294.86	295.16	295.10	295.26	295.53		
mb17up	7882			289.34	289.40	289.48	289.46	289.53	289.63		
mb17down	7901			289.24	289.28	289.37	289.36	289.40	289.49		
mb13up	8685			287.15	287.28	287.50	287.46	287.56	287.78		
mb13down	8707			287.05	287.16	287.41	287.37	287.49	287.73		
mb09bdown	9792			284.15	284.37	284.76	284.72	284.84	285.05		
mb09aup	9975			283.69	283.97	284.44	284.38	284.49	284.65		
mb09adown	10014			283.34	283.60	284.07	283.97	284.14	284.37		
mxs34	4166			337.23	337.28	337.38	337.35	337.41	337.55		
mxs33	4448			327.88	327.91	327.98	327.96	328.00	328.10		
mxs32	4651			322.88	322.92	323.01	322.98	323.04	323.16		
mxs31	4825			318.47	318.51	318.60	318.58	318.63	318.77		
mxs30	5045			313.60	313.67	313.84	313.78	313.88	314.04		
mxs29	5300			308.50	308.57	308.73	308.69	308.78	309.01		
mxs28	5438			306.73	306.85	307.12	307.05	307.20	307.56		
mxs27	5658			304.40	304.51	304.78	304.70	304.85	305.16		
mxs26	5921			301.71	301.82	302.07	302.01	302.14	302.39		
mxs25	6121			300.36	300.45	300.63	300.59	300.67	300.83		
mxs24	6359			298.16	298.27	298.53	298.47	298.61	298.82		
mxs23	6599			296.62	296.70	296.86	296.83	296.90	297.07		
mxs22	6786			295.56	295.65	295.84	295.80	295.91	296.16		
mxs21	6997			294.19	294.32	294.60	294.55	294.69	294.95		
mxs20	7272			292.64	292.74	292.95	292.91	293.02	293.23		
mxs19	7430			291.59	291.67	291.80	291.78	291.84	291.95		
mxs18	7723			290.14	290.19	290.27	290.26	290.31	290.40		

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
mxs17	7920			289.13	289.17	289.26	289.25	289.29	289.39		
mxs16	8106			288.51	288.57	288.68	288.67	288.72	288.83		
mxs15	8358			287.57	287.61	287.73	287.71	287.77	287.93		
mxs14	8617			287.24	287.37	287.56	287.54	287.62	287.80		
mxs13	8766			286.95	287.06	287.31	287.27	287.40	287.63		
mxs12	8947			286.63	286.74	287.04	286.99	287.16	287.48		
mxs11	9176			286.15	286.29	286.66	286.60	286.82	287.26		
mxs10	9391			285.51	285.66	286.06	285.99	286.21	286.67		
mxs9	9633			284.67	284.86	285.30	285.23	285.44	285.87		
mb09bup	9756			284.17	284.40	284.84	284.79	284.95	285.30		
mxs08	9837			284.02	284.25	284.64	284.59	284.69	284.85		
mxs6	10022			283.32	283.58	284.06	283.96	284.13	284.36	284.28	284.83
mxs5	10064			283.27	283.55	284.05	283.95	284.12	284.36	284.25	284.82
mxs4	10089			283.26	283.55	284.05	283.95	284.12	284.35	284.25	284.82
mxs3	10137			283.20	283.50	284.03	283.92	284.10	284.34	284.20	284.80
mxs2	10192			283.14	283.47	284.02	283.90	284.10	284.34	284.17	284.80
mxs1	10232			283.14	283.46	284.02	283.90	284.10	284.34	284.16	284.80

F.3 Otamatea Stream

Cross-section (2018 survey)	Model Chainage (m)	Existing top of bank		Peak flood levels						Design Levels (with Freeboard)	
				Current climate			2130 climate				
		Left bank	Right bank	2% AEP	1% AEP	0.2% AEP	2% AEP	1% AEP	0.2% AEP	1% AEP	1% AEP 2130
oxs17	1040			290.30	290.32	290.39	290.38	290.41	290.50		
oxs16	1240			289.40	289.43	289.49	289.48	289.52	289.61		
oxs15	1431			288.73	288.76	288.87	288.86	288.94	289.13		
oxs14	1609			288.37	288.48	288.73	288.72	288.84	289.07		
oxs13	1870			288.26	288.37	288.65	288.65	288.77	289.00		
oxs12	2065			288.16	288.28	288.57	288.57	288.69	288.91		
oxs11	2290			287.59	287.66	287.82	287.82	287.90	288.09		
oxs10	2453			287.15	287.21	287.34	287.34	287.42	287.61		
oxs09	2644			286.75	286.82	286.99	286.99	287.08	287.34		
ob08up	2829			286.56	286.64	286.84	286.83	286.94	287.25		
ob08down	2847			286.50	286.58	286.77	286.77	286.87	287.18		
oxs08	2866			286.49	286.57	286.76	286.76	286.87	287.18		
oxs07	3062			286.40	286.49	286.68	286.68	286.79	287.11		
oxs06	3268			286.30	286.38	286.59	286.57	286.70	287.05		
ob06down	3315			286.12	286.22	286.43	286.41	286.55	286.94		
oxs05	3463			286.02	286.12	286.39	286.35	286.52	286.92		
ob04up	3620			285.91	286.03	286.35	286.31	286.50	286.91		
ob04down	3645			285.44	285.59	286.12	286.02	286.30	286.79		
oxs04	3735			285.27	285.42	286.01	285.89	286.20	286.72		
oxs03	3889			284.83	284.99	285.76	285.60	285.93	286.46		
oxs02	4076			284.31	284.66	285.58	285.40	285.73	286.25		
oxs01	4286			284.06	284.58	285.52	285.34	285.64	286.12		