



Report

Waitangi Modelling and Calibration Report

14 AUGUST 2013

Prepared for
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Introduction

1.1 Project Background

The Priority River 2011/2012 project seeks to improve the work that was done for the Priority Rivers Flood Risk Reduction Project. The Waitangi River Model that was developed in the earlier project was found by the Northland Regional Council (NRC) to be in need of improvement in order to have confidence in the flood mapping for the river's catchment.

The January 2011 storm event presented an opportunity, as it was identified as a good calibration storm, to calibrate the improved model based upon the best available data to date. After the calibration event new gauges were installed and an event in 2012 provides another set of data for an smaller event that will allow a good calibration of other areas of the catchment that was not possible to calibrate with the set of data from 2011.

It was also identified by NRC that areas of the model should be modified to improve the description of features within the model. The details of these modifications as listed in Modelling Scope.

1.2 Catchment Description

The Waitangi catchment is located on the east coast of Northland, approximately 80 kilometres north of Whangarei. It flows east from its origins close to the northern shore of Lake Omapere, reaching the Bay of Islands close to the historic settlement of Waitangi.

Figure 1-1 provides a general location plan of the catchment.

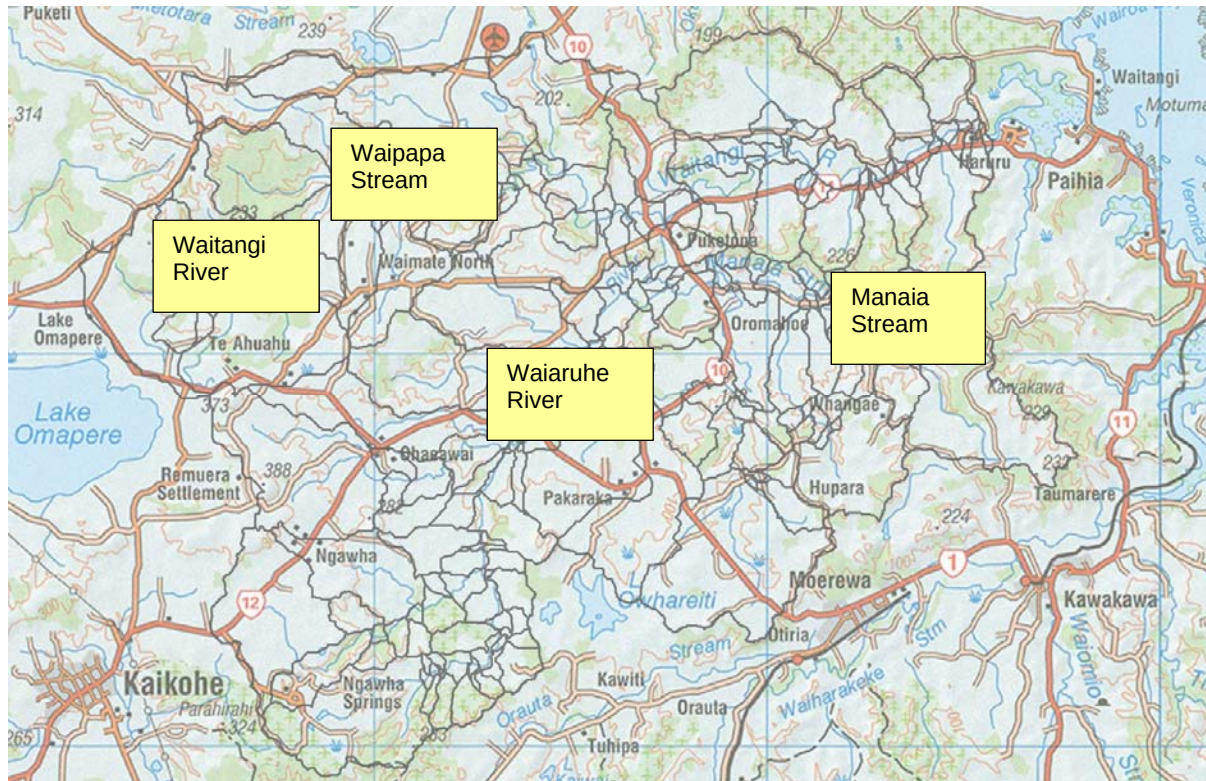
The Waitangi catchment consists of three main tributaries:

- Waitangi River: Located from the western boundary of the catchment
- Waipapa Stream: Located from the north western boundary of the catchment
- Waiaruhe River: Located in the central south of the catchment
- Manaia Stream: Located in the South East of the catchment

The confluence of the Waiaruhe River, Manaia Stream and Waitangi River are at Puketona on the State Highway 10 (SH10).

1 Introduction

Figure 1.1 General location plan of the Waitangi catchment and tributaries



Topography

The Waitangi River has its origins close to the northern shore of Lake Omapere. The high point within this area is Remuera Settlement, at 388 m above sea level (aSL). The upper areas of the catchment are characterised by steep incised gullies draining well defined sub-catchment areas. The base of the Waitangi catchments is an estuary around 0.5m above sea level.

The Waiaruhe River and Manaia Stream drains a flatter area with less well defined boundaries. The headwaters are located along the central southern boundary of the catchment with average height of approximately 80m above sea level.

Haruru Falls are located about three kilometres inland from Waitangi, the waterfall is about 5m high and spans approximately 35m. A camp ground and small residential settlement is located at the downstream side of the falls.

1.3 General Modelling Approach

The present project work uses the modelling methodology explained in the NRC Priority Rivers Modelling Report, Feb 2010. This modelling report is prepared as a supplementary report to the NRC Priority Rivers Modelling Report, Feb 2010. GIS and integrated modelling are central to the modelling methodology. This method assures a comprehensive model, accurate outputs and the ability to be continually upgraded.

1 Introduction

1.4 Modelling Scope

The general objective of the model improvement and calibration is to increase the accuracy of the model results in comparison to known flooding and gauged flooding events. The scope covers a variety of modifications in different areas. Details of these are listed and described below.

1.4.1 Merge Upstream/Downstream Model at Haruru Falls

Currently the model is predicting flood levels that are excessive for Haruru Falls. Therefore this scope of work will seek to improve this assessment. Tasks include:

- Merge the river model upstream of Haruru Falls with the river model downstream of the waterfall. The waterfall will need to be represented appropriately.
- Calibration of the model with observed flood levels.

1.4.2 New surveyed cross sections for estuary

Incorporate additional surveyed channel sections and bed level survey in the downstream portion of the model, specifically for the estuary downstream of the Haruru falls. Approximately 8 sections will be provided by NRC. Incorporating these cross sections is expected to increase confidence in the estimated flood levels established downstream of Haruru Falls. It is suspected the current 10% AEP flood extent is overestimated. The previous river sections in this part of the model were extracted from LIDAR data that has an important part of the bottom section missing, as the sea level was approximately +0.5m OTP when the LiDAR was flown and this masked the bathymetry. Additionally, the coastal part of the model was not originally calibrated – at least no results for the calibration event downstream of the falls were obtained from MWH. Further March 2007 flood levels have been obtained during survey of the estuary sections.

The complete merge model of the Waitangi catchment and estuary will be treated as one model thereafter. That will include tasks related to calibration, design events and flood mapping.

1.4.3 Review and revise critical bridges

Review the critical bridges within the model to verify length, soffit levels and assure appropriate spills are incorporated. The review of Haruru Falls Bridge revealed incorrect bridge dimensions including bridge length, and soffit height, and no spill unit to enable bridge overflow. The other critical bridges which will be checked are the SH 10 bridges over the Waitangi, Waiaruhe and Oromahoe Rivers (Puketona area). Connections and adjustments to bridges and spills units to be undertaken as required. Additional bridge survey is to be carried out by NRC and provided to URS for inclusion.

1.4.4 Waiaruhe at Puketona

Currently, the 1% AEP with climate change event is higher than the SH10 elevation, but no overland flows occur. The 1D sections in the model run diagonally away from the SH10 on the downstream side of the right bank.

Changes to this section of the model will incorporate 2D modelling around SH10 to allow for overland flow.

1 Introduction

1.4.5 Waitangi River at SH10, Puketona

Tasks consist of adjusting the SH10 highway crest elevation as per NZTA as-built elevations which are higher than LiDAR levels. The highway has been raised since the LiDAR was flown. It is assumed that NRC will provide the required as-built information.

1.4.6 Incorporate additional channel networks

Incorporation of channel network extensions as per shape files provided by NRC will include:

- Culverts under Puketona Road.
- Extension to tributary at coordinate 1690380e, 6094150n, due to development on South side of Puketona Road, and flood risk to Puketona Road.
- Extensions to network in the vicinity of Haruru Falls are proposed as this area has been identified for growth / development under the Bay of Islands Structure Plan.
- Extension of model up to the flow gauge at Waitangi River at Waimate North Road. The gauge is located about 5kms upstream of the LiDAR extent that is also the model extent for that area. This will be extended based in the 20m contours and estimation/assumptions of the section shapes. This extension will allow a better calibration of the flow through this gauge, but not for levels unless proper river survey is available around the gauge location.

Additional channel survey data including cross sections in the vicinity of the gauge sites will be provided by NRC for inclusion in the model.

1.4.7 Resolve erroneous flood extent

Initial inspection of the current model has highlighted erroneous flood extent results which will be rectified at the following locations:

- 1693100e, 6094550n Puketona Road, all design storm events
- 1687300e, 6093010n Wairauhe immediately u/s SH10 bridge left bank, all design storm events
- 1687720e, 6092100n Wairauhe house site 10% AEP only
- 1688039e, 6094267n North bank of Waitangi d/s Puketona 1% AEP CC only

1.4.8 Proposed additional model corrections and improvements

A preliminary review of the current model, developed by MWH, indicated that the model presents some irregularities and deficiencies in critical areas. Improvements to the model are essential to assure a viable and reliable calibration and accurate results. Appendix A includes some figures showing the critical deficiencies that require improvement. An outline of the actions required is presented below:

1. Some of the sub-catchments were incorrectly connected to the river network, draining to the wrong streams. This will be corrected.
2. A review of the catchment breakdown of some areas in the lower catchment is proposed. This would improve the distribution of the runoff over the flood plains.
3. Some sub-catchments do not have a proper definition in the hydrological model, and no delay time was attributed to sub-catchments draining from far away from the discharge point. This will be rectified.
4. Significant deficiencies to network spills and links were observed and require improvement.

1 Introduction

5. The model includes a number of incomplete storage areas which will need to be completed. It is also suggested that additional storage areas are included to better represent large storage areas draining into 2D polygons. In this way the runoff can be discharged directly into the flood plains to be distributed by the 2D meshes.
6. Improvements are proposed for some critical river cross sections in order to provide a better description of contractions, expansions and large flood plains included in the 1D model. This last one is generally minor modifications.

1.4.9 Re-calibration the Waitangi River Model

The Waitangi River model has issues associated with it other than those listed in sections 1.2.1 – 1.2.8. Re-calibration should also include the following:

1. Verify the calibration results (March 2007 event) including flood level elevations and gauged hydrograph at Wakelins river gauge (NIWA site 3722). The modelled flood elevation for Haruru Falls – calibration event, is 1m lower than initially reported. The modelled flood peak at Wakelins gauge was reported as 13.08m, but the model file for calibration event gives a different figure at the gauge site.
2. New flow gauges have been installed in Waimate North Rd and Puketona areas since the MWH model was produced in 2010, however no major events have yet occurred since their installation. As discussed with NRC it is proposed that the revised Waitangi Model be calibrated against the March 2007 event and a smaller event to be specified by NRC. This would provide more confidence for those areas with new information, especially regarding the distribution of the runoff over the catchment. NRC is required to provide rain data and flow/level records for all gauges with information for both events. The second event will need to be confirmed.
3. As preliminary options for the secondary calibration event are the storms of March 2012 and December 2011. The first one is a double peak event and it is slightly higher than the one in 2011 that has only one peak.
4. A Non-Linear Reservoir method is proposed to be used for the Waitangi catchment as applied with success on other NRC catchments (such Ruakaka, Kawakawa and Waihou). Migrating the model to such a hydrological method requires the estimation of few parameters. Those parameters will be calculated using GIS. Independent of hydrological method to be used, the hydrological parameters will be adjusted during the calibration.
5. March 2007 and January 2011 calibration event levels will also be reviewed in the Puketona area.
6. Calibration targets and thresholds will initially be based on those used for the Priority Rivers 2010 project and will be reviewed and agreed with NRC for use with this model.

1.4.10 Re-run design events and generation of flood maps

Once the Waitangi model has been calibrated and approved by NRC, the design events will be re-run to generate new flood maps for the catchment. These tasks will consider:

1. New design storms for 24 hr event will initially be run with ARF of 0.94, instead of TP108 ARF for 200km² catchment of 0.86. The application of the ARF will be reviewed and, if required amended to better represent the catchment.
2. Design storm flood levels 1% AEP with climate change are currently lower than Jan 2011 u/s Waitangi SH10 bridge. The 1% AEP CC flood levels are similar to Jan 2011 flood levels u/s

1 Introduction

Waiaruru SH10 bridge. Debris levels available for the storm of January 2011 will be compared against the design events flood extent.

3. Re-run 24hr design storms with new parameters from calibration and revised ARF. Produce flood maps for 10, 50, 100 and 100 years plus climate change design storms. The revised flood maps will have the same format for those produced in the RMP.

The model results will be exported to GIS to generate flood depth and flood level rasters.

Data Collection

2.1 Data Collection

NRC provided all of the data used to improve, extend and calibrate the model for the March 2012 event and March 2007 event. The data received is listed and described below:

- Proposed 1D model extension (shape file),
- Proposed 2D polygons extension (shape file)
- Proposed estuary storage extension (shape file)
- New survey with photos (estuary survey, cross sections, bridges, culverts, flow/level stations),
- Rain gauges and rainfall for the events of March 2012 and March 2007,
- Level/flow gauges and series for the events of March 2012 and March 2007,
- Debris level for the events of March 2012 and March 2007,
- Some photos from the events of March 2012 and March 2007,
- Verification of some gauges datum.

2.1.1 Survey

Survey data consisted in the following items:

- Cross sections of previous streams where more detail was required (including some bridges)
- Cross sections of new streams or branch to be included in the model.
- Cross section of channel at level gauges location.
- Some culverts in main streams.
- Gauge datum verification.

This survey was processed in GIS and included in the model.

2.1.2 Calibration Event Data – Match 2012

The following information was received for the event of March 2012.

- Daily and auto rain gauges rainfall.
- Level/Flows and velocity measurements for Waitangi at Wakelins and Waitangi at Waimate
- Level records for Waiaruhe at Puketona (new site)
- Rating curve for Waitangi at Wakelins, Waiaruhe at Puketona (old site) and Waitangi at Waimate
- Tide records for Veronica Channel at Opuha Wharf
- No debris level available, but some photographs and maximum levels at gauges to assist the calibration.

2.1.3 Calibration Event Data – Match 2007

The following information was received for the event of March 2007.

- Daily and auto rain gauges rainfall.
- Level/Flows and velocity measurements for Waitangi at Wakelins
- Rating curve for Waitangi at Wakelins, Waiaruhe at Puketona (old site) and Waitangi at Waimate
- Tide records for Veronica Channel at Opuha Wharf
- Debris flood levels for March 2007 (14 points)
- Debris flood levels for January 2011 (137 points)

Modelling Modifications

3.1 Previous IWRS Model

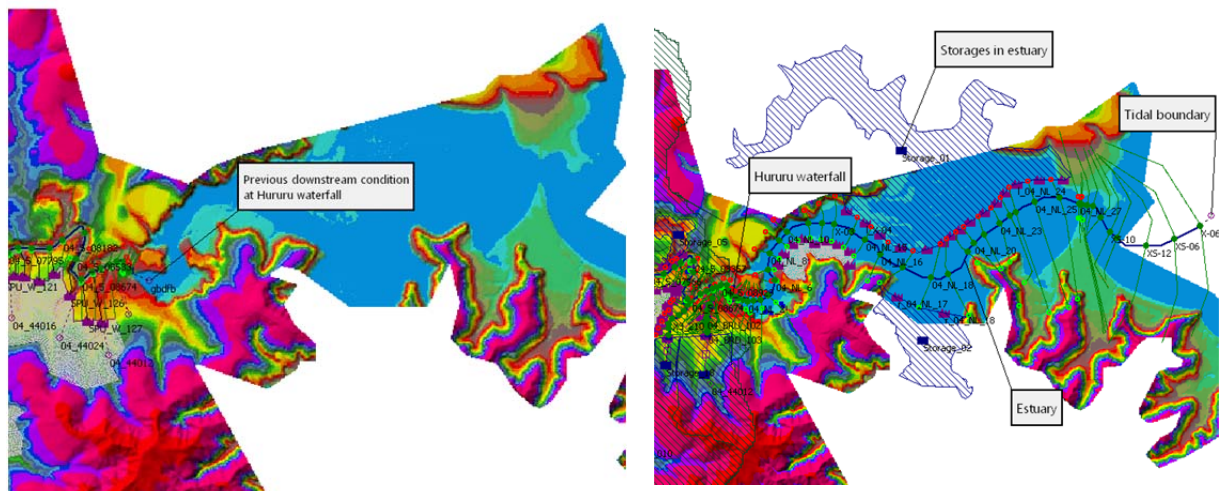
The Waitangi River was defined as a Priority 1 catchment during the Priority River Flood Risk Reduction Project. A model of Waitangi catchment was developed built and calibrated, by MWH. NRC has provided the model, developed by MWH as the starting point of the current work.

In general the previous model was stable, but was not well defined in many areas. The model presented some irregularities and deficiencies in critical areas. Improvements to the model were essential to assure a reliable calibration and accurate results.

The following is a description and analysis of the important aspects that were corrected and/or improved in the model prior the calibration stage.

3.2 Downstream Boundary Condition (Tidal Boundary)

The river model has been merged with the estuary model at the Haruru falls. The estuary description has been improved by using the bed level survey information to create a ground model of the bed bathymetry; also large storage polygons in the estuary were included. Stability issues related to the waterfall were solved and the tide level boundary was assigned at the downstream end.

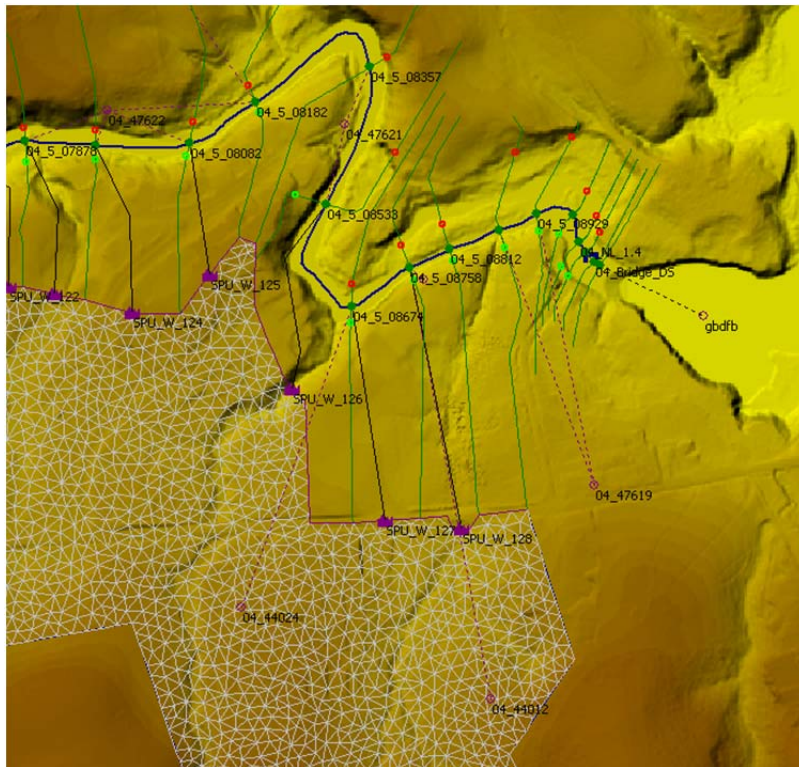


Previous model

New model

3.3 1D and 2D Model Extent

Several new stream branches were added in the model in areas of interest. Most of these areas have survey information or LiDAR cross section was utilized. Also several culverts and bridges were created and improved from its previous description. In total 45 new storage polygons were created, 332 new river sections, 13 new 2D polygons, 13 culverts and 352 additional spill units among several other type of objects such as bridges and junctions. Figures below show some examples of the new model extensions.



New 2D extent with detail in ground features (roads, streams, etc.)

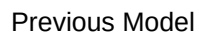
Hururu fall

New stream with culverts

New stream with culverts

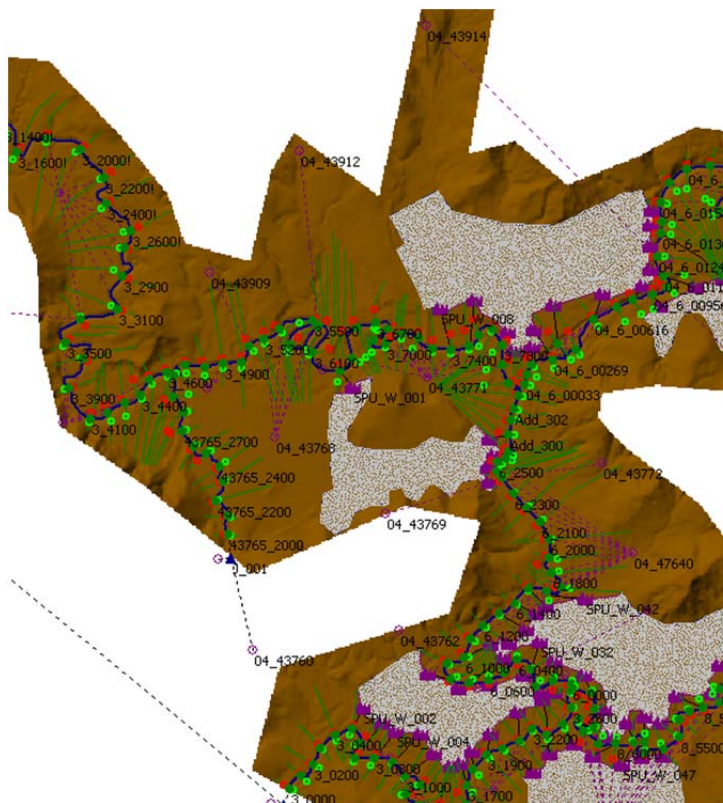
Storages US of culverts
Receiving runoff from sub-catchments

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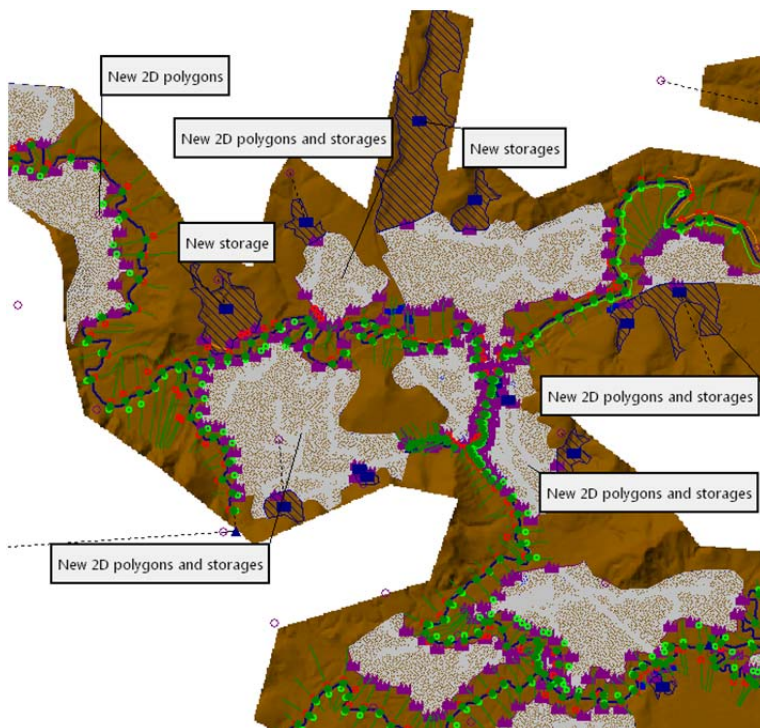




3 Modelling Modifications

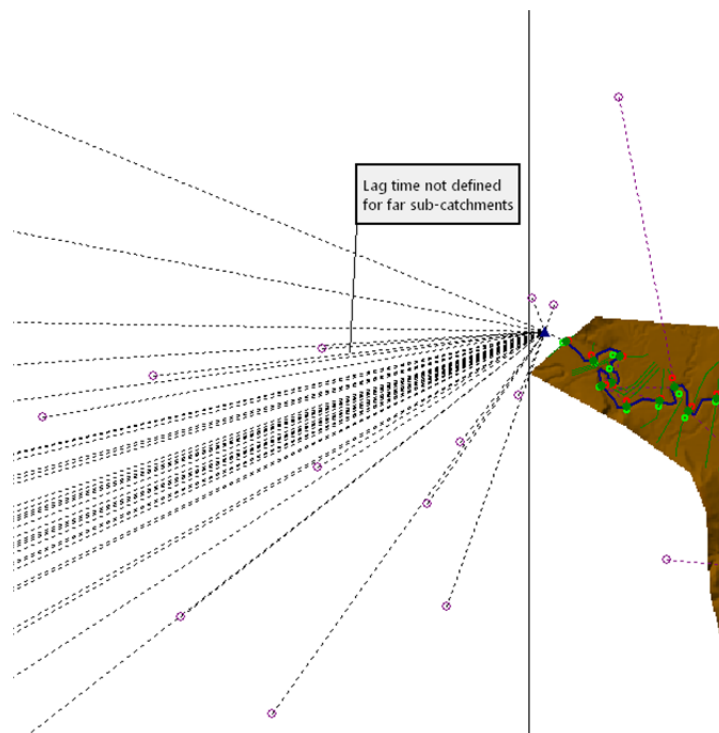


Previous model

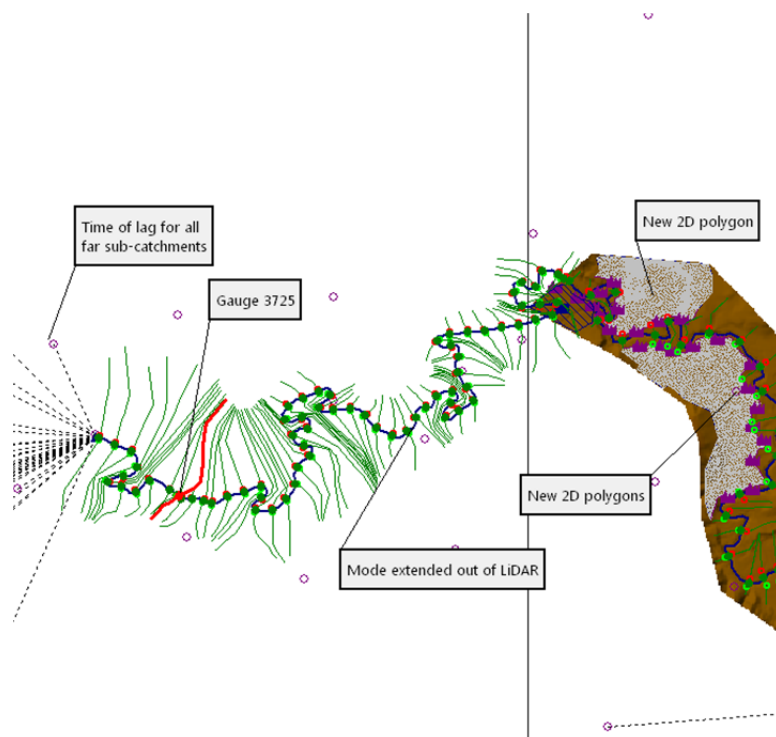


New Model

3 Modelling Modifications

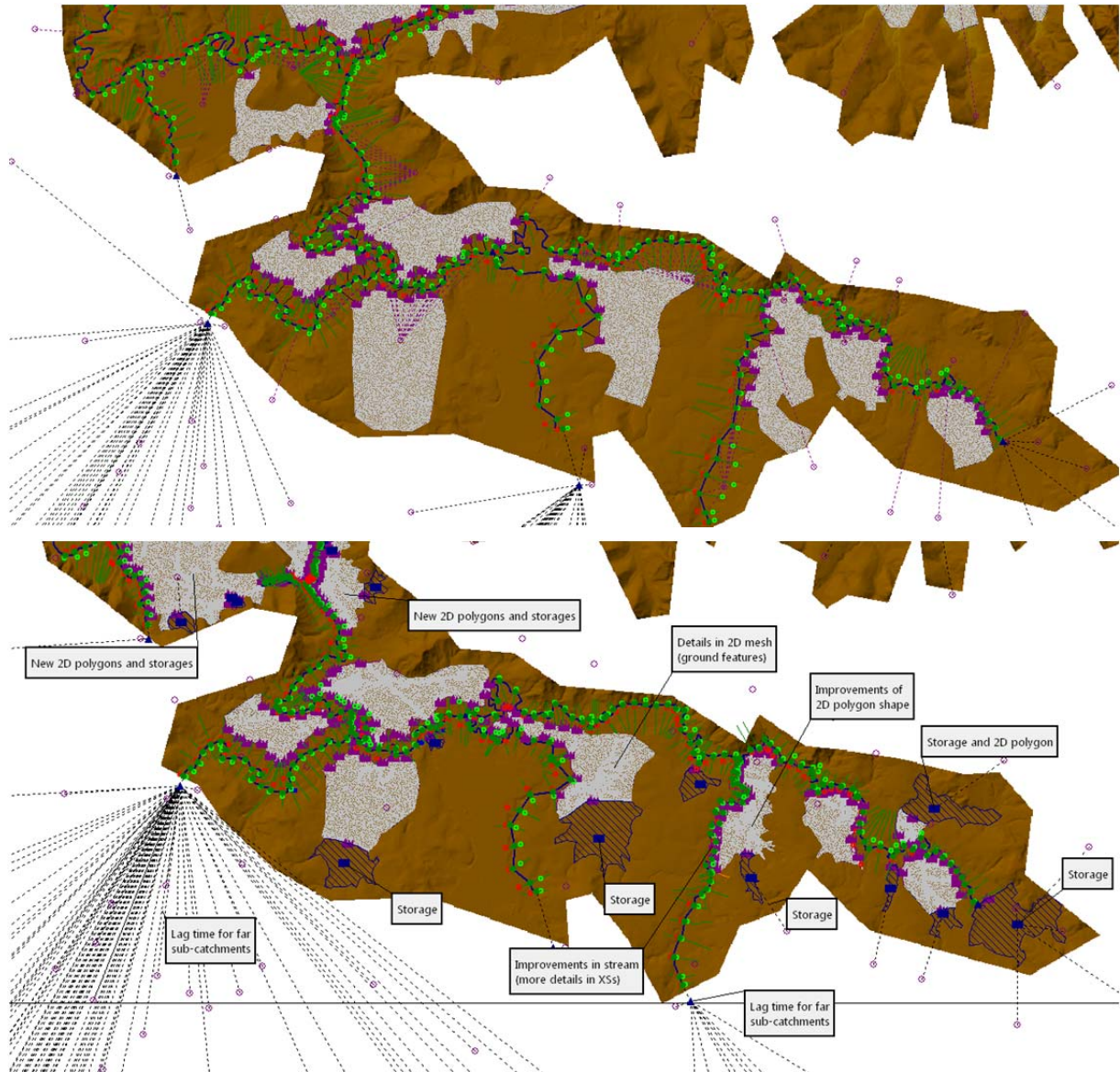


Previous model



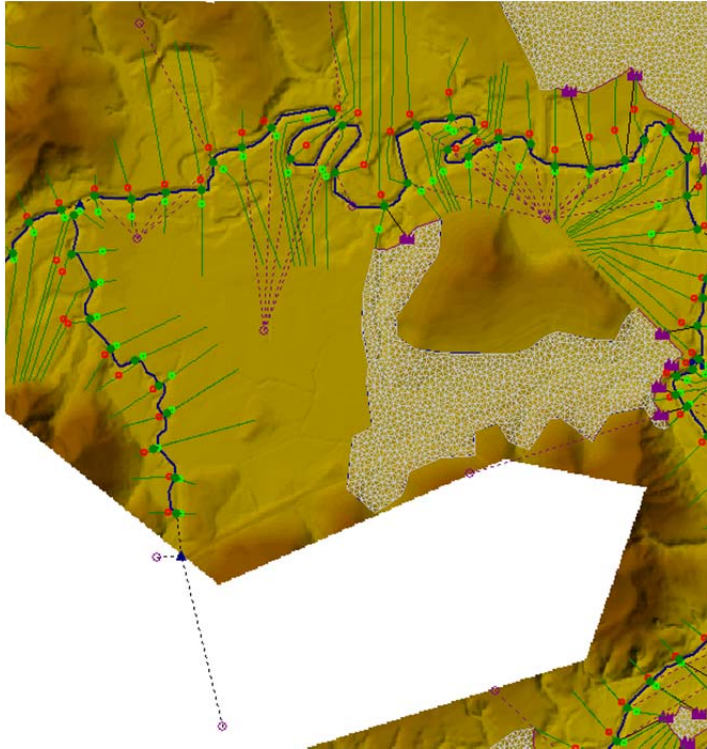
New Model

3 Modelling Modifications

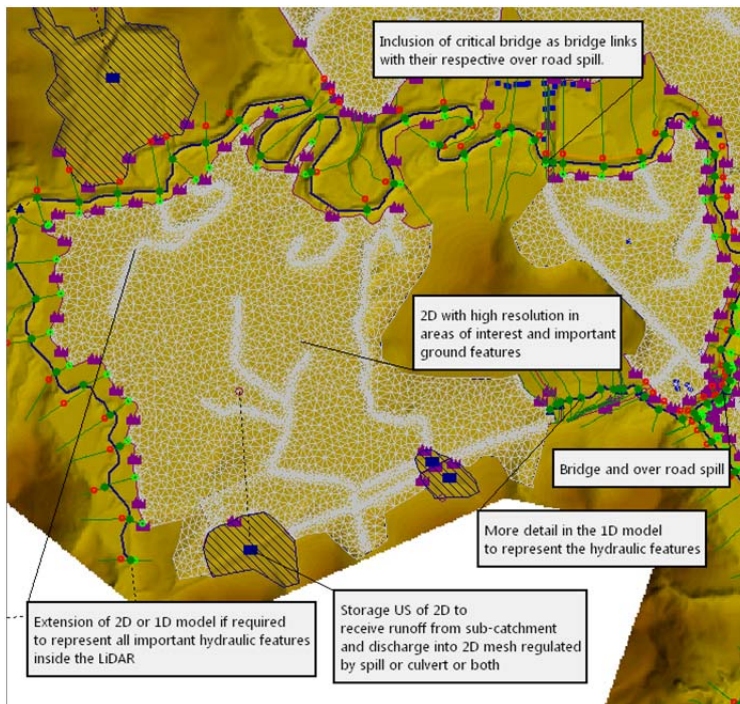


Previous model vs new model

3 Modelling Modifications



Previous model



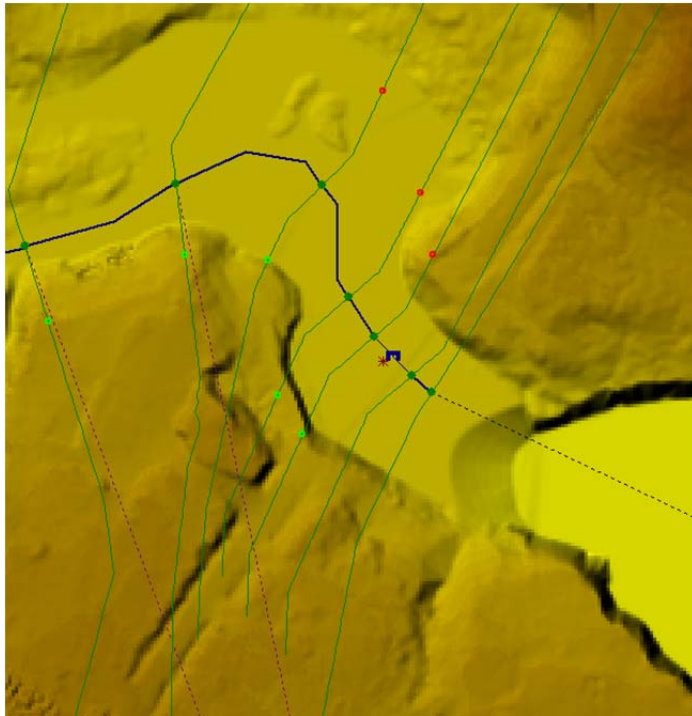
New Model

3 Modelling Modifications

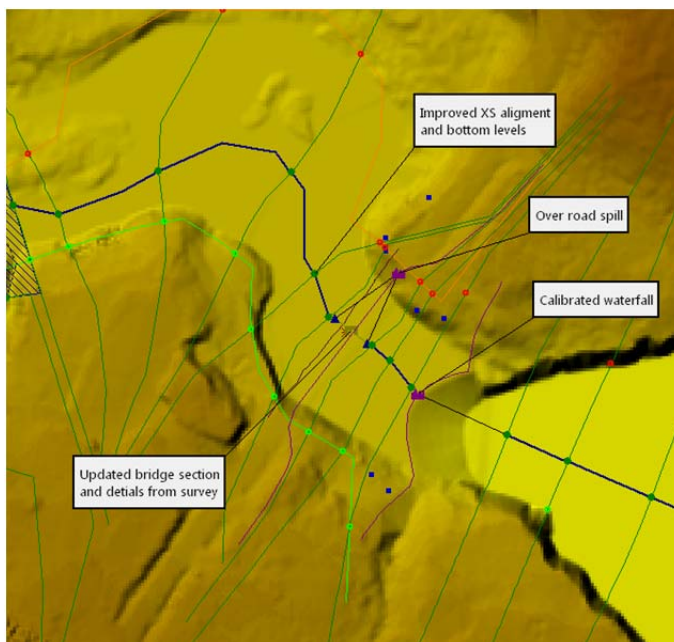
3.4 Bridges

Four critical bridges were required to be included or improved in detail in the model. Survey is available for all of the bridges.

3.4.1 Haruru Falls Bridge



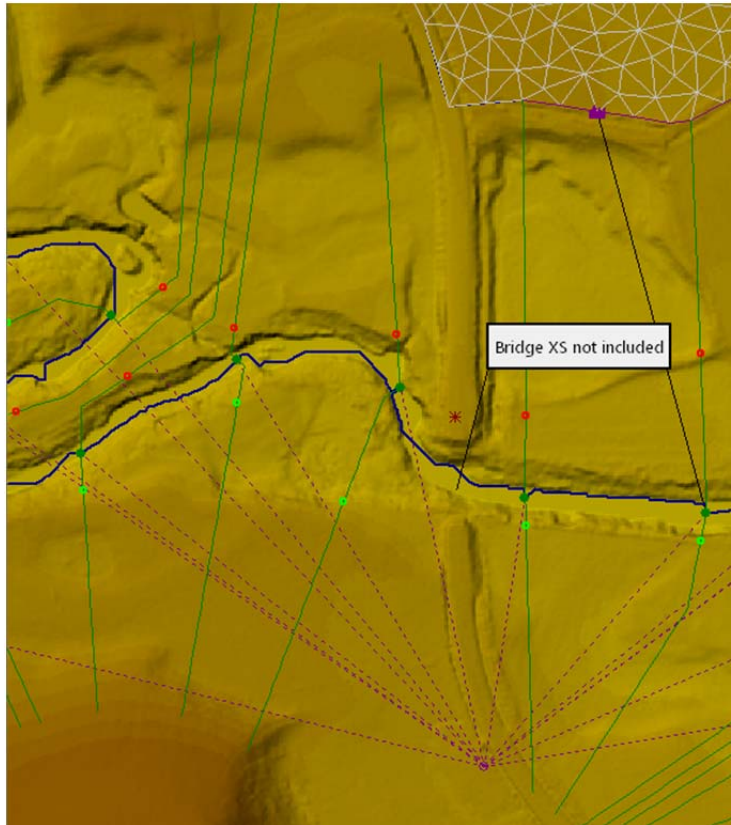
Previous Model



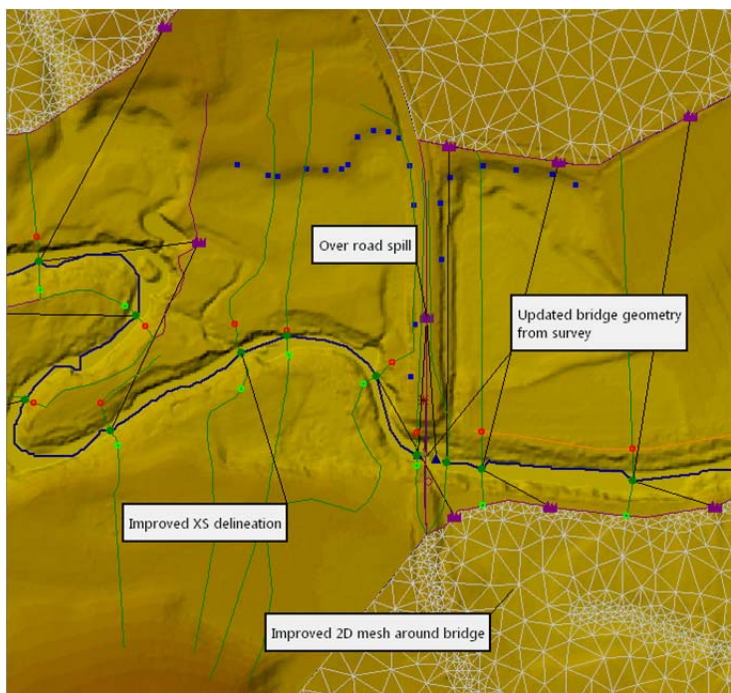
New Model

3 Modelling Modifications

3.4.2 SH10 Bridge over Waitangi River



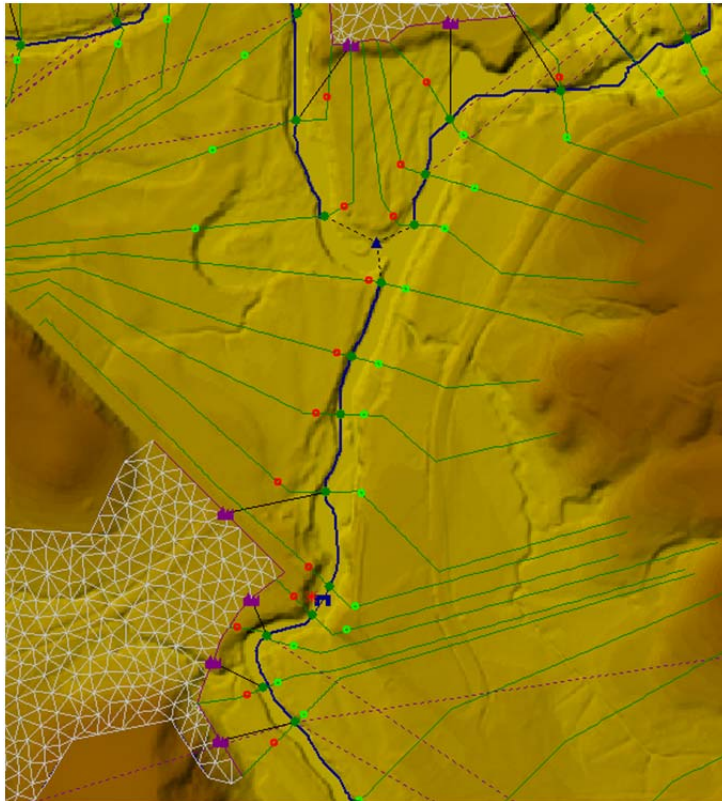
Previous Model



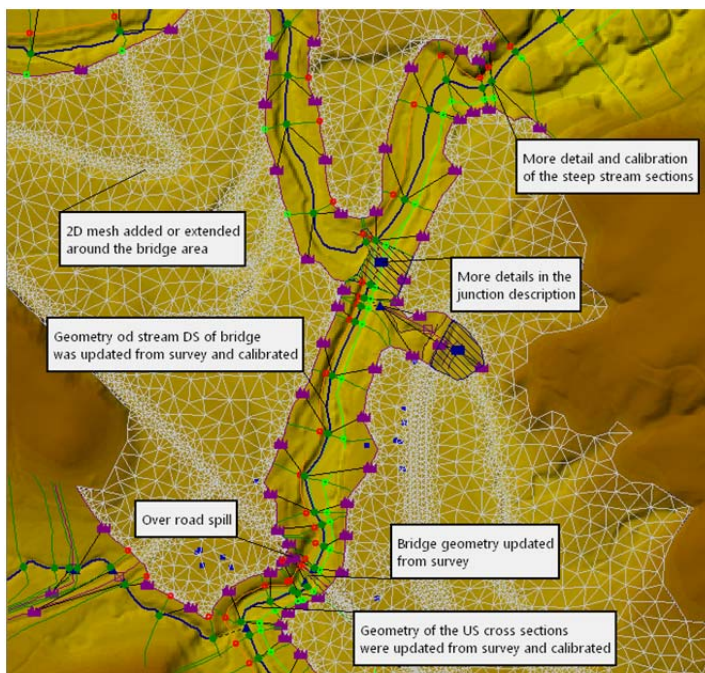
New Model

3 Modelling Modifications

3.4.3 SH10 Bridge over Waiaruhe River



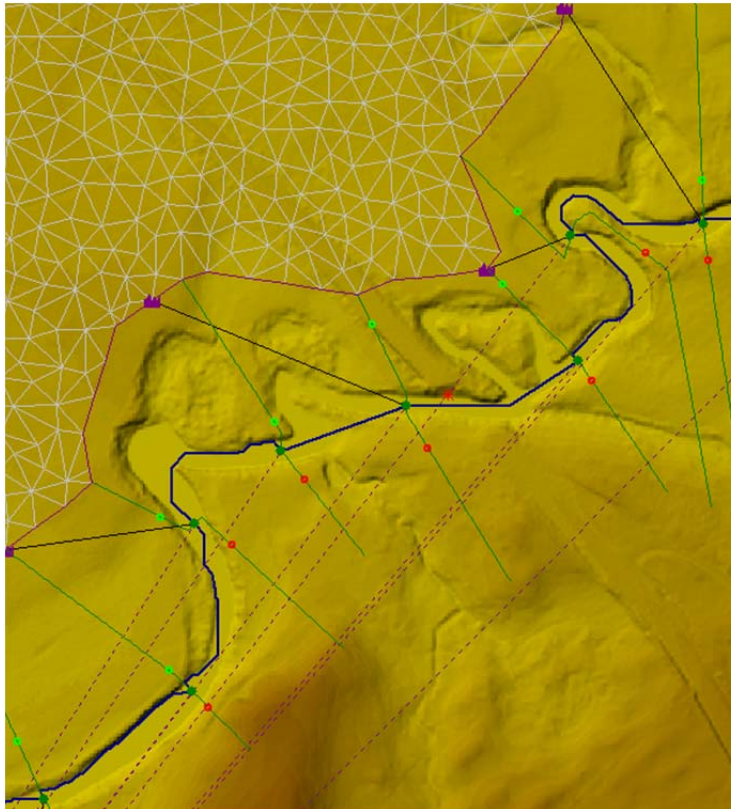
Previous Model



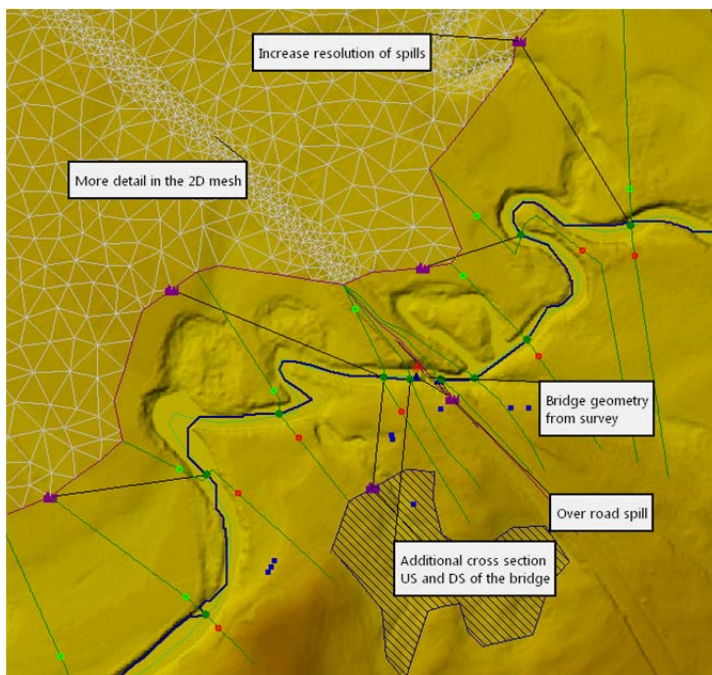
New Model

3 Modelling Modifications

3.4.4 SH10 Oromahoe River



Previous Model



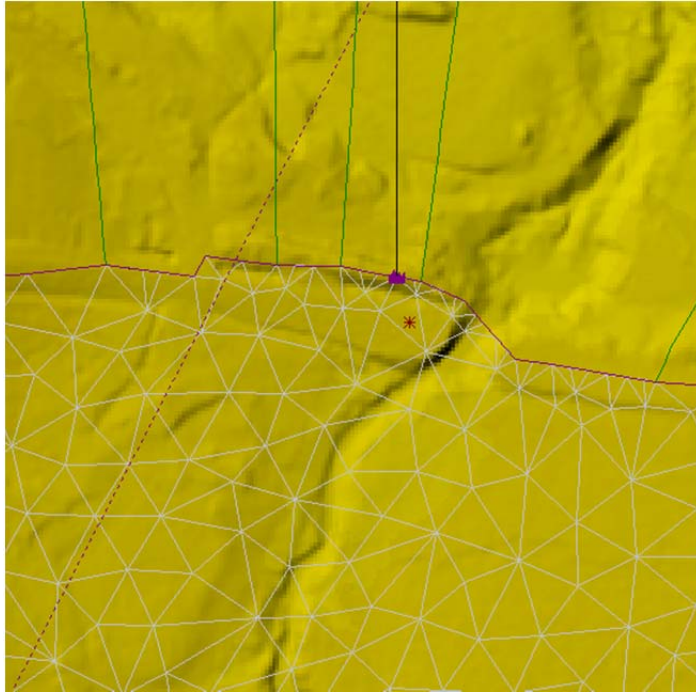
New Model

3 Modelling Modifications

3.4.5 Other Bridges

Several bridge sections were added from survey or LiDAR in critical locations. Some examples are shown below.

Approximate location X(m NZTM) = 1692243, Y(m NZTM) = 6094225



Previous Model



New Model

3 Modelling Modifications

Approximate location X(m NZTM) = 1694432, Y(m NZTM) = 6095244



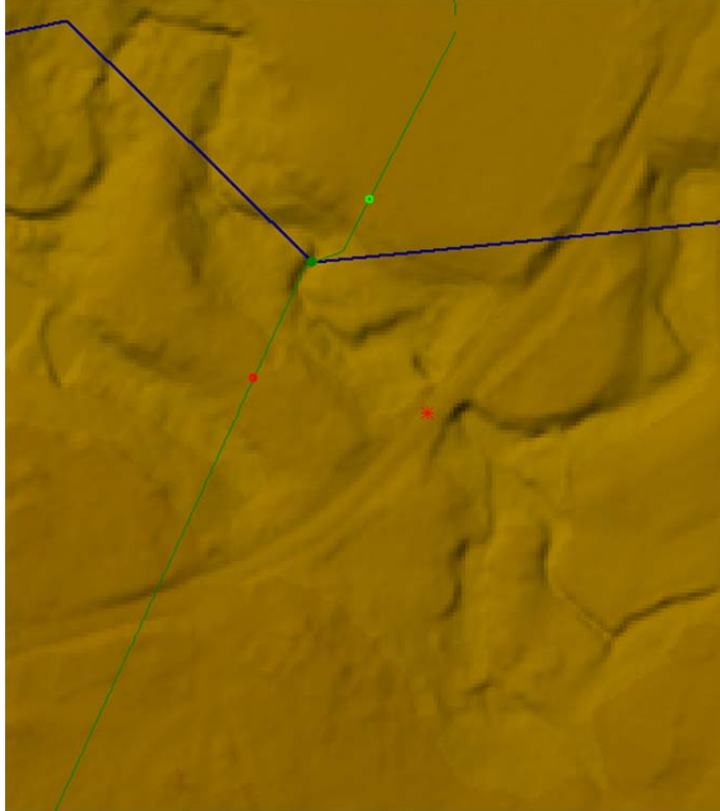
Previous Model



New Model

3 Modelling Modifications

Approximate location X(m NZTM) = 1688911, Y(m NZTM) = 6091606



Previous Model



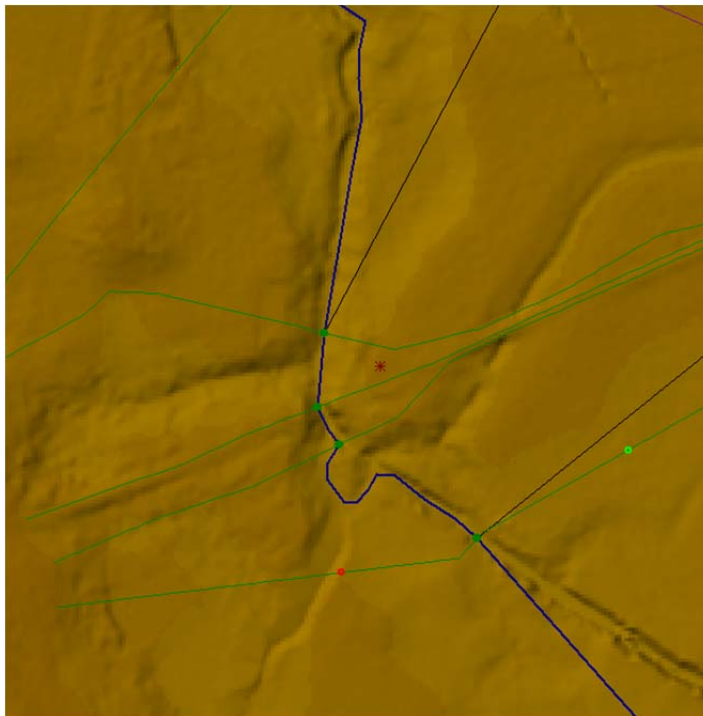
New Model

3 Modelling Modifications

Approximate location X(m NZTM) = 1689401, Y(m NZTM) = 6091468



Previous Model



New Model

3 Modelling Modifications

Approximate location X(m NZTM) = 1691566, Y(m NZTM) = 6091321



Previous Model



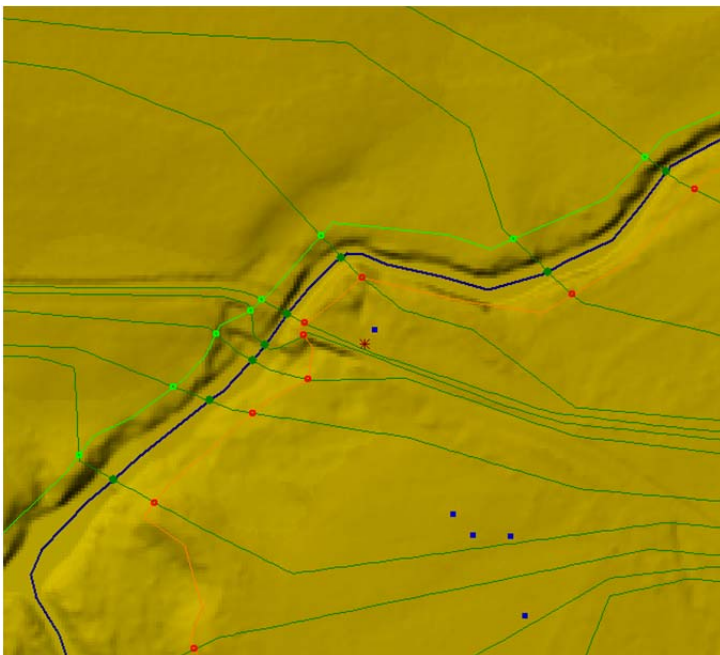
New Model

3 Modelling Modifications

Approximate location X(m NZTM) = 1690644, Y(m NZTM) = 6095564



Previous model



New Model

3 Modelling Modifications

3.5 Hydrological Model

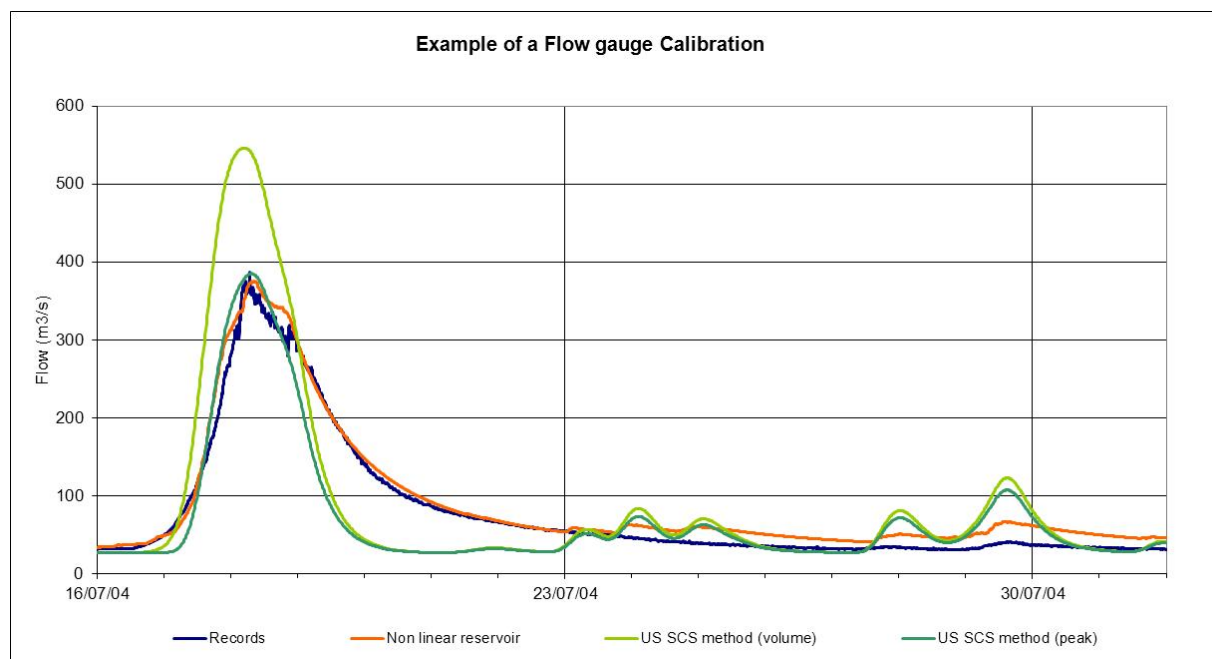
3.5.1 US SCS Method

The previous Waitangi River model used an US SCS unit hydrograph method as the hydrological model. A CN value was to be derived for each sub-catchment based on the land-use and soil type. The main concern with the US SCS method for Northland catchments of larger size is that, in general, peak flows and flow volumes cannot be calibrated simultaneously. This was found to be true of the previous calibration of Waitangi catchment. The results are not satisfactory and do not represent the hydrologic behavior of Waitangi sub-catchments properly.

Further experience and analysis in NRC catchments, as well as other catchments in New Zealand, suggests that a better and more versatile hydrologic model alternative to simulate the sub-catchments runoff is the Non Linear Reservoir method.

The following figure shows a comparison between the US SCS method (applied to calibrated peak flows and flow volumes separately) and the Non Linear method (calibrated both peak and volumes). This example is of the Rangitaiki River catchment in New Zealand.

Figure 3-1 Example of a flow gauge calibration using different hydrological models



3.5.2 Non-Linear Reservoir Method

The Non Linear method consists of representing each sub-catchment as a reservoir with a non-linear discharge. Two parameters are required to calibrate the shape of the hydrograph, K and p :

$$V(t) = K \cdot Q(t)^p$$

Where V is the storage volume in the reservoir, and $Q(t)$ is the flow or runoff from the sub-catchment.

3 Modelling Modifications

Then, the volume balance defines a differential equation to solve the function $Q(t)$.

$$\frac{dV}{dt} = K \cdot p \cdot Q(t)^{(p-1)} \cdot \frac{dQ(t)}{dt} = I(t) - Q(t)$$

The previous differential equation cannot be solved analytically unless $p=1$. This equation is solved numerically by InfoWorks RS over each sub-catchment to obtain its respective runoff as a response to a given rain series $I(t)$ as intensity.

Parameter K can be estimated based on catchment features such as length, slope and land cover. Those are available for all Waitangi sub-catchments.

Part of this project is to calibrate Waitangi catchment with an alternative and more suitable hydrological model. Based on the previous explanations, a Non-Linear Reservoir Method has been used to calibrate two storms: March 2012 and March 2007.

3.5.3 IWRs Non-Linear Reservoir parameters

InfoWorks has a Non-Linear Reservoir hydrological model implemented as part of its boundary condition alternatives. Volume parameters can be defined whether using a runoff coefficient or an infiltration rate in mm/hr. Both methods have advantages and disadvantages, and as a part of this work they were tested and analysed to establish which method is more appropriate for NRC projects and particularly for the Waitangi catchment. This approach does not estimate runoff volumes and infiltration rates (depths) based on a runoff parameter such as US SCS method which has been developed in conjunction with the CN value.

The infiltration method has been used as it offers a better description of the rain losses for big events, and it showed partial advantages over the runoff coefficient method.

The hydrograph shape is controlled by the parameters K and p shown in the previous section. These parameters estimate the shape of the hydrograph to find the best match for flow volume, peak and tail flows. Coefficient p defines the order of the reservoir. If $p=1$ that would describe a Linear Reservoir method and would allow for the estimation of a unit hydrograph for each sub-catchment, and allowing the use of other methods available for rain losses (like US SCS), however, most of the time $p \neq 1$.

A time of delay was assigned to those sub-catchments that were discharging into streams a great distance from the respective sub-catchment point of discharge. Further details were explained in section 3.2.

3.5.4 Constant Infiltration Rate

There is an important difference between the methodology used previously with the US SCS method based on CN values, and the current approach using the infiltration rate and the non-linear reservoir method. The CN value was previously defined for each sub-catchment based in local land use; the current methodology has instead selected a unique infiltration rate to be applied over the whole catchment.

3 Modelling Modifications

3.6 Sub-catchment delineation

The sub-catchment delineation is defined by the resolution and extent of the hydrological catchment. In the Priority Rivers Flood Risk Reduction project these sub-catchments were based on 20m contours for the catchment. The resolution was good enough for the purpose of that project. As part of the scope of this project, a sub-catchment review and re-delineation was considered. In a few of the areas sub-catchments were re-defined including higher resolution 1m grid derived from LiDAR data. These new sub-catchments followed more detailed features and aim to distribute the water more accurately into the respective streams, storages or 2D areas.

Additionally, several sub-catchments are connected from far discharging point directly into the 1D or 2D model. In order to do that an adjustment of the time of arrival of the runoff need to be done by applying a lag time that was not defined in the previous version of the model. Such lag time was estimated and calibrated to adjust the hydrograph peak time and calibration of flows mainly at the Waimate and Puketona gauges.

3.6.1 Base flow and Infiltration Rate expected ranges

The base flow was estimated to be between $1\text{m}^3/\text{s}$ and $2\text{m}^3/\text{s}$ at the Wakelins gauge. The peak flow at the same location is about $650\text{m}^3/\text{s}$ as records show, but further analysis suggests that the flow might be up to $750\text{m}^3/\text{s}$. The peak flow compared with the base flow is negligible and found not to be important. However, for stability issues the total base flow at Wakelins gauge was defined for different simulations to be between 1 to $10\text{m}^3/\text{s}$; this range is still negligible compared with the $750\text{m}^3/\text{s}$ for the 2007 event.

Infiltration was found to be between 4.0 to 4.5mm/hour for both calibration events, although infiltration estimates are strongly dependent on the quality of the rain data over the catchment. In this case the data was considered to be of good quality and these values were applied to model calibration.

Data Analysis

4.1 Survey data process and other GIS tasks

As per the methodology, modelling tasks were assisted by GIS. New and previous surveys, location and details of rain and level gauges were processed in GIS before being imported into the IWRS model.

Other calculations, such as time of delay for hydrologically routed sub-catchments, 2D break lines and sub-catchment re-delineation were also assisted by GIS analysis.

4.2 Calibration Event Analysis

The calibration event is the storm of March 2007, however, this storm only has data for the gauge at Wakelins. For a more accurate calibration of the hydrological and hydraulic parameters the model was first calibrated for the storm of March 2012 that has several gauge records, and after that the March 2007 event was calibrated to match the Wakelins record and debris levels. Also, debris levels for the storm of January 2011 were used to estimate the head losses at bridges and provide more information of the expected flooding areas.

Before the calibration, it was necessary to perform a few analytical processes in order to estimate:

- Rainfall distribution (temporal and spatial)
- Base flow
- Rainfall losses and effective rainfall volume

4.2.1 Rainfall distribution for Calibration Event

The rainfall analysis utilised 18 rain gauges. 10 auto gauges and 8 daily gauges. Table 2.1 below summarises the available information. Figure 4-1 shows the distribution of rain gauges used for calibration of the Waitangi catchment model.

Table 4-1 Rain gauge details

Site ID	Station name	X_NZTM (Easting)	Y_NZTM (Northing)	Record	Recording Authority
533818	Waitangi at Wiroa Road	1676190	6096020	Auto	NRC
533817	Waitangi at Ohaeawai	1679407	6087015	Auto	NRC
543010	Waitangi at McDonald Road	1693794	6089872	Auto	NRC
534811	Otiria at Ngapipito	1681610	6077860	Auto	NRC
A53487	Kaikohe AWS	1674639	6079827	Auto	Met Service
532915	Kerikeri at BOI Golf Club	1685742	6101484	Auto	NRC
A53295	Kerikeri AERO AWS	1682884	6097723	Auto	
532821	Maungaparerua at Tyrees Ford	1680246.2	6100325.7	Auto	NIWA

4 Data Analysis

543111	Opuia at Veronica Channel	1701905	6091780	Auto	NRC
A53191	Kerikeri EWS	1683526	6108254	Auto	Met Service
A54301	Kawakawa WTP	1699145	6084431	Daily	Met Service
543012	Waitangi at Whangae	1693891	6087808	Daily	NRC
A53293	Kerikeri AERO 2	1683169.5	6097575.3	Daily	Met Service
A54211	Russell	1701863.2	6097124.8	Daily	Met Service
543110	Opuia Parry Street	1701660.5	6091588.7	Daily	NRC
	Veronica Channel M and P			Daily	
532710	Puketia Road at Candy	1668388.2	6097699.3	Daily	NRC
532611	Waihou Valley at Graham	1663475.4	6094989.6	Daily	NRC

All auto gauges were analysed and compared against their respective daily record. They were then processed to compare their accumulated rainfall profile against each other. This was done to establish similarity of spatial distribution and gain understanding in the delays in temporal distribution.

There are two rain auto gauges that have an important influence in the catchment covering more than 50% of it in both storms (based in Thiessen polygons). Those are gauges 533817 (auto) and 543010 (auto). Figure 4-1 shows the area of influence of the gauges for the storm of 2007.

The previous analysis helped to understand the dynamics of the calibration event developing the respective floods. Also it enabled an estimate of the rainfall pattern for the daily gauges 533817 and A53293 based on the surrounding gauges.

4 Data Analysis

Figure 4-1 Rain gauge location and Thiessen distribution over Waitangi catchment

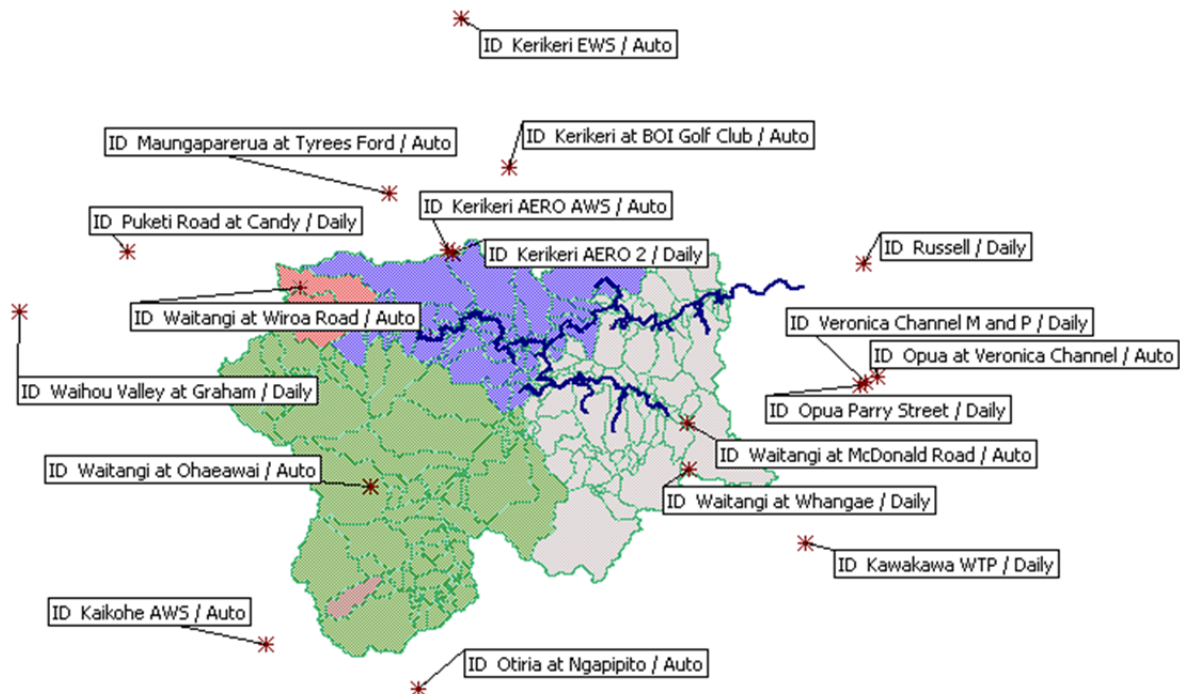


Table 4-2 Rain gauge data summary for the storms of March 2007 and March 2012

Site ID	Station name	Type	Total rainfall Storm 2012 (mm)	Model 2012 (% of catch)	Total rainfall storm 2007 (mm)	Model 2007 (% of catch)
533818	Waitangi at Wiroa Road	Auto	266.5	11.9%	0.0	0.0%
533817	Waitangi at Ohaeawai	Auto	190.5	32.4%	276.0	44.1%
543010	Waitangi at McDonald Road	Auto	203.0	18.8%	357.0	30.8%
534811	Otiria at Ngapipito	Auto	184.5	4.9%	0.0	0.0%
A53487	Kaikohe AWS	Auto	213.8	0.8%	205.6	0.8%
532915	Kerikeri at BOI Golf Club	Auto	254.0	3.1%	0.0	0.0%
A53295	Kerikeri AERO AWS	Auto	253.4	15.9%	0.0	0.0%
532821	Maungaparerua at Tyrees Ford	Auto	0.0	0.0%	421.0	3.7%
543111	Opua at Veronica Channel	Auto	170.0	0.0%	0.0	0.0%
A53191	Kerikeri EWS	Auto	0.0	0.0%	353.2	0.0%

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A54301	Kawakawa WTP	Daily	0.0	0.0%	325.0	0.0%
543012	Waitangi at Whangae	Daily	168.5	12.2%	313.5	0.0%
A53293	Kerikeri AERO 2	Daily	0.0	0.0%	419.3	20.6%
A54211	Russell	Daily	0.0	0.0%	0.0	0.0%
543110	Opua Parry Street	Daily	194.0	0.0%	338.9	0.0%
	Veronica Channel M and P	Daily	207.0	0.0%	0.0	0.0%
532710	Puketi Road at Candy	Daily	161.0	0.0%	293.0	0.0%
532611	Waihou Valley at Graham	Daily	0.0	0.0%	149.0	0.0%

The rain gauges in Table 4-2 with the percentage of rain coverage for the two calibration events were included in the model as an input. The following figures show the rainfall intensity and accumulated rainfall of these rain gauges.

4 Data Analysis

Figure 4-2 Rain for the calibration event of March 2007

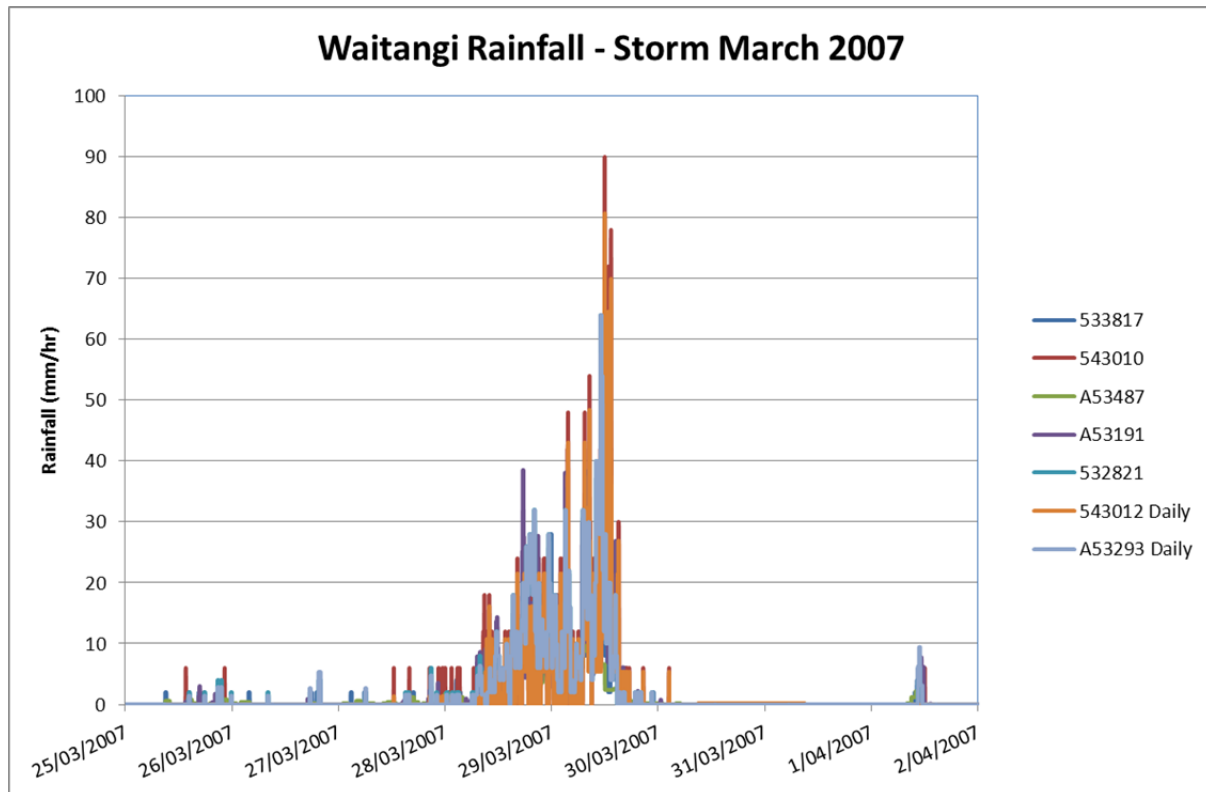
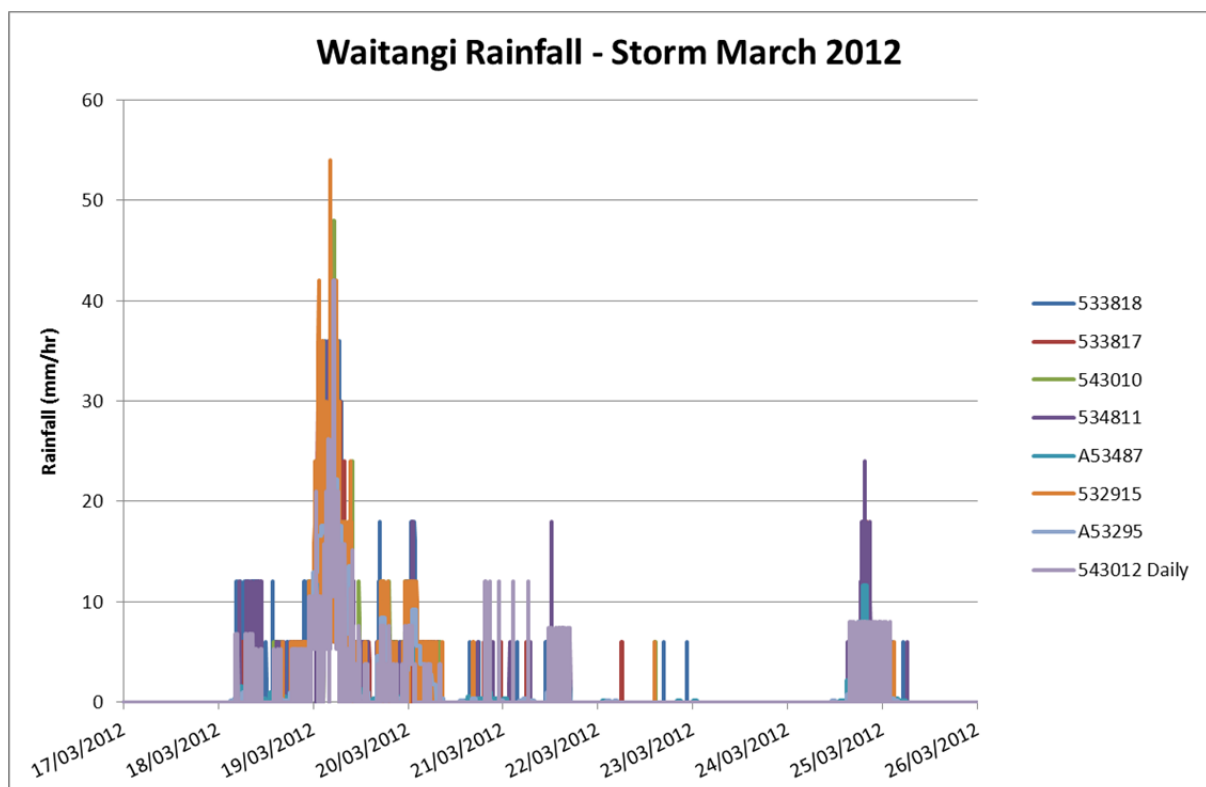


Figure 4-3 Rain for the calibration event of March 2012



4 Data Analysis

4.2.2 Flow/Level gauges analysis for Calibration Event

There are five water level gauges available in the catchment. They are listed below in Table 4-3 with their details and data availability.

Table 4-3 Level gauges details

Site ID	Site Name	X_NZTM (Easting)	Y_NZTM (Northing)	SG Zero (m OTP)	Recording Authority	Record	Period of Record
3722	Waitangi at Wakelins	1695269	6095801	6.074	NIWA	Auto (irregular)	22.02.1979 - present
3725	Waitangi at Waimate North Road	1682006	6093690	60.890	NRC	Auto (5 mins)	04.10.2011 - present
3707 new	Waiaruhe at Puketona (new site)	1687311	6092989	42.000	NRC	Auto (5 mins)	09.12.2011 - present
3707 old	Waiaruhe at Puketona (old site)	1687352	6093005	40.730	NRC	Auto (15 mins)	01.02.1984 - 10.05.2000
3835	Veronica Channel at Opuia Wharf	1701913	6091757	-1.560	NRC	Auto (15 mins)	26.04.1990 - present

Level records are available for most locations for the storm of March 2012, but only for Waitangi of Wakelins for March 2007. A summary of the data available for each calibration event is shown in Table 4-4.

Table 4-4 Level gauges details

Site ID	Datum	Rating Curve	Level Records	Flow Records	Maximum Recs
3722	2007 / 2012	2007 / 2012	2007 / 2012	2007 / 2012	2007 / 2012
3725	2007 / 2012	2007 / 2012	2012	2012	2007 / 2012
3707 new	2007 / 2012		2012		2007 / 2012
3707 old	2007 / 2012	2007 / 2012			2007 / 2012
3835 (Tidal)	2007 / 2012		2007 / 2012		2007 / 2012

Flow records analysis show runoff coefficients between 0.45 and 0.59 and these appear to be realistic. A closer review of these values compared between the two events and a volume variance of the whole catchment suggests a global value of around 0.55 for both events.

4 Data Analysis

4.2.3 Debris levels

There are 151 surveyed debris levels available for the Waitangi catchment. 14 of them are for the event of March 2007 that can be directly calibrated. The other 137 points refer to the storm of January 2011 and provide a description of the flood extent of a similar large event like 2007; as well it allows estimation of the head losses at the main bridges.

Calibration

The model was calibrated for the two events of March 2012 and March 2007, against the respective recorded levels and flows, as described in Sections 2 and 4.

The following table summarises the important calibrated variables.

Table 5-1 Calibrated parameters

HYDRAULIC MODEL	Value
Manning	
Main channels	0.042 - 0.085
Flood plains	0.050 - 0.15
2D polygons	0.070 - 0.080
Spill coefficients	
Natural banks	0.90
Roads	0.9 - 1.2
Upper storage outlets	1.0 - 1.5
Orifice coeff (culverts)	0.85
Haruru Waterfall	1.10
HYDROLOGICAL MODEL	
Non-linear Reservoir	
K (variable based on catch parameters)	2.0 - 68.22
p (upper catchment)	0.30
p (middle catchment)	0.45
p (lower catchment)	0.60
Infiltration Rate 2012 (mm/hr)	4.40
Infiltration Rate 2007 (mm/hr)	4.30
Time of lag (minutes)	0 - 340

The manning calibration responds to a review of the losses and levels in different areas. Some high manning numbers were required in areas where the no LiDAR or survey information was available, like the extension of the 1D model up to the Waimate flow/level gauge that has an extension of over 7kms. The sections were assumed based on few cross sections by the gauge and the closest LiDAR ground data. Manning coefficient was then used to adjust the head loses and levels required to calibrate the rating curve by the gauge.

The Non-Linear Reservoir (NLR) coefficient *K* was defined for each sub-catchment based on the Izzard function available in InfoWorks RS. This function related the topographic parameters of each sub-catchment with the NLR coefficients.

The calibration of the Hydrological model had a few steps before the final setup. Initially the flows were calibrated to match the peak flows of each gauge. This assumed that the whole set of records, specially rating curve, were reliable. The first calibration shows good match for flows, but it was not possible to match the higher debris and gauges levels. Attempts to fix this were first focused to identify singular loses, roughness coefficients, bed level review, potential obstructions and bridges/culverts

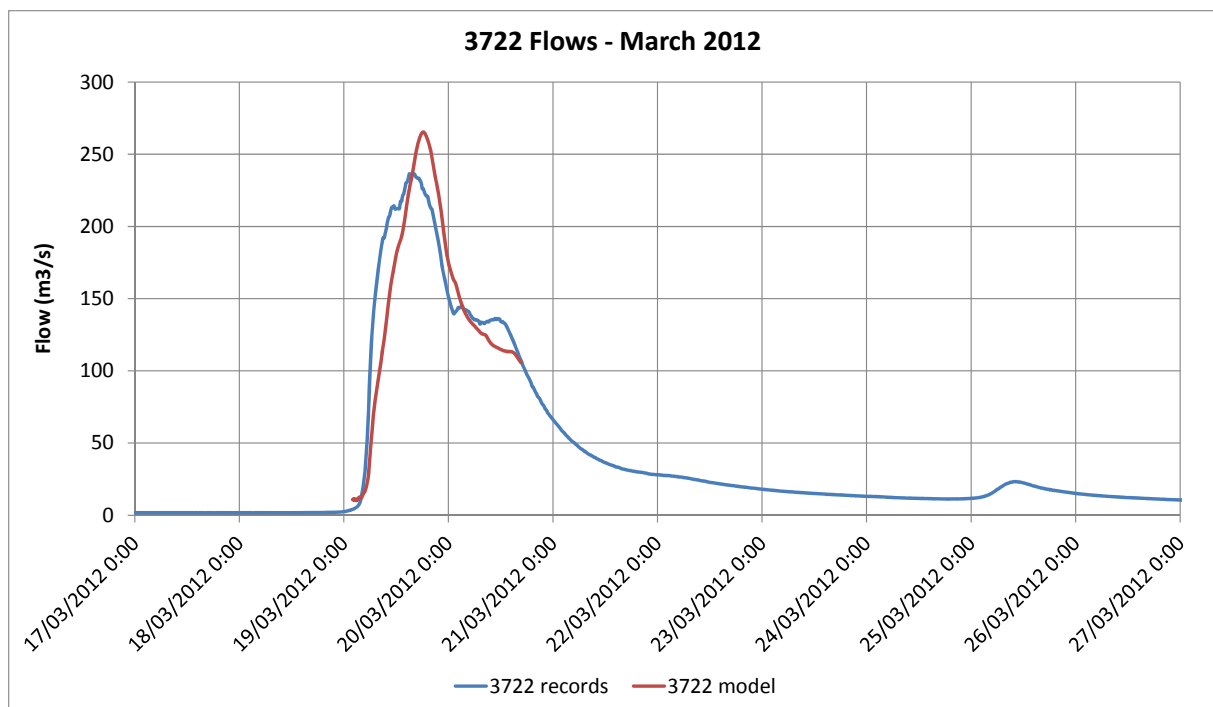
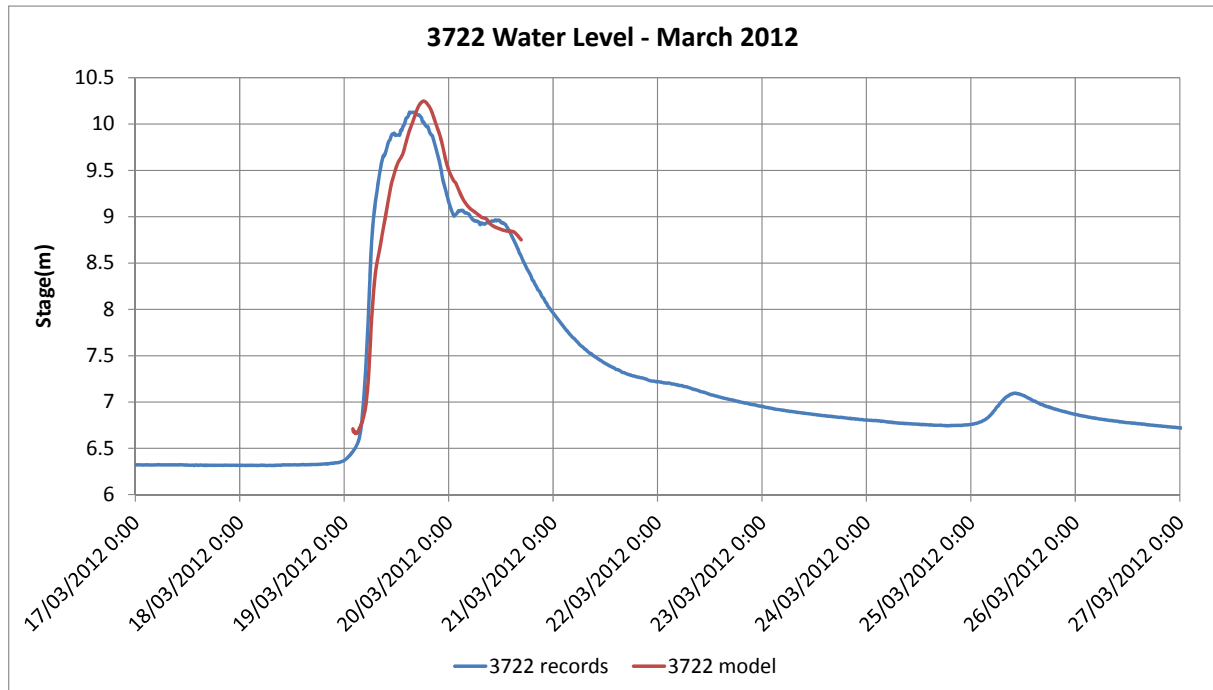
5 Calibration

description. These tests showed that the levels would not increase in the required amount by these parameters, and that it was necessary to increase the peak flows in some locations to achieve a better match with level records. The preliminary calibration also showed certain mismatches between the recorded and modelled peak time that allowed a good match for the volume and a lower peak calibration. A second stage of the calibration allowed higher flows for certain areas, especially for the Waitangi at Wakelins gauge to improve the calibration of the debris and gauge levels. This adjustment on the peak flows was done by slightly adjusting the peak timing and modifying the parameter p of the hydrographs for the middle and lower catchment (as shown in Table 5-1).

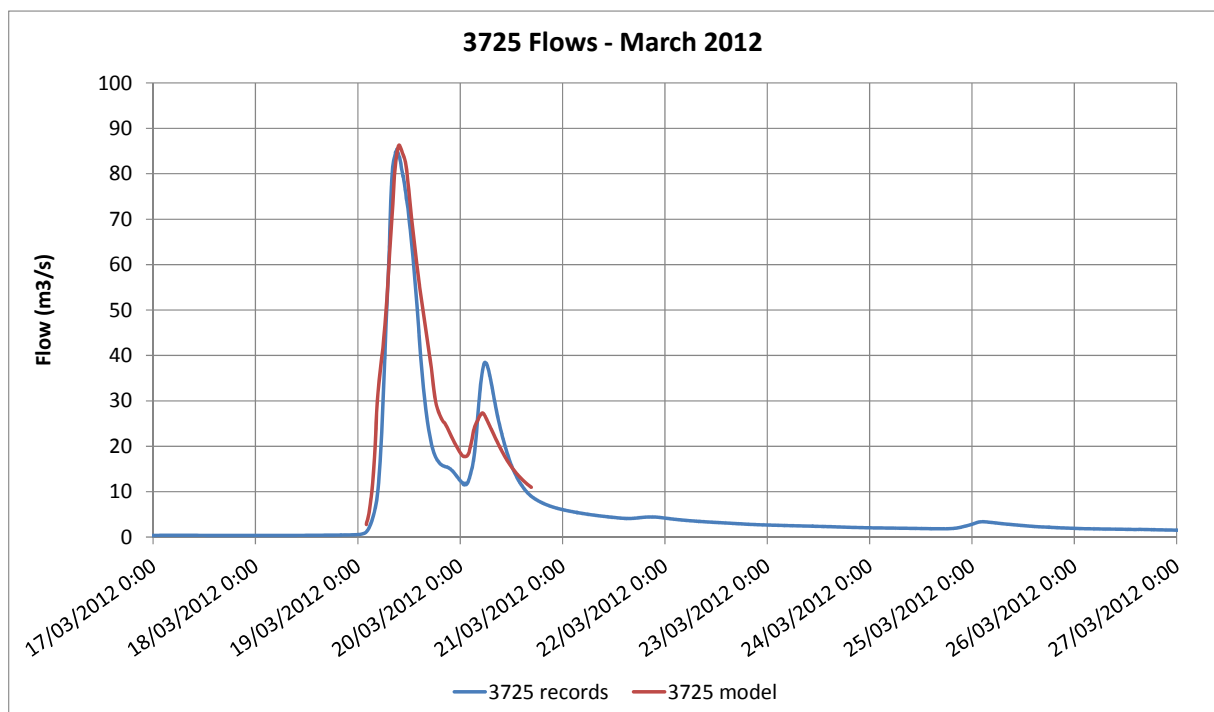
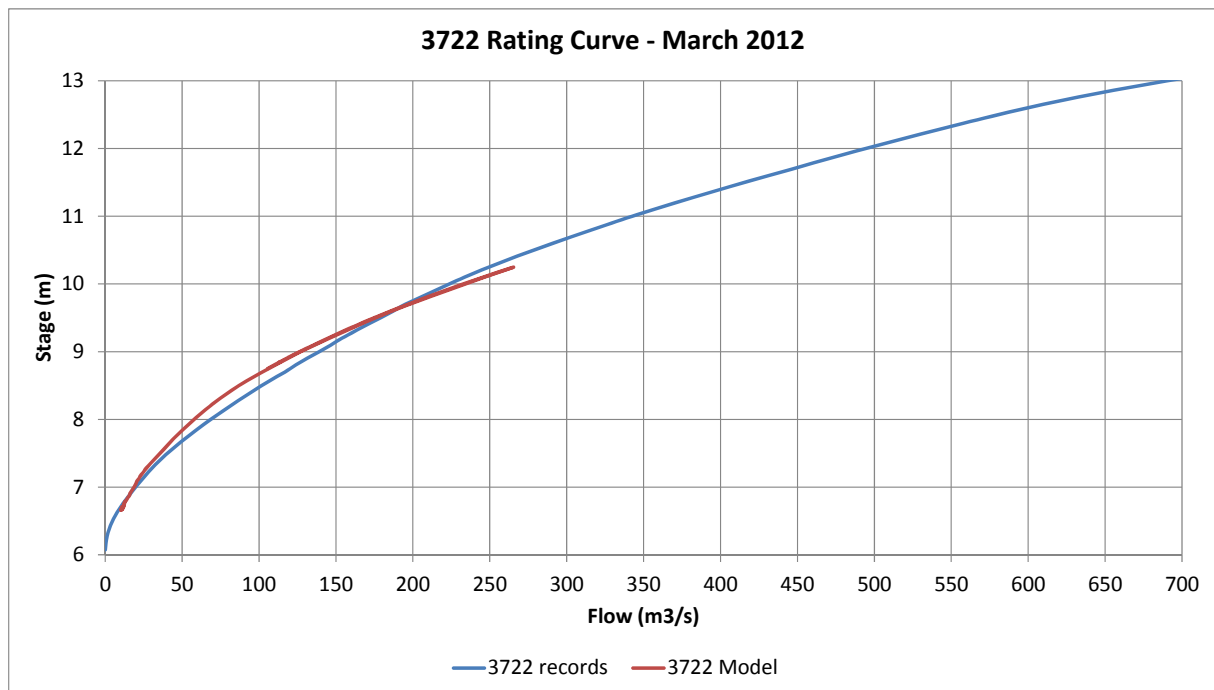
The results of the final calibration are shown in the following sections.

5 Calibration

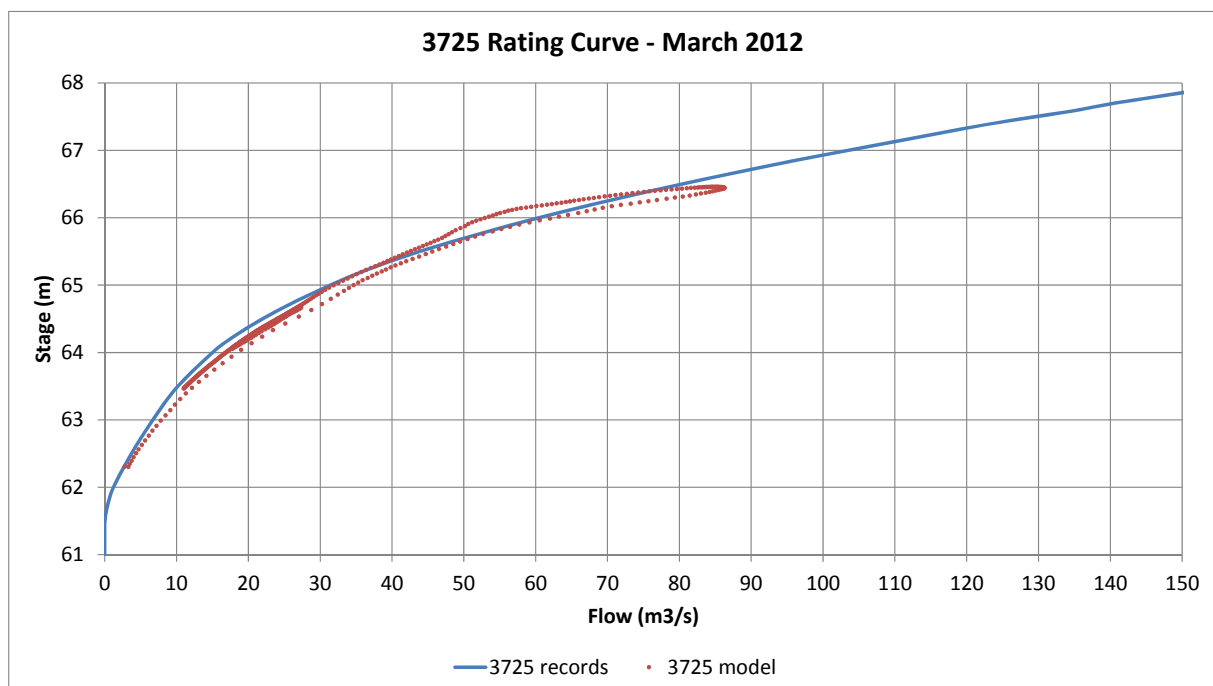
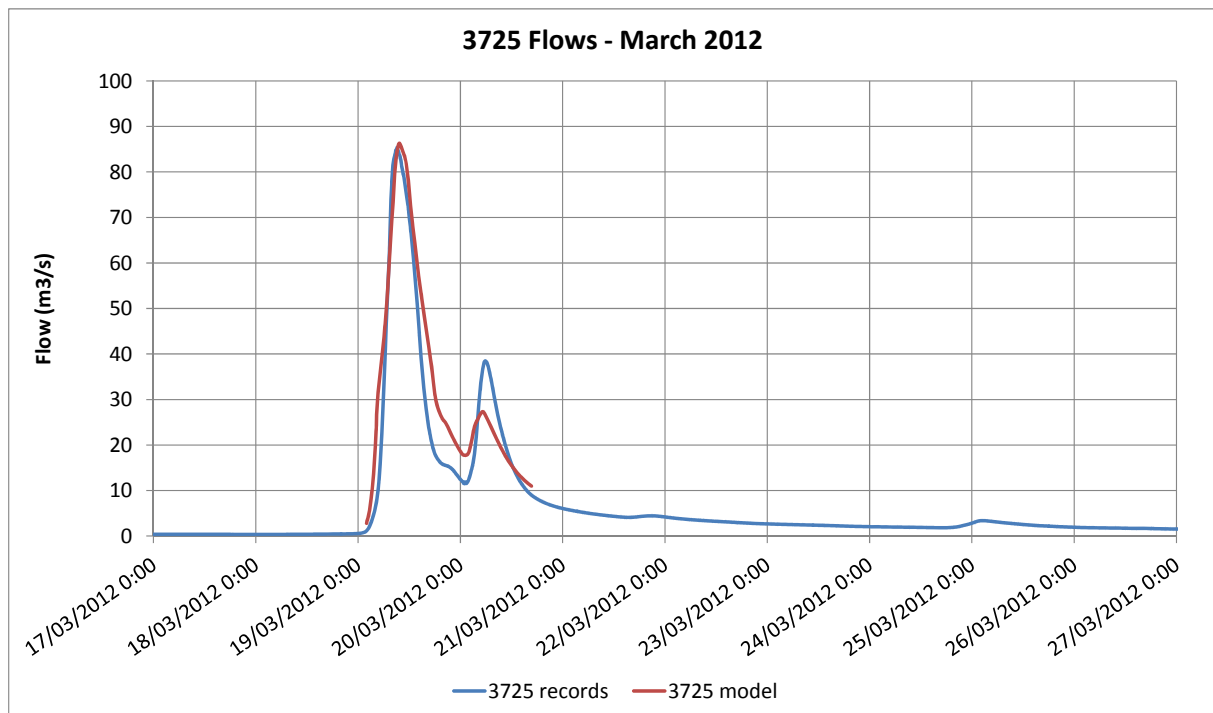
5.1 Calibration March 2012



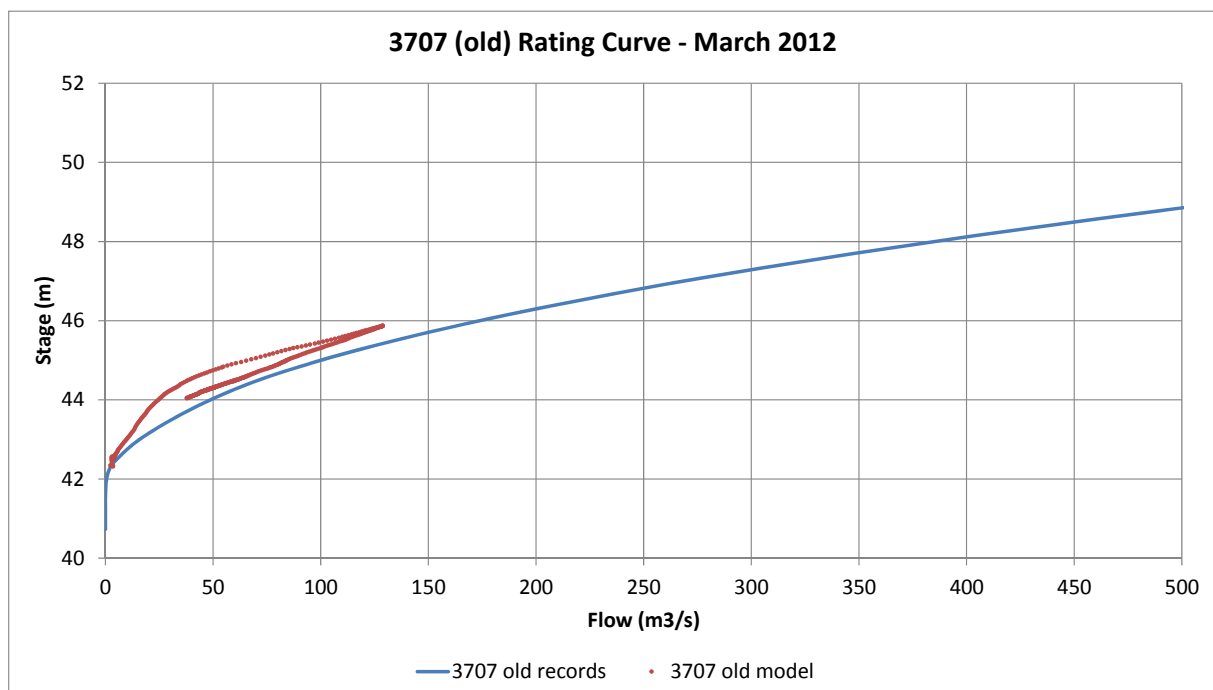
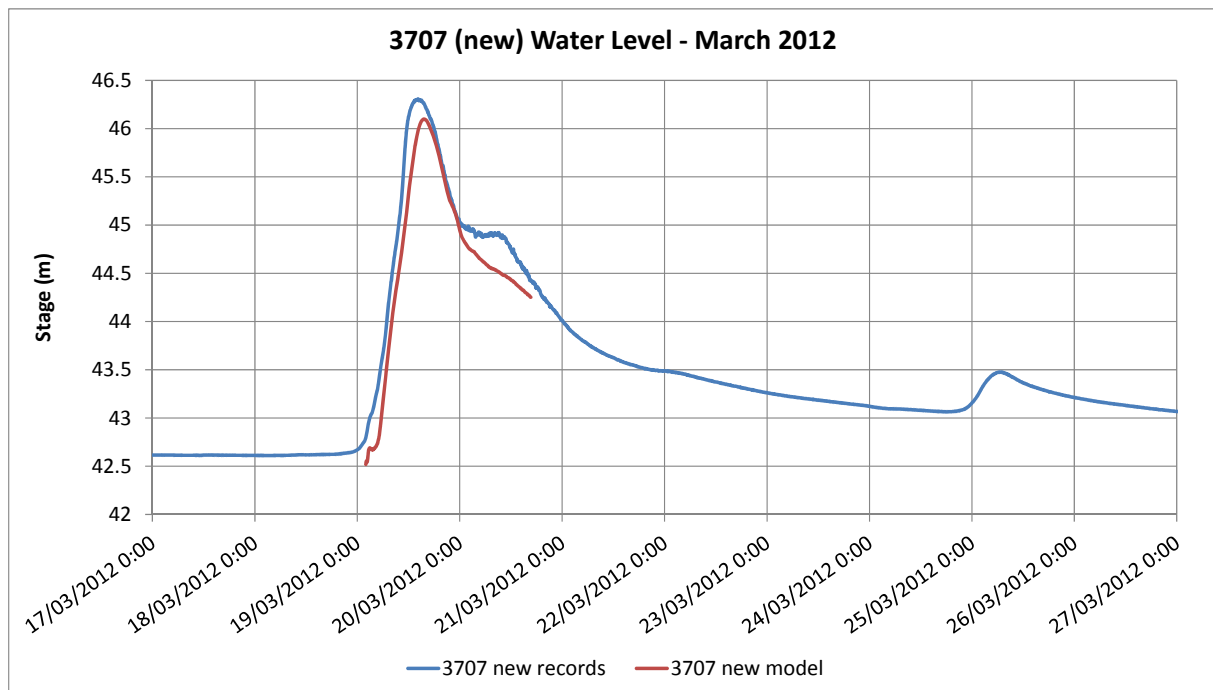
5 Calibration



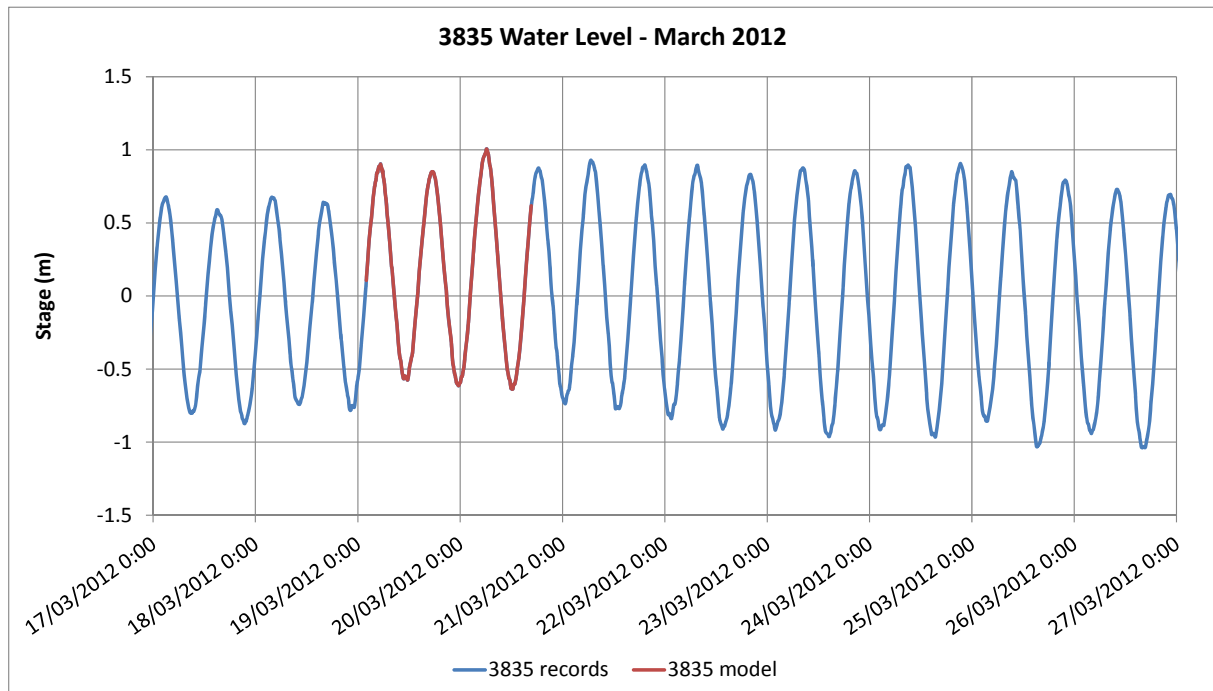
5 Calibration



5 Calibration



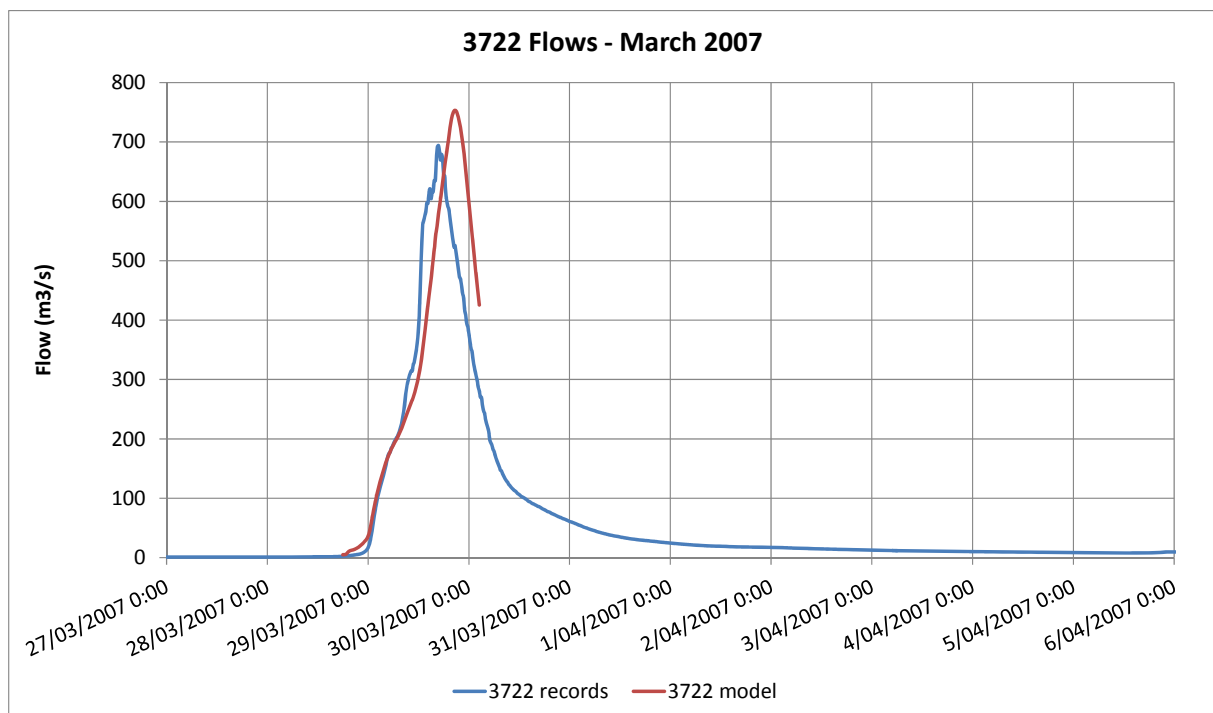
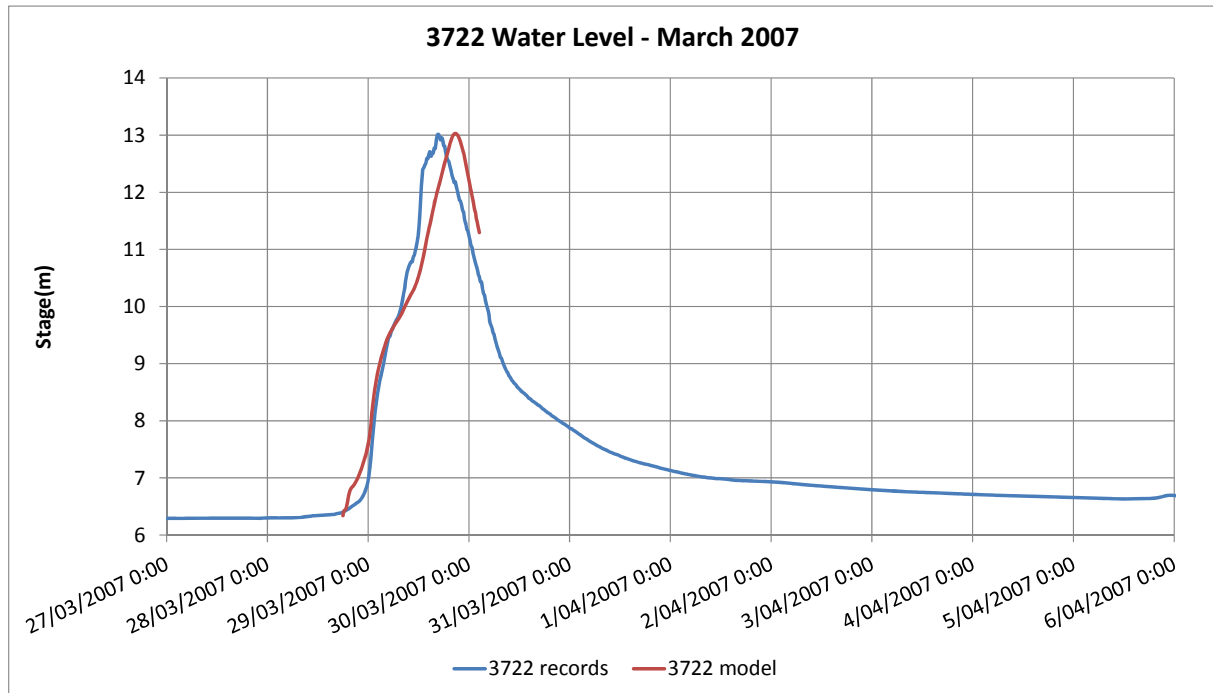
5 Calibration



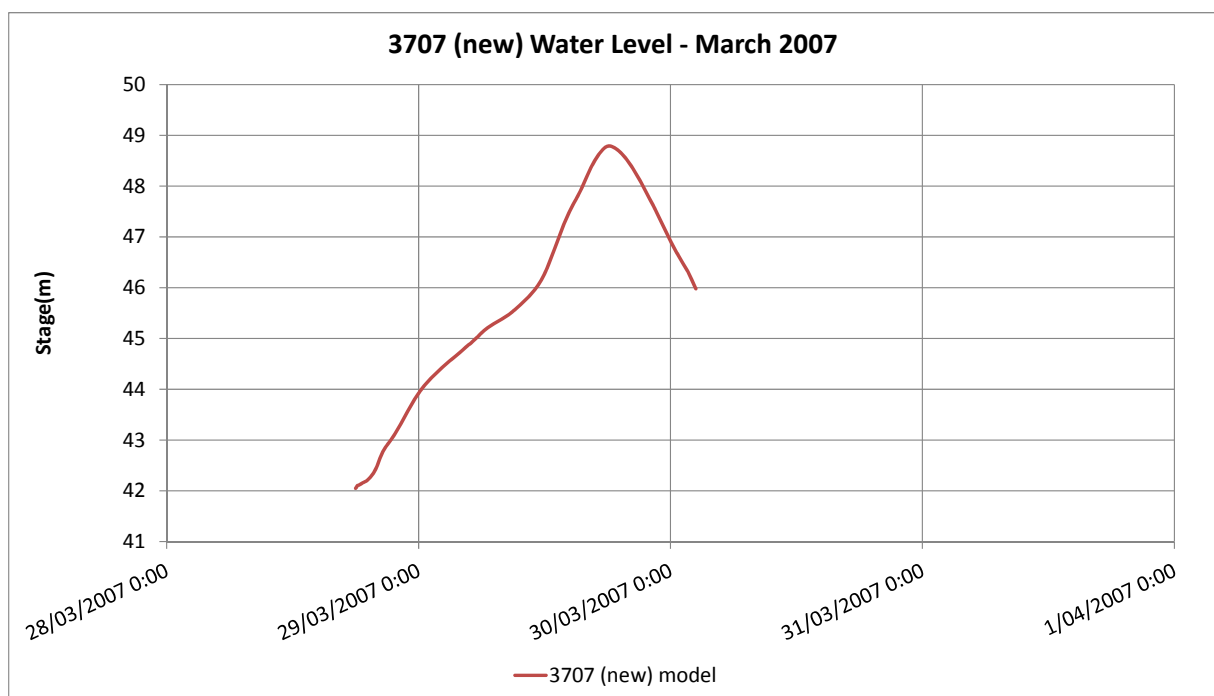
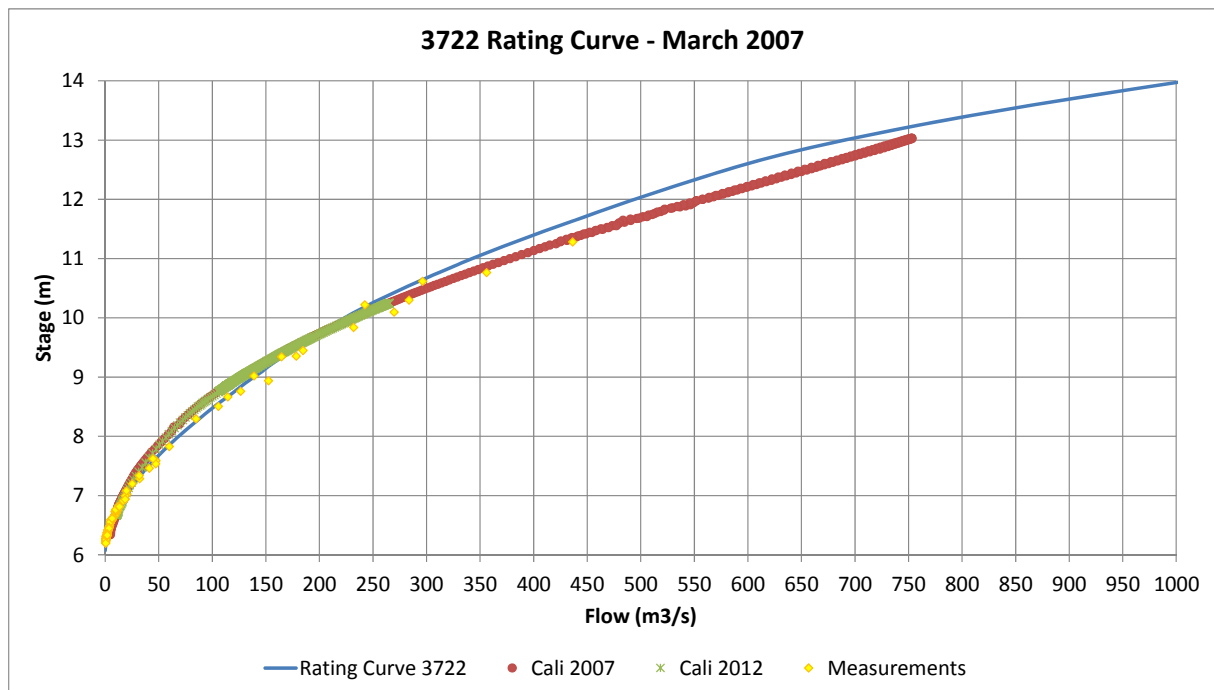
Site ID	3722	3725	3707 new	3707 old	3835
Site Name	Waitangi at Wakelins	Waitangi at Waimate North Road	Waiaruhe at Puketona (new site)	Waiaruhe at Puketona (old site)	Veronica Channel at Opua Wharf
Max flood elevation Mar 2012 (m OTP)	10.128	66.616	46.308	46.030	1.006
Predicted Peak Flow Mar 2012 (from rating curve) m ³ /s	236.420	85.409		176.000	
Time of flood peak	19/03/2012 16:00	19/03/2012 9:10	19/03/2012 14:15	19/03/2012 14:15	19/03/2012 17:35
Model Maximum Level	10.248	66.461	46.099	45.87	1.005
Model Maximum Flow	265.42	86.31	122.235	128.732	381.06
Model Time of Peak	19/03/2012 18:15	19/03/2012 10:15	19/03/2012 15:35	19/03/2012 15:35	20/03/2012 6:10

5 Calibration

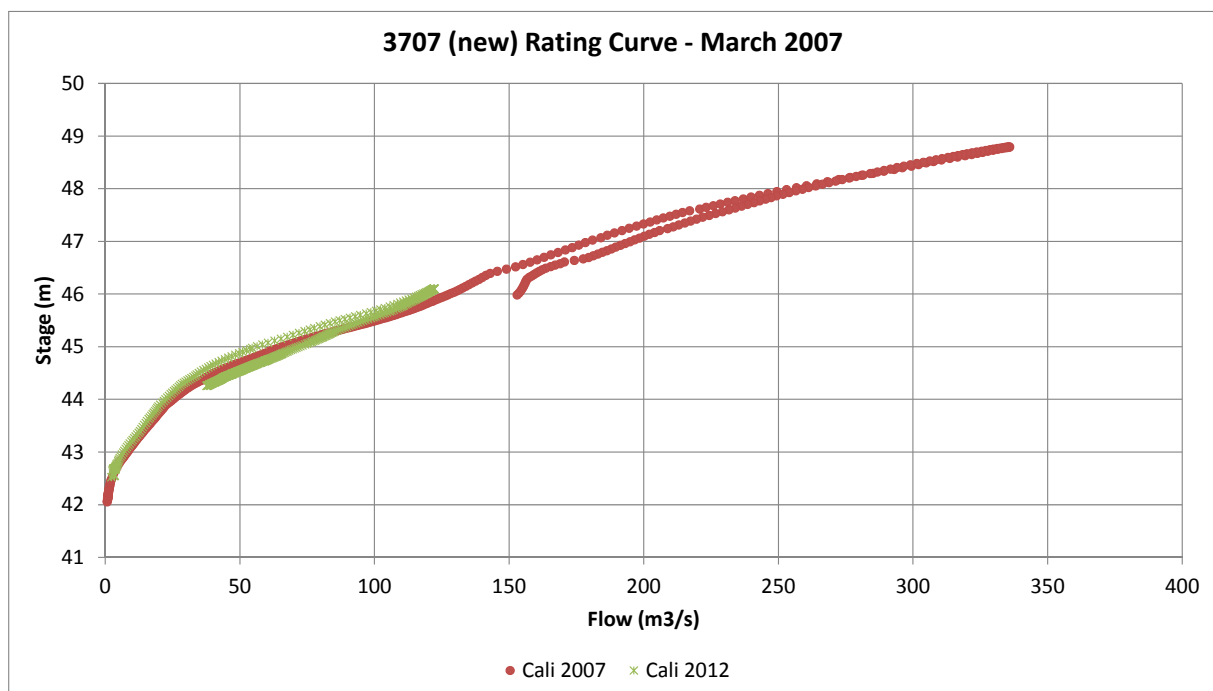
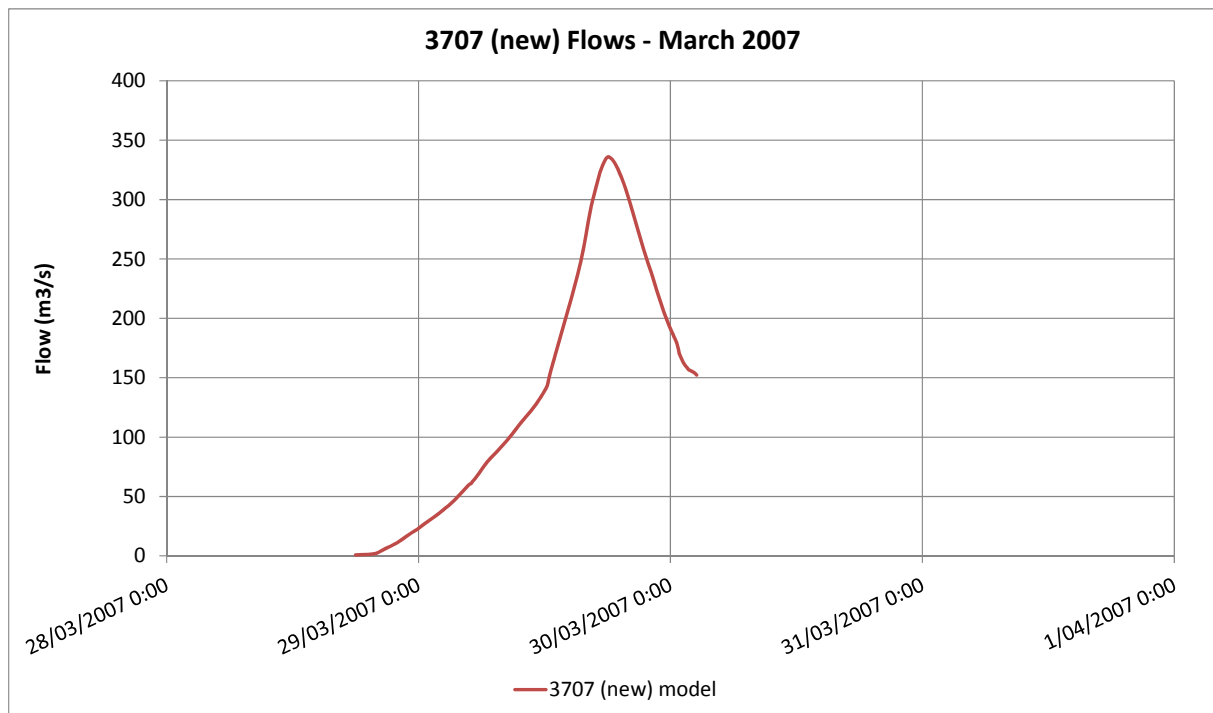
5.2 Calibration March 2007



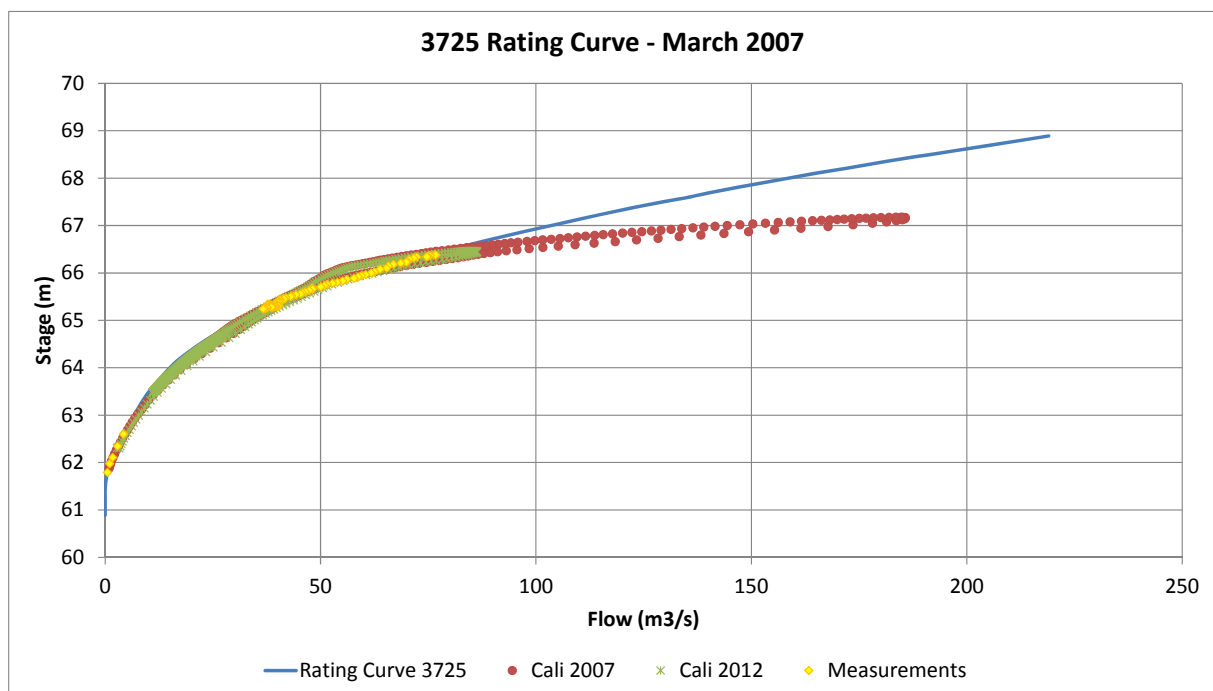
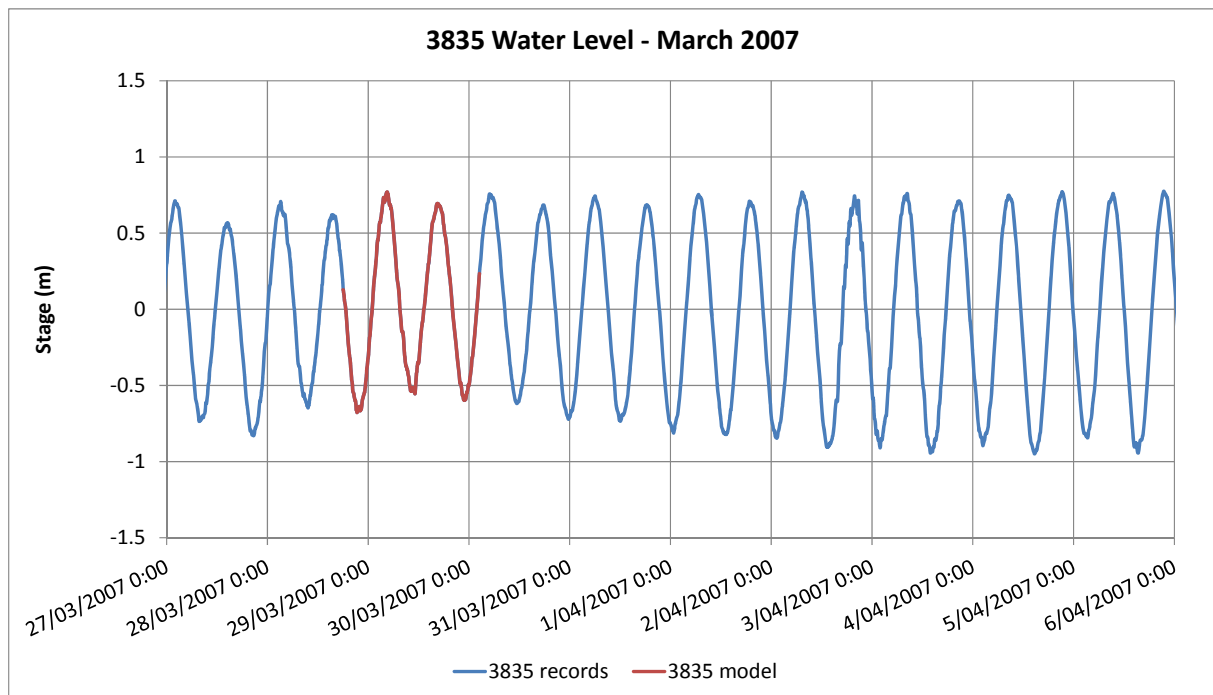
5 Calibration



5 Calibration



5 Calibration



5 Calibration

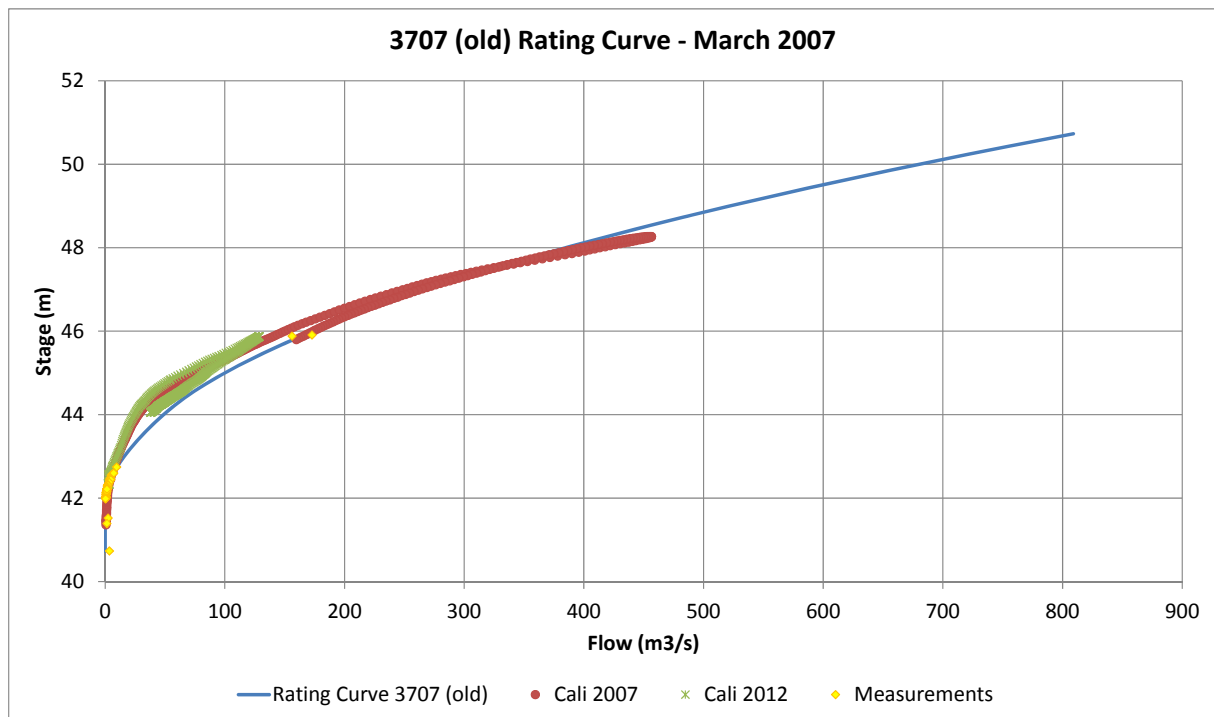


Table 5-2 Measured and modelled debris level points

Debris Level Location	X (m)	Y (m)	Debris Level (m)	Ground Level (m AD)	Max Flood Level (m AD)	Diff (m)	Comments
18 / 2007	1695580.99	6095654.85	11.66	11.591	11.703	0.043	<10cms. US of Bridge at waterfall. Adjustable.
19 / 2007	1695600.48	6095631.34	10.79	10.531	10.910	0.120	<20cms. DS of bridge at waterfall. Adjustable.
20 / 2007	1695879.49	6095477.87	3.5	3.039	3.130	0.370	Might be due of 2D flow features at DS of waterfall. Debris level facing waterfall flow direction at meander.
831 / 2007	1693614.89	6094932.12	17.78	17.868	17.396	0.384	- Next to Wai8. See Wai8 comments.
GAUGE / 2007	1695268.53	6095800.7	13.01	9.827	13.029	0.019	<10cms. At Wakelins gauge.
OPUS / 2007	1691202.76	6094469.15	32.09	31.169	32.315	0.225	Manning or spill coef. could be adjusted.
WAI1 / 2007	1688053.25	6094234.52	45.87	45.983	46.111	0.241	Manning or spill coef. could be adjusted.
WAI2 / 2007	1686817.06	6093742.01	48.77	48.94	48.566	0.204	Adjusted.

5 Calibration

WAI3 / 2007	1687130.67	6093364.18	47.8	47.884	48.031	0.231	Adjustable. Manning DS of bridge 0.07 (try 0.06?). Also need to increase manning US of bridge to adjust head loss. Maybe more losses on the bridge.
WAI4 / 2007	1687301.55	6093099.08	47.96	48.11	48.105	0.145	<20cms. DS of Puketona Bridge
WAI5 / 2007	1687267.45	6093020.62	48.6	48.419	48.908	0.308	US of Puketona Bridge. Model bridge head loss 0.8m
WAI6 / 2007	1687528.02	6093327.02	47.81	47.81	47.907	0.097	<10cms
WAI7 / 2007	1691917.19	6094417.79	29.39	29.382	29.477	0.087	<10cms. Read manually from XS 04_5_03317
WAI8 / 2007	1693615.03	6094932.13	17.73	17.868	17.396	0.334	-
101 / 2011	1687595.97	6092752.19	49.343	49.52	49.297	0.046	-
102 / 2011	1687599.72	6092750.85	49.382	49.475	49.296	0.086	-
103 / 2011	1687446.6	6092832.07	49.023	48.891	49.034	0.011	-
104 / 2011	1687443.06	6092823.75	49.064	48.512	49.034	0.030	-
105 / 2011	1687480.28	6092792.74	48.962	49.112	49.114	0.152	-
106 / 2011	1687485.86	6092778.67	49.008	49.146	49.150	0.142	-
107 / 2011	1687494.96	6092765.32	49.022	49.166	49.182	0.160	-
108 / 2011	1687432.71	6092818.73	49.034	47.299	48.936	0.098	-
109 / 2011	1687430.2	6092817.18	48.975	46.764	48.936	0.039	-
110 / 2011	1687451.31	6092910.12	48.748	48.824	48.873	0.125	-
111 / 2011	1687443.16	6092917.84	48.817	48.906	48.870	0.053	-
112 / 2011	1687431.86	6092928.38	48.797	48.844	48.868	0.071	-
115 / 2011	1687276.48	6093010.83	49.025	48.396	48.906	0.119	-
116 / 2011	1687246.62	6093012.53	49.062	48.378	48.909	0.153	-
117 / 2011	1687240.74	6093025.01	49.054	48.373	48.911	0.143	-
118 / 2011	1687244.08	6093028.8	49.073	48.245	48.911	0.162	-
120 / 2011	1687426.72	6092978.64	48.275	48.199	47.964	0.311	-
121 / 2011	1687453.16	6093111.54	48.127	47.666	47.978	0.149	-
122 / 2011	1687451.74	6093111.38	48.086	47.702	47.981	0.105	-
123 / 2011	1687415.93	6093136.56	48.16	47.477	48.007	0.153	-

5 Calibration

124 / 2011	1687464.66	6093223.05	48.097	46.572	47.969	-	0.128
125 / 2011	1687454.11	6093174.33	48.133	47.004	47.981	-	0.152
126 / 2011	1687453.9	6093159.8	48.133	47.234	47.982	-	0.151
127 / 2011	1687450.99	6093139.61	48.127	47.264	47.980	-	0.147
128 / 2011	1687445.17	6093141.41	48.138	47.316	47.983	-	0.155
129 / 2011	1687532.03	6093326.46	48.012	48.134	47.907	-	0.105
130 / 2011	1687531.66	6093323.58	48.025	48.119	47.916	-	0.109
131 / 2011	1688125.21	6093769.48	46.562	47.086	46.400	-	0.162
132 / 2011	1688104.66	6093756.16	46.576	46.688	46.450	-	0.126
133 / 2011	1688083.12	6093744.28	46.516	46.291	46.500	-	0.016
134 / 2011	1688083.69	6094247.04	45.675	45.968	46.172	-	0.497
135 / 2011	1688057.24	6094233.26	45.927	45.796	46.111	-	0.184
136 / 2011	1688011.3	6094240.1	45.812	45.709	46.129	-	0.317
137 / 2011	1687997.89	6094244.61	45.97	46.145	46.130	-	0.160
138 / 2011	1687989.82	6094246.38	45.991	45.686	46.131	-	0.140
139 / 2011	1687984.39	6094247.62	46.015	46.213	46.133	-	0.118
140 / 2011	1687972.92	6094252.01	45.887	46.025	46.133	-	0.246
141 / 2011	1687956.91	6094259.92	45.91	46.159	46.134	-	0.224
142 / 2011	1687345.33	6093618.75	48.063	48.447	47.942	-	0.121
146 / 2011	1690671.41	6095512.53	36.606	36.682	36.278	-	0.328
147 / 2011	1690677.35	6095506.03	36.586	36.721	36.278	-	0.308
148 / 2011	1690689.06	6095505.88	36.55	36.717	36.278	-	0.272
149 / 2011	1690693.24	6095481.52	36.568	36.718	36.277	-	0.291
150 / 2011	1690690.03	6095461.54	36.579	36.736	36.277	-	0.302
151 / 2011	1690668.07	6095457.26	36.586	36.739	36.277	-	0.309
152 / 2011	1690654.7	6095444.73	36.61	36.745	36.277	-	0.333
153 / 2011	1690660.16	6095427.79	36.634	36.78	36.278	-	0.356
154 / 2011	1690669.1	6095406.56	36.618	36.794	36.278	-	0.340
155 / 2011	1690674.6	6095384.51	36.673	36.779	36.279	-	0.394

5 Calibration

156 / 2011	1690690.72	6095369.72	36.647	36.757	36.279	-	0.368
157 / 2011	1690700.04	6095353.18	36.659	36.753	36.243	-	0.416
158 / 2011	1690695.4	6095336.09	36.736	36.824	36.235	-	0.501
159 / 2011	1690688.27	6095316.09	36.743	36.803	36.167	-	0.576
160 / 2011	1690681.55	6095301.45	36.755	36.848	36.119	-	0.636
161 / 2011	1690647.42	6095568.86	36.3	36.153	36.269	-	0.031
162 / 2011	1686947.38	6093681.49	48.191	47.414	48.065	-	0.126
163 / 2011	1686946.64	6093717.44	48.214	48.238	48.066	-	0.148
164 / 2011	1686952.73	6093733.85	47.9	48.313	48.072	-	0.172
165 / 2011	1686973.59	6093741.32	48.091	48.333	48.100	-	0.009
166 / 2011	1686995.11	6093738.28	48.133	48.305	48.086	-	0.047
167 / 2011	1687017.7	6093735.96	48.088	48.369	48.074	-	0.014
168 / 2011	1687032.69	6093729.17	48.118	48.197	48.065	-	0.053
169 / 2011	1686836.33	6093735.3	48.815	48.961	48.543	-	0.272
170 / 2011	1686842.36	6093734.46	48.835	48.964	48.531	-	0.304
171 / 2011	1686861.03	6093739.45	48.84	48.946	48.511	-	0.329
172 / 2011	1686873.39	6093738.77	48.867	49.176	48.495	-	0.372
173 / 2011	1686883.55	6093739	48.802	49.002	48.479	-	0.323
174 / 2011	1686887.6	6093742.34	48.813	49.058	48.472	-	0.341
175 / 2011	1686893.55	6093759.35	48.847	49.07	48.461	-	0.386
176 / 2011	1686903.68	6093763.78	48.797	49.07	48.440	-	0.357
177 / 2011	1686913.32	6093763.33	48.806	48.882	48.429	-	0.377
178 / 2011	1686920.09	6093759.18	48.71	48.803	48.423	-	0.287
179 / 2011	1686926.9	6093741.02	48.879	47.995	48.407	-	0.472
180 / 2011	1686929.34	6093716.13	48.888	48.05	48.423	-	0.465
181 / 2011	1686930.47	6093680.83	48.929	47.853	48.374	-	0.555
182 / 2011	1686930.37	6093640.39	48.885	48.465	48.316	-	-

5 Calibration

						0.569	
183 / 2011	1686927.54	6093606.83	48.684	47.928	48.283	-	0.401
184 / 2011	1687606.31	6092206.1	50.035	48.002	49.731	-	0.304
185 / 2011	1687600.84	6092215.66	49.993	48.019	49.725	-	0.268
190 / 2011	1691198.38	6094470.16	31.798	31.018	32.331	-	0.533
191 / 2011	1691209.85	6094455.16	31.738	31.138	32.303	-	0.565
192 / 2011	1692037.65	6094437.61	28.898	29.112	29.284	-	0.386
193 / 2011	1692041.58	6094441.02	28.892	29.057	29.284	-	0.392
194 / 2011	1692050.42	6094447.09	28.967	28.075	29.284	-	0.317
195 / 2011	1692296.96	6094649.98	28.539	27.528	28.750	-	0.211
196 / 2011	1692274.81	6094642.32	28.809	27.71	28.793	-	0.016
502 / 2011	1688367.68	6091643.54	50.349	50.311	50.521	-	0.172
503 / 2011	1688277.38	6091606.7	50.023	49.984	50.371	-	0.348
504 / 2011	1688275.49	6091602.79	49.997	50.142	50.369	-	0.372
505 / 2011	1688273.21	6091599.02	49.966	50.13	50.365	-	0.399
506 / 2011	1688353.51	6091688.16	50.346	50.345	50.564	-	0.218
507 / 2011	1688354.61	6091685.88	50.412	50.438	50.568	-	0.156
508 / 2011	1688385.3	6091705.06	50.498	50.647	50.659	-	0.161
509 / 2011	1688431.03	6091706.33	50.505	50.675	50.774	-	0.269
510 / 2011	1688442.92	6091706.02	50.536	50.628	50.779	-	0.243
511 / 2011	1688455.28	6091704.95	50.448	50.551	50.782	-	0.334
514 / 2011	1687605.4	6092203.45	49.986	48.045	49.732	-	0.254
515 / 2011	1687591.56	6092196.07	49.963	47.998	49.737	-	0.226
516 / 2011	1687595.39	6092125.96	49.963	49.417	49.751	-	0.212
517 / 2011	1687574.8	6092105.65	49.947	49.717	49.812	-	0.135
518 / 2011	1687571.73	6092117.96	49.956	49.418	49.772	-	0.184
519 / 2011	1687565.76	6092112.47	49.826	49.434	49.779	-	0.047
521 / 2011	1687834.12	6092219.85	50.086	50.3	50.164	-	0.078
522 / 2011	1687840.79	6092216.14	49.925	49.917	50.164	-	0.239
523 / 2011	1687851.71	6092207.55	50.084	50.088	50.166	-	0.082
531 / 2011	1687193.49	6091190.2	50.489	50.705	50.746	-	0.257
532 / 2011	1687188.29	6091194.75	50.556	50.638	50.750	-	0.194
533 / 2011	1687176.7	6091194.01	50.473	50.653	50.772	-	0.299
801 / 2011	1695576.08	6095578.96	9.927	9.867	10.617	-	0.690
802 / 2011	1695581.8	6095573.48	9.835	10.062	9.266	-	0.569

5 Calibration

803 / 2011	1695591.47	6095634.03	9.786	9.627	11.040	1.254	
804 / 2011	1695580.81	6095653.79	11.575	11.14	11.703	0.128	
805 / 2011	1695580.99	6095658.27	11.505	11.576	11.732	0.227	
806 / 2011	1695595.54	6095671.59	10.975	10.624	11.779	0.804	
807 / 2011	1695829.68	6095488.23	3.229	1.433	3.158	0.071	
808 / 2011	1695837.86	6095483.58	3.043	1.612	3.151	0.108	
809 / 2011	1695964.59	6095526.2	2.947	2.704	3.065	0.118	
810 / 2011	1695957.61	6095545.71	2.894	2.366	3.054	0.160	
811 / 2011	1696032.29	6095985.15	1.984	1.504	2.271	0.287	
815 / 2011	1694630.33	6095546.87	14.765	14.676	14.405	0.360	
816 / 2011	1694640.87	6095554.88	14.788	14.403	14.397	0.391	
817 / 2011	1694653.95	6095565.12	14.899	14.383	14.383	0.516	
818 / 2011	1694716.31	6095629.1	14.799	14.679	14.319	0.480	
819 / 2011	1694706.87	6095621.87	14.778	14.722	14.340	0.438	
820 / 2011	1694681.17	6095606.93	14.822	14.692	14.358	0.464	
821 / 2011	1694677.68	6095601.96	14.846	14.617	14.361	0.485	
822 / 2011	1695266.04	6095814.03	12.519	12.313	13.032	0.513	
823 / 2011	1695257.4	6095791.82	13.054	13.01	13.028	0.026	
824 / 2011	1695251	6095786.14	13.158	13.098	13.028	0.130	
825 / 2011	1695252.77	6095783.31	13.041	13.075	13.024	0.017	
829 / 2011	1692180.97	6094304.26	27.957	27.183	28.285	0.328	
830 / 2011	1692179.12	6094303.18	27.964	27.702	28.285	0.321	
832 / 2011	1693614.05	6094936.51	17.203	17.258	17.397	0.194	
833 / 2011	1693617.71	6094946.49	17.139	17.178	17.397	0.258	
834 / 2011	1693622.23	6094958.94	17.325	17.328	17.400	0.075	
835 / 2011	1693624.06	6094966.16	17.284	17.323	17.400	0.116	
836 / 2011	1693594.57	6094887.21	16.546	16.86	17.392	0.846	

5 Calibration

From the 2011 debris levels the head losses at the main bridges have been assessed. The table below summarizes the results.

Table 5-3 Head losses at main bridges

Description	US Level point	DS Level point	Model head loss (m)	Data head loss (m)
Haruru Falls bridge	18 / 2007	19 / 2007	0.793	0.870
Bridge of SH10 on Waitangi River	181 / 2011	162 / 2011	0.309	0.738
Bridge of SH10 over Waiauruhe river (Puketona)	WAI5 / 2007	WAI4 / 2007	0.804	0.640
Bridge of SH10 at Oromahoe	509 / 2011	506 / 2011	0.210	0.159

Table 5-4 Summary of global values

Site ID	3722	3725	3707 new	3707 old	3835
Site Name	Waitangi at Wakelins	Waitangi at Waimate North Road	Waiauruhe at Puketona (new site)	Waiauruhe at Puketona (old site)	Veronica Channel at Opua Wharf
Max flood elevation Mar 2012 (m OTP)	13.013				
Predicted Peak Flow Mar 2012 (from rating curve) m ³ /s	693.95				
Time of flood peak	29/03/2007 16:45				
Model Maximum Level	13.03	67.174	48.79	48.264	0.77
Model Maximum Flow	753.28	185.805	335.98	455.491	884.716
Model Time of Peak	29/03/2007 20:45	29/03/2007 13:20	29/03/2007 18:15	29/03/2007 18:05	

Design Events

6.1 Introduction

The 10, 50, 100 and 100yrs plus climate change events were simulated with the calibrated Waitangi model. The details of these simulations are listed below:

6.2 Rain depths and profile

All Design events have a storm duration of 24hrs and a profile defined by NRC in its Hydrological report of 2010. The areal reduction factor is defined by Shamseldin (2008) equal to 0.937 for the Waitangi catchment. The rain depth is defined by HirdsV3 for all sub-catchment centroids for the respective extreme event. For that reason each event has a variable rain depth distribution over the catchment. The table below shows the rain depth for each design event after applying the respective areal reduction factor.

Table 6-1 Summary of global values

Design Event	ARF	Average Rain depth (mm)	Maximum Rain depth (mm)	Minimum Rain depth (mm)
10yrs	0.937	186.6	206.7	165.3
50yrs	0.937	262.5	290.8	232.6
100yrs	0.937	303.4	336.1	268.8
100yrs+CC	0.937	354.5	392.6	314.1

6.3 Rain abstractions

The rain abstractions for the design event are defined with a constant infiltration rate as required by the NLR hydrological method. As for other NRC catchment models, a conservative 2mm/hr. infiltration rate was used for all design events for the Waitangi model. This considers that high levels of moisture are in the soil at the moment the design storms hit the catchment.

6.4 Downstream Tidal Boundary Condition

The Tidal condition is defined by the 2yrs generic tide series produced by NRC and explained in the report of 2010. The peak of time of each series has been preliminarily adjusted to approximately match the time of arrival of the flow peak at the tidal influenced zone.

6.5 Flood Maps

The 10, 50, 100 and 100yrs plus climate change 24 hours design events were simulated and the model results exported to GIS to produce the respective flood maps. The flood maps are included in Appendix A of this report.

6 Design Events

6.6 Design Event Results

The maximum flow and level results for the four design events at the sites are summarized below in Table 6-2.

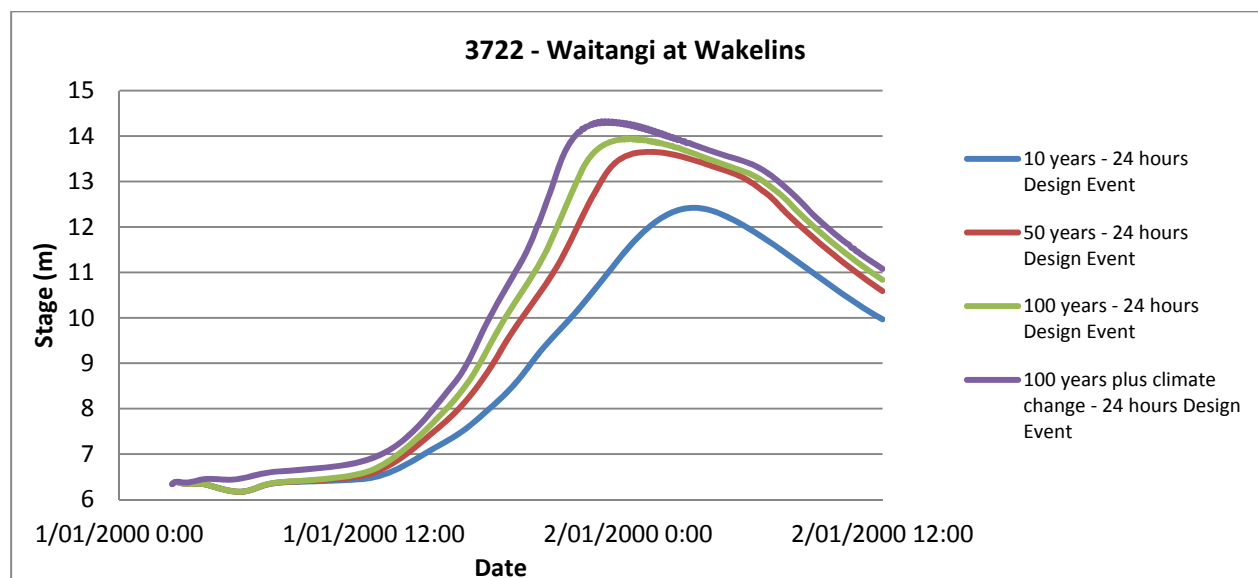
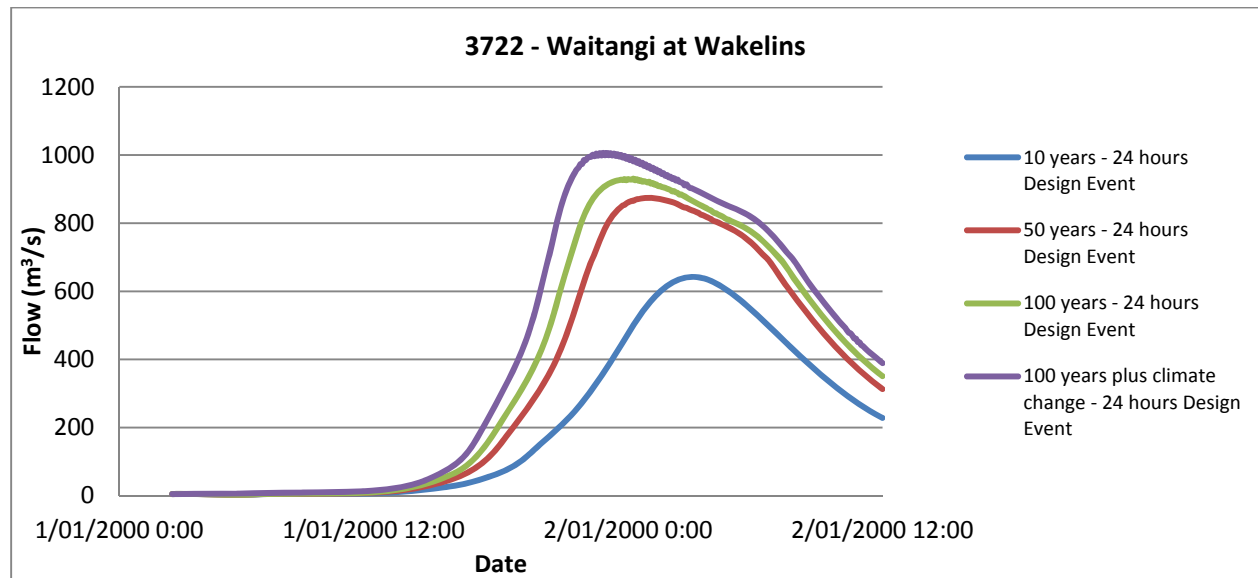
Table 6-2 Level gauges –Design Event Results Summary

Site ID	3722	3725	3707 new	3707 old	3835
Site Name	Waitangi at Wakelins	Waitangi at Waimate North Road	Waiaruhe at Puketona (new site)	Waiaruhe at Puketona (old site)	Veronica Channel at Opua Wharf
10 years - 24 hours					
Model Maximum Level (m)	12.4	67.2	48.4	47.9	1.3
Model Maximum Flow (m ³ /s)	643.3	194.7	299.6	395.3	892.3
Model Time of Peak	02/01/2000 03:10	01/01/2000 19:48	01/01/2000 23:53	01/01/2000 23:50	02/01/2000 03:35
50 years - 24 hours					
Model Maximum Level (m)	13.7	67.9	49.6	48.9	1.3
Model Maximum Flow (m ³ /s)	874.6	354.4	448.8	610.5	1073.1
Model Time of Peak	02/01/2000 01:00	01/01/2000 19:15	01/01/2000 21:38	01/01/2000 21:41	02/01/2000 03:21
100 years - 24 hours					
Model Maximum Level (m)	13.9	68.2	49.6	49	1.3
Model Maximum Flow (m ³ /s)	930.6	443.1	475.1	610.9	1102.3
Model Time of Peak	02/01/2000 00:15	01/01/2000 19:00	01/01/2000 21:35	01/01/2000 20:20	02/01/2000 03:35
100 years plus climate change - 24 hours					
Model Maximum Level (m)	14.3	68.5	49.7	49	1.8
Model Maximum Flow (m ³ /s)	1006.2	549.1	436.9	621.2	1229.5
Model Time of Peak	01/01/2000 23:00	01/01/2000 19:00	01/01/2000 19:30	01/01/2000 19:50	02/01/2000 03:23
Calibration Event – March 2007					
Model Maximum Level	13.0	67.1	48.8	48.3	0.8
Model Maximum Flow	753.3	185.8	335.9	455.5	884.7
Model Time of Peak	29/03/2007 20:45	29/03/2007 13:20	29/03/2007 18:15	29/03/2007 18:05	

6 Design Events

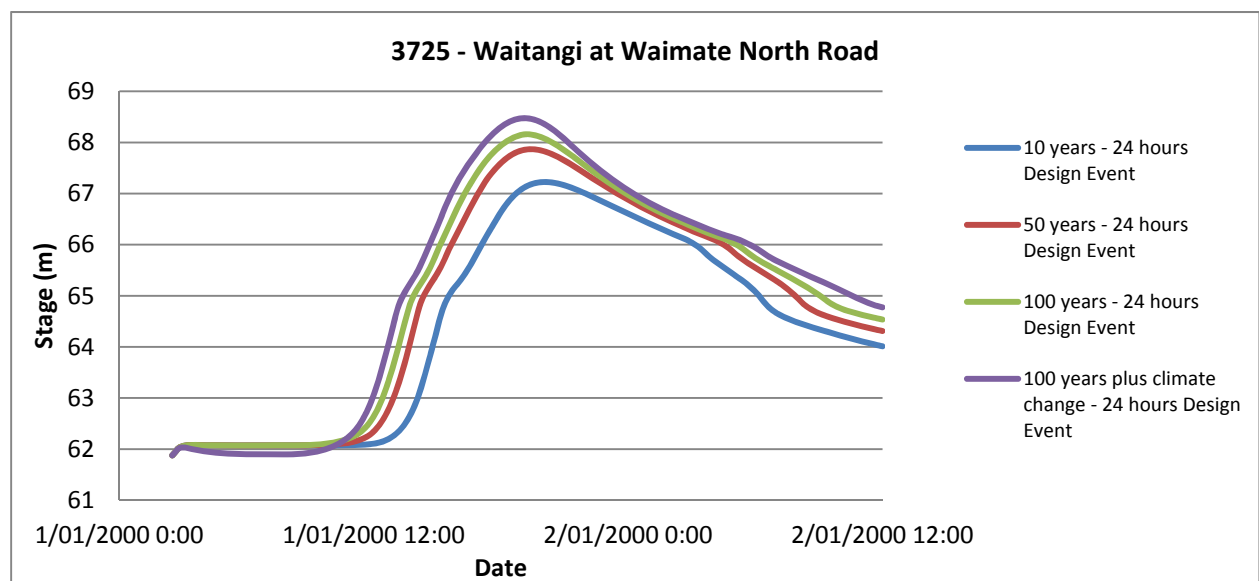
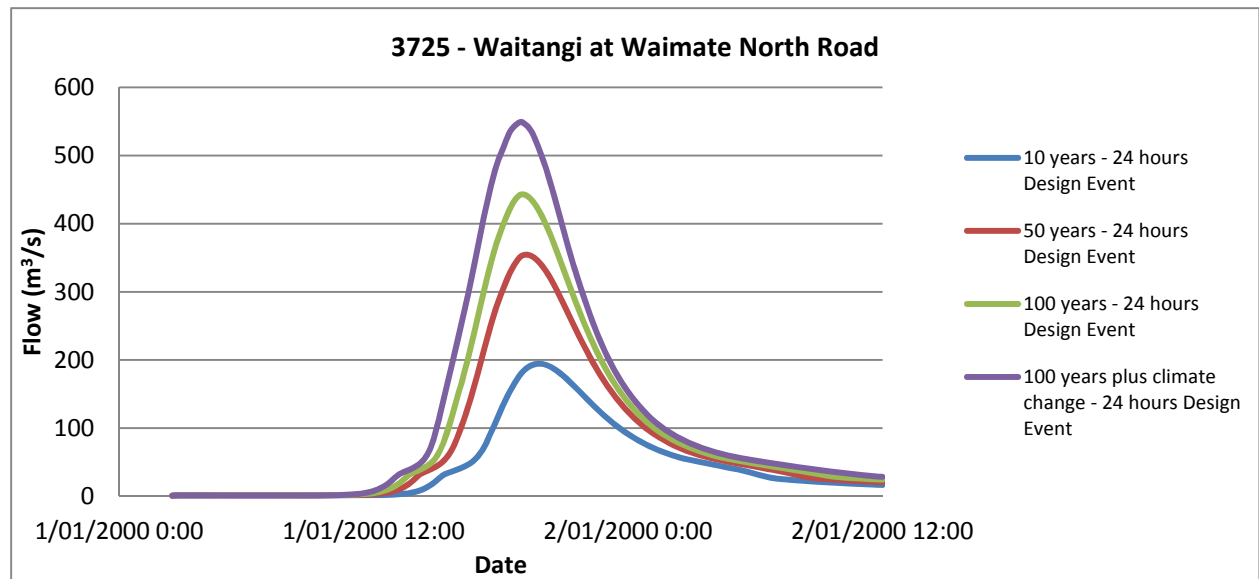
Below is flow and level hydrographs comparing the design events at each site.

Site 3722 - Waitangi at Wakelins



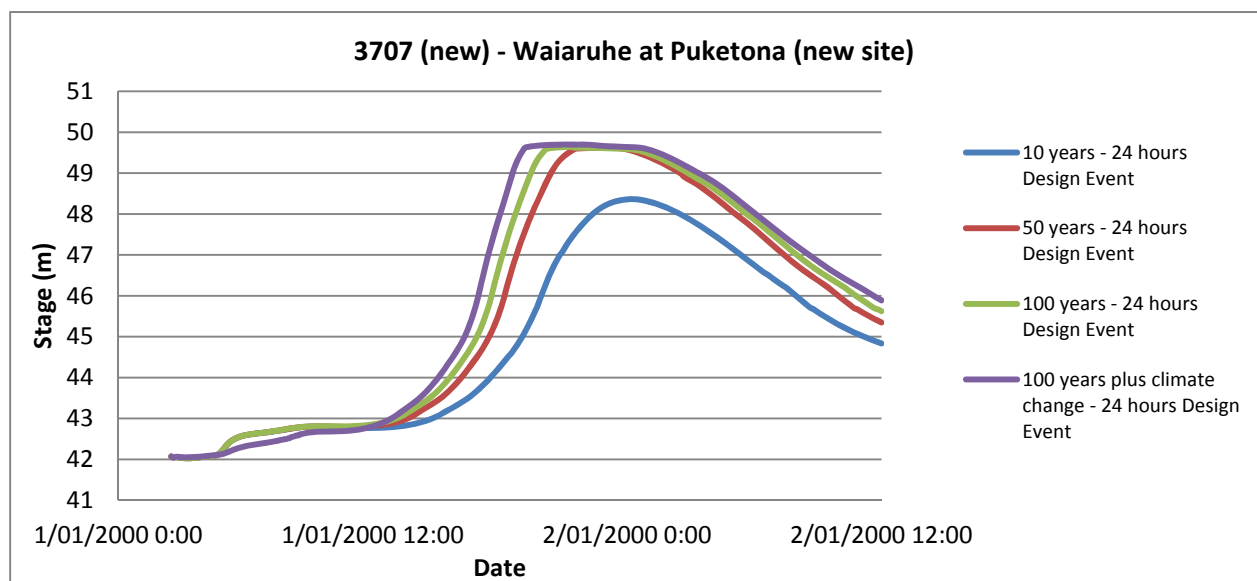
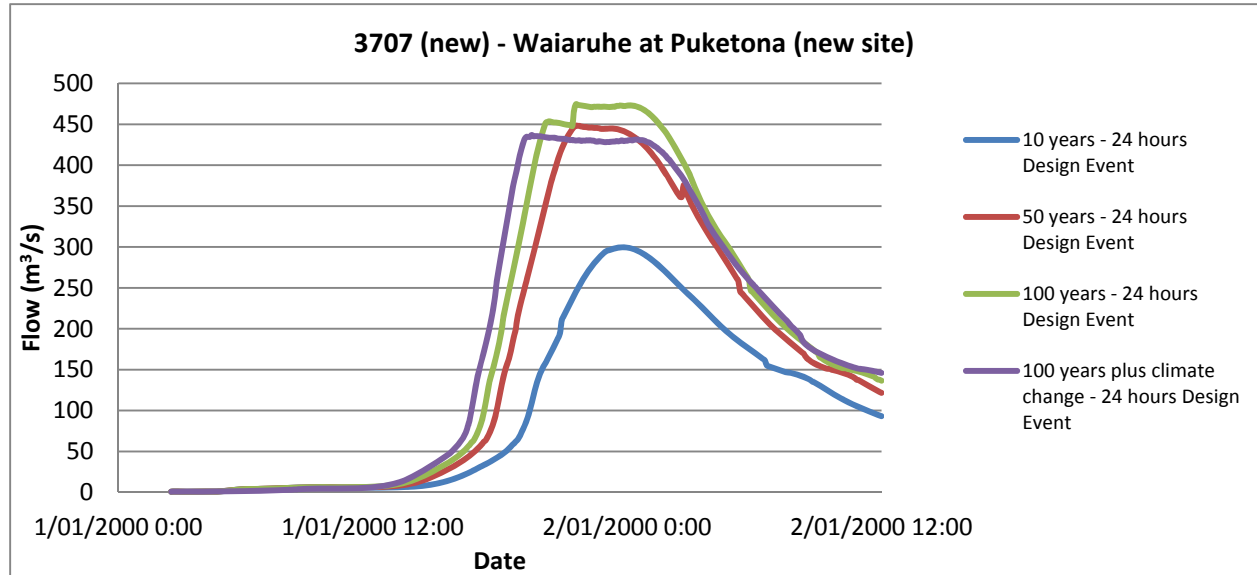
6 Design Events

Site 3725 - Waitangi at Waimate North Road



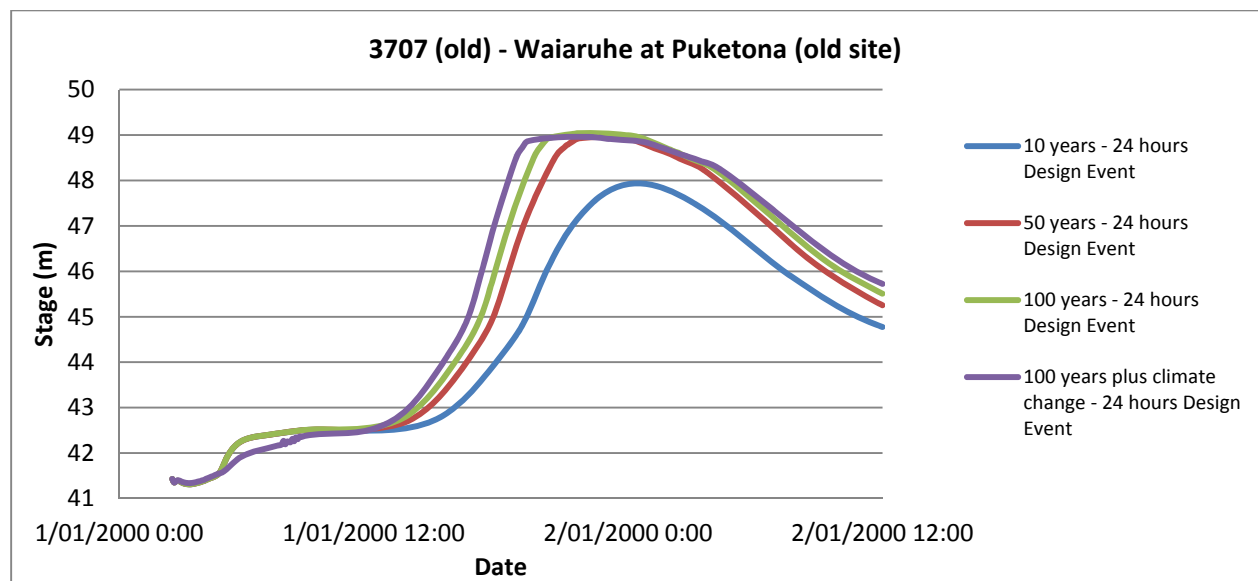
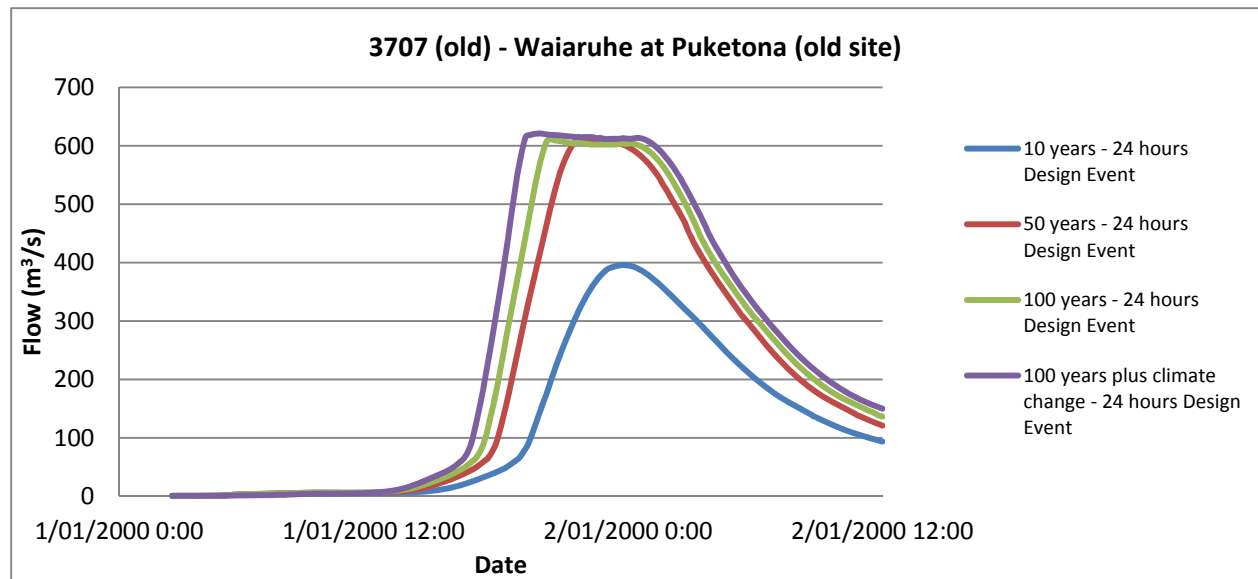
6 Design Events

Site 3707 (new)- Waiaruhe at Puketona (new site)



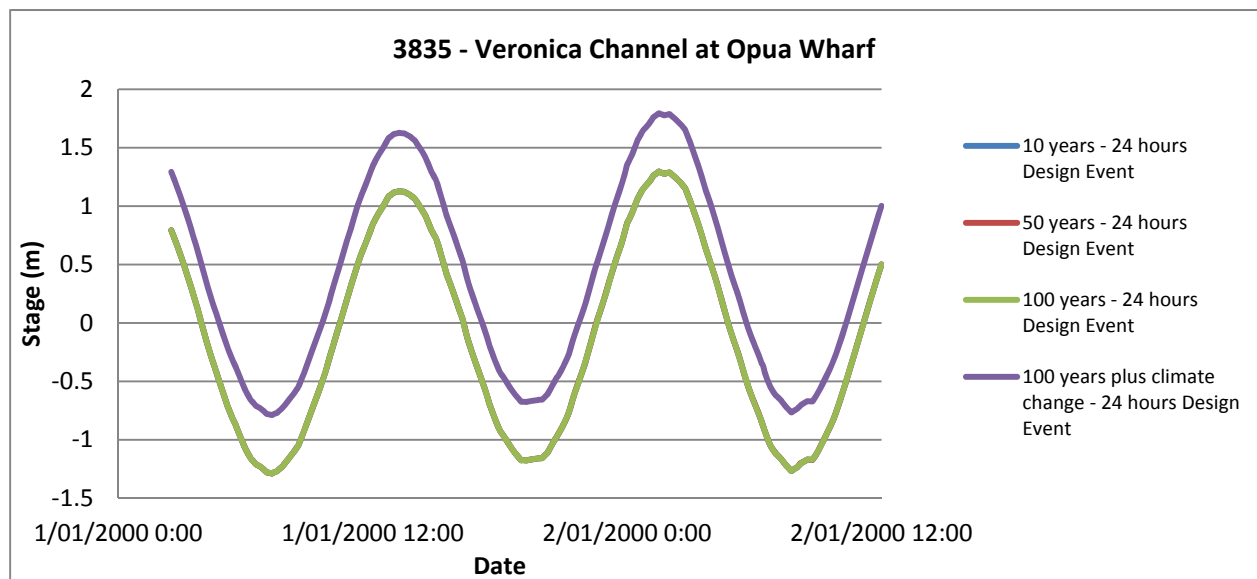
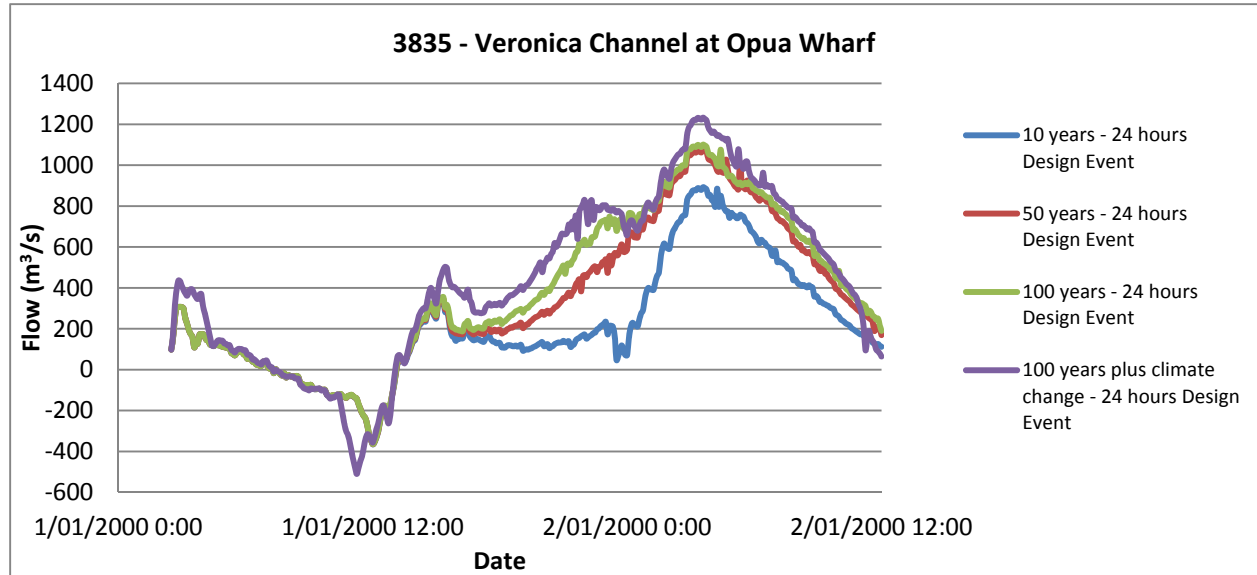
6 Design Events

Site 3707 (old)- Waiaruhe at Puketona (oldsite)



6 Design Events

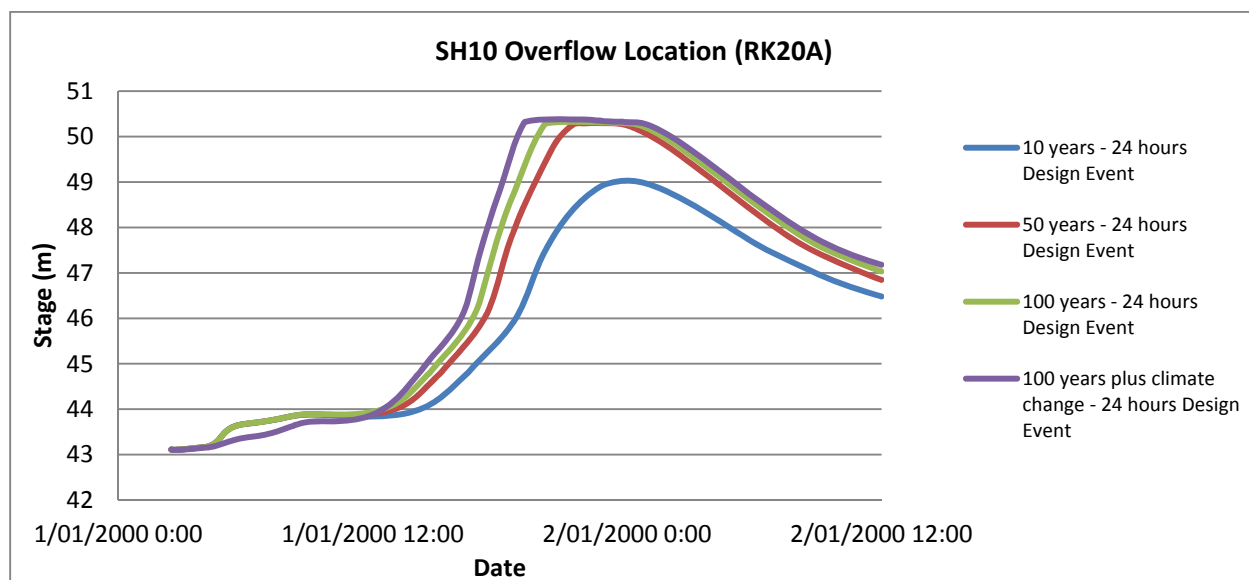
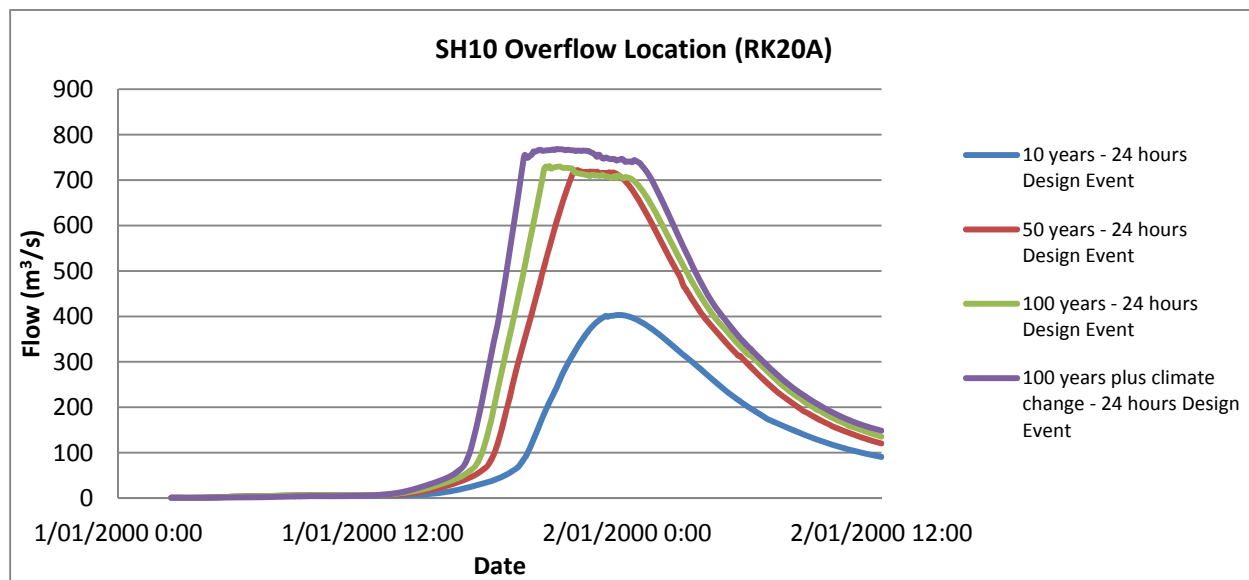
Site 3835 - Veronica Channel at Opua Wharf



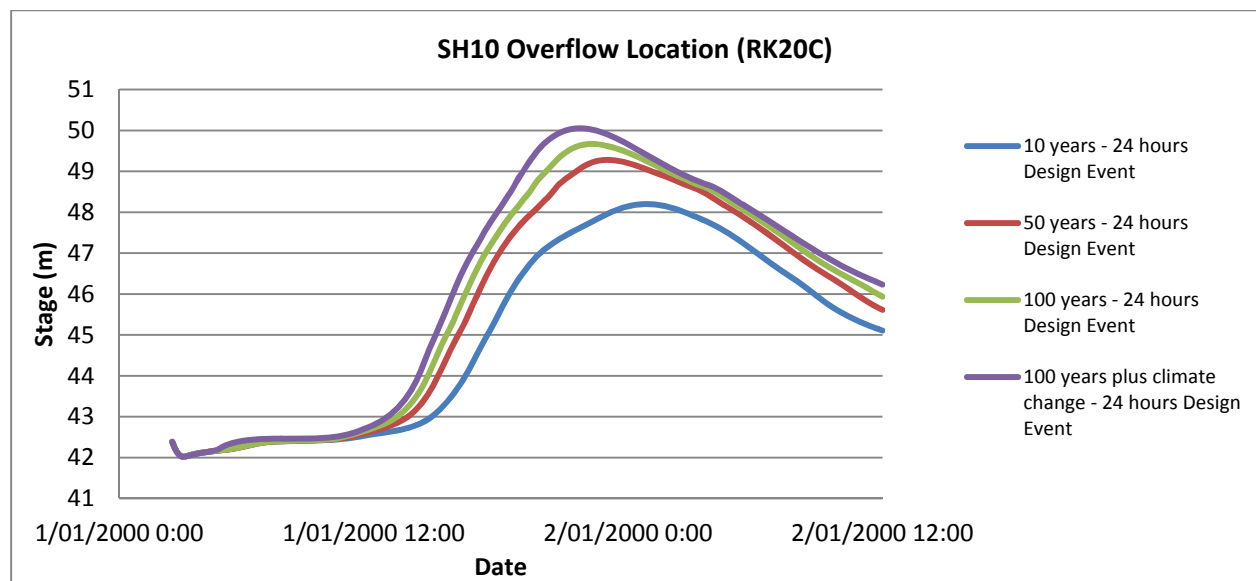
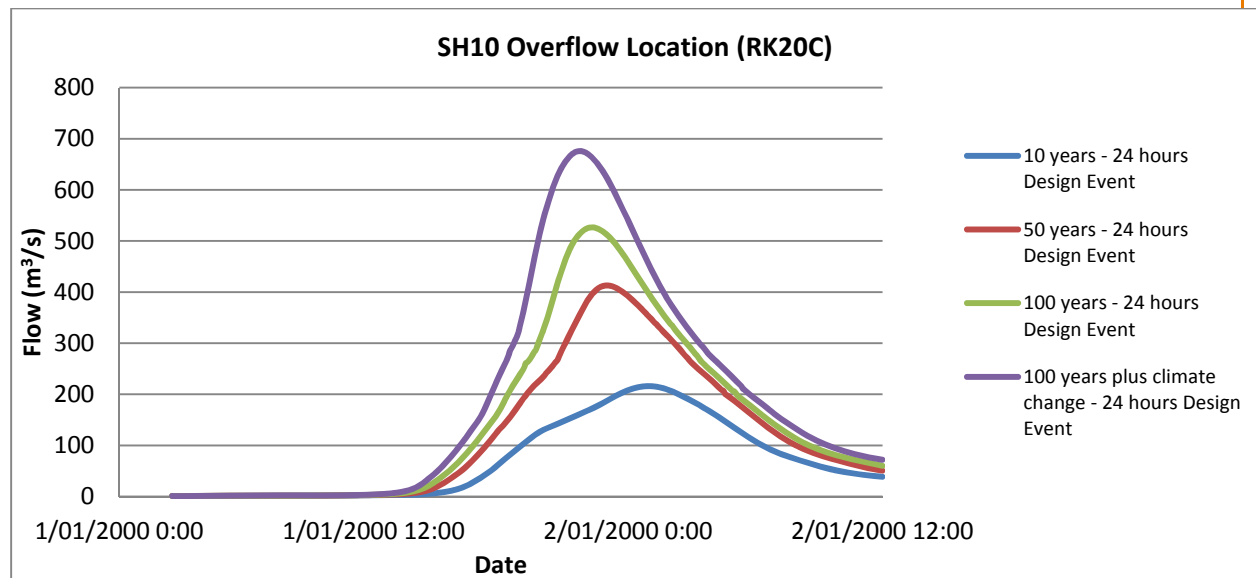
6 Design Events

6.7 SH10 Overflow locations

Two overflow locations on the flood maps have been identified for SH10, These are RK20A and RK20C.



6 Design Events



6.8 Calibration March 2007 Return Period

From the modelling results for the calibration a time of concentration of 9 to 10 hours was identified. Calculating the average rain depth over a 6 to 12 hour range and comparing the results to the frequency analysis of the design events resulted in the following:

Table 6-3 Calibration Event (March 2007) Return Period

Duration	6 hours	9 hours	10 hours	12 hours
Max rain depth (mm)	111	143	150	171
Return Period (years)	12	21	26	17

Discussion and Conclusion

7.1 Discussion Overview

The most critical portion of the calibration was proper and well defined hydraulic features represented in the model of the catchment. Some of the critical hydraulic components are bridges, storage areas, spills, 2D areas and well interpolated use of various survey data. In total 45 new storage polygons were created, 332 new river sections, 13 new 2D polygons, 13 culverts and an additional 352 spill units among several other type of objects such bridges and junctions. These aspects were essential to achieving the calibration results and were complemented with the hydraulic parameters such as roughness and discharge coefficients.

The hydrological model was also important to describe flows and accurate volumes to enable the achievement of a good calibration. The non-linear reservoir method allowed us to have a more realistic description of the hydrograph and a better match of volumes, peak and recession flows. The preliminary analysis and constant review of the model results against the whole set of records and debris levels allows better understanding of the dynamics of the flooding and to identify potential anomalies in some of the records. This lead to adjustments in some of the rating curves and head losses in some sensitive areas such the Haruru falls and the Puketona bridge.

The final calibration was closely reviewed by URS and NRC and accepted.

For the design events it is important to note that the level of saturation of the soil is a decision that would depend on the scenario to be modelled. For the purposes of this study the calibrated infiltration rate was determined to be about 4.4 mm/hr. A conservative infiltration rate of **2mm/hr** was adopted for all design storms to account for the saturated soils that would be expected during the winter months. This is considerably lower than the 10mm/hr estimated from the US SCS method, and lower than the calibration estimate of 4.0 – 4.5mm/hr.

The records of flows and rain in Northland catchments suggest that the base flow in all catchments is not of significance, and it has been considered negligible in the design events. However, some base flow (between 2 – 10m³/s at Wakelins) was input into the model to avoid instabilities during the low flow periods at the beginning and end of storms.

The final flood maps for 10, 50, 100 and 100yrs with climate change AEP are included in the Appendix A.

Limitations

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It is prepared in accordance with the scope of work and for the purpose outlined in the URS Proposal dated 04/10/2012.

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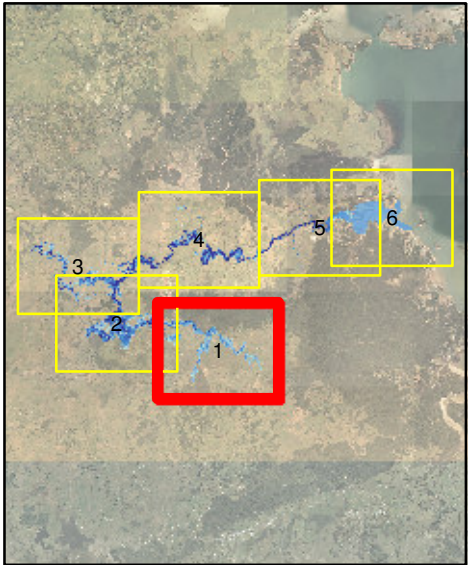
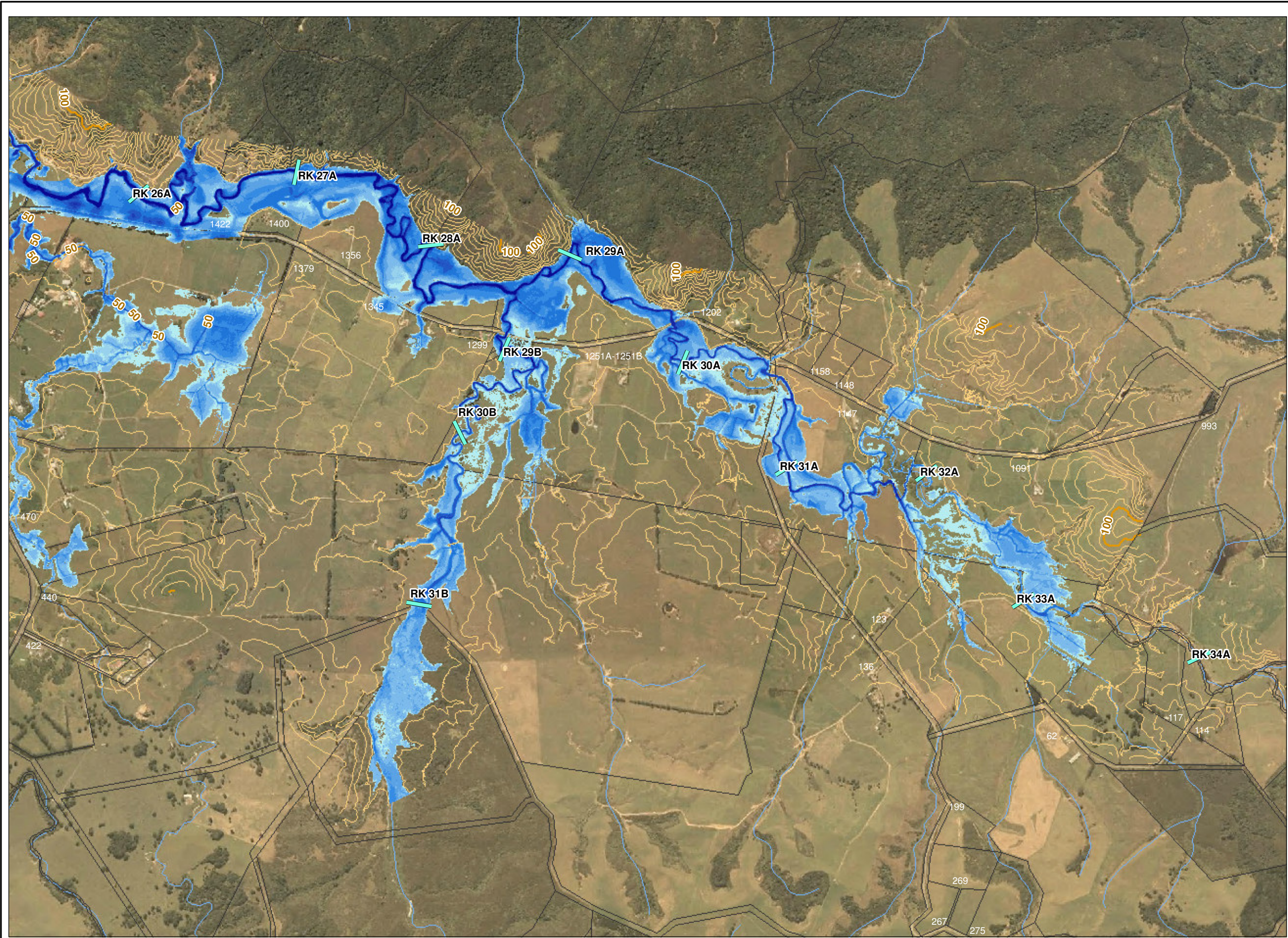
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Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

Appendix A Flood Maps



- 10 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

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Scale: 1:15,000

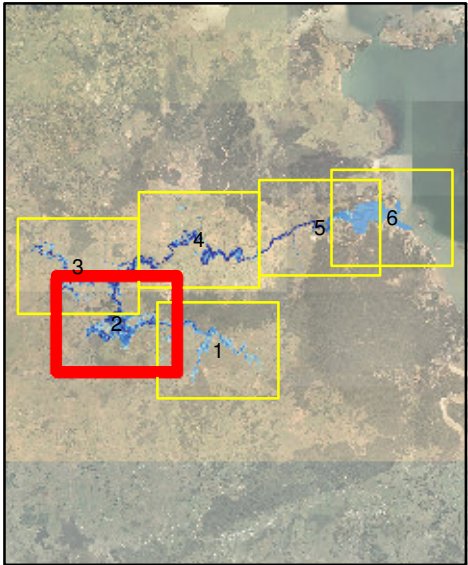
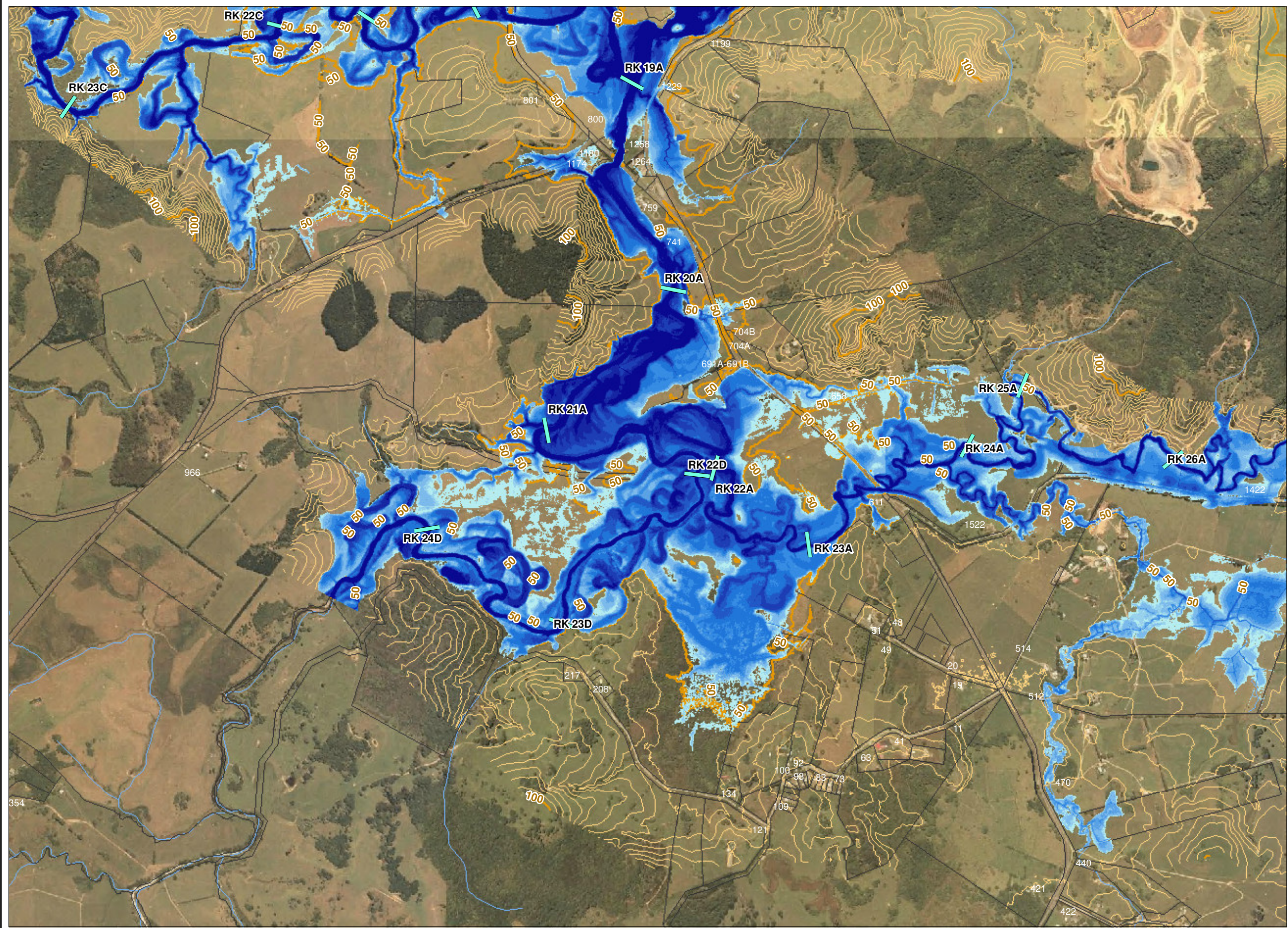
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FLOOD MAPS

WAITANGI RIVER 10 YEAR ARI

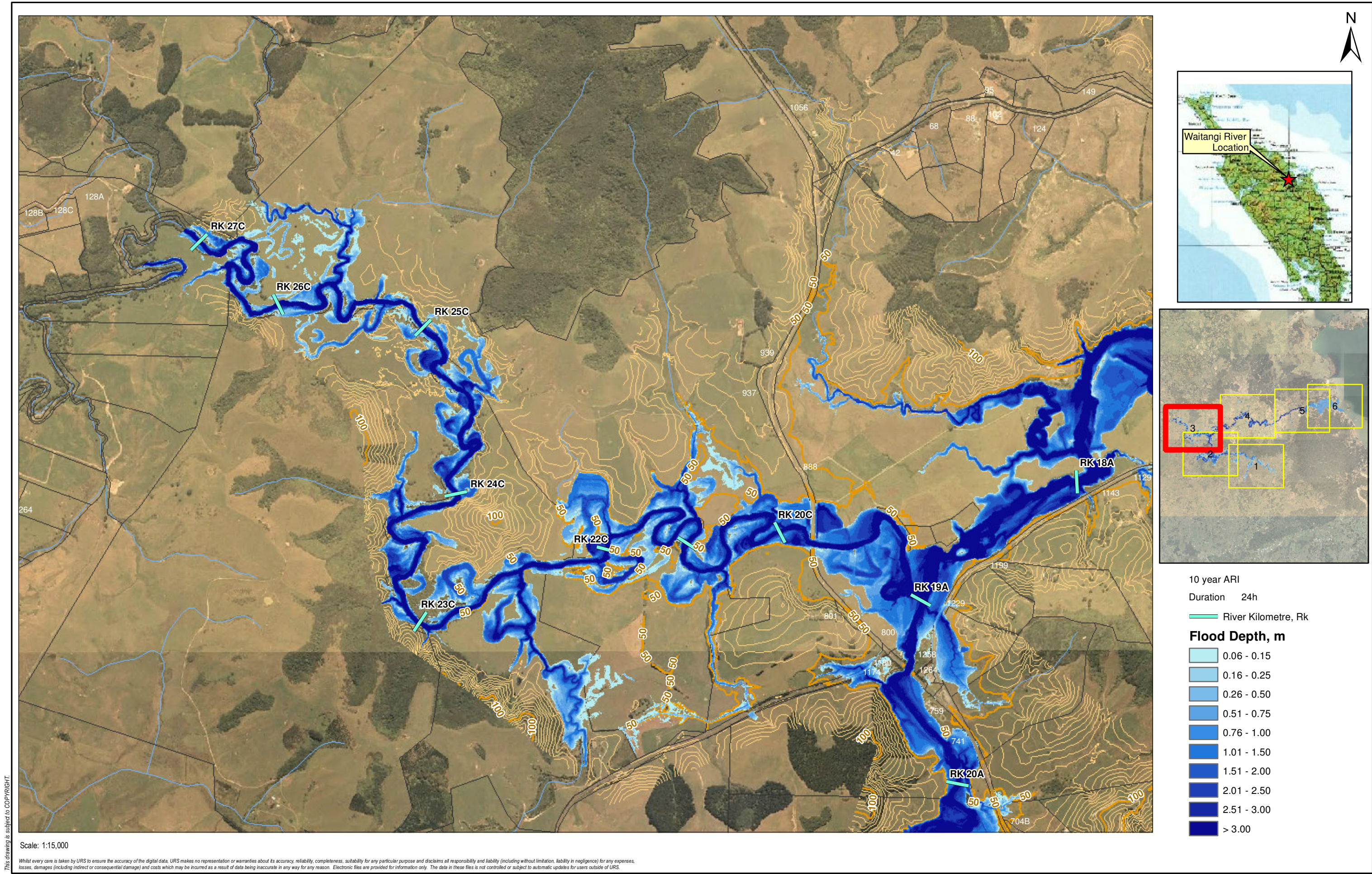


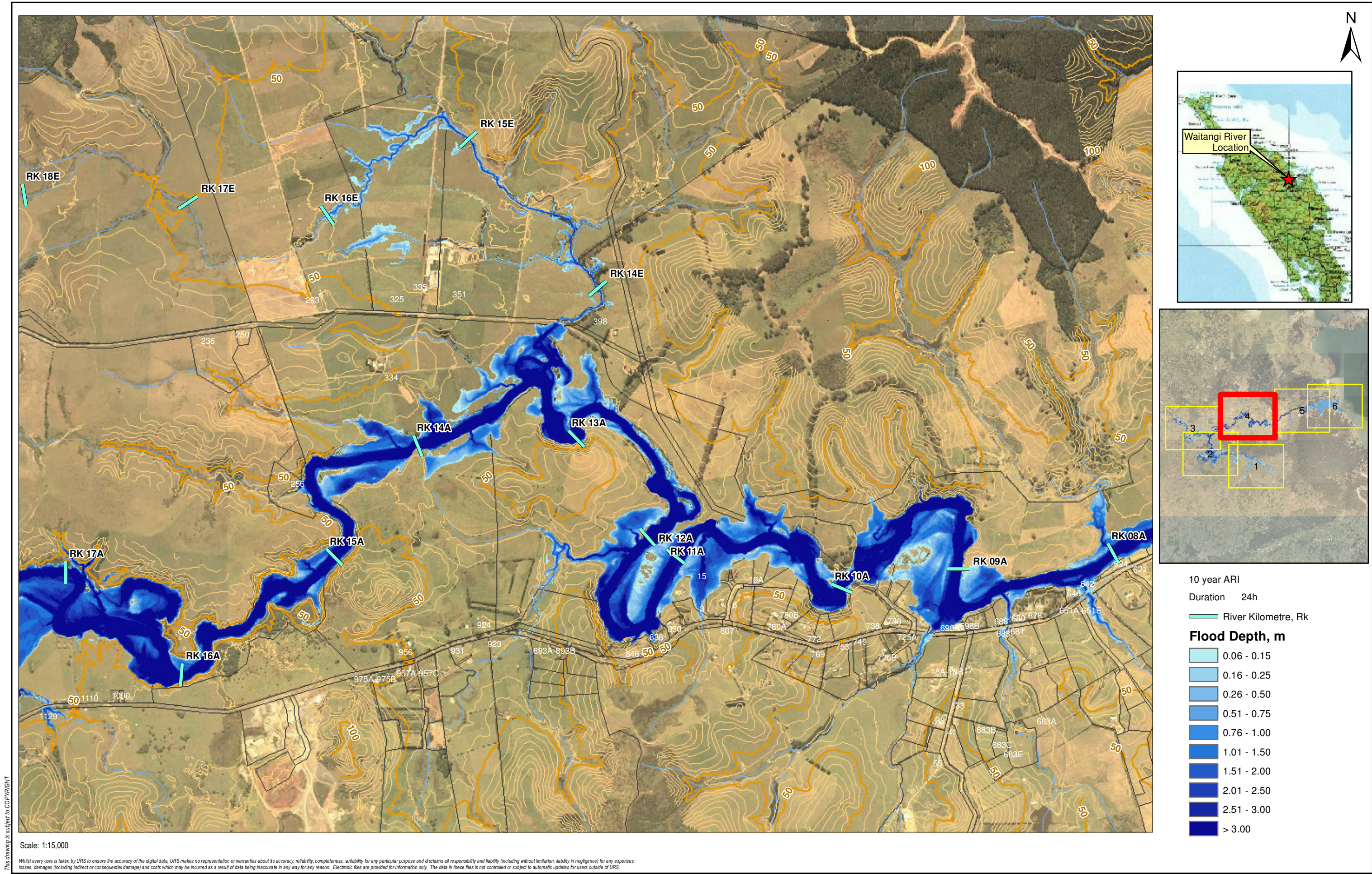


- 10 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

Scale: 1:15,000

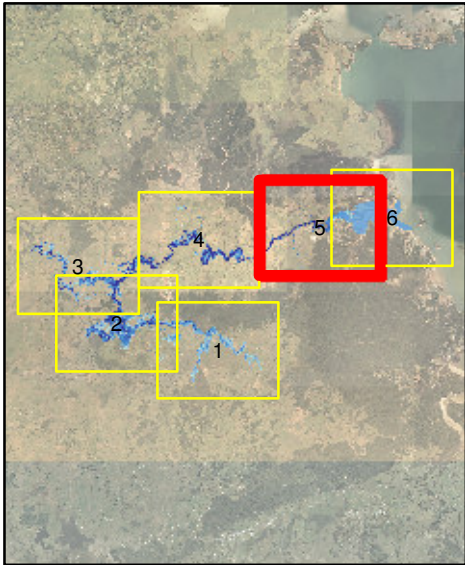
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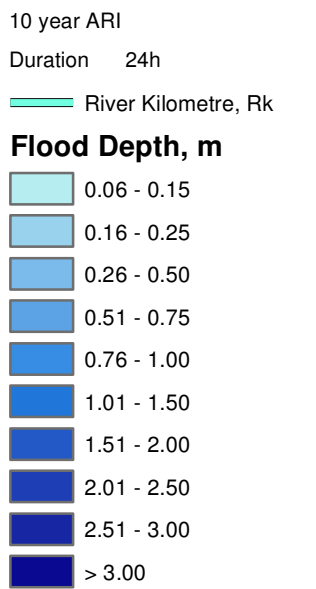
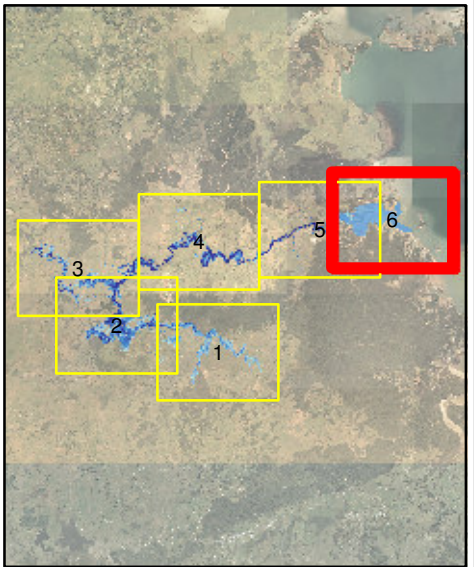


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FLOOD MAPS

WAITANGI RIVER 10 YEAR ARI

URS

File: 42071138\FloodMaps\04_WAITANGI_RIVER\Flood_Maps.mxd

Drawn: FP

Approved: JM

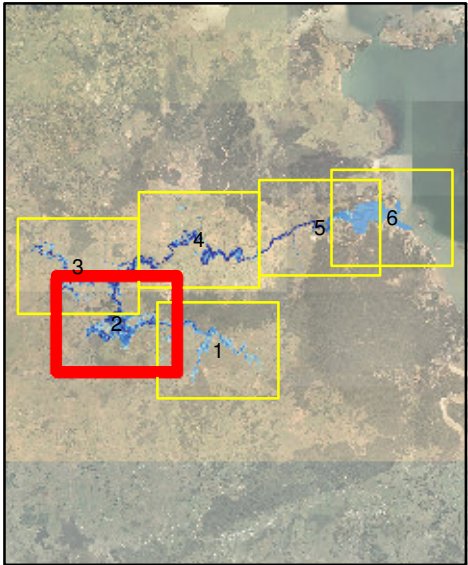
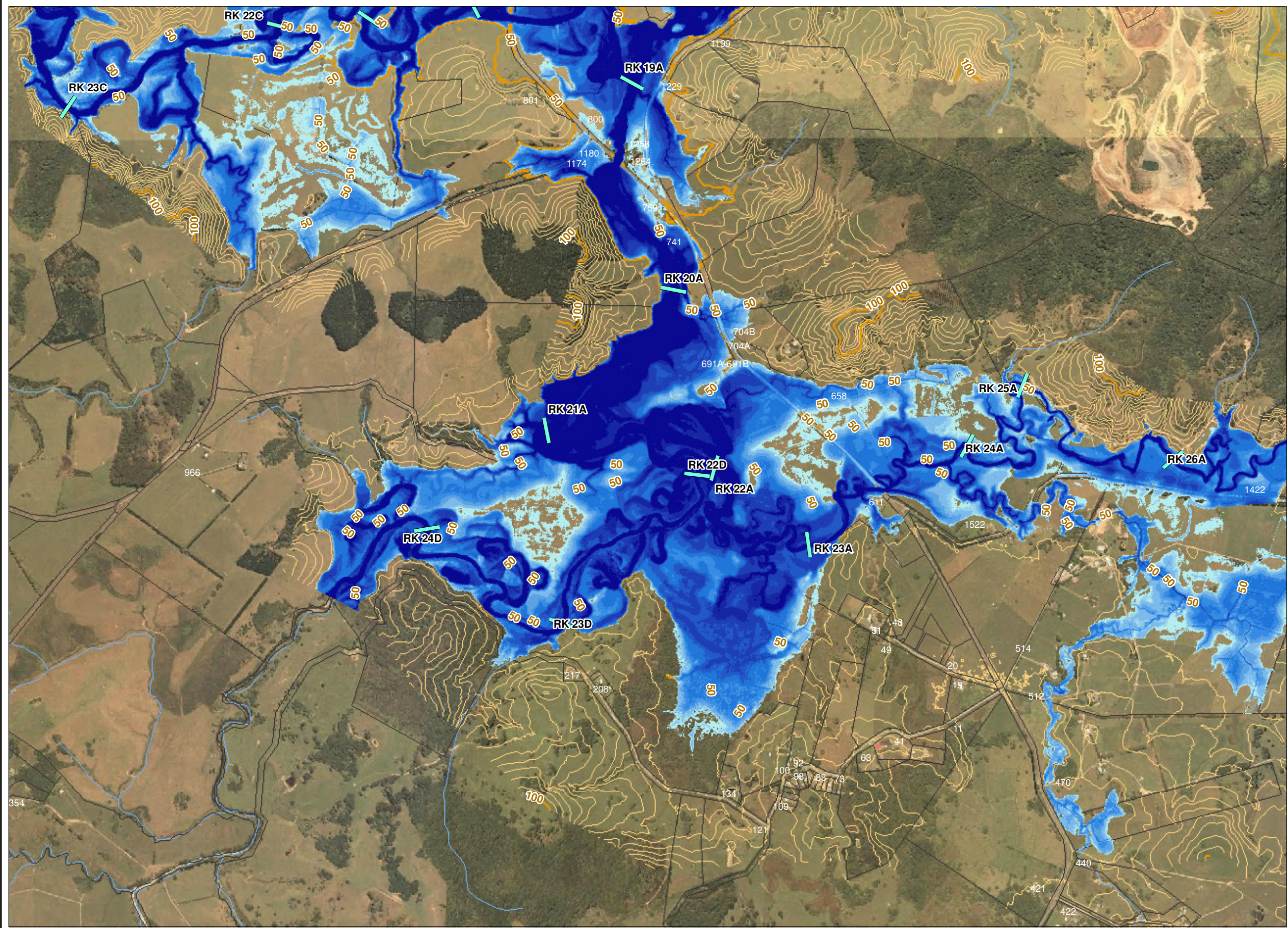
Date: 15/08/2013

Sheet 6 of 6

Rev. A

A3





- 50 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

Scale: 1:15,000

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FLOOD MAPS

WAITANGI RIVER 50 YEAR ARI



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Drawn: FP

Approved: JM

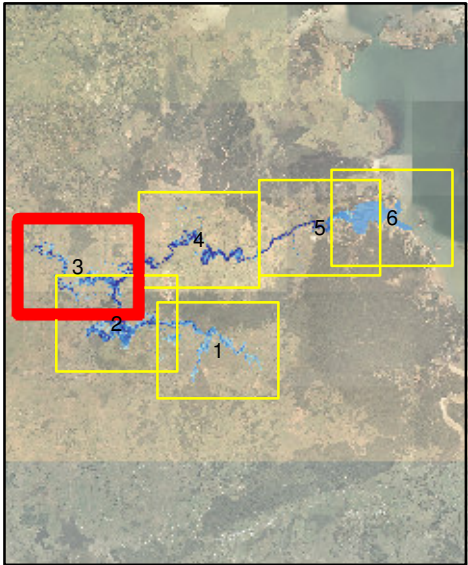
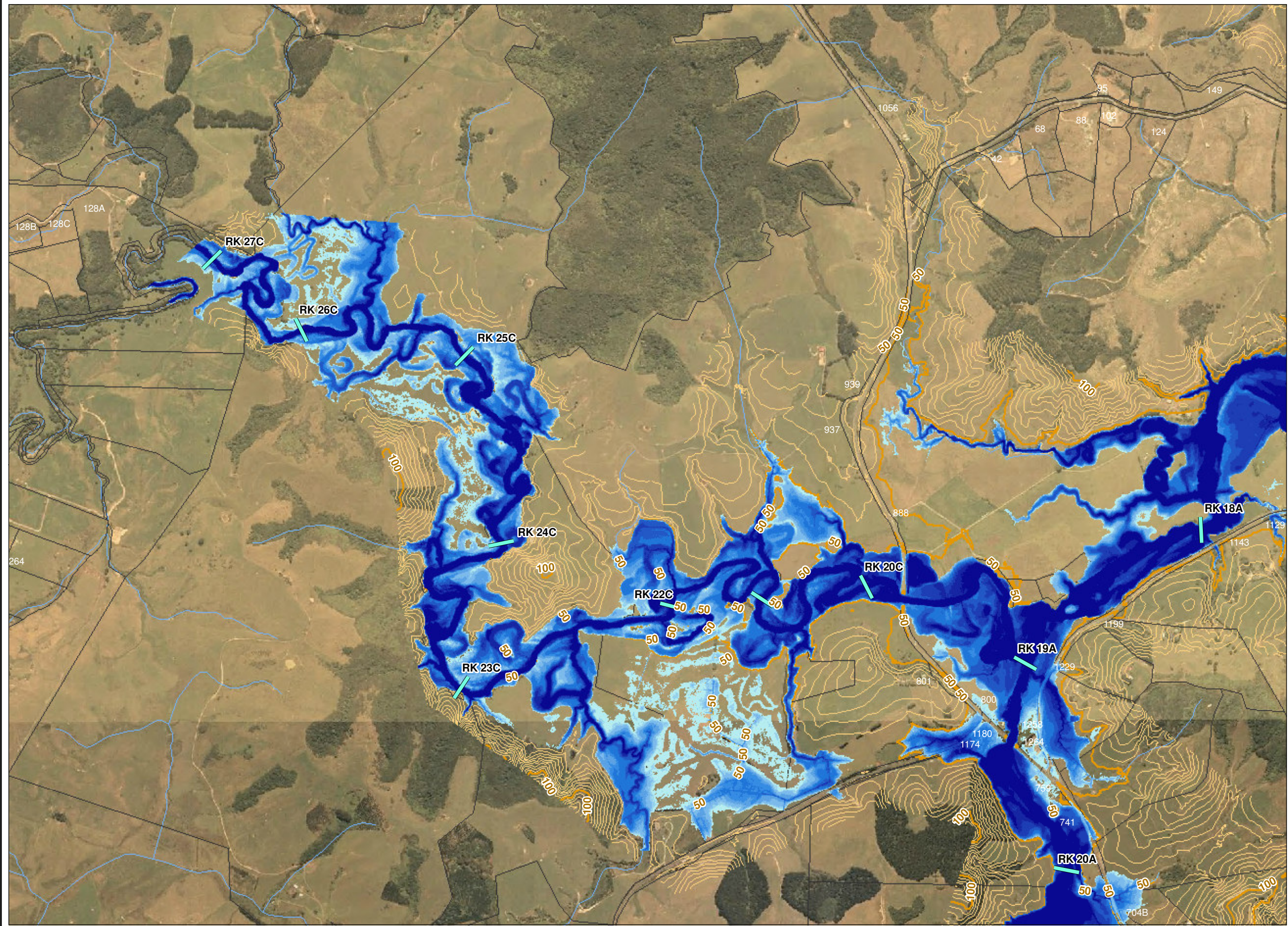
Date: 15/08/2013

Sheet 2 of 6

Rev. A

A3





- 50 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

Scale: 1:15,000

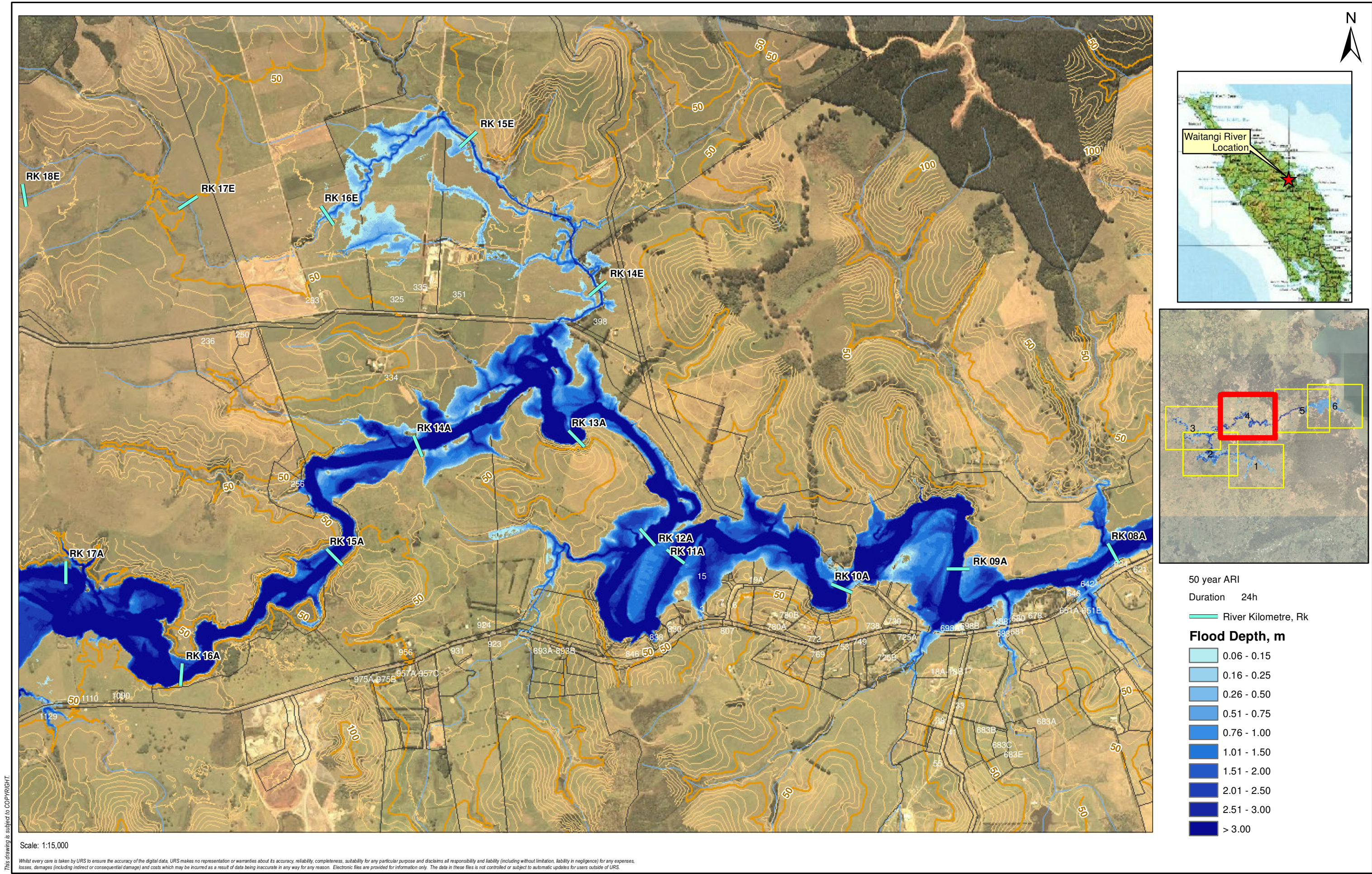
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FLOOD MAPS

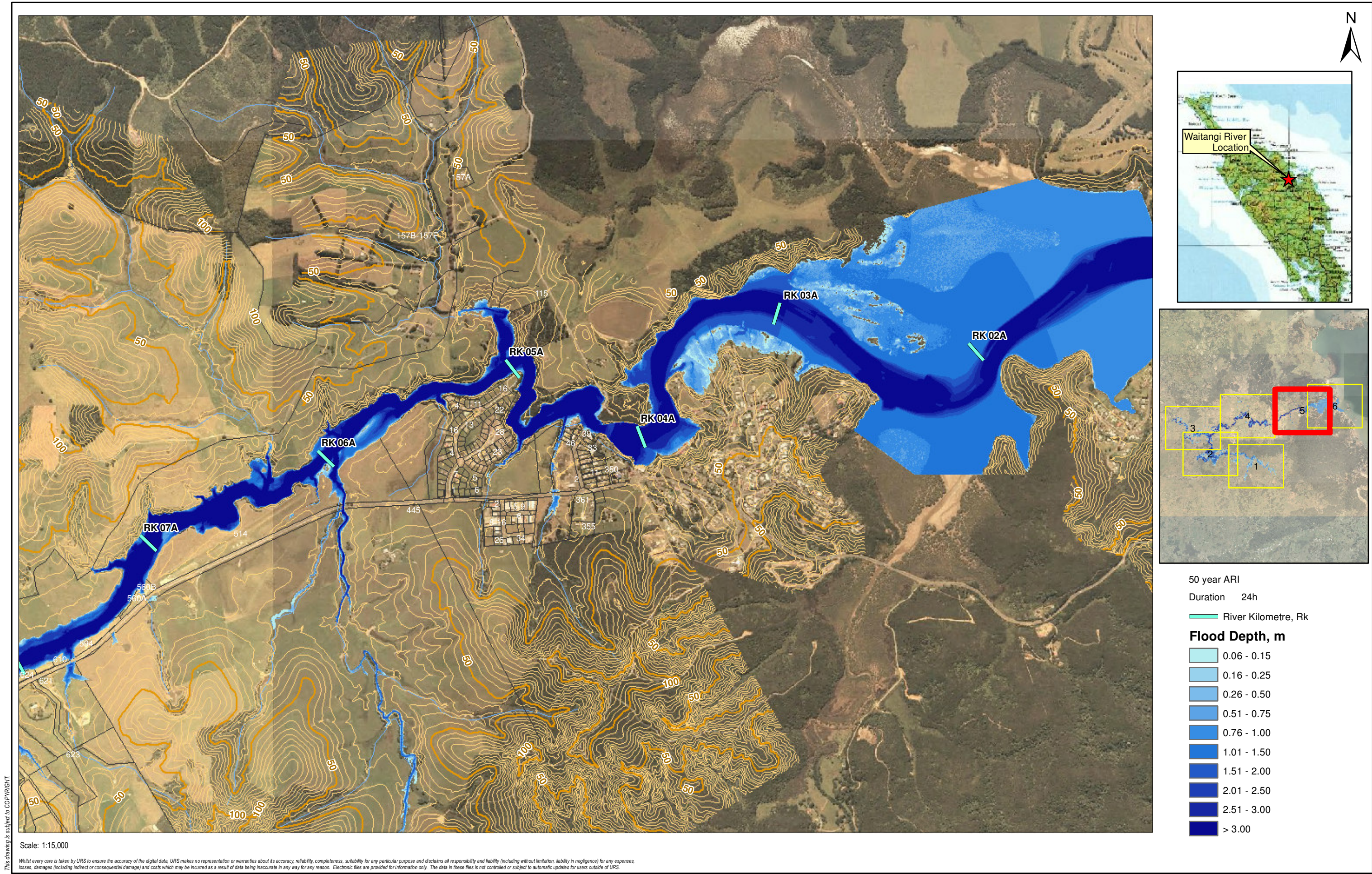
WAITANGI RIVER 50 YEAR ARI





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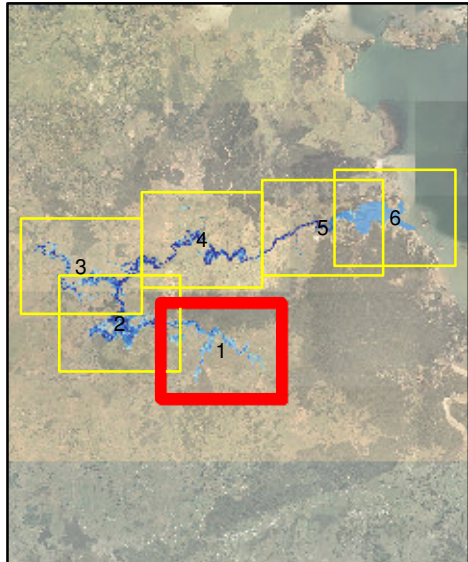
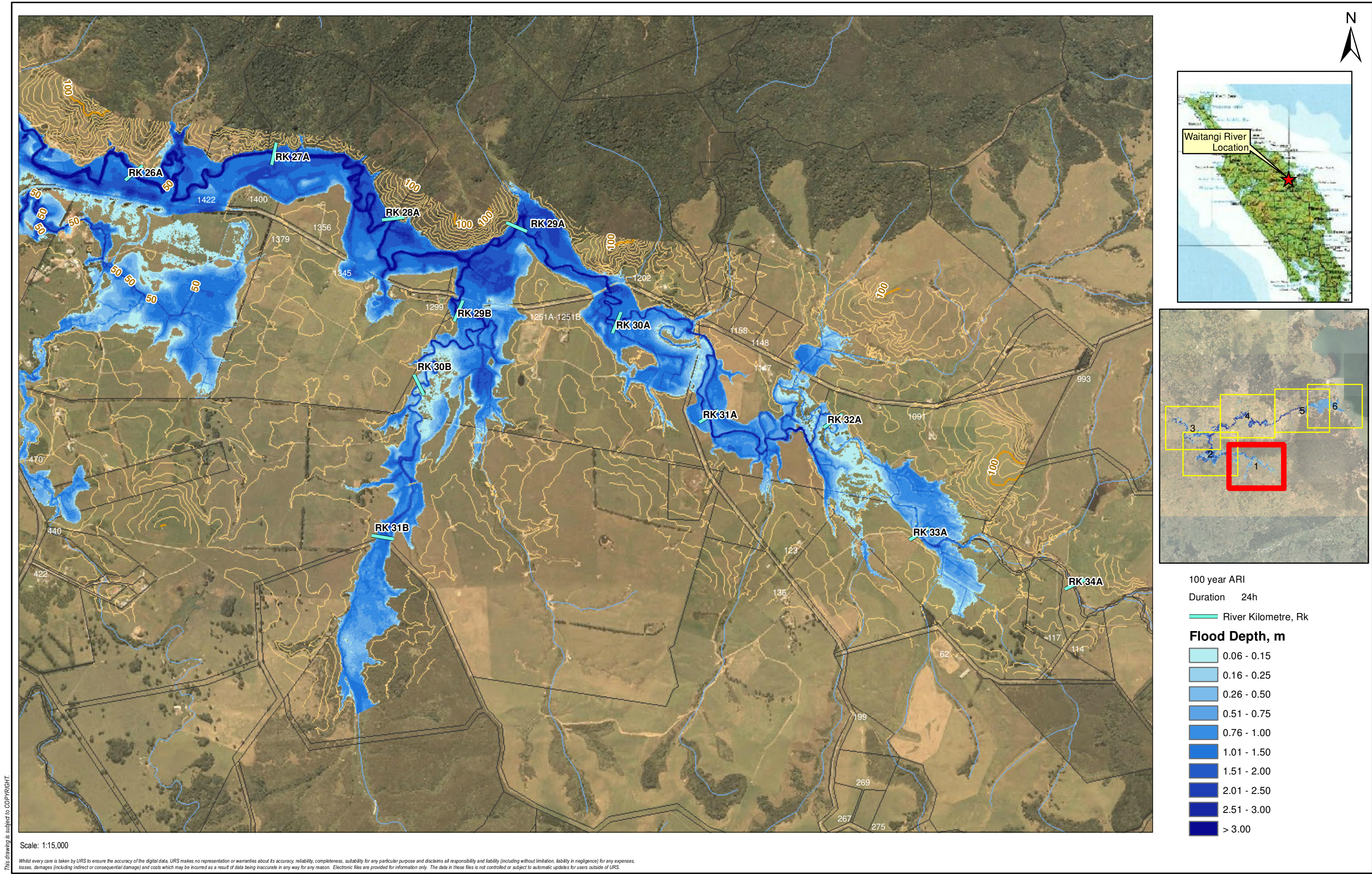
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- 100 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

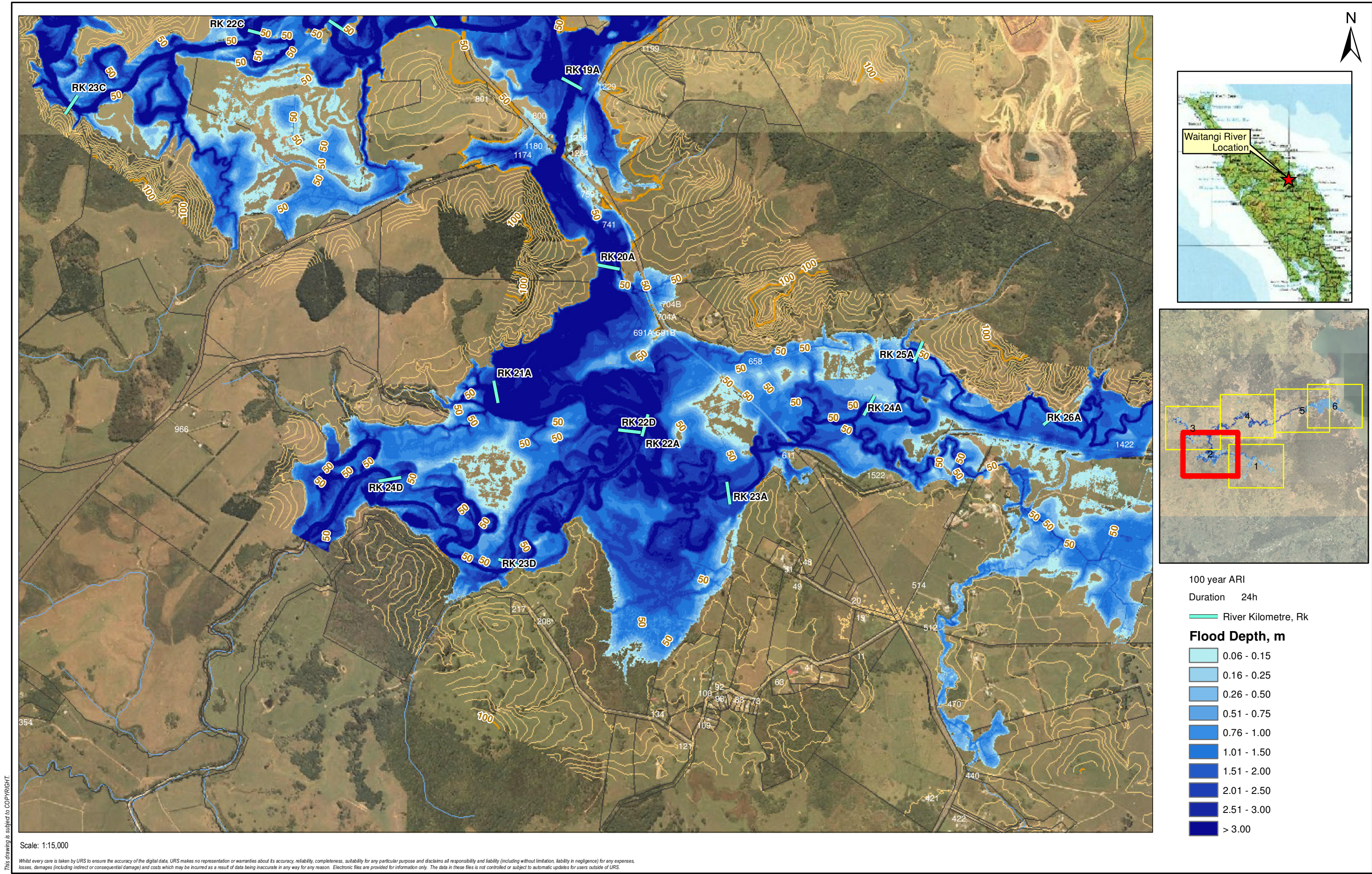
Manaki Awa



FLOOD MAPS

WAITANGI RIVER 100 YEAR ARI

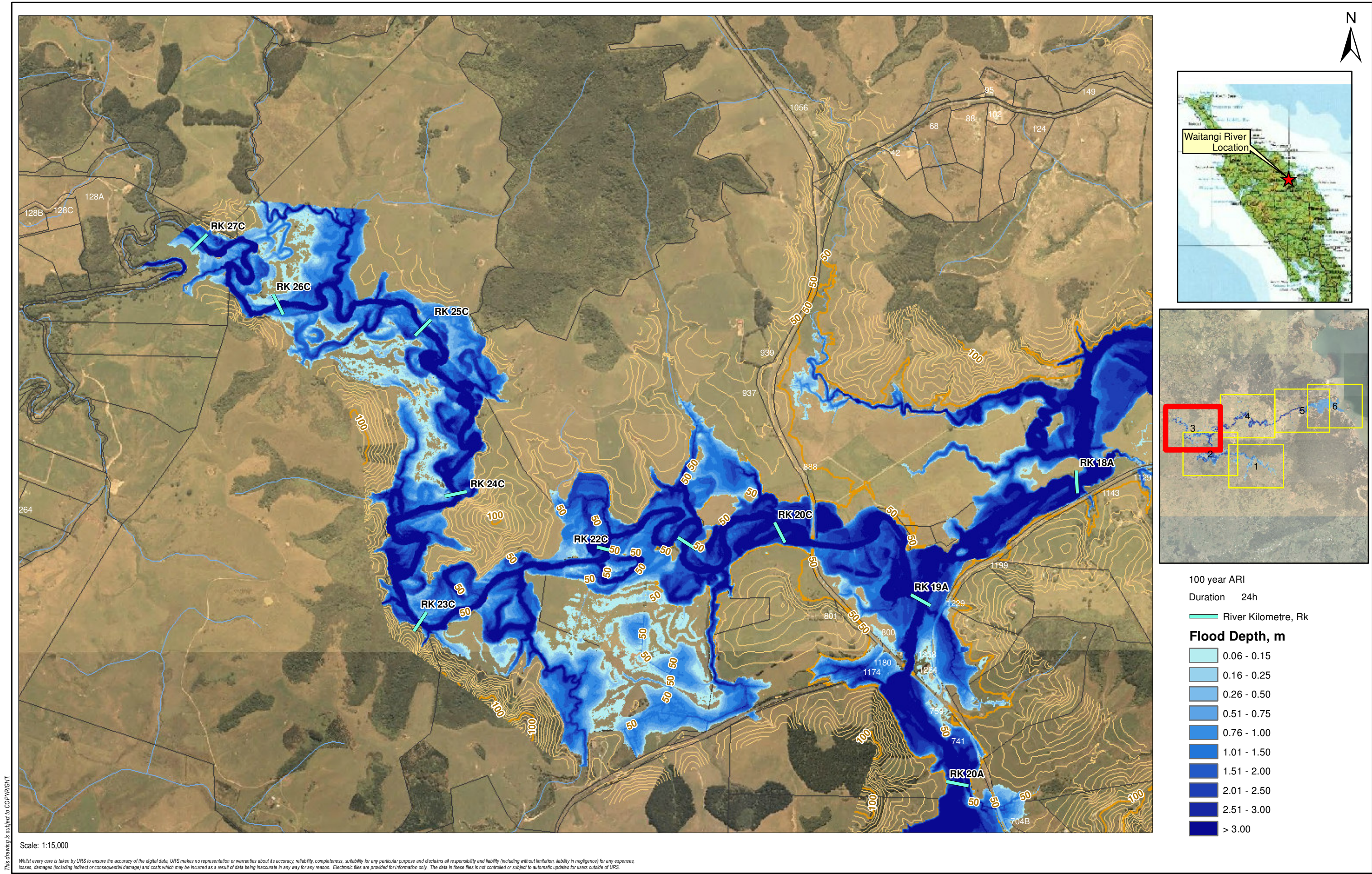




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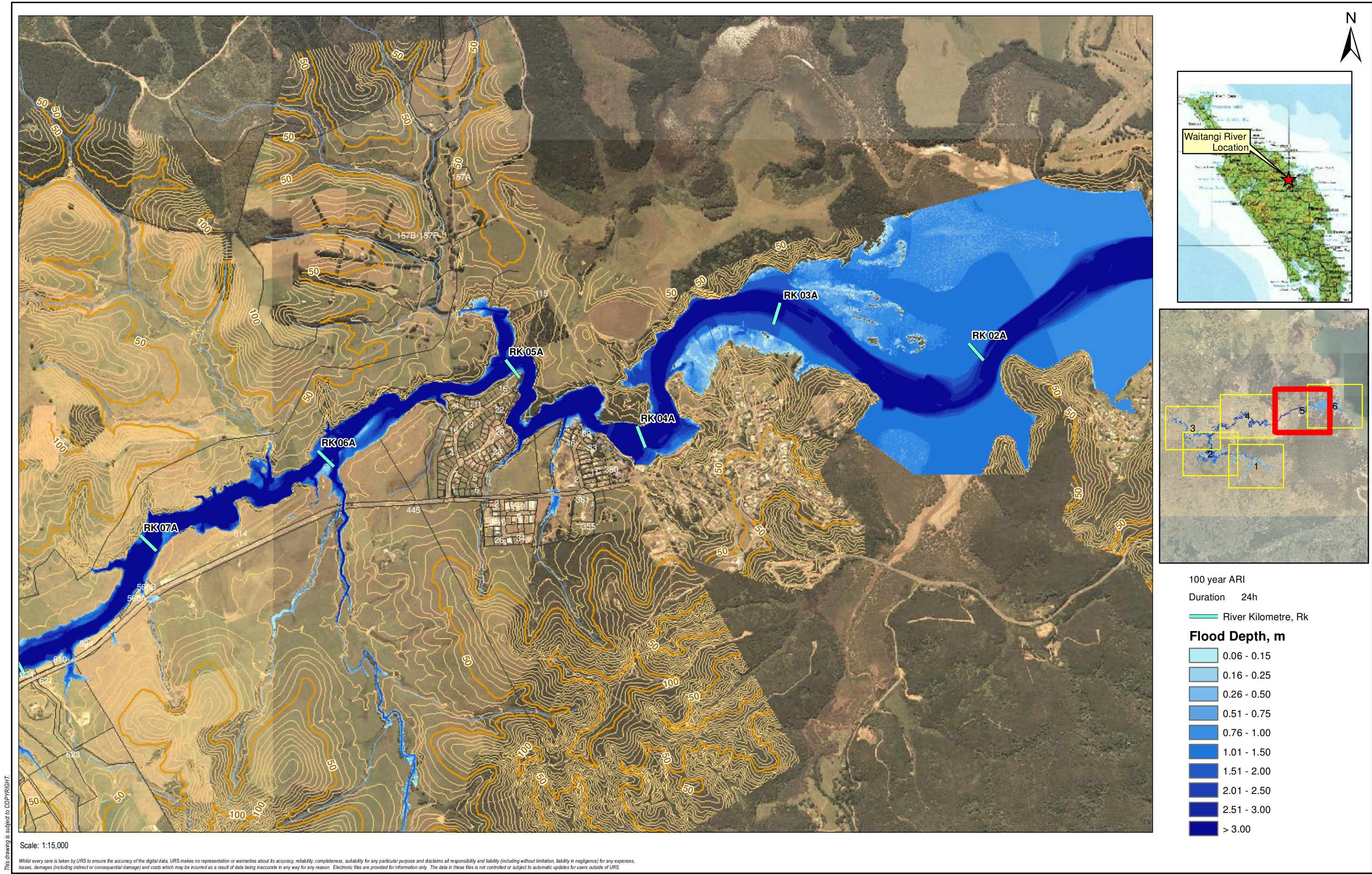
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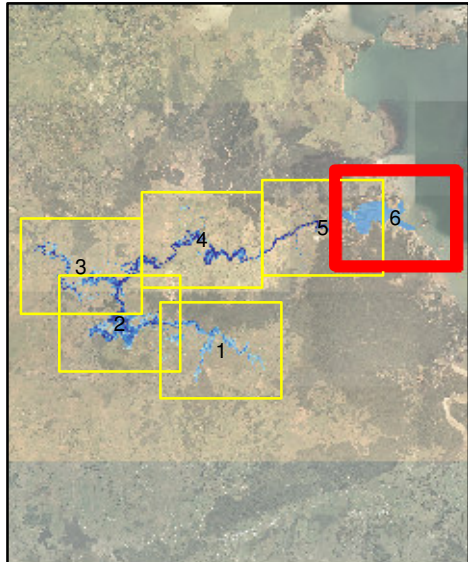
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- 100 year ARI
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- River Kilometre, Rk
- Flood Depth, m**
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 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

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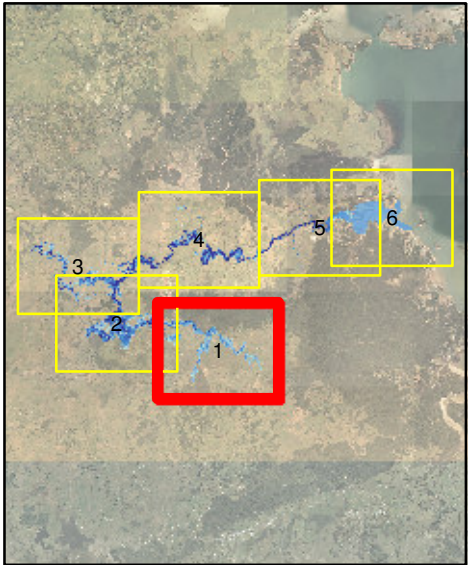
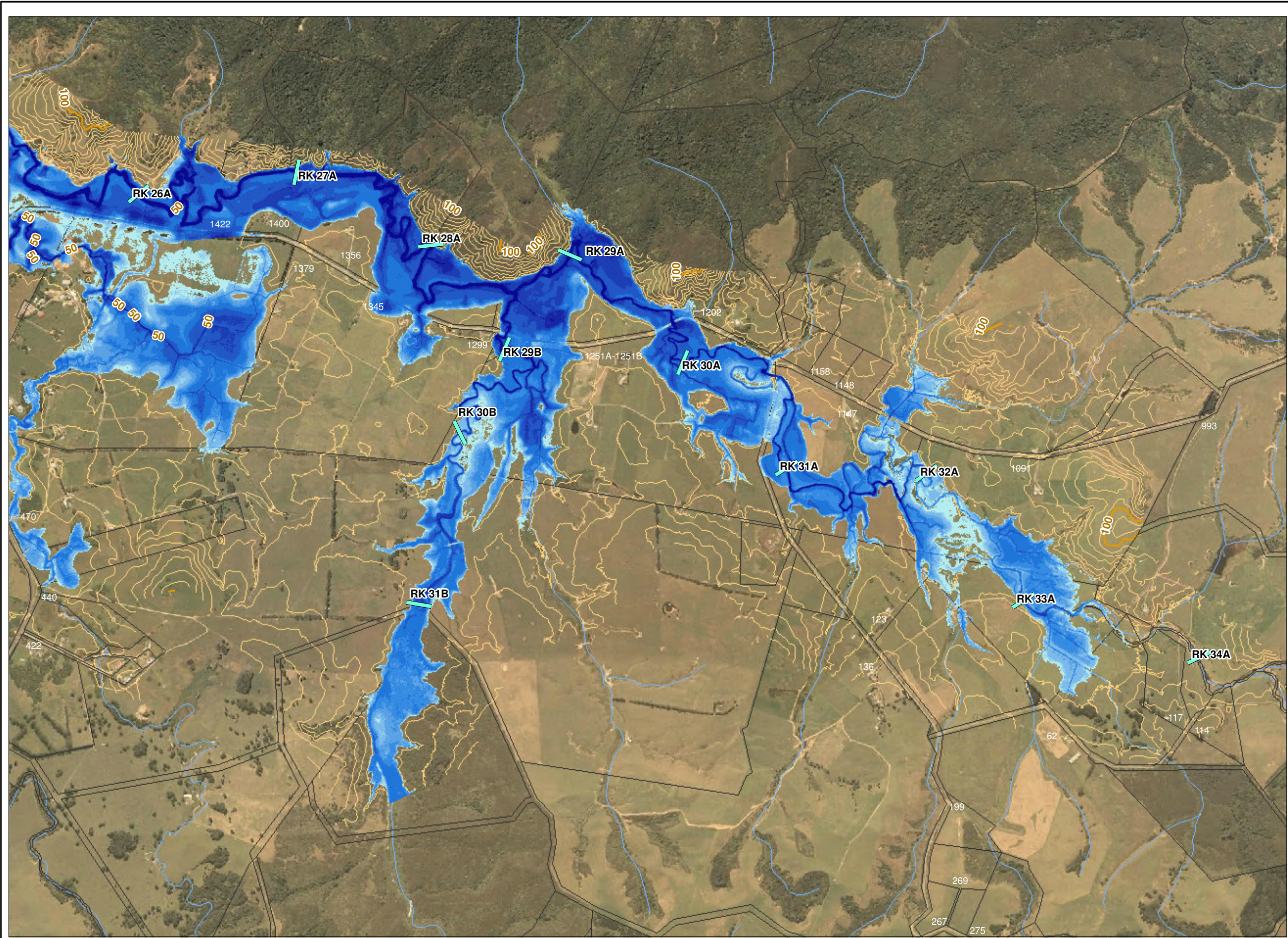
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FLOOD MAPS

WAITANGI RIVER 100 YEAR ARI



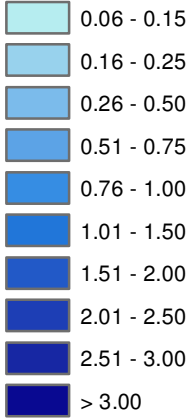


100 year ARI plus Climate Change

Duration 24h

— River Kilometre, Rk

Flood Depth, m



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FLOOD MAPS

WAITANGI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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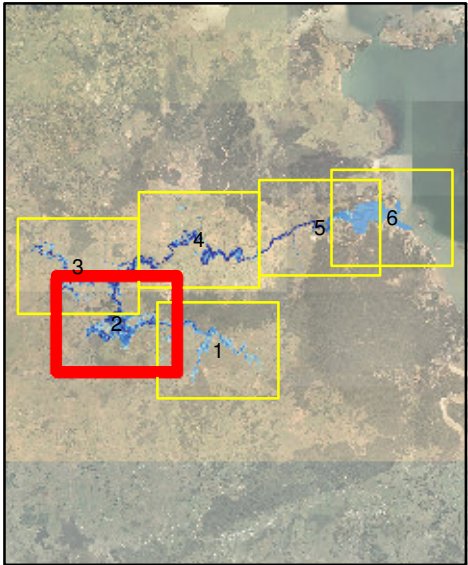
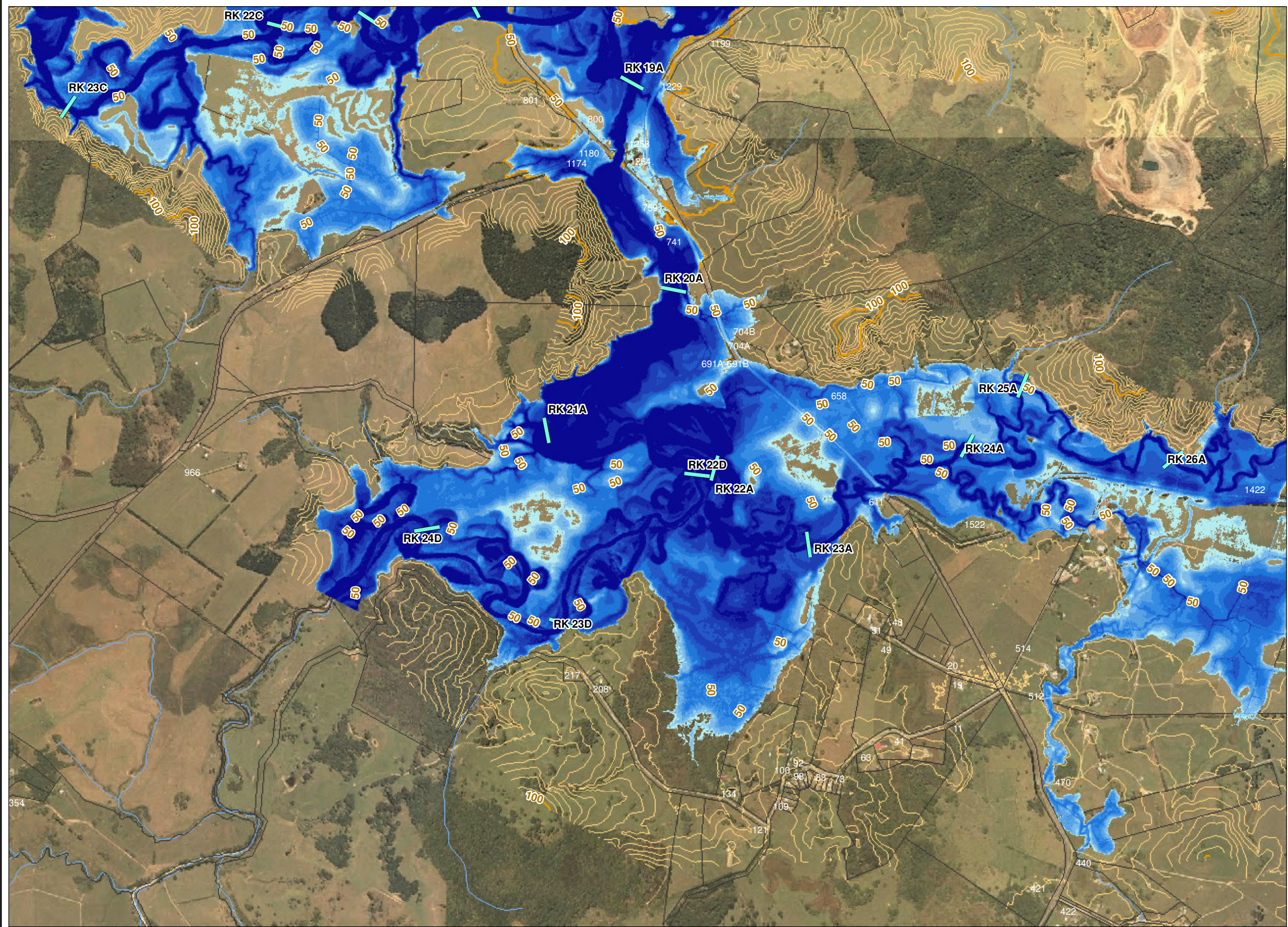
Date: 15/08/2013

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Rev. A

A3





100 year ARI plus Climate Change
Duration 24h

— River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
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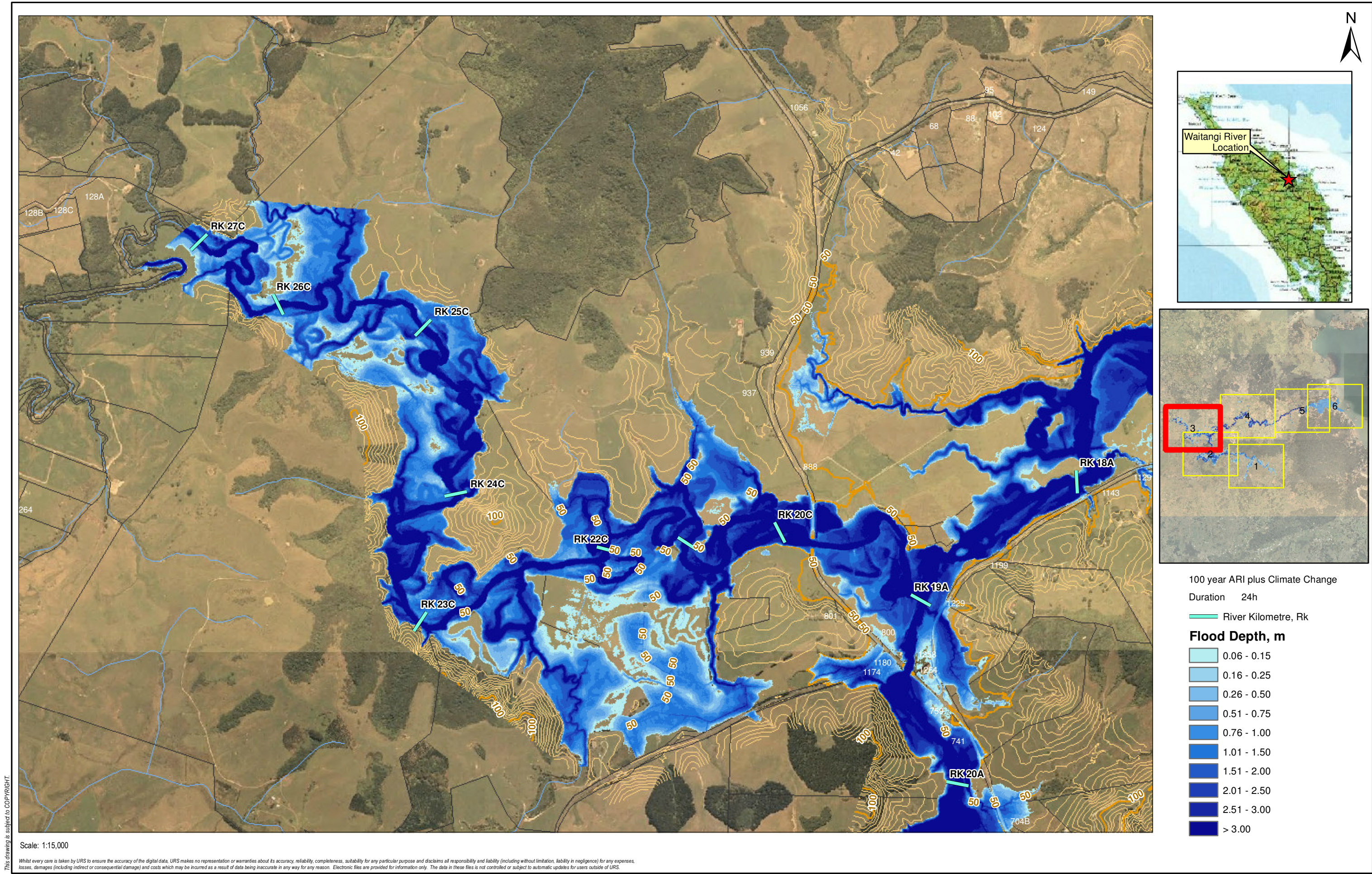
Manaki Awa



FLOOD MAPS

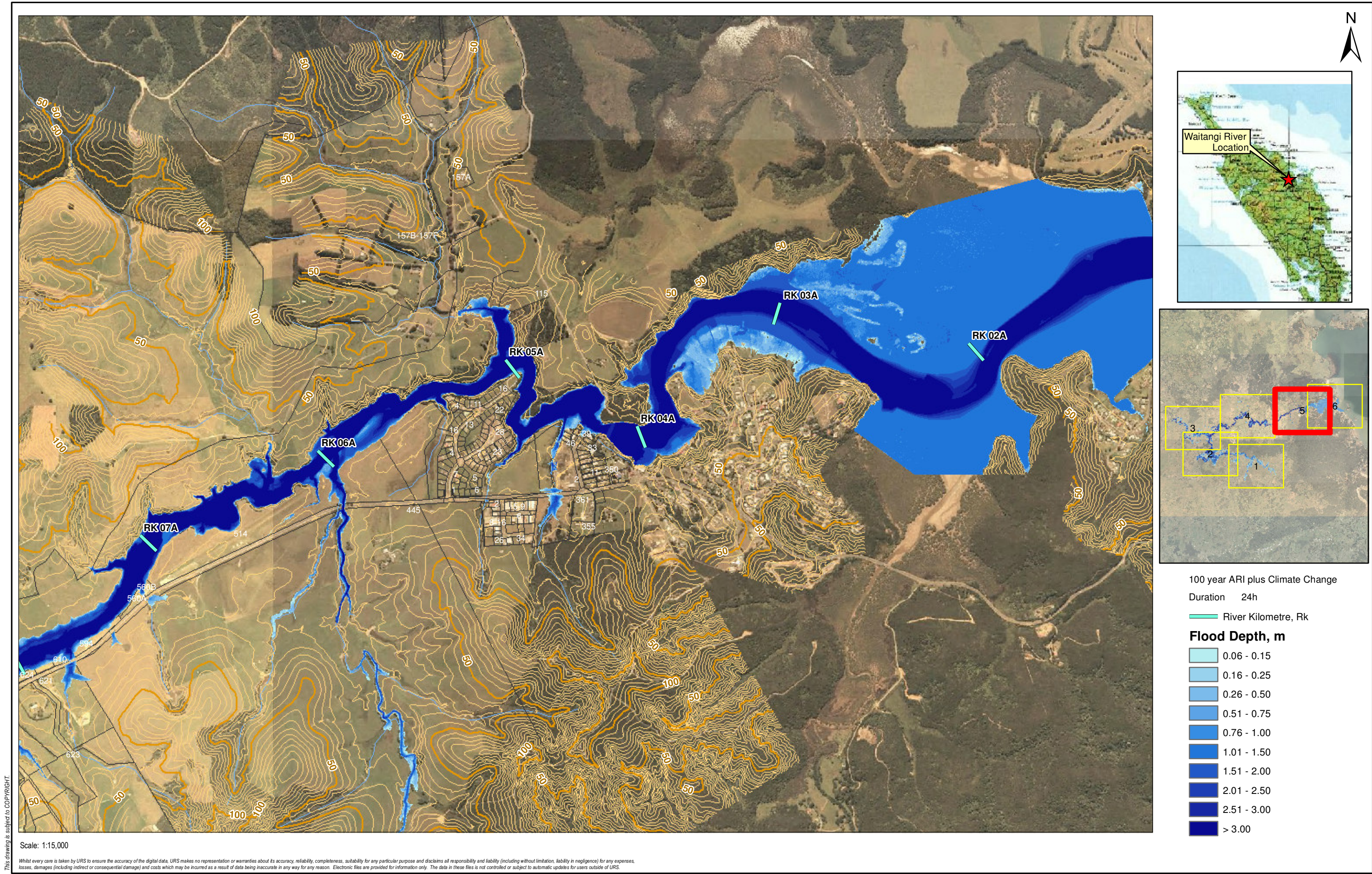
WAITANGI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE





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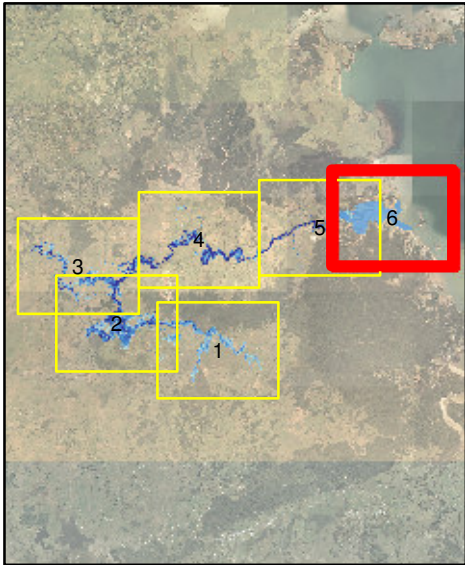
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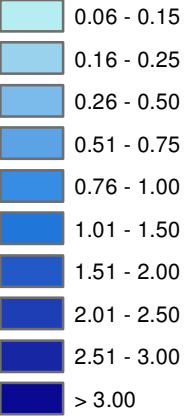




100 year ARI plus Climate Change
Duration 24h

— River Kilometre, Rk

Flood Depth, m



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FLOOD MAPS

WAITANGI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE





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