Report

Ruakaka Modelling and Calibration Report

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Prepared for

Northland Regional Council

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42071138

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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 Ruakaka River Model that was developed in the earlier project was found by the Northland Regional Council 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. This data came from the two new automatic rain gauges in the catchment and an existing flow gauge from the Wilson's dam. This data was used in conjunction with the other established gauging stations within the catchment. These stations provided better rain and flow gauge information for calibration of the model.

It was also identified that certain areas of the model should be extended to include a few critical components such as the Wilson's Dam. Again this has improved the confidence in the modelling results.

1.2 Catchment Description

The Ruakaka catchment is located on the east coast of Northland, approximately 15 kilometres south of Whangarei. Figure 1-1 provides a general location plan of the catchment.

The Ruakaka catchment consists of five main tributaries:

- Ruakaka River: Located along the northern boundary of the catchment
- Waiwarawara Stream: Located in the south of the catchment
- Waipapa Stream: Located in the central south of the catchment
- Waikokopa Stream: Located along the western boundary of the catchment
- Sanford Drain: Located on the eastern Boundary of the catchment

The confluence of the Waikokopa tributary with the Ruakaka River is 1 kilometre downstream of State Highway 1 (SH1) at Cotton Road.

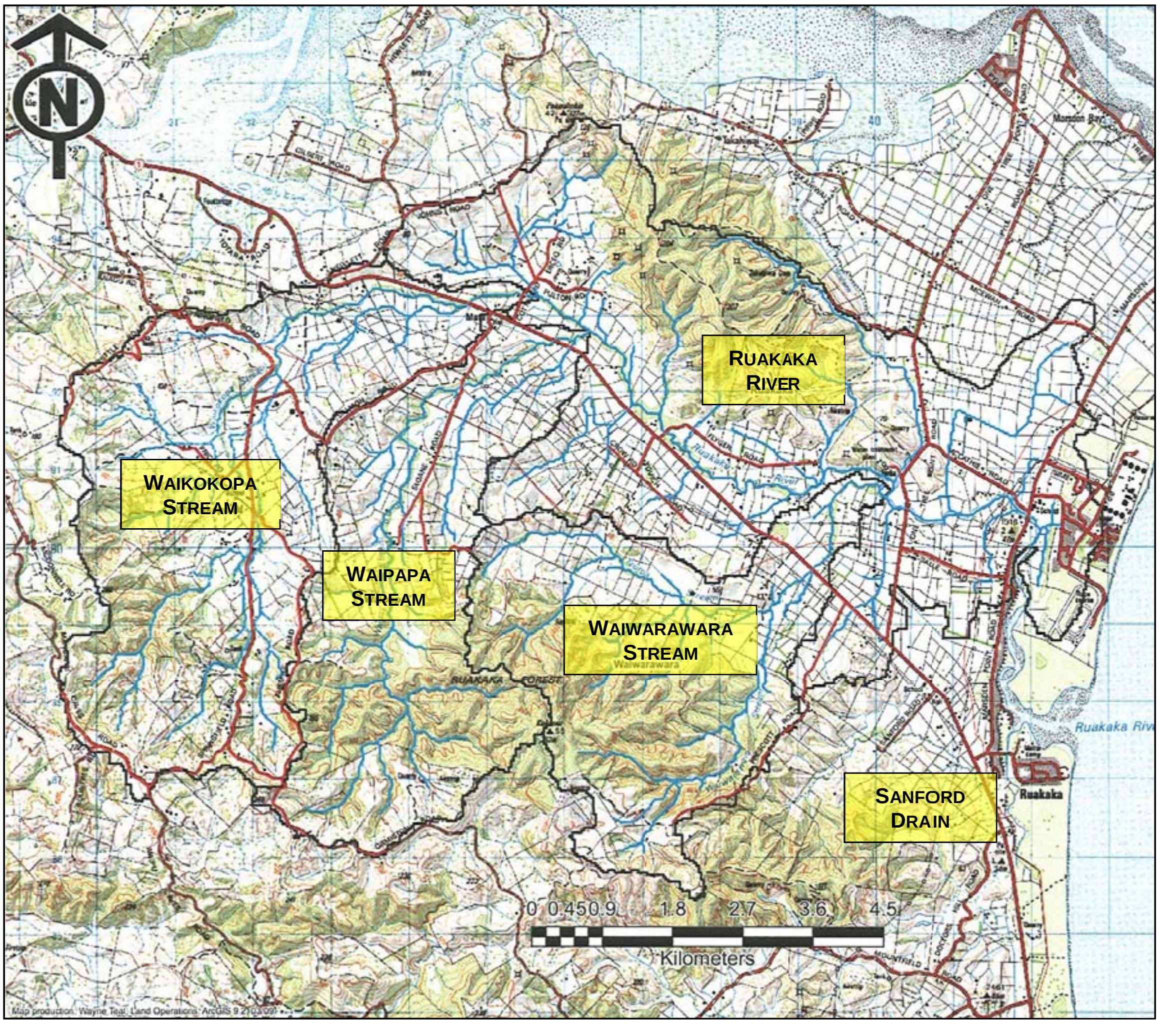
The confluence of Waipapa Stream with the Ruakaka River is approximately 1 kilometre downstream of Cotton Road.

The confluence of the Waiwarawara Stream with the Ruakaka River is approximately 0.5km upstream of One Tree Point Road, close to the Water Treatment Plant.

The Sandford Drain, to the south, has its confluence with the Ruakaka River at the outlet to Bream Bay.

1 Introduction

Figure 1.1 General location plan of the Ruakaka catchment and tributaries



Topography

The Waiwarawara Stream and Waipapa Stream have their headwaters located in the Ruakaka Forest area of the catchment. The high point within this area is Kukunui, at 262 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 hill areas for the Waiwarawara and Waipapa catchments is around 40 m above sea level. Once out of the hill area both watercourses meander to their confluence with the Ruakaka River in the north.

The Waikokopa Stream drains a flatter area with less well defined boundaries. The headwaters are located along the western boundary of the catchment with average height of approximately 100 m above sea level.

The Ruakaka River drains an area, similar to the Waikokopa Stream, on the northern area of the catchment. The headwaters are approximately 60m above sea level, with the exception of the small area around Takahiwai where the high point is approximately 200 m above sea level.

1 Introduction

The Sandford Drain is located along the coastal strip of land on the eastern side of the catchment and includes the Ruakaka settlement area. The elevation of this catchment is low being near the coast. The headwaters of this catchment are located on the southern edge of the Ruakaka Forest where the isolated high point is approximately 171 m above sea level.

Notable Features

There are a number of notable features within the Ruakaka River catchment. These are outlined below.

Takahiwai Dam: Located in the hill area close to the northern boundary of the catchment. The structure retains approximately 1,000 cubic metres of water that has historically been used for water supply within the surrounding area. As of 2003 the Wilson's Road Dam secured the water supply for the wider area reducing the requirement for the Takahiwai Dam.

Wilsons Dam: Located in the foothills of the Ruakaka Forest, serves as a water supply reservoir for the area.

Pakauhokio Pa is located on the highest point of the northern boundary, at 127 metres above mean sea level. Another Pa site is located to the south of Ruakaka Township the western side of State Highway 1. This is located atop a small hill measured at 34 metres above mean sea level.

The Marsden Point – Ruakaka Structure Plan makes reference to the 'old Ruakaka Lake' and two remnant dune lakes. These features are located at the junction of McEwan and Marsden Point Roads.

The Ruakaka wastewater treatment plant is located between Flyger Road and One Tree Point Road, close to the northern boundary of the catchment. Although this site does not have a measured height it would appear to be located atop a local outcrop at approximately 40 metres above mean sea level.

A number of quarries are located within the catchment, mainly in the hill areas. The most notable of these are located close to the Takahiwai Dam, to the south of Ruakaka Forest and Springfield Road in the north-eastern corner of the catchment.

State Highways 1 and 15A are located within the Ruakaka catchment, together with main roads linking Ruakaka and Ruakaka Beach with Marsden Point and the State Highways.

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.

1.4 Modelling Scope

The scope included an extended network, see Figure 3-11, to include the Wilson's Dam with the spillway. The extended network covers the areas of overland flow that were not included in the previous model, yet deemed critical by NRC.

The model was able to assess and resolve the problem at the junction as described in Section 3.3.2.

1 Introduction

Modelling Objectives

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 four main objectives are as follows:

- Incorporate new survey and extend the model
- Review the hydrologic model and employ the Non-linear Reservoir model
- Recalibrate the model based on the Jan 2011 Ex TC Wilma flood
- Rerun design storms for the new calibrated model and generate new flood maps

Issues identified in the original model verification

Issues identified in the Ruakaka verification that have been addressed by this model are:

- Flows predicted by the river gauge are likely to be inaccurate for large events. The site rating for Flygers Road is only reliable to the top of the river bank. It may be better to rely on the gauged flood levels at the high stage for re-calibration.
- There is a loop off the main river just upstream of the river gauge which has been omitted from the flood mapping
- There appeared to be a few glitches in the flood mapping (straight divides across the flood plain).
- An area in the upper flood plain where Jan 2011 flood levels exceeded 1% AEP CC event has been addressed in calibration.

Other issues identified during model improvement and calibration

- Some of the sub-catchments were incorrectly connected to the river network
- Some sub-catchments did not have a proper definition in the hydrological model
- Catchment boundary had to be corrected
- Low 2D resolution of important areas for critical streams
- Significant revisions to network spills and links
- Incomplete storage areas
- Bottom of the channels had to be corrected for main river

Data Collection

2.1 Data Collection

NRC provided all of the data used to improve, extend and calibrate the model for the January 2011 event. The data received is listed and described below:

- Proposed new channel detail (shape file),
- New survey with photos (cross sections, bridges, culverts, flow/level stations, Wilson spillways and dam),
- Rain gauges and rainfall for the event of January 2011,
- Level/flow gauges and series for the event of January 2011,
- Debris level for the event of January 2011 (in two sets of data),
- Storage curve for Wilson dam and as-built drawings in pdf format,
- Verification of gauge datum.

2.1.1 Survey

Survey data consisted in the following items:

- Cross sections of previous streams where more detail was required.
- Cross sections of new streams or branch to be included in the model.
- Cross section of channel at level gauges location.
- Auxiliary and service weir at Wilson Dam.
- Wilson Dam levels.
- 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

The following information was received for the event of the 29th January 2011.

- Daily and auto rain gauges rainfall.
- Level/Flows for Flyger Road station and Residual Weir station.
- Rating curve for Flyger Road station.
- Level records for Wilson Reservoir.
- Debris flood levels.

2.1.3 Hydraulic Rating Curves

The following hydraulic curves were provided and have been included in the model:

- Wilson's Reservoir storage curve.
- Wilson's Dam service spillway discharge curve.
- Wilson's Dam auxiliary weir discharge curve.

Modelling Methodology

3.1 Previous IWRS Model Analysis

The Ruakaka River was defined as a Priority 1 catchment during the Priority River Flood Risk Reduction Project. A model of Ruakaka 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.

3.2 Boundary Conditions

There are two boundary conditions:

- A stage – time tidal condition that required a stage time series to define the downstream boundary levels.
- A hydrological model to calculate runoff inflows from rainfall.

Downstream Boundary Condition (Tidal Boundary)

The network has been extended downstream far enough to include the influence of the tidal boundary at the mouth of the river. This provides good definition of the water levels at the discharge point of the river into the sea. Therefore it is considered that the downstream boundary condition is well defined in the model.

Upstream Boundary Condition (Sub-catchment hydrological model)

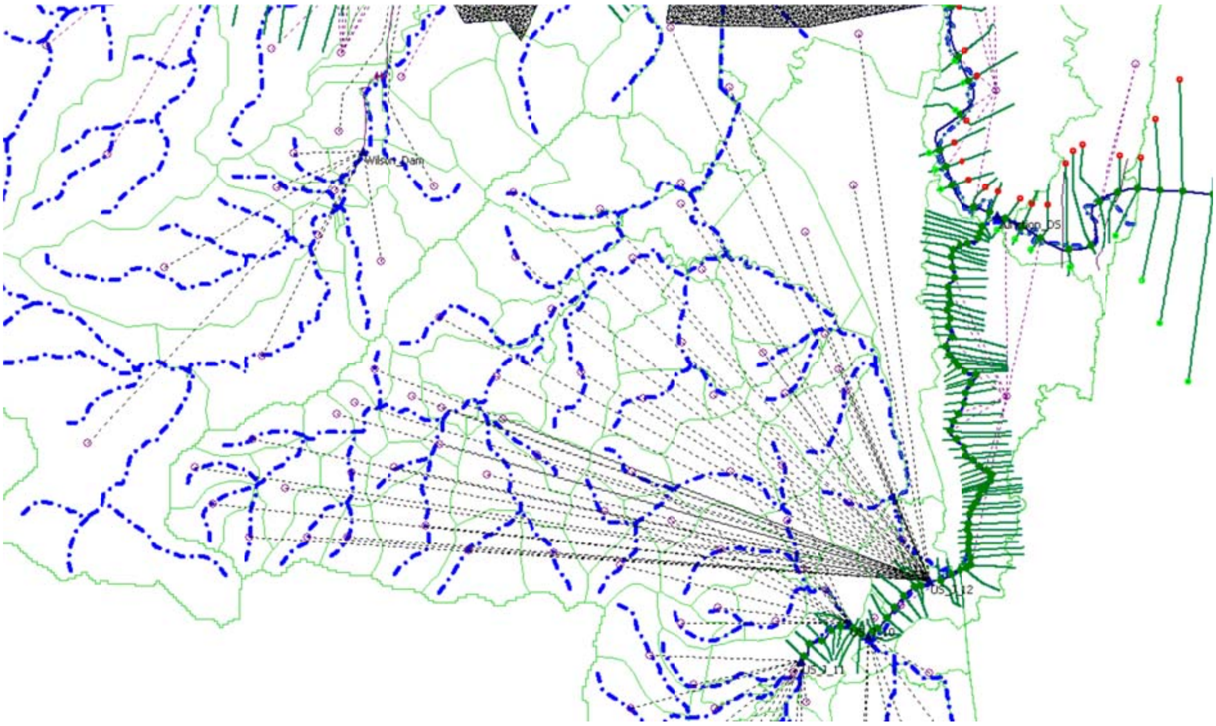
The hydrological model is the upstream boundary condition and is contained within a boundary node defined for each sub-catchment. These nodes discharge runoff into the network as a lateral inflow or a point inflow. The boundary nodes contain all pertinent hydrological parameters required to run the US SCS method implemented in InfoWorks RS. Those parameters are in agreement with the criteria defined for the NRC Priority catchments as explained in the NRC Priority Rivers Modelling Report, Feb 2010.

It was discovered that many of the points of discharge to the network were not well defined. There were many situations where sub-catchments were located a great distance from their discharge point to the network. This would not pose a problem if they were connected to the river system at the proper point, with the appropriate delay time. There were two issues noted. The first issue was a few sub-catchments were not connected to the river network at the correct point. The second issue was more serious as many sub-catchments that had these long travels times to the network did not have any time delay incorporated into their nodes and therefore discharged their runoff directly to the river network immediately. This was the case for most of the sub-catchments that were connected to the network from great distances. Without the inclusion of the time of delay, the routing of flow from these sub-catchments incorrectly impacted the network and distorted previous calibration results.

Figure 3.1 shows an example of the situation. The problem was corrected by using the ARC TP108 formulation to estimate a time of delay for each sub-catchment based on the stream link. The delay time of the stream link was estimated using GIS tools, taking as input the long profile of the missing stream and difference in elevation.

More details about the modifications of the hydrological model are in the section Hydrological Model section of this chapter.

Figure 3-1 Example of Sub-catchment nodes connected at a great distance from the point of discharge with no delay time



3.3 Network Model Objects

As part of the scope, it was considered necessary to improve certain specific areas of the model as previously described. However, it was also necessary to review the general model structure details (such as variables, connections, assumptions, etc.) to assure the model could meet the new requirements defined for this project.

All of the hydraulic networks physical attributes and how to represent them in the model appropriately network model objects are well understood. Typical network objects are river cross sections, spills, bridges, storages areas, 2D areas, river links, junctions, etc.

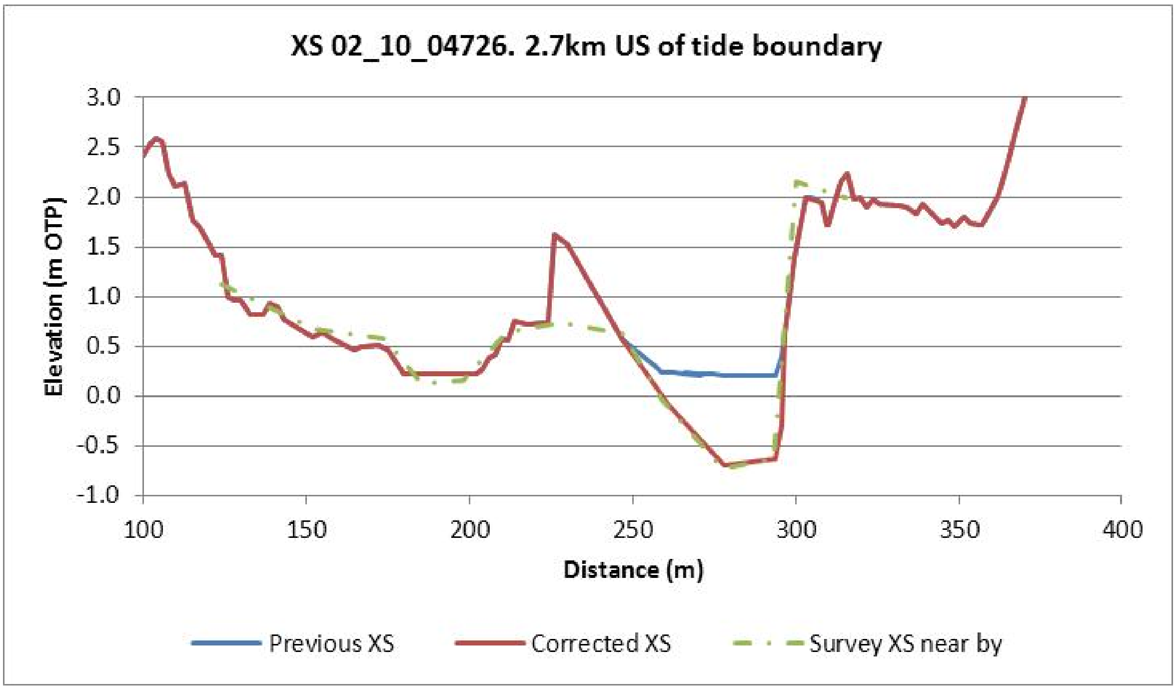
The critical network objects that required correction in order to achieve good calibration results are discussed in sections 3.3.1-3.3.5.

3.3.1 River Sections

The lower part of the main river's section levels of the bottom portion of the channel presented irregularities. A portion of the channel bottom cannot be estimated from LiDAR information as it is below water level. The missing portion of the channel bottom shape and level can be interpolated using surveyed cross sections and merging them with LiDAR information. The missing portion of the channel bottom, in the provided model, was found to be typically between 0.5m to 1.0m deep. Early calibration results confirmed, this aspect was significantly affecting the quality of results and needed to be corrected.

Bottom levels were corrected along 8.0 kilometres of the main river extending upstream from the mouth of Ruakaka River.

Figure 3-2 Example of correction of cross section bottom levels



3.3.2 Spills

The scope of this project included the extension and modification of some critical 2D areas. This involved modification of the spills connecting the river with the respective 2D areas. However, in many areas where 2D modifications were not required, low quality spills were discovered. These spills typically don't follow the banks along the river or their section resolution is so poor that it incurs a major inaccuracy in the solution. The example below shows a spill that was defined incorrectly out of the banks and was wrongly sending 70% of the flow away from the main river that should have remained in the main river.

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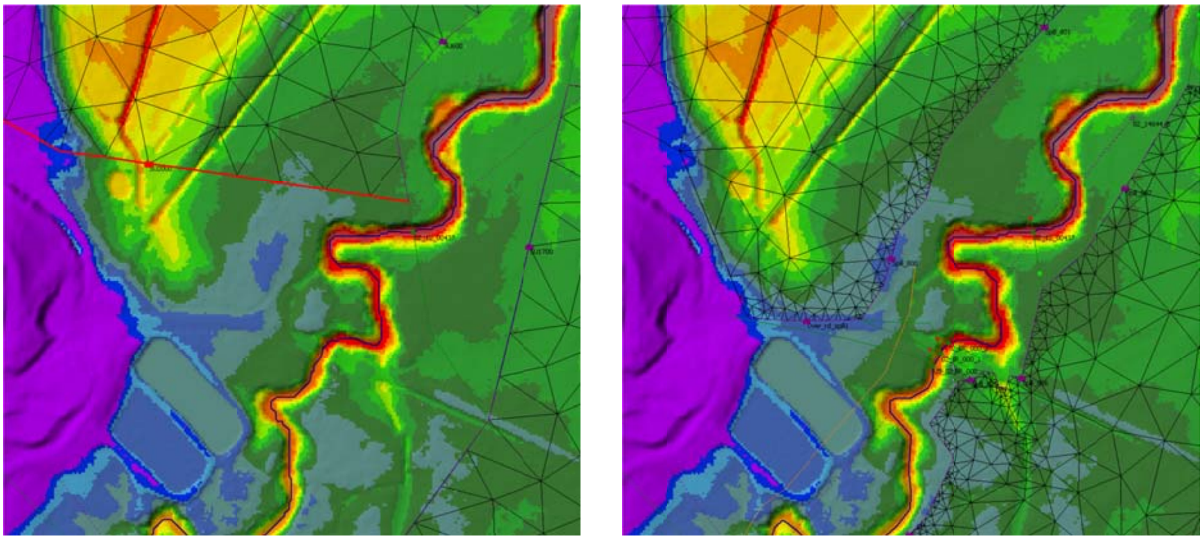
Figure 3-3 Example of spill corrections



Previous spill and 2D area borders   Corrected spills and 2D area borders

3.3.3 2D Polygons

The resolution of the previous models 2D polygons was good enough for a rough description of the flood plains. Break lines and better resolution in many areas were required in order to meet requirements of calibration. Additional 2D areas were also added to assure a good description of the flooding. Other polygons were reduced in resolution as they were at higher elevations and remained dry.

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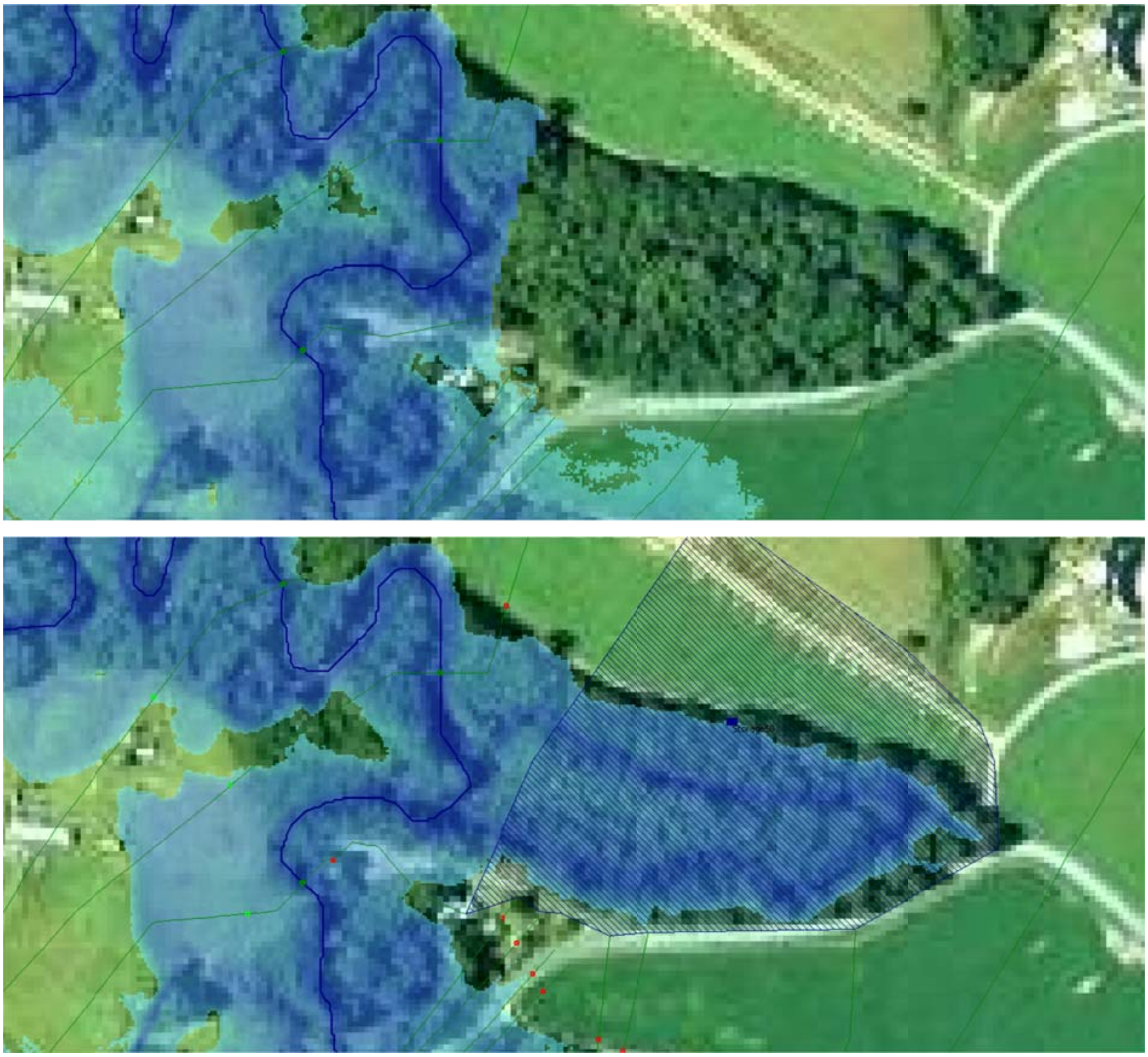
Figure 3-4 Previous and improved 2D mesh, as well as new 1D stream channel model extent. Example at downstream of Wilson Reservoir

3.3.4 Flood Compartment

Flood compartments are necessary to interpolate model level results into a water surface and generate the flood maps over the LiDAR ground model. If the flood compartments are not well defined or they do not cover areas that flood, then the flood mapping will show erratic wet/dry areas. These compartments required correction to assure a good representation of the flooded areas.

Figure 3-5 Flood compartment corrections; furthermore, storage added to represents volume of river loop



3.3.5 Storage Areas

It was discovered in the previous model that many sub-catchments were draining directly to the main stream even though there were important flood plain storage areas they should have drained to before reaching the river. This had to be corrected in order to get a good fit for the calibration. The newly calibrated January 2011 model has added more detailed storage areas that have improved the actual floodplain areas. This also improved the routing of the water between sub-catchments and rivers. The example shown below in Figure 3.6 shows the previous and current model detail of two upper sub-catchments that flow over a flood plain before reaching the river. The purpose of improving these

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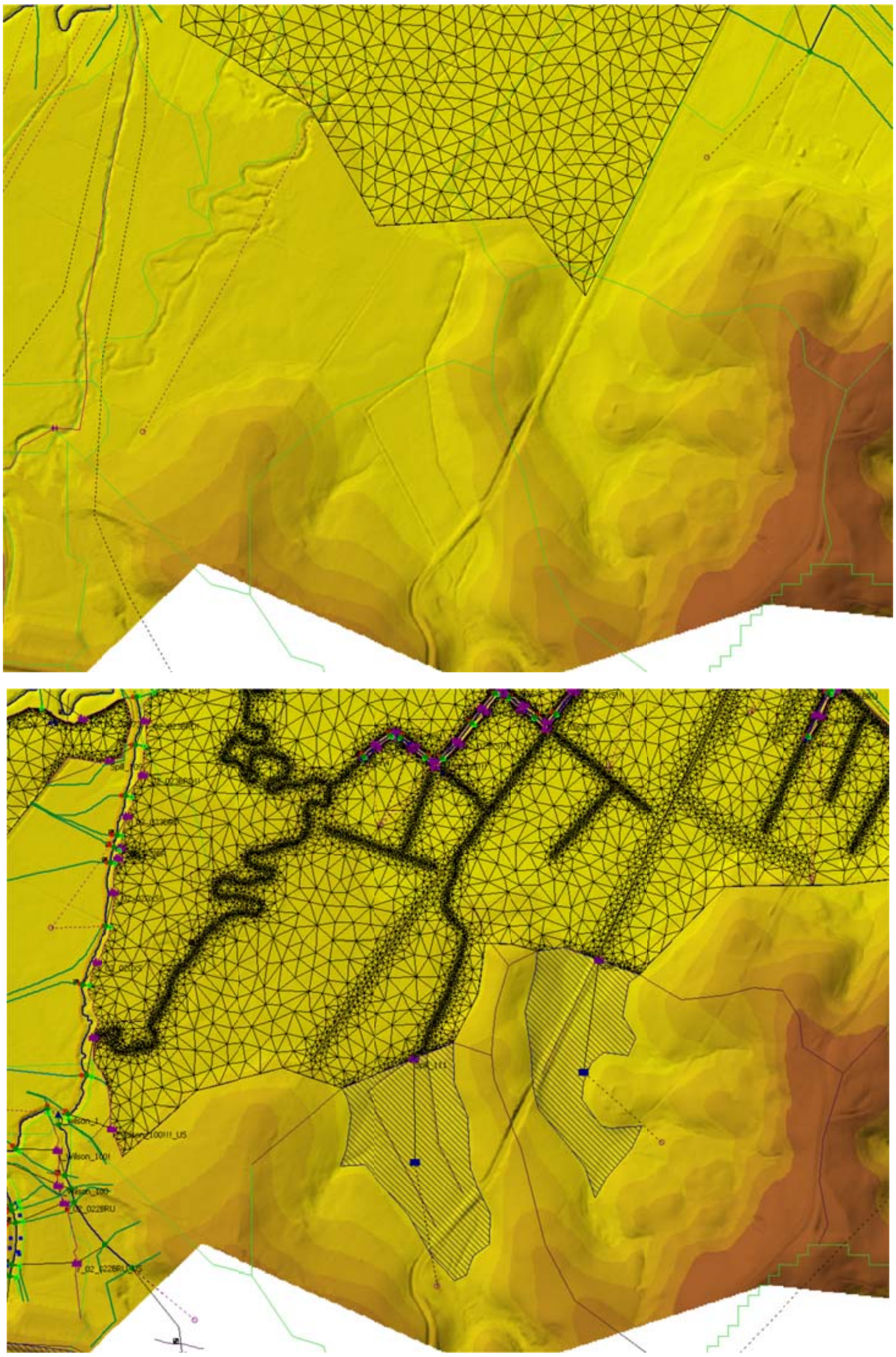
areas, besides the better resolution 2D mesh, are the two storage areas added upstream of the flood plain to properly receive and distribute the runoff onto the 2D flood plain.

Figure 3-6 Example of additional storage areas; local sub-catchments draining into storage to describe the flow of runoff through flood plains



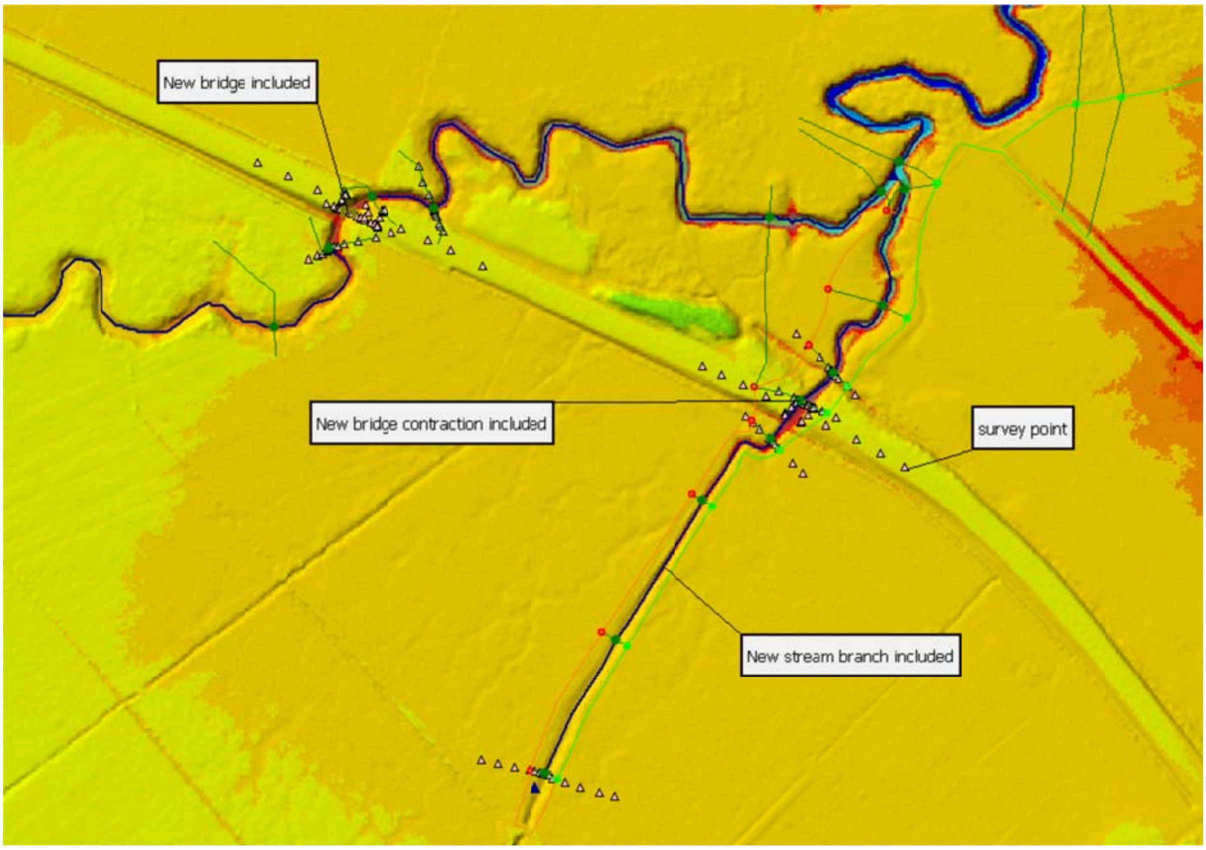
3.4 Survey and Model Extent

The previous survey taken in 2010 was available in the model represented as cross sections lines or bank lines. The survey was useful for analysis of results and model performance. Most of the critical survey information was included in the model as river cross sections. Unfortunately there were many other critical areas where the survey information was not included. This led to irregularities in the model. The data was added or corrected if it was required in modelling modification tasks.

New survey data was provided by NRC in 2011 and 2012. This information was added to the model and linked to their survey photos. This data was used to improve and/or add stream cross sections in areas where more detail was required. It was also used to add some bridges and culverts to improve the hydraulic performance of the model.

Figure 3-7 shows an example where the 1D river network was improved and extended using new survey information.

Figure 3-7 Example of improved extension of the 1D model



3.5 Hydrological Model

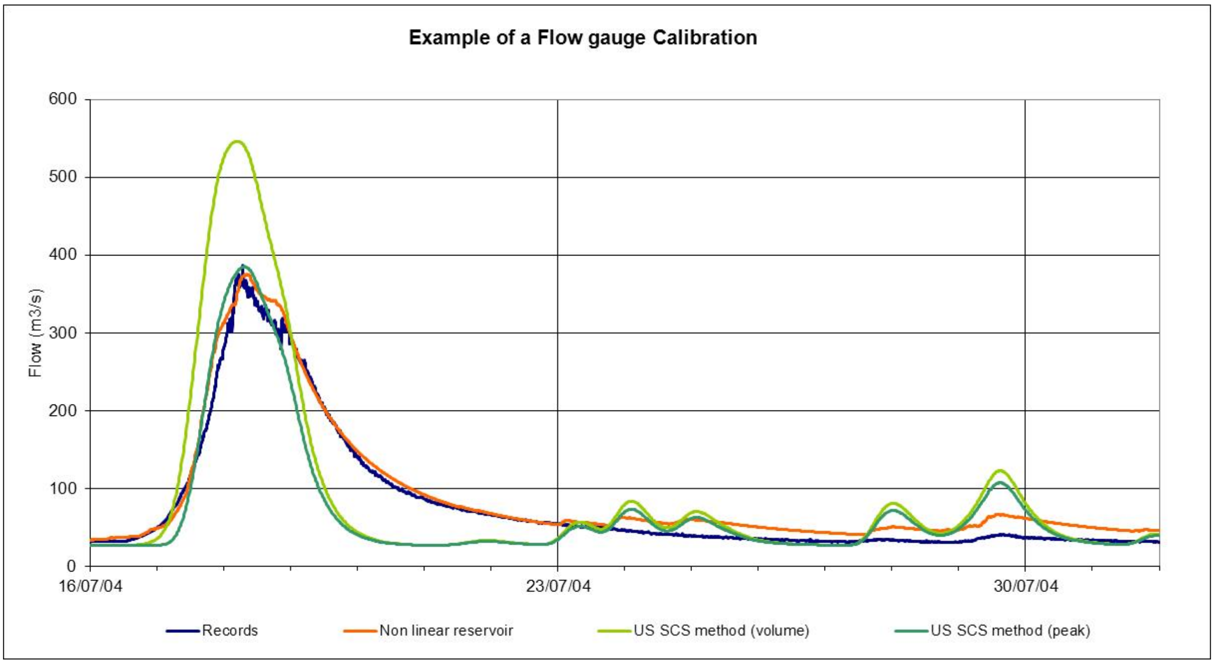
3.5.1 US SCS Method

The previous Ruakaka 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 Ruakaka catchment. The results are not satisfactory and do not represent the hydrologic behavior of Ruakaka 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 3-8 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.

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 Ruakaka sub-catchments.

Part of this project is to calibrate Ruakaka catchment with an alternative and more suitable hydrological model. Based on the previous explanations, a Non-Linear Reservoir Method has been used to calibrate the storm of January 2011 for Ruakaka catchment.

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 Ruakaka 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. A few points regarding this matter:

- The infiltration rate has been estimated based on real rain and flow records to calculate the rainfall losses and the effective rain. Only one location – at the middle of the catchment- was available for that purpose to calculate and average infiltration to be applied over the whole catchment.
- The constant and uniform infiltration rate is useful as the whole catchment is practicably rural and previous CN value differences are not as important.
- A spatially variable infiltration rate is still possible based in the CN based approach. However, any estimation is strongly dependant on the moisture conditions of each sub-catchment.
- The complex exercise does not offer comparative benefits in terms of accuracy, as uncertainties and assumptions are still significant.

3.5.5 Base flow and Infiltration Rate expected ranges

There was not enough information to allow a reliable base flow to be estimated for each sub-catchment. The only available information was Flyger Road station records that showed a base flow less than 0.5 cumecs before the calibration storm. Flyger Road catchment is half of the whole Ruakaka river catchment, so if we consider the same rate of base flow for the rest of the catchment we would obtain less than 1 cumec of base flow at the mouth of Ruakaka River. This compared to the 250-300 cumecs expected at that location in the calibration event makes the base flow negligible.

Infiltration was found to be between 5-6 mm per hour for the calibration event, 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.

Base flow and infiltration rates will change for each scenario, and they would need to be chosen with care to assure a well-defined scenario considering different levels of soil moisture relative to that specific rain event. That is to say calibrating the model for a different rainfall event will require the same diligence in understanding and selecting these values.

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.

During these tasks, an area was identified from the LiDAR information that suggested a different catchment boundary for the Ruakaka catchment.

The following figures explain the reasoning and conclusion for the correction of the catchment boundary. More detail on the new sub-catchments can also be appreciated in surrounding areas.

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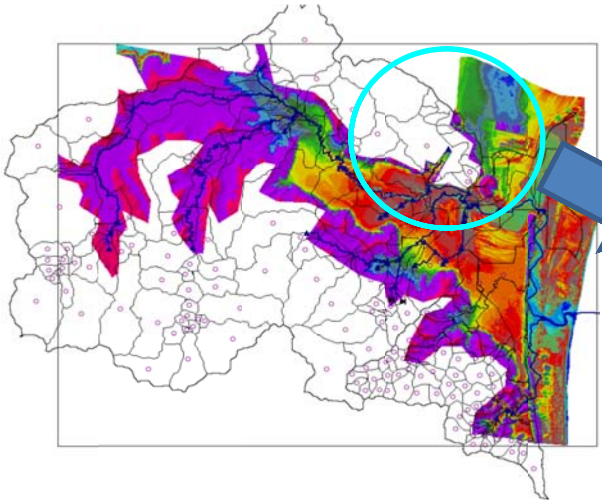
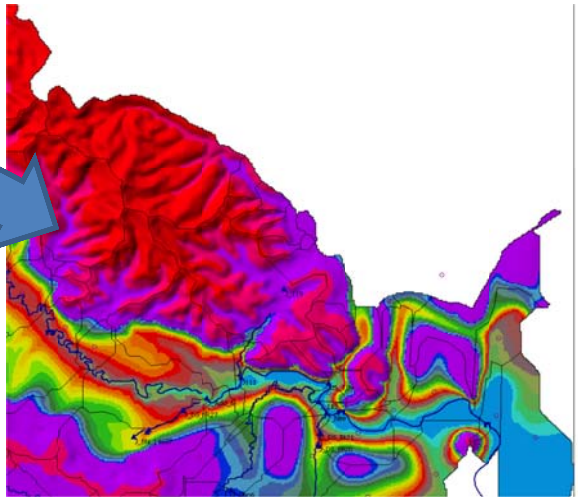
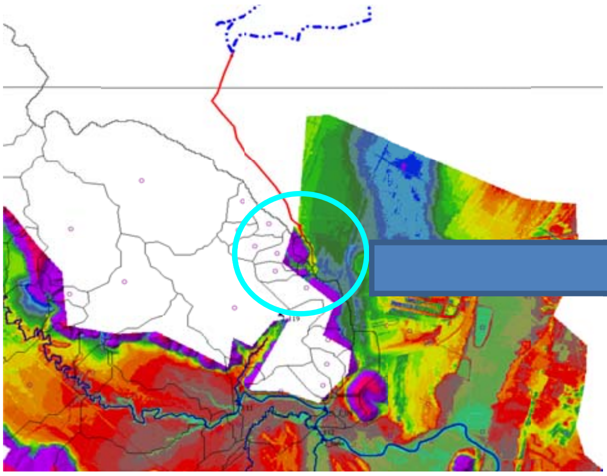
Figure 3-9 Analysis of northern border of Ruakaka catchment



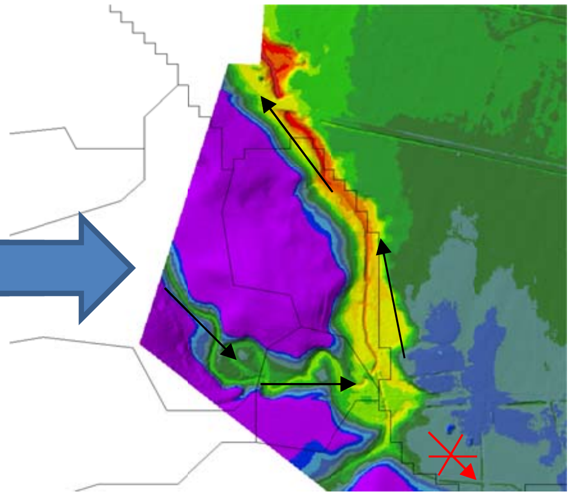
Ruakaka Catchment showing area of correction.



Catchment and sub-catchments delineation based on 20 m contours.



Red line shows a stream present in the aerial photograph. The blue broken line is the coast line.



LiDAR information suggests that the stream in the image follows the direction shown by arrows (previously modelled flowing to the southwest). Therefore the stream and its associated catchment area should not be included in the Ruakaka catchment.

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Figure 3-10 Previous catchment delineation vs. new borders

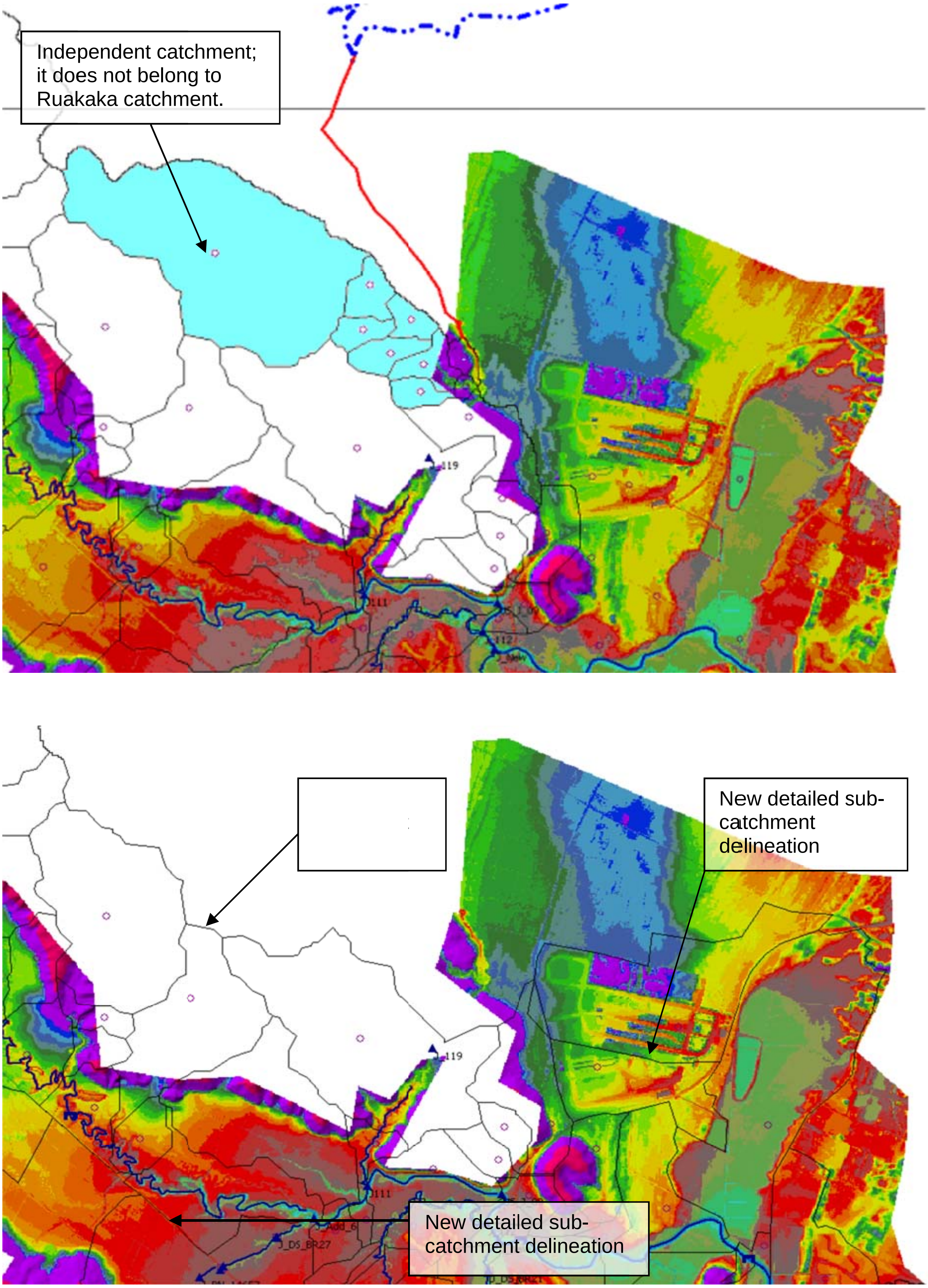

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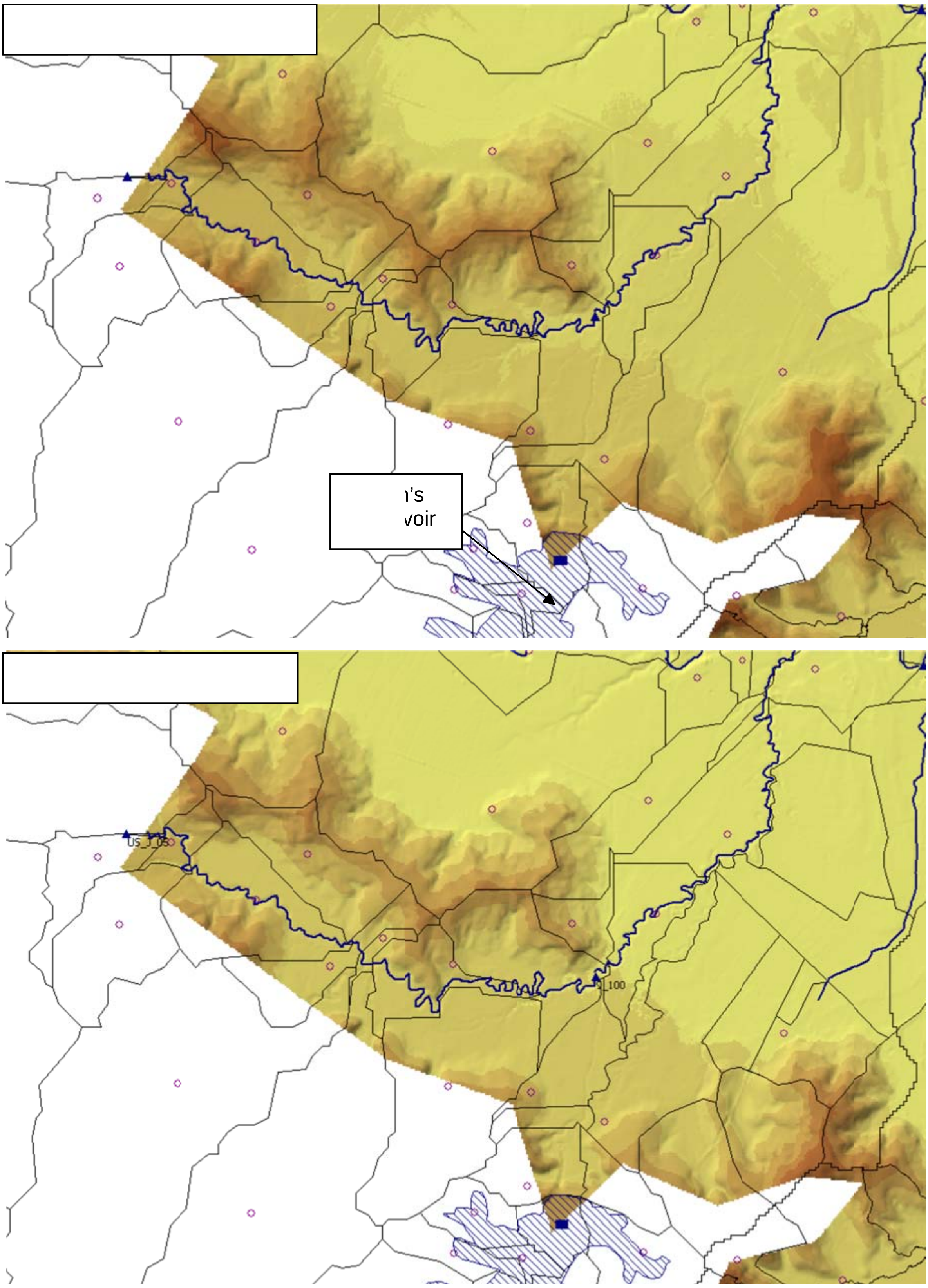
Figure 3-11 Previous catchment delineation vs. new sub-catchments downstream of Wilson's Dam; new sub-catchments follow roads, channels and banks present in LiDAR ground model



Data Analysis

4.1.1 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, as well as geo-referenced and analysis of satellite images of the storm of January 2011.

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.

4.1.2 Calibration Event Analysis

The calibration event for Ruakaka catchment is the storm recorded the 29th January 2011. This is an interesting event as it was estimated to be greater than a 50 year ARI storm.

Another interesting feature of this event is that it happened during the summer time, when usually the soil is drier and the infiltration rate is higher. However, just a week before, on the 23rd of January 2011, another significant storm, estimated to be approximately a 2 year ARI event, had taken place.

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

4.1.3 Rainfall distribution for Calibration Event

The rainfall analysis utilised 8 rain gauges. 6 auto gauges (with readings between 1min and 1hr) and 2 daily gauges. Table 2.1 below summarises the available information. Figure 2.1 shows the distribution of rain gauges in the Ruakaka catchment.

4 Data Analysis

Table 4-1 Rain gauge details

	Auto Gauges						Manual Gauges	
NZMS1								
NZMS260	Q07 340 028						Q07 429 901	
X_NZTM (Easting)	1723299	1719411	1728142	1734574	1738080	1727646	1732227	1733323
Y_NZTM (Northing)	6040999	6027666	6025879	6033328	6034400	6010353	6028325	6045202
Catchment	Onerahi	Waikokopa	Waiwarawara	Whangarei harbour	Whangarei Heads	Waihoihoi (Waipu)	Ruakaka	Pataua
Location	Outside catchment (North West)	Catchment boundary (West)	Inside catchment (South)	Outside catchment (North East)	Outside catchment (North East)	Outside catchment (South)	Inside catchment (East)	Outside catchment (North)
Altitude (m)	37m	200m	60m	5m	120m	350m	7m	80m
Record	Auto (1hr)	Auto (5 mins)	Auto (5 mins)	Auto (1 min)	Auto (2 min)	Auto (5 min)	Daily at 09:00	Daily at 07:30
Recording Authority	Met service	NRC	NRC	NRC	NRC	NRC	NRC	NRC
Period of Record	01.08.1990 -	03.11.2010 -	20.12.2007 -	20.09.2006 -	31.10.2010 -	16.02.1981 -	01.01.2000 -	05.01.2010 -
Site ID	A54737	548315	548412	548215	NRC 8010111	640436	548213	547413
Station name	Whangarei AERO AWS	McDonnell Road	Wilson's Dam	Marsden Point	Ody Road Air Shed	Brynderwyn	Ruakaka at Fosters	Pataua at Taraunui Road (Kay)
Daily Gauges match with which AUTO record	Daily totals to 09:00	Daily totals match records AUTO records if read at 9:00	Daily totals to 09:00	Daily totals to 09:00	Daily totals to 09:00	Daily totals to 09:00	Daily totals to 09:00	Daily totals to 07:30
20/01/2011	0.0	0.0	0.0	0.5	0.0	0.0	0.0	No reading
21/01/2011	0.0	0.0	0.0	0.0	0.0	1.0	0.0	No reading
22/01/2011	15.4	5.5	16.0	2.0	1.9	5.5	13.5	No reading
23/01/2011	99.8	90.0	99.0	51.5	146.4	79.0	89.0	No reading
24/01/2011	3.8	12.0	11.0	2.5	0.6	11.5	6.5	150.4
25/01/2011	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3
26/01/2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27/01/2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28/01/2011	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
29/01/2011	211.4	187.5	253.5	229.5	274.1	190.0	268.5	296.2
30/01/2011	0.2	1.5	0.5	0.5	0.2	0.5	1.0	0.4
31/01/2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/02/2011	0.2	1.0	0.5	0.0	0.1	0.5	1.5	0.0
2/02/2011	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8
3/02/2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/02/2011	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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. Satellite images were also available to complement the analysis, providing valuable information regarding the dynamics and distribution of the event.

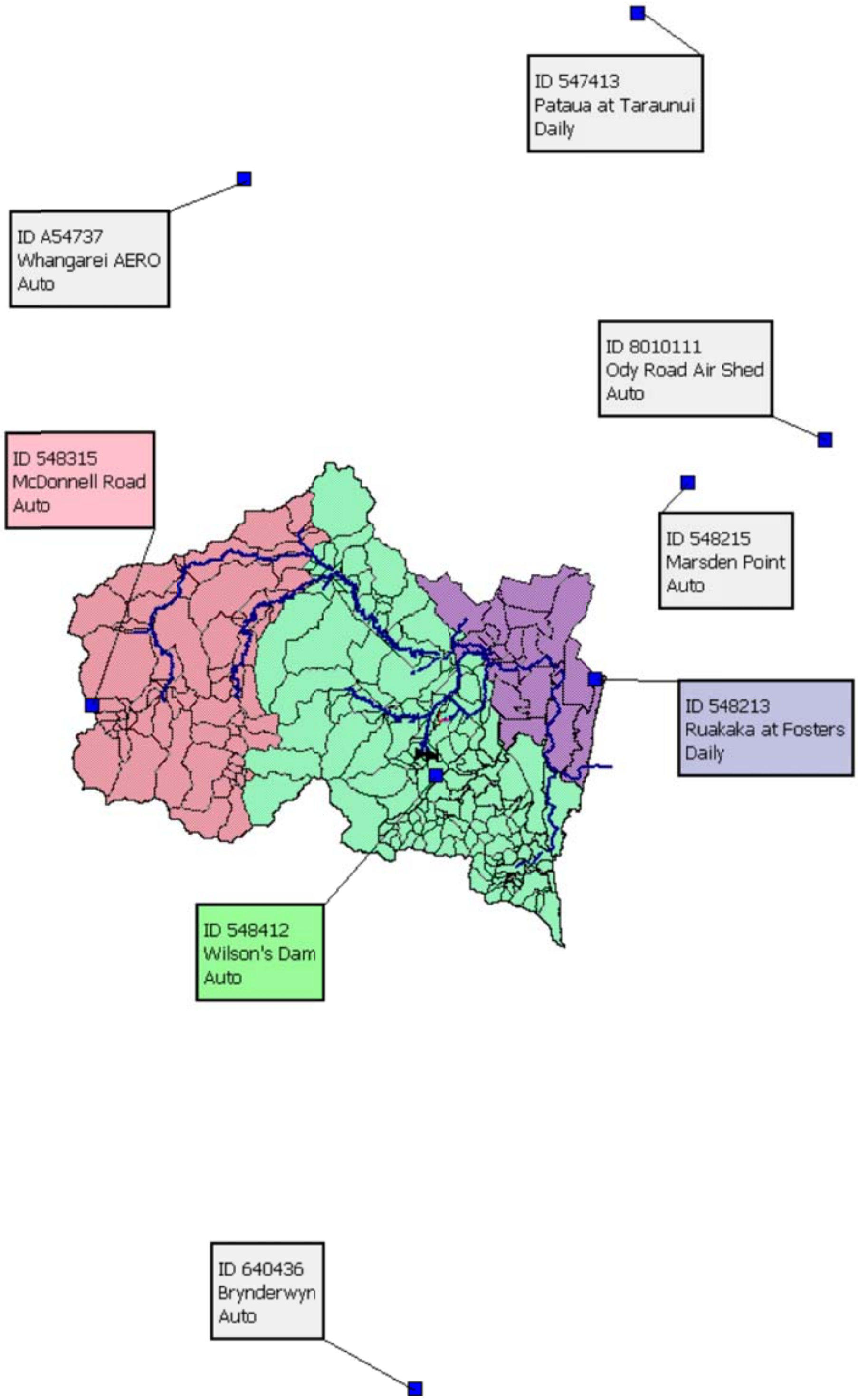
From the previous analysis, the difference between times of maximum rainfall intensity, for remote locations in the catchment, is less than 30 minutes. This small difference can be confidently represented with three rain gauges to distribute the rain along the catchment.

There are three rain gauges that have an important influence in the catchment (based in Thiessen polygons). Those are gauges 548315 (auto), 548412 (auto) and 548213 (daily). These gauges have differences in time distribution of less than 10 minutes when compared with Wilson's Dam rain gauge (548412, at the centre of the catchment) and in relations with all the other surrounding gauges. Figure 4.1 shows the area of influence of those three gauges over the catchment based on Thiessen polygons.

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 gauge 548213, similar to Wilson's Dam (548412), except 9 minutes earlier, indicating the storm came from northeast.

4 Data Analysis

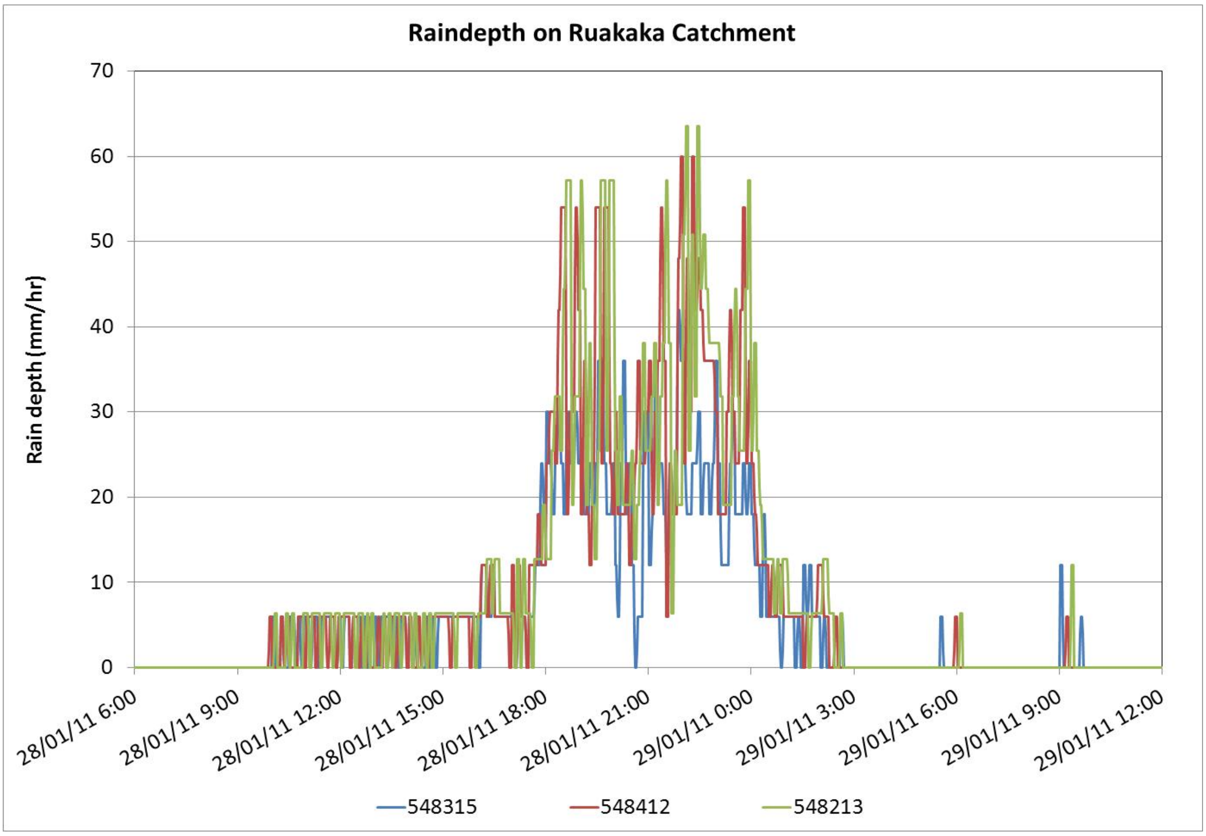
Figure 4-1 Rain gauge location and Thiessen distribution over Ruakaka catchment

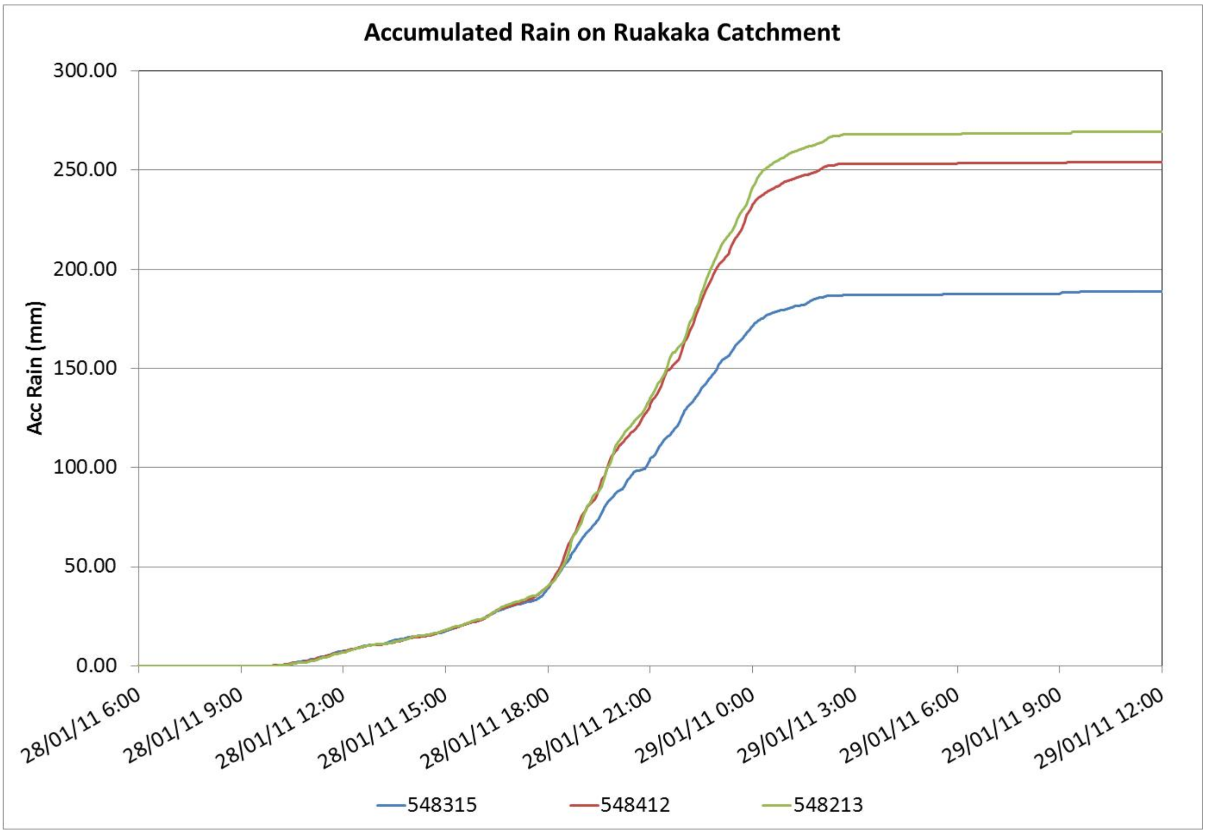


Rain gauges 548315 (auto), 548412 (auto) and 548213 (daily/estimated pattern) were used as inputs to the model for calibration. The following figures show the rainfall intensity and accumulated rainfall of these three rain gauges.

4 Data Analysis

Figure 4-2 Distributed and accumulated rain for the calibration event





4.1.4 Reservoir Analysis

The storage curve and discharge curves for the spill way and emergency weir are available for Wilson's Reservoir. The storage curve was completed using LiDAR information and the discharge rating curves were analysed to assure the datum and volumes are well represented. Figure 4.3 and Figure 4.4 show the storage curve and discharge curves for Wilson's Dam.

The discharge curves show a discharge coefficient of 1.65 for the auxiliary weir, and a variable coefficient between 1.6 and 1.0 for the service weir. As these parameters are variable, an explicit table of Q-Z was input into the model to describe the outflows from the Wilson's Reservoir.

The reservoir is the most reliable area to estimate rainfall losses as there are water levels records available for the calibration event. These records in conjunction with the discharge curves permit an estimation of the time series for the outflows from the reservoir in January 2011. Furthermore, based now on a volume balance of the reservoir it is possible to estimate the flow discharging into the reservoir. These estimations will serve as a guide to calibrate the inflows/outflows of the reservoir and to estimate the rainfall losses based on the volume of rain. Figure 4.5 and Figure 4.6 show the estimated inflow, estimated outflow and water level for the reservoir.

Figure 4-3 Wilson's Reservoir storage curve extended using LiDAR information

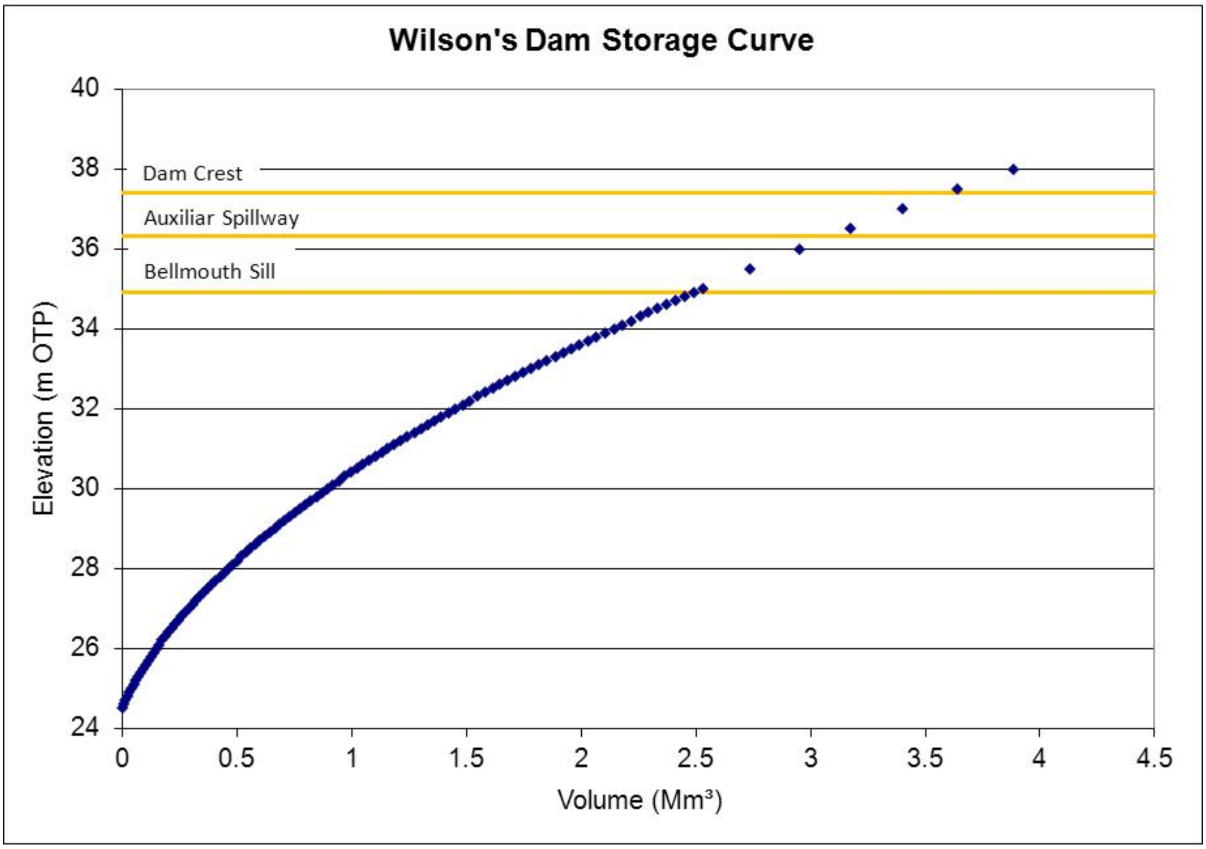
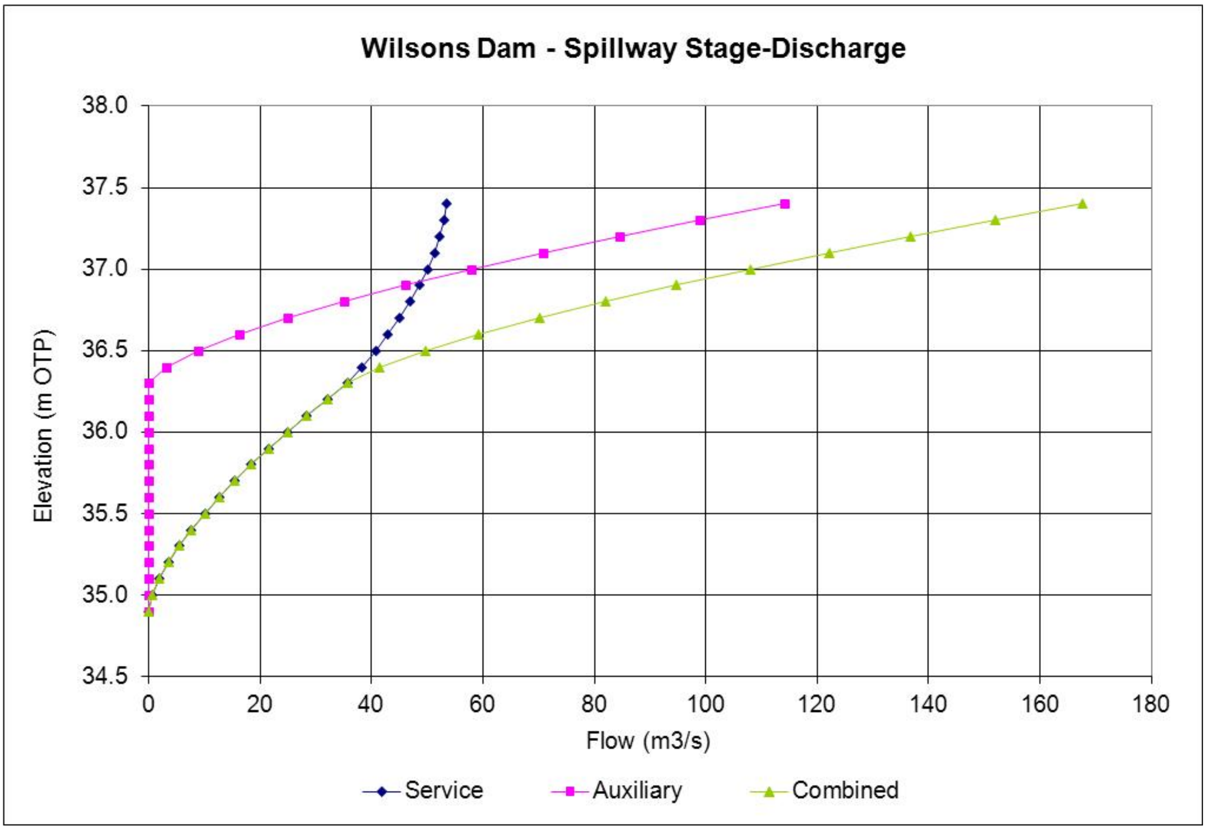


Figure 4-4 Wilson's Dam spillway discharge curves



4 Data Analysis

Figure 4-5 Wilson's Reservoir recorded and estimated levels; post Jan 2011 event GPS survey of debris level of reservoir were in the range 35.75m to 35.80m OTP.

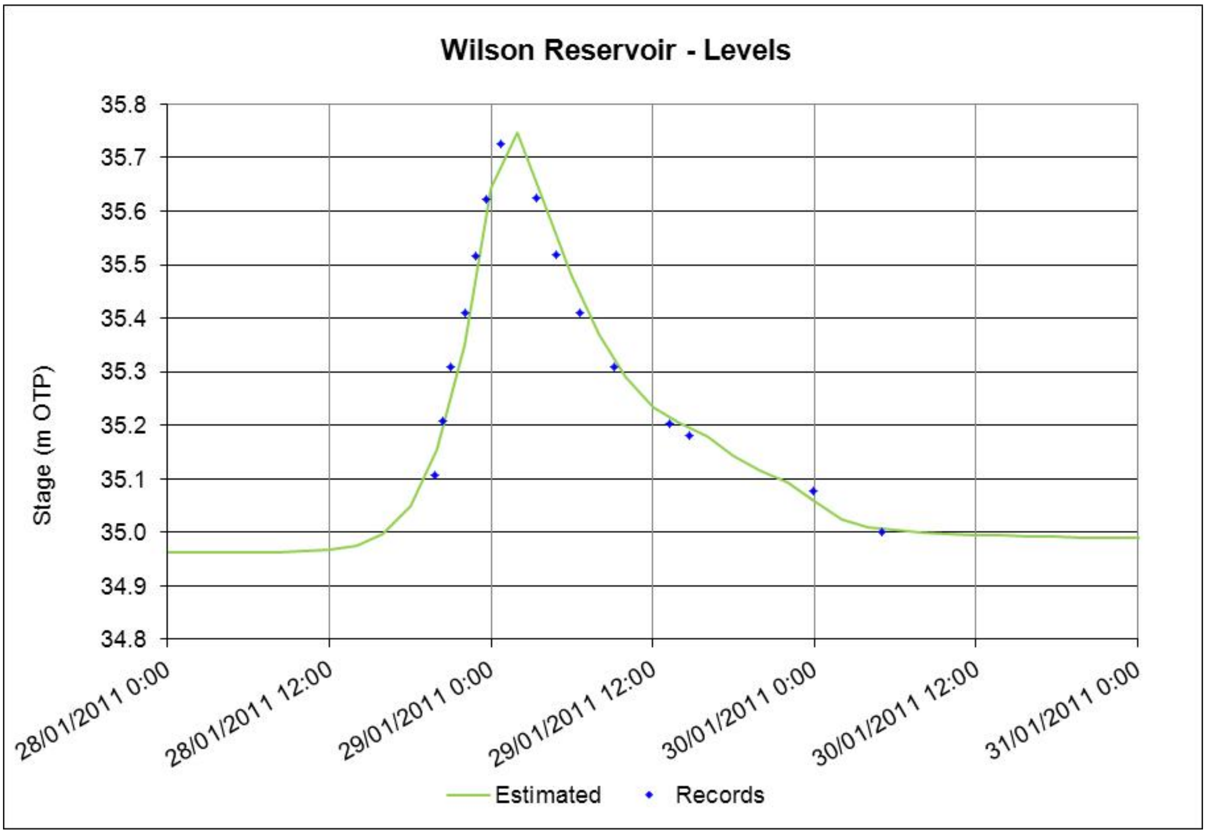
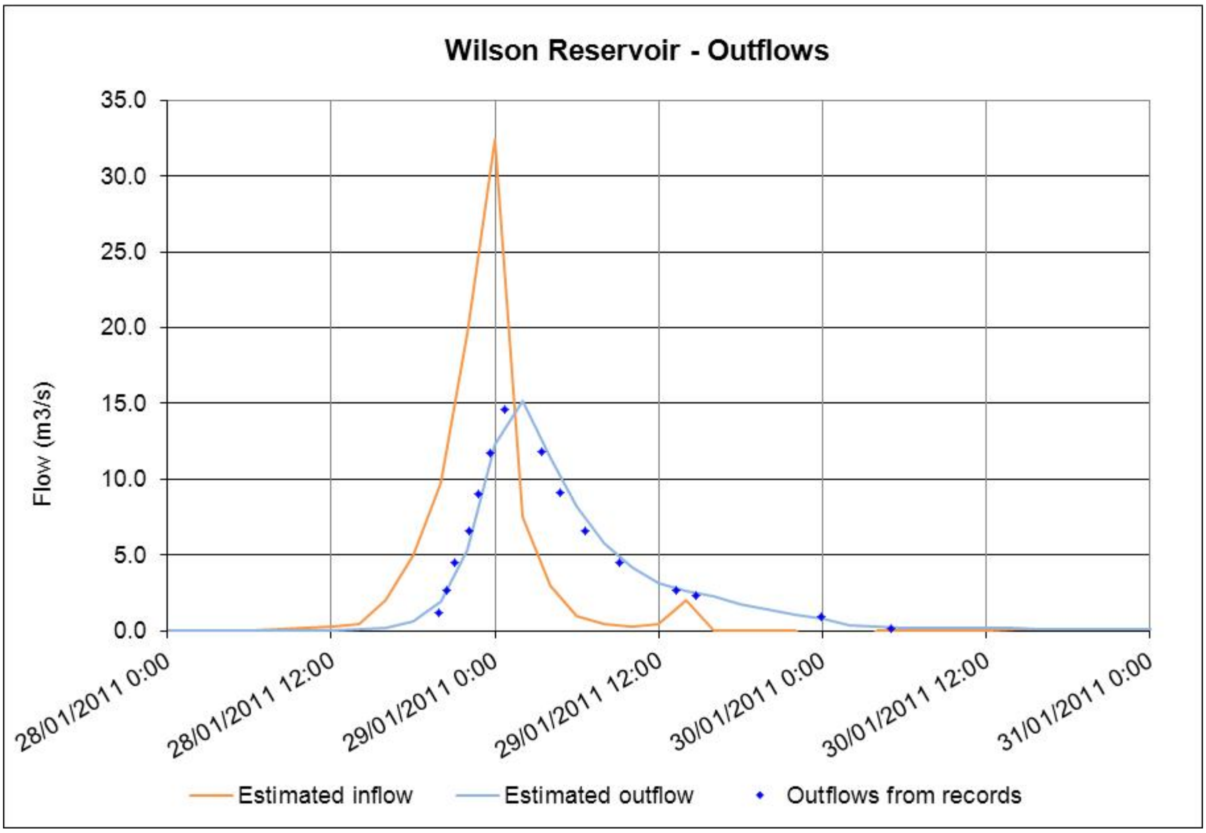


Figure 4-6 Wilson's Reservoir estimated inflow and outflow



Finally, the rainfall volume can be estimated using the rain gauge placed at Wilson's Dam (gauge 548412). The catchment area draining into Wilson's Reservoir is approximately 39 ha. Using this data enabled an estimation of the total runoff coefficient (RC) of RC=0.60 for the event of January 2011. This information is invaluable for the calibration tasks.

Furthermore, an average infiltration rate was also estimated to be between 5mm/hr. and 6mm/hr. for the event at the end of January 2011. Based on records it was not possible to estimate a base flow for Wilson's Reservoir catchment, and as previously stated it was assumed negligible.

4.1.5 Flow/Level gauges analysis for Calibration Event

There are five level gauges available in the catchment. They are listed below in Table 4-2 with their details and data availability.

Level records are available for four of these gauges; the station in Tauroa Stream did not have recorded levels available, only an estimation of maximum levels and flows during the calibration event. Flow records are only available for one station: Ruakaka at Flyger Road, but Wilson's reservoir inflows and outflows are estimated in figure 4-6, based on water level data and the discharge curves.

Datum and levels records were checked against LiDAR information and debris level survey. The following sections there are brief descriptions of all five stations and the quality of their data.

4 Data Analysis

Table 4-2 Level gauges details

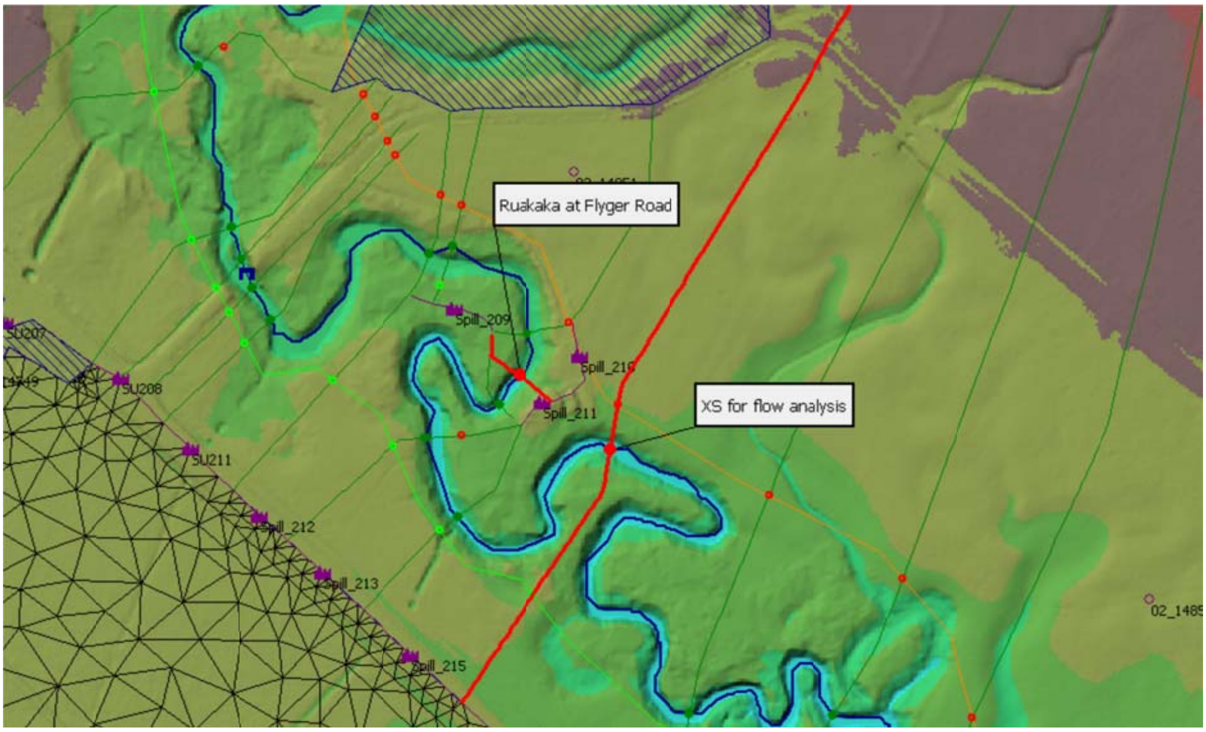
	Water Level Sites				
X_NZTM (Easting)	1726744	1727785	1727801	1734608	1728455
Y_NZTM (Northing)	6029604	6026360	6026628	6033357	6027900
Recording Authority	NRC	WDC	WDC	NRC	WDC
SG Zero (m OTP)	3.080	24.443	16.630	-1.680	5.570
Catchment name	Ruakaka	Waiwarawara	Waiwarawara	Sea level	Tauroa
Catchment area km2	45.3	4.00	4.1	n/a	12.46
Type of record for Jan 2011	Auto	Auto	Auto	Auto	No record for Jan 2011
Site ID	5901	Dam021_LT01	Dam021_LT02	5801	WPS052_LT1
Site Name	**Ruakaka at Flyger Road**	**Wilsons Reservoir Level**	**Wilsons Dam Residual Flow Weir**	**Marsden Point (Tidal)**	**Tauroa Stream Pump Intake**
Max Stage event Jan 2011 (SG) m	4.789	11.227	2.39	2.711	2.830
Max flood elevation Jan 2011 (m OTP)	7.869	35.670	19.020	1.031	8.400
Time of peak	29/01 @ 01:15	29/01 @ 00:42	~29/01 @ 00:42	29/01 @ 02:43	not known (n/k)
Wilsons Bellmouth Invert Level		34.90			
Max Stage above Bellmouth Invert (mm)		770			
Wilsons Auxillary Spillway Level		36.30			
Max Gauging at site - Level (SG) mm	4015				2.13
Max Gauging at site Flow (m3/s)	64.100				52.000
Confidence in predicted peak flow estimate	*Low at high stage due to flow diversion across flood plain*	*From MWH Supplied Rating Curve for Wilsons Dam*	*Suspect recorder malfunction for Jan 2011 event*		*From as builts pdf Section B on page TS1*
Predicted Peak Flow Jan 2011 (from rating curve) m3/s	152.194	~ 16	~ 16		*No rating curve available*

4.1.5.1 Ruakaka at Flyger Road

The Flyger Road gauging station is located in the centre of the catchment, just downstream of Flyger Road. The level gauge is located at a bend of the river where flood diversion happens across the flood plain during high flow events. For that reason there is low confidence in the flows records for high stage flows. To include this in the analysis, flow has been checked at the next downstream cross section that includes all the entire flood plain, as shown by the highlighted redline in Figure 4-7. The figure also shows the location of the Flyger Road Station.

The catchment draining to the Flyger Road station is approximately 4676 ha, or 49.5% of the total catchment of the Ruakaka River. The effective rainfall volume was compared against the flow volume of this station for the 29th of January 2011 storm. The flow volume calculated also considered the few days following the storm to consider the slow response of the catchment. Through this exercise a runoff coefficient of 0.62 was estimated for the upper catchment applicable to the calibration storm (very close to the RC=0.60 assessed for Wilson's reservoir in Section 4.1.4). This translated to an average infiltration rate between 5mm/hr and 6mm/hr for the whole catchment.

Figure 4-7 Flyger Road station



4.1.5.2 Wilson Reservoir Level

Reservoir water levels are available and an estimation of inflows and outflows has been made to assist the calibration tasks. Additional debris levels obtained by NRC are available for the maximum level of the reservoir for the calibration event, survey which is consistent with recorded maximum levels at this level gauge.

Details of the Wilson reservoir analysis are covered in Section 4.1.4.

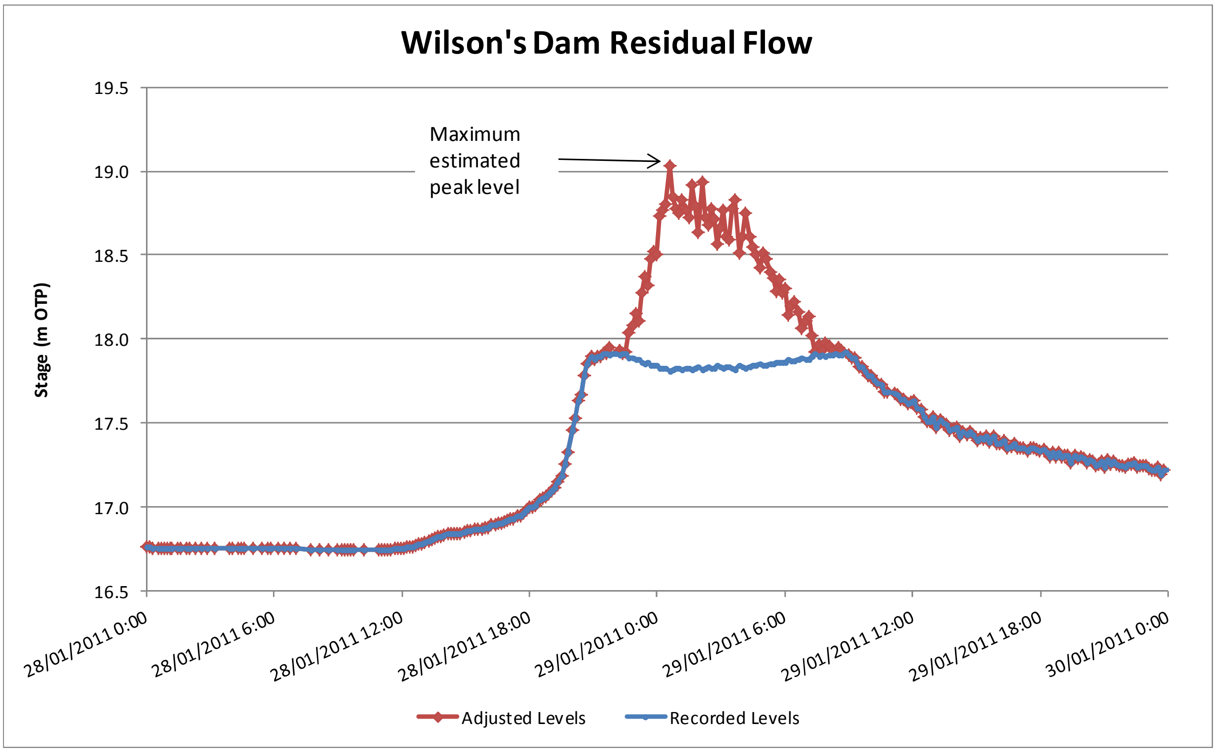
4.1.5.3 Wilson Dam Residual flow

Located just downstream of Wilson Dam, this flow gauge station is a weir gauge to measure the residual flow from the reservoir (WDC SCADA data). NRC surveyed the weir invert level at 16.63m OTP and the Jan 2011 flood level adjacent to the weir at 19.02m OTP (see Table 4-2) The original dataset from WDC SCADA for the residual weir contained 2 peaks at 21:30 (on 28/01) and 08:20 (on 29/01) which were not consistent with the timing of the peak level in the reservoir (recorded 00:42 on 29/01). NRC survey at this site established that the peak level recorded in the SCADA data of 1.29m Stage (17.92m OTP) for the weir was much lower than surveyed flood level of 19.02m OTP for the Jan 2011 event. As both the recorded peaks on SCADA were at the same level it is possible that the residual flow recorder was outside of its range between the 2 recorded peaks, resulting in an inverted peak in the dataset. The data in this period was therefore adjusted by NRC using a uniform conversion to achieve a peak level consistent with the surveyed flood level. The adjusted residual weir data shown in figure 5-7 has a peak which occurs around the same time as the maximum reservoir level recorded for the Jan 2011 event.

4 Data Analysis

The outflows from the reservoir have been calibrated on the basis of recorded reservoir levels, dam spillway discharge curves, surveyed debris levels along the water race downstream of the reservoir stilling basin, and adjusted residual flow weir data.

Figure 4-8 Wilson's Dam Residual Flow station; recorded and adjusted levels



4.1.5.4 Tidal Gauge - Marsden Point

Marsden Point is a tidal station located only 7.5kms from Ruakaka River mouth. Its records have been used as the tidal level boundary condition.

4.1.5.5 Tauroa Stream Pump Station

No records are available for this location, only a survey of the maximum level (debris) and an estimation of the peak flow for the event on 29th of January 2011 (Table 4-2).

4.1.6 Debris Level points for Calibration Event

One hundred and eleven debris level points were surveyed and were available for the calibration event. All points were checked against LiDAR information and they cover important areas of the catchment, providing valuable information for the calibration event.

5 Calibration

The model was calibrated against the recorded levels and flows available, as described in Sections 2 and 4.

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. These aspects were more essential to achieving the calibration results and were more critical than 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 following table summarises the important calibrated variables

Table 5-1 Calibrated parameters

Variable	Value
HYDRAULIC MODEL	
Manning	
Main channels	0.020 - 0.060
Flood plains	0.060 - 0.110
Open bridges or culverts	0.070 - 0.080
2D polygons	0.060
Spill coef	
Natural bank	0.59
Roads	0.82
Upper storage outlets	1.00
Orifice coeff (culverts)	0.7 - 0.8
Wilson Dam	
Spillway and weir	*available curve*
Storage curve	*available curve*
HYDROLOGICAL MODEL	
Non-Linear Reservoir	
K =	5.0
p =	0.7
Infiltration Rate (mm/hr)	5.0
Time lag (minutes)	*as per TP108*

5.1 Debris Levels Points Results Match

Table 5-2 Measured and modelled debris level points

Point	X (m)	Y (m)	Description	Flood Level (mOTP)	Model (mOTP)	dZ (m)	Comments
ID=001	1723650.5	6031514.3	Flood Level	17.680	17.795	0.115	Low detail in model.
ID=002	1724936.7	6031687.9	Flood Level	13.719	13.636	-0.083	
ID=003	1724980.6	6031669.8	Flood Level	13.815	13.620	-0.195	
ID=004	1725438.9	6030776.1	Flood Level	12.992	13.155	0.163	
ID=005	1725435.4	6030795.3	Flood Level	13.117	12.918	-0.199	
ID=006	1725672.6	6030567.5	Shy Flood extent	13.280	13.346	0.066	
ID=007	1725616.1	6030639.9	Shy Flood extent	13.681	13.911	0.230	
ID=008	1725646.4	6030565.7	Shy Flood extent	13.695	13.530	-0.165	Channel off model, levels reflect flood plain levels but not small channel levels. Level point just outside of flooded 2D zone.
ID=009	1726556.8	6029591.2	Flood Level	8.319	8.109	-0.210	
ID=010	1727565.7	6028629.7	Extent of scour	4.913	4.995	0.082	
ID=011	1727684.8	6028512.6	Extent of scour	4.930	5.328	0.398	Lateral small channel off main stream. Not define in model
ID=012	1728337.0	6028820.7	Flood Level	5.809	5.182	-0.627	Surrounding points suggest this survey point is high. Maybe because it is locate at the outside of a close meander. It might be a 2D phenomenon. Maybe wrong survey level reading.
ID=013	1728968.0	6029203.7	Flood Level	4.627	4.725	0.098	
ID=014	1729688.8	6028775.3	Flood Level	3.823	3.980	0.157	
ID=015	1729661.2	6028717.5	Flood Level	3.819	4.012	0.193	
ID=016	1730045.8	6028629.1	Flood Level	3.760	3.825	0.065	
ID=017	1730262.8	6028703.5	Flood Level	3.598	3.784	0.186	
ID=018	1730255.4	6028702.8	Flood Level	3.635	3.786	0.151	
ID=019	1730244.2	6028703.4	Flood Level	3.651	3.787	0.136	
ID=020	1730419.6	6028666.1	Flood Level	3.551	3.747	0.196	
ID=021	1730755.5	6028839.1	Flood Level	3.664	3.695	0.031	
ID=022	1730743.9	6028841.1	Flood Level	3.696	3.699	0.003	
ID=023	1731107.3	6028842.7	Flood Level	3.313	3.670	0.357	Area controlled by DS. DS levels generally high.
ID=024	1731097.0	6028804.2	Flood Level	3.290	3.639	0.349	Area controlled by DS. DS levels generally high.
ID=025	1731344.8	6028614.7	Flood Level	3.066	3.182	0.116	
ID=026	1731350.1	6028609.9	Flood Level	3.041	3.178	0.137	
ID=027	1731359.3	6028604.4	Flood Level	3.055	3.175	0.120	

Table 5-3 Measured and modelled debris level points (continuation)

Point	X (m)	Y (m)	Description	Flood Level (mOTP)	Model (mOTP)	dZ (m)	Comments
ID=028	1731251.4	6028670.3	Flood Level	3.040	3.540	0.500	DS levels generally high. Possible that mouth geometry is modified by high flows in large events. Main channel was slightly increased to reduce high velocities in that area. Current velocities in mouth are still over 1.5m/s that suggest channel cross sectional area could be increased.
ID=029	1731326.8	6028339.0	Flood Level	2.623	3.031	0.408	(same as previous)
ID=030	1731333.9	6028347.7	Flood Level	2.680	3.030	0.350	(same as previous)
ID=031	1731339.4	6028355.9	Flood Level	2.661	3.035	0.374	(same as previous)
ID=032	1731230.7	6028190.7	Flood Level	2.375	2.836	0.461	(same as previous)
ID=033	1727940.0	6026380.4	Debris Line	35.767	35.743	-0.024	
ID=034	1727944.2	6026378.9	Debris Line	35.778	35.743	-0.035	
ID=035	1727948.6	6026378.3	Debris Line	35.754	35.743	-0.011	
ID=036	1727952.6	6026378.8	Debris Line	35.800	35.743	-0.057	
ID=037	1727789.4	6026531.5	Flood Level	19.595	19.435	-0.160	
ID=038	1727791.1	6026536.2	Flood Level	19.466	19.373	-0.093	
ID=039	1727792.6	6026543.4	Flood Level	19.513	19.242	-0.271	Levels slightly low at the upper end of this channel. Possible because losses are higher of estimated. Current manning already high at around n=0.060 for the main channel.
ID=040	1727793.8	6026546.6	Flood Level	19.515	19.165	-0.350	(same as previous)
ID=041	1727798.3	6026573.0	Flood Level	19.185	19.078	-0.107	
ID=042	1727799.9	6026587.1	Flood Level	19.047	19.033	-0.014	
ID=043	1727810.3	6026632.4	Flood Level	19.020	18.890	-0.130	
ID=044	1727807.1	6026639.2	Flood Level	19.010	18.870	-0.140	
ID=045	1727812.9	6026620.8	Flood Level	19.024	18.918	-0.106	
ID=046	1727814.6	6026587.2	Flood Level	19.055	19.011	-0.044	
ID=047	1727811.0	6026566.8	Flood Level	19.229	19.068	-0.161	
ID=048	1727811.6	6026564.1	Flood Level	19.280	19.081	-0.199	
ID=049	1727807.4	6026529.2	Flood Level	19.675	19.439	-0.236	(same as ID=40)
ID=050	1727961.9	6027168.9	Flood Level	13.336	13.081	-0.255	
ID=051	1727963.6	6027167.7	Flood Level	13.229	13.100	-0.129	
ID=052	1727960.2	6027169.3	Flood Level	13.219	13.099	-0.120	
ID=053	1727863.4	6027355.1	Flood Level	12.076	12.213	0.137	
ID=054	1727865.4	6027350.3	Flood Level	12.165	12.237	0.072	
ID=055	1727857.1	6027350.8	Flood Level	12.072	12.257	0.185	
ID=056	1727857.5	6027366.0	Flood Level	12.139	12.213	0.074	
ID=057	1727860.5	6027427.6	Flood Level	12.170	12.227	0.057	
ID=058	1727867.5	6027430.1	Flood Level	12.175	12.198	0.023	
ID=059	1728123.3	6027563.5	Flood Level	10.734	10.838	0.104	
ID=060	1728101.8	6027567.4	Flood Level	10.740	10.958	0.218	
ID=061	1728089.2	6027577.6	Flood Level	10.860	10.999	0.139	

5 Calibration

Table 5-4 Measured and modelled debris level points (continuation)

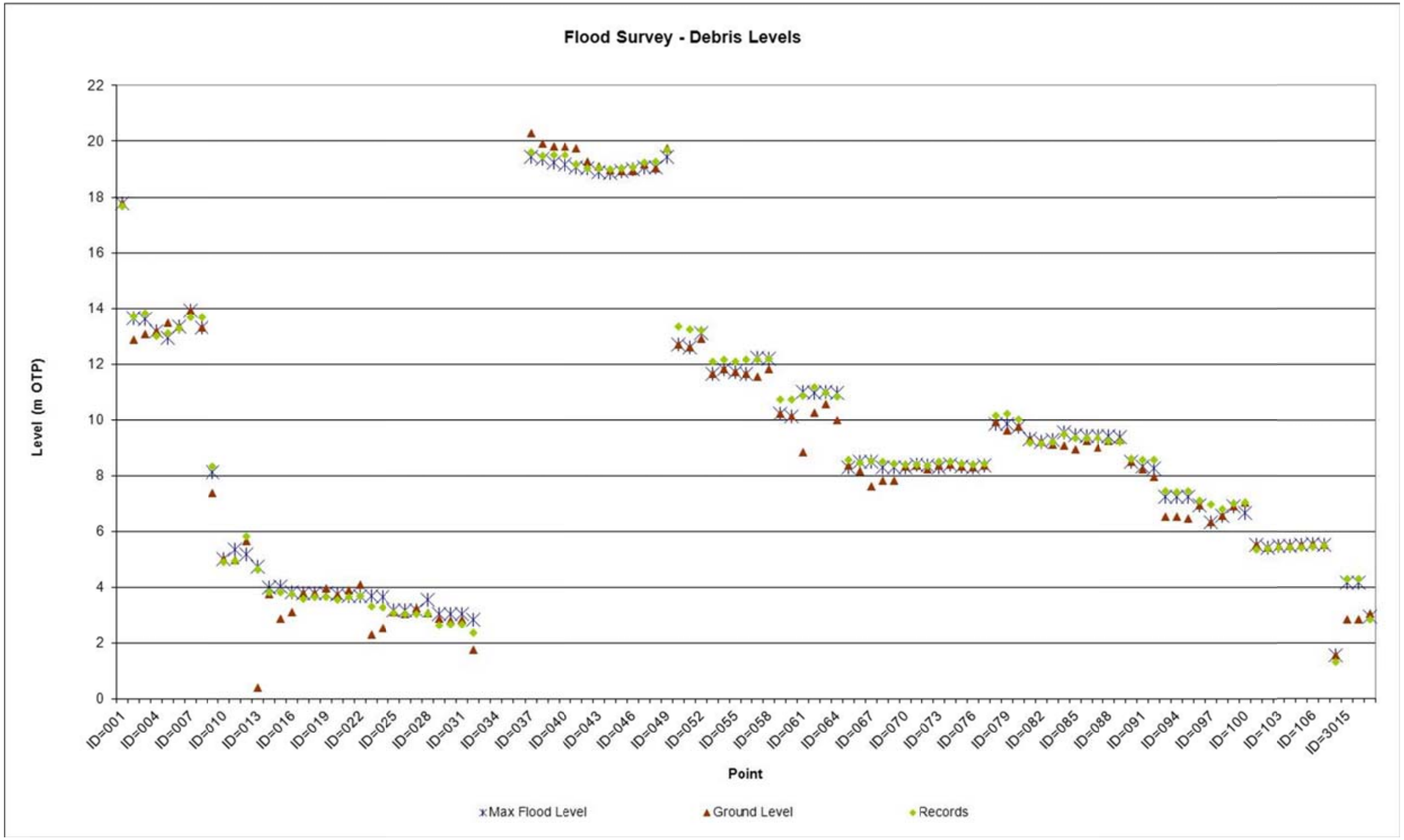
Point	X (m)	Y (m)	Description	Flood Level (mOTP)	Model (mOTP)	dZ (m)	Comments
ID=062	1728076.6	6027580.6	Flood Level	11.174	10.986	-0.188	
ID=063	1728076.9	6027588.8	Flood Level	10.964	10.993	0.029	
ID=064	1728083.9	6027586.2	Flood Level	10.832	10.981	0.149	
ID=065	1728489.4	6027918.3	Flood Level	8.560	8.301	-0.259	
ID=066	1728470.6	6027874.8	Flood Level	8.476	8.480	0.004	
ID=067	1728462.6	6027869.1	Flood Level	8.526	8.487	-0.039	
ID=068	1728497.2	6027871.0	Flood Level	8.488	8.303	-0.185	
ID=069	1728489.6	6027897.5	Flood Level	8.413	8.302	-0.111	
ID=070	1728481.0	6027905.2	Flood Level	8.406	8.302	-0.104	
ID=071	1728448.7	6027925.5	Flood Level	8.387	8.384	-0.003	
ID=072	1728452.0	6027923.7	Flood Level	8.355	8.374	0.019	
ID=073	1728539.2	6027879.4	Flood Level	8.486	8.303	-0.183	
ID=074	1728546.9	6027871.9	Flood Level	8.479	8.405	-0.074	Flood point just outside of flood extent
ID=075	1728553.7	6027865.8	Flood Level	8.422	8.312	-0.110	(same as previous)
ID=076	1728557.7	6027862.0	Flood Level	8.409	8.282	-0.127	(same as previous)
ID=077	1728562.4	6027857.9	Flood Level	8.413	8.374	-0.039	(same as previous)
ID=078	1728334.4	6027310.8	Flood Level	10.171	9.863	-0.308	Suspected losses need to be high, but manning of main channel n = 0.050.
ID=079	1728334.2	6027311.2	Flood Level	10.226	9.863	-0.363	(same as previous)
ID=080	1728337.8	6027313.3	Flood Level	10.030	9.753	-0.277	(same as previous)
ID=081	1728440.4	6027277.0	Flood Level	9.165	9.310	0.145	
ID=082	1728439.4	6027278.9	Flood Level	9.146	9.222	0.076	
ID=083	1728424.8	6027290.7	Flood Level	9.193	9.291	0.098	
ID=084	1728372.3	6027333.1	Flood Level	9.471	9.540	0.069	
ID=085	1728379.8	6027327.1	Flood Level	9.355	9.446	0.091	
ID=086	1728390.0	6027318.5	Flood Level	9.328	9.412	0.084	
ID=087	1728391.6	6027320.7	Flood Level	9.343	9.412	0.069	
ID=088	1728394.1	6027315.3	Flood Level	9.252	9.398	0.146	
ID=089	1728397.3	6027312.9	Flood Level	9.218	9.392	0.174	
ID=090	1728529.6	6027399.8	Flood Level	8.599	8.484	-0.115	
ID=091	1728563.1	6027369.6	Flood Level	8.577	8.327	-0.250	Only included main channels, rest on 2D areas.
ID=092	1728576.5	6027359.0	Flood Level	8.569	8.275	-0.294	(same as previous)
ID=093	1728883.8	6027528.9	Flood Level	7.460	7.250	-0.210	(same as previous)
ID=094	1728888.3	6027491.6	Flood Level	7.407	7.250	-0.157	(same as previous)
ID=095	1728892.3	6027513.3	Flood Level	7.432	7.250	-0.182	(same as previous)
ID=096	1728715.7	6027940.6	Flood Level	7.098	6.925	-0.173	
ID=097	1728788.2	6027838.2	Flood Level	6.970	6.481	-0.489	2D flood plain with channels. Detail out of model.
ID=098	1728846.8	6027631.3	Flood Level	6.798	6.568	-0.230	
ID=099	1728726.4	6027720.0	Flood Level	7.014	6.913	-0.101	

5 Calibration

Point	X (m)	Y (m)	Description	Flood Level (mOTP)	Model (mOTP)	dZ (m)	Comments
ID=100	1729108.2	6027348.2	Flood Level	7.026	6.677	-0.349	Level on small channel not included in model. Covered by flood plain of main stream in 1D model. Rough results expected.
ID=101	1729363.6	6027662.3	Flood Level	5.333	5.508	0.175	
ID=102	1729351.7	6027657.8	Flood Level	5.368	5.413	0.045	Flood point just outside of flood extent
ID=103	1729349.1	6027657.8	Flood Level	5.406	5.469	0.063	Flood point just outside of flood extent
ID=104	1729344.9	6027657.0	Flood Level	5.428	5.489	0.061	Flood point just outside of flood extent
ID=105	1729342.2	6027656.5	Flood Level	5.429	5.529	0.100	Flood point just outside of flood extent
ID=106	1729330.4	6027653.3	Flood Level	5.454	5.560	0.106	
ID=107	1729316.1	6027649.2	Flood Level	5.475	5.515	0.040	
ID=2000	1731055.9	6026070.2	Flood Level	1.310	1.542	0.232	
ID=3015	1729487.2	6028536.0	Flood Level	4.300	4.156	-0.144	
ID=3016	1729487.3	6028536.3	Flood Level	4.310	4.156	-0.154	
ID=4000	1731288.7	6028284.1	Flood Level	2.837	2.934	0.097	

5 Calibration

Figure 5-1 Measured and modelled debris level points



5.2 Wilson's Reservoir results

Figure 5-2 Measured and modelled levels at Wilson's Reservoir

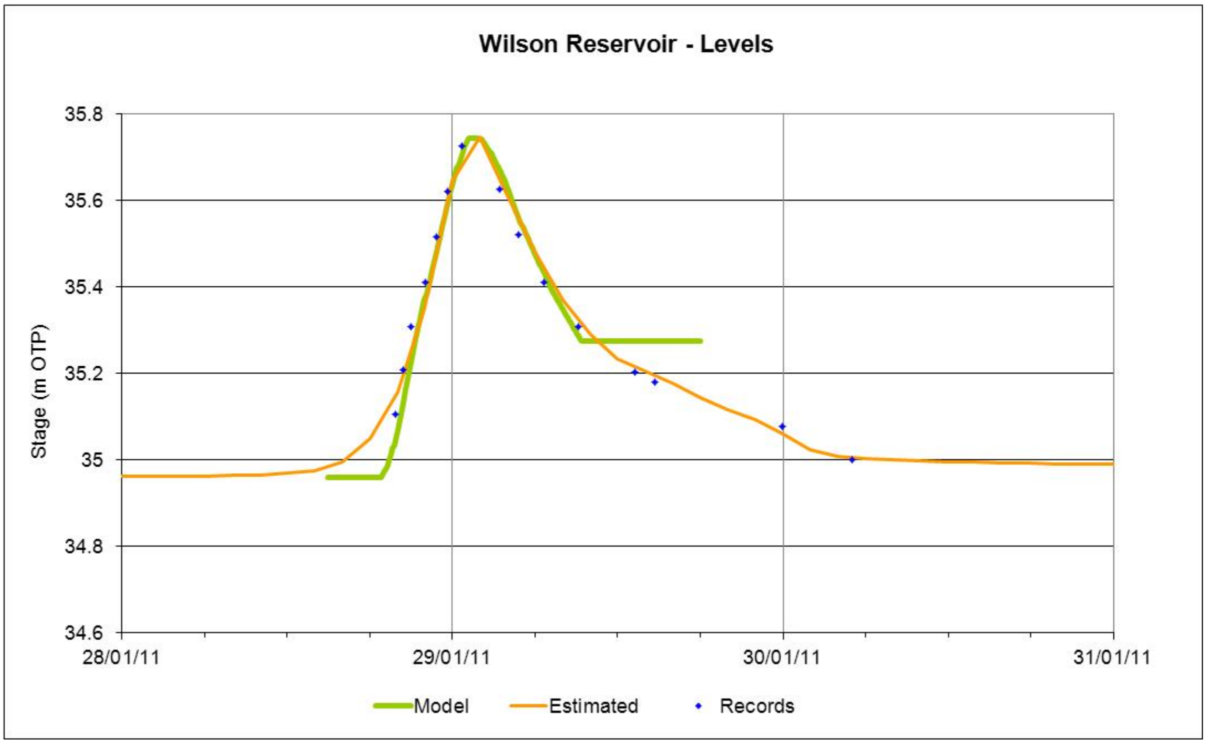


Figure 5-3 Estimated and modelled outflows from Wilson's Reservoir

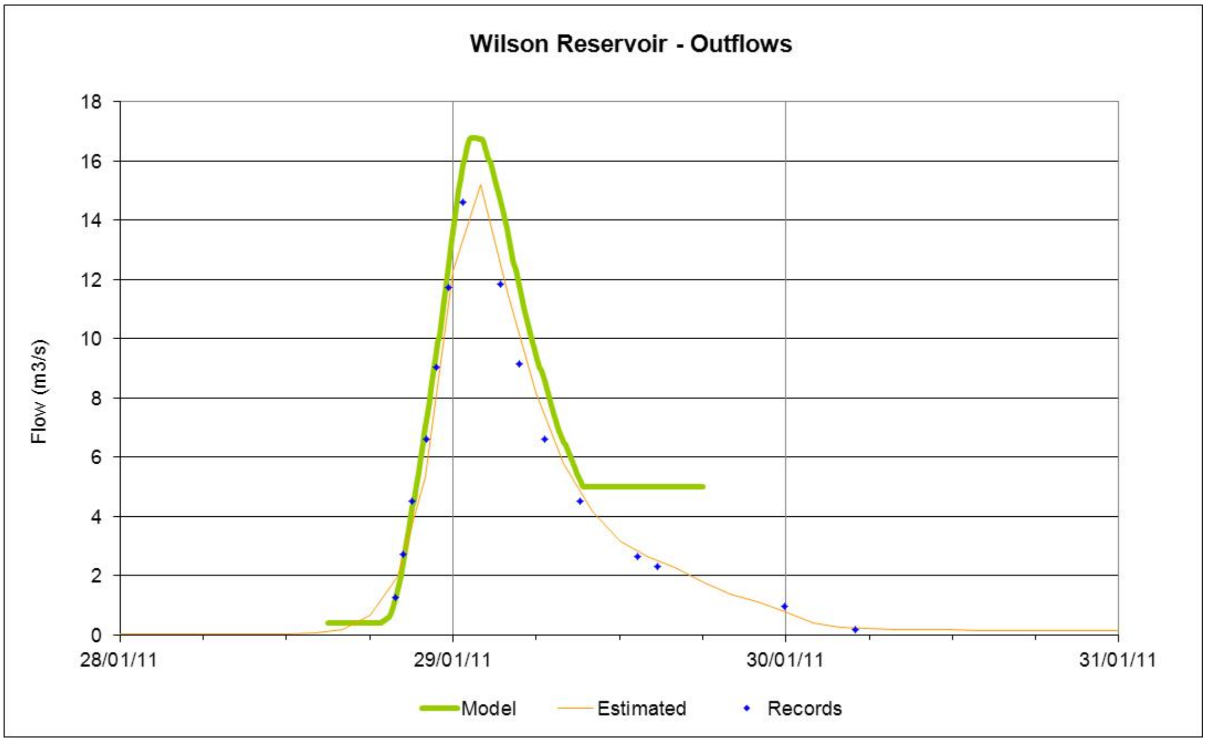
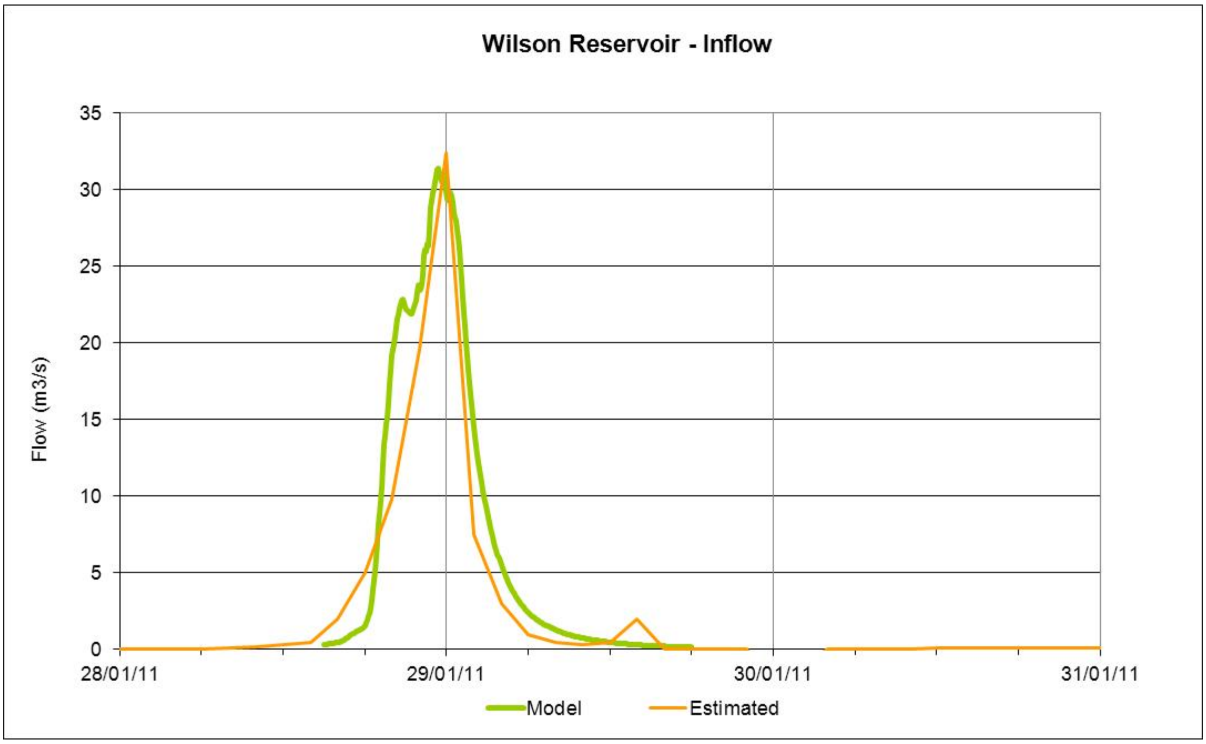
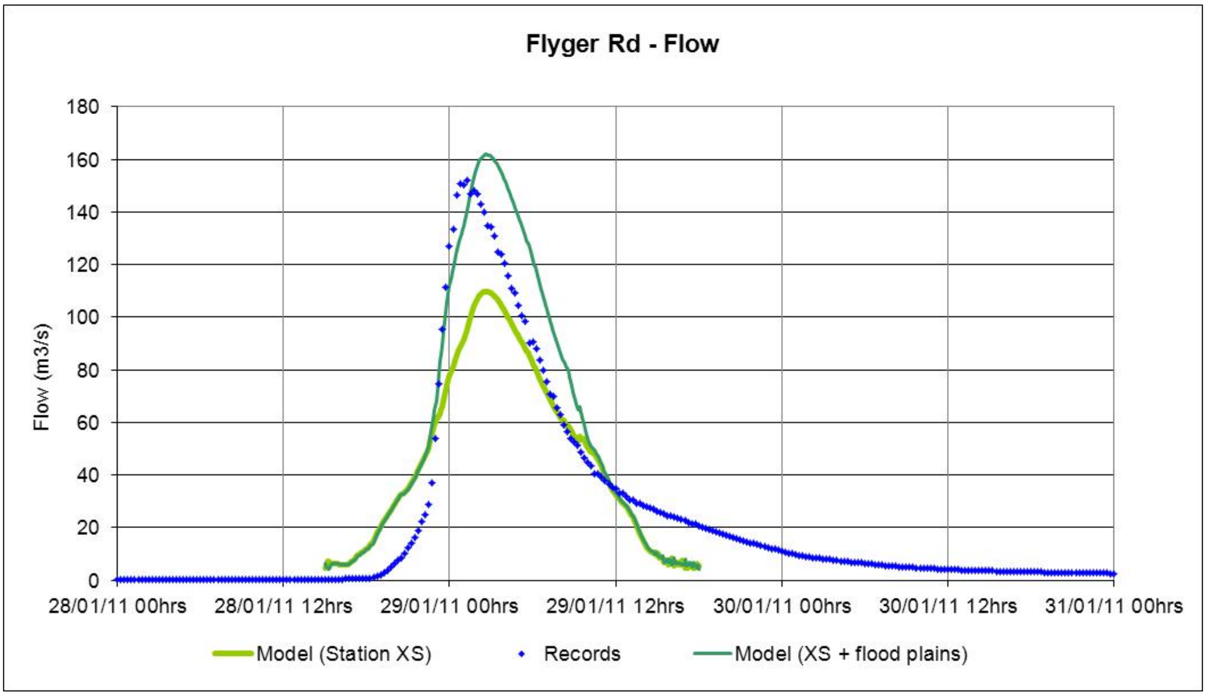


Figure 5-4 Estimated and modelled inflows into Wilson's Reservoir



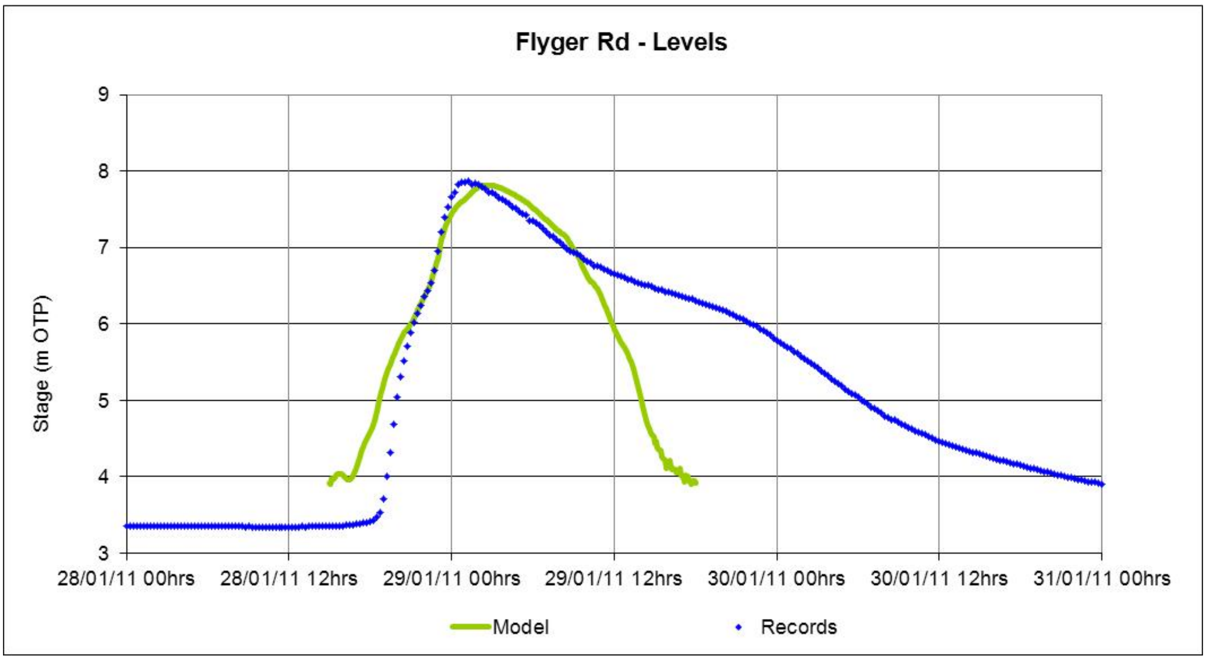
5.3 Ruakaka at Flyger Road

Figure 5-5 Recorded and modelled flows at Flyger Road station



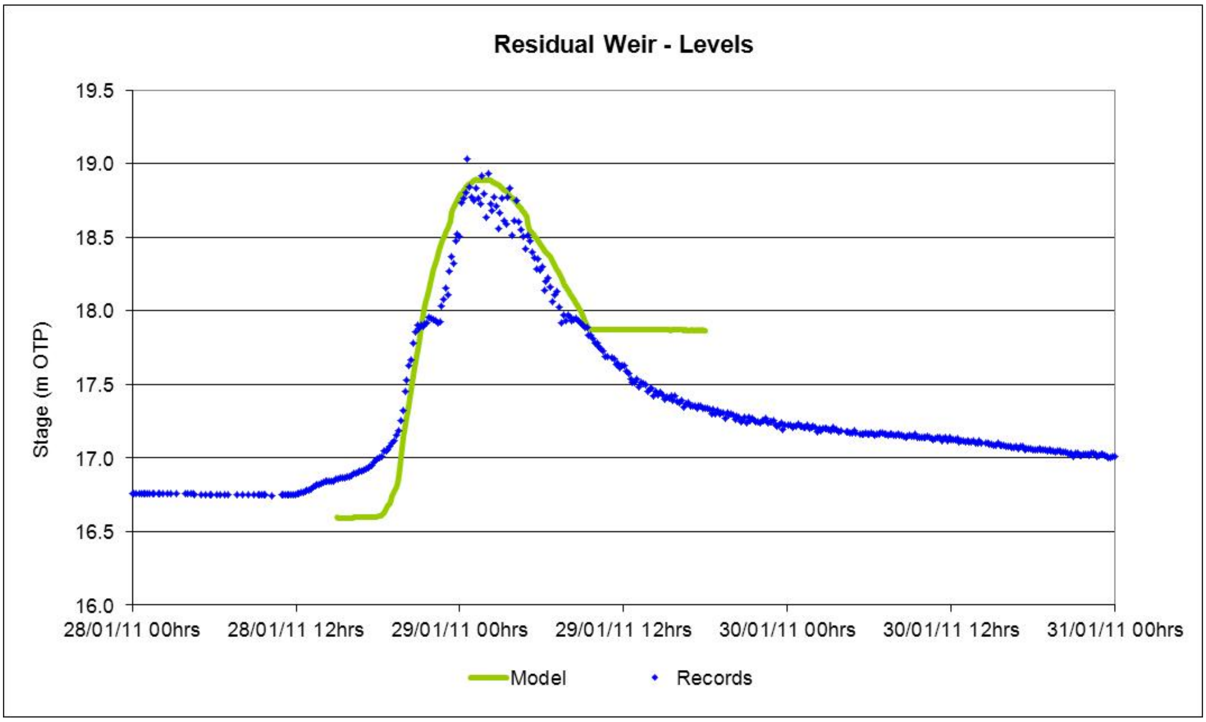
5 Calibration

Figure 5-6 Recorded and modelled levels at Flyger Road station



5.4 Residual Weir

Figure 5-7 Recorded and modelled levels at Residual Weir station



5.5 Marsden Point

Marsden Point records had been used as boundary condition input. No calibration was required at this location.

5.6 Maximum Values

Table 5-5 Summary of global values

	Site Name	Ruakaka at Flyger Road	Wilsons Reservoir Level	Wilsons Dam Residual Flow Weir	Marsden Point (Tidal)	Tauroa Stream Pump Intake
	Site ID	5901	Dam021_LT01	Dam021_LT02	5801	WPS052_LT1
	Type of record for Jan 2011	Auto	Auto	Auto	Auto	*No record for Jan 2011*
RECORDS	Max Elevation Records (mOTP)	7.869	35.670	19.020	1.031	8.400
RECORDS	Recorded time of peak	29/01/2011 @ 01:15	29/01/2011 @ 00:42	29/01/2011 @ ~ 00:42	29/01/2011 @ 02:43	not known (n/k)
RECORDS	Max Gauging at site Flow (m3/s)	64.100				*52.000*
RECORDS	Estimated Peak Flow (from records, m3/s)	152.194	~ 16	~ 16		*No rating curve available*
RECORDS	Estimated runoff coefficient	0.62	0.60			
MODEL	Calibration max flow	148.72	18.13	18.36		51.99
MODEL	Calibration max level	7.74	35.79	18.931	1.017	8.47
MODEL	Model Level Peak Time	29/01/2011 @ 3:15	29/01/2011 @ 1:40	29/01/2011 @ 1:15	29/01/2011 @ 2:43	29/01/2011 @ 0:35
MODEL	Modelled runoff coefficient	0.61	0.72			

Discussion and Conclusion

6.1 Discussion Overview

Critical improvements in the model performance, both the definition of hydraulic and hydrological features, allowed the achievement of high quality calibration results.

In general the volumes, peaks and flood levels are very close to records as it is shown in Section 5. An exception is the runoff coefficient of the Wilson's reservoir catchment. In Section 4.1.4 records suggests a 60% of the total rain volume as runoff, however Table 5-5 shows a final coefficient of 72% for that area.

Initial attempts to set the volumes to a 60% in Wilson's reservoir were grossly underestimating the water levels in the reservoir. Further tests showed us that greater volumes were reproducing better the reservoir water levels (Figure 5-2) that is the actual record available for this station. Inflows and outflows are shown to be overestimated compared with their respective estimations (Figure 5-3 and Figure 5-4). However, the guide curves for these variables are only rough estimations done from a very discrete set of level points, and differences are allowed. The 72% runoff coefficient from the reservoir not only reproduced better the level records in that location, but also the debris level surveyed for the area downstream of the dam.

It is important to understand that many important modifications were made to the modelling objects in order to achieve these results. But it should be noted that there are two critically sensitive variables that need to be well understood for calibration. These are base flow and infiltration rate.

6.1.1 Base Flow and Infiltration Rate

Base flow and infiltration rate have an intrinsic relationship with the soil moisture. This can be understood by categorising the relationships into the three antecedent moisture conditions. The antecedent moisture condition III of high soil moisture, or saturated soils, results in lower surface infiltration rate and typically has greater base flows. Conversely, if the soil moisture is low, but still wet, then surface infiltration rates will typically be higher and have lowered base flow. The third condition is relevant to drought conditions and was not considered for this report.

The calibration event presented satisfactory outputs, but they rely on the well understood and therefore specifically selected parameters based on the available data from January 2011 event.

If other scenarios are required to be simulated, then a comprehensive analysis is necessary in order to estimate these parameters properly.

The event of January 2011 occurs in special conditions; it was summer season and a week after a significant storm event. Under this specific circumstance an infiltration rate of 5mm/hr and a null base flow was appropriate. Under similar circumstances, with the exception of the preceding storm event a higher infiltration rate may be expected in summer. It is also reasonable to assume that a lower infiltration rate would be more appropriate for a typical winter.

6.1.2 Non-Linear Reservoir

The selection of an appropriate hydrological model applied to the Ruakaka catchment was critical. The non-linear reservoir model was best suited for modelling of the catchment. The initial losses in this model were not well defined because the purpose of these models is to calibrate or run large storm events (over 10yrs). The initial losses are relatively unimportant as they represent a small portion of the rainfall and are typically inconsequential shortly after the beginning of the storm event of a significant duration.

We encourage further analysis in terms of the moisture condition, infiltration and base flow values. These can be used to create relationships and the catchment volume balance from the historical records of level/flow gauges to estimate effective rain and base flow under varying conditions.

6.2 Design Storm Profile details

The twelve hour design storm duration was used for the 10, 50, 100 and 150yrs (or 100yrs with climate change) AEP events which were simulated with the calibrated model of Ruakaka Catchment. The rain depths, rain profile, spatial distribution and rain duration were taken directly from the modelling completed during the Priority River Flood Risk Reduction project. The rain duration of 12 hours was previously selected for the Ruakaka catchment following a catchment analysis of its time of concentration. For more details regarding this aspect refer to the “NRC Priority Rivers Modelling Report”, section “Hydrology”.

The table below summarized the design event rain depths before any areal reduction factor:

Table 6-1 Design storm rain depth

Design Storm	12hrs Rain depth (mm)
ARI 002	84.1
ARI 010	126.1
ARI 050	181.6
ARI 100	211.8
ARI 100F	247.4

The final flood maps for all design events are included in the Appendix A.

6.3 Areal Reduction Factor

As advised by NRC, a new areal reduction factor was to be applied in the new version of Ruakaka catchment model. The new coefficient was to be applied based in Shamseldin 2008 study. However, it was determined that more accurate flooding was being presented without the use of the ARF and therefore the ARF was disregarded for this project. This was discussed and agreed with NRC.

6.4 Rainfall Spatial Distribution Factor approach

In the previous NRC Priority Rivers Project all of the rainfall’s spatial distribution was implemented through a factor applied directly over the hydrograph, instead the hyetograph. This was possible because the previous method used the US SCS method as its hydrological model. The US SCS method determines a flow hydrograph based on a unit hydrograph approach which calculates runoff though a linear operation.

This was a convenient method as one rain depth was required as an input in the model for each sub-catchment (boundary node). The sub-catchment would hold a coefficient factor that was applied over the hydrograph to adjust the rain depth spatially.

As the Non-Linear Reservoir method is indeed non-linear (unless *p=1*), such a procedure cannot be executed easily, and therefore such factors need to be applied directly to the rain profile. In theory each sub-catchment has a different value for this coefficient that means rain series are needed in the same number of sub-catchments (256 sub-catchments).

To reduce the number of rain series to input, the spatial distribution factor was organized in twelve classes that range from 0.950 to 1.000. In this way only twelve rain series are required, each of them with the design storm event weighted by its respective coefficient.

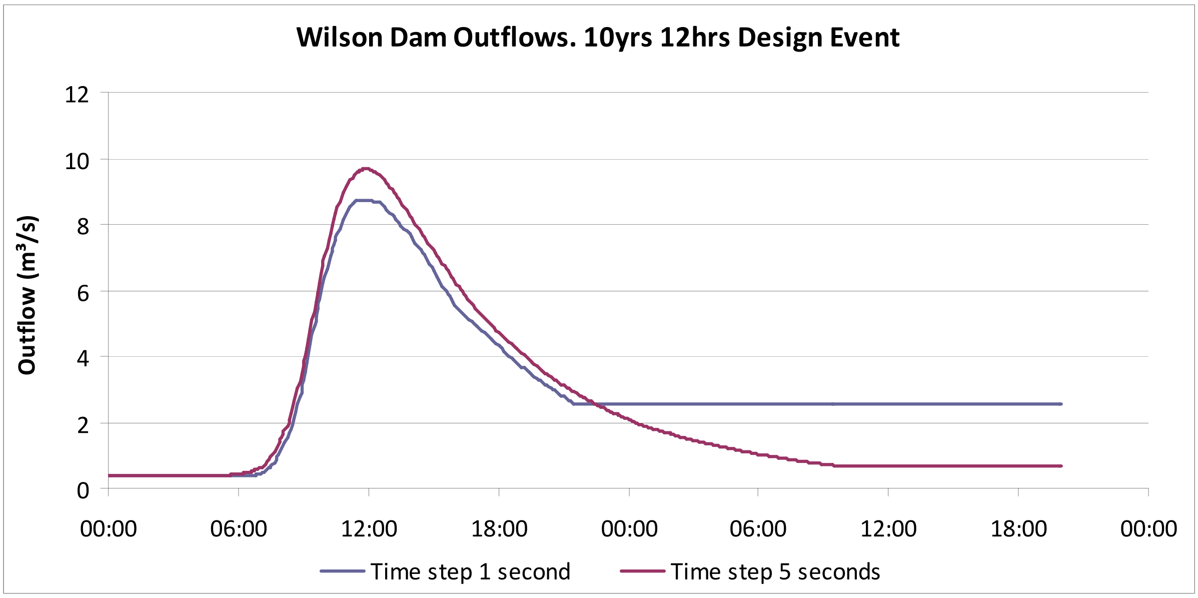
6.5 Outflows from Wilson Dam

The time step for the Ruakaka design events models is between 0.5 to 1 second. This ensured a good solution for all hydrologic and hydraulic objects, with the exception of Wilson Dam.

Wilson's Reservoir has an area of around 39 ha, variation in the reservoir level in a time step of 0.5 second is small. They are so small that IWRS simulation calculations regard them as negligible, and therefore the solution is not accurate. The problem is more evident for small storms. To resolve this problem the Wilson Dam was simulated separately using a time step of 5 second, and the results were used as an input for the design events.

The Figure 6.1 shows the outflow from Wilson's Dam for the 10yrs event using 1 and 5 second time steps.

Figure 6-1 Example of different results as results of simulation time steps



6.6 Infiltration and base flow

The calibration storm of January 2011 has a total duration of approximately 19 hours with an estimated total rainfall depth, over the Ruakaka catchment, of 232mm. 200mm of the rainfall occurs within 12 hours. This put the event of January 2011 between a 50yrs and 100yrs ARI event.

The calibrated infiltration rate of 5 mm/hr would correspond to an approximated CN of 71.7. The previous calibration equivalent CN value used, with the US SCS method, for Ruakaka on the calibration event of March 2007, was 73.9.

On the other hand, the 12 hour design event would produce an approximate average infiltration rate at the peak time over 10mm/hr. (CN=71.7). This is higher than the previously calibrated estimated rate (73.9). This leads to an interesting aspect of the US SCS method. Rain abstraction using the US SCS method experiences an incremental increase when intensity increases. This infiltration response of the SCS method may not have a strong physical basis (Ven Te Chow, Applied Hydrology).

It is clear that the effective rain will depend on a few variables related to the rain such as storm duration, initial moisture condition (previous rains) and even rainfall intensity.

Another interesting aspect is that the calibration event presented an infiltration rate closer to 5mm/hr. even when the storm happened during the summer season. That may suggest that for the same storm happening in winter the infiltration rate would be lower. It is noted that a 2 year storm event occurred a week before the calibration storm, as previously stated, and this may have contributed to the specific moisture conditions of the later event.

Other catchments in Northland region have presented different infiltration rates depending on the antecedent rainfall depths that defined the moisture conditions. Those values range from 1mm/hr to 6mm/hr.

6.7 Conclusion

In conclusion, 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 5 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 5-6mm/hr. A 2 mm/hr is very conservative as it is equivalent to a CN over 85 for all design events.

The records of flows and rain in Northland catchments suggest that the base flow in all catchments is not of big importance, and it has been considered negligible on the design events.

The final flood maps for 10, 50, 100 and 150yrs (or 100yrs with climate change) AEP are included in the Appendix A.

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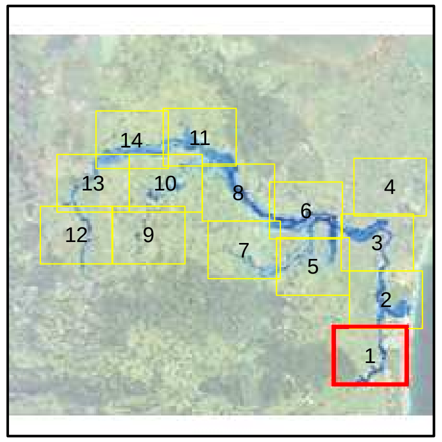
Appendix A Flood Maps



10 year ARI

Duration 12h

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 1:8,000

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FLOOD MAPS

RUAKAKA RIVER 10 YEAR ARI

Final

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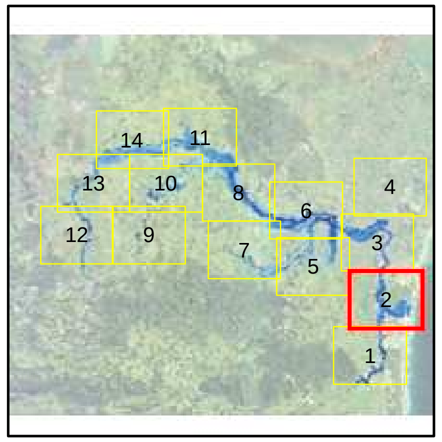

10 year ARI

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Scale 1:8,000

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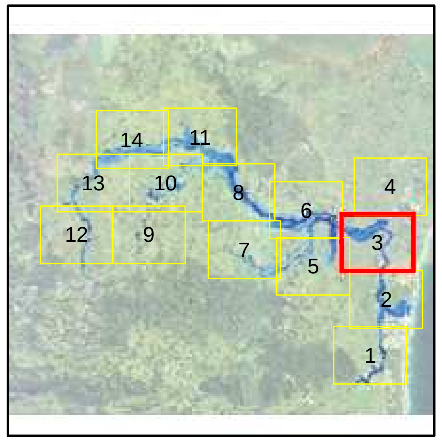

10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
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RUAKAKA RIVER 10 YEAR ARI

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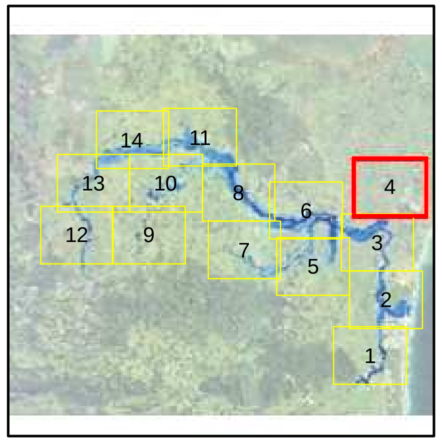

10 year ARI

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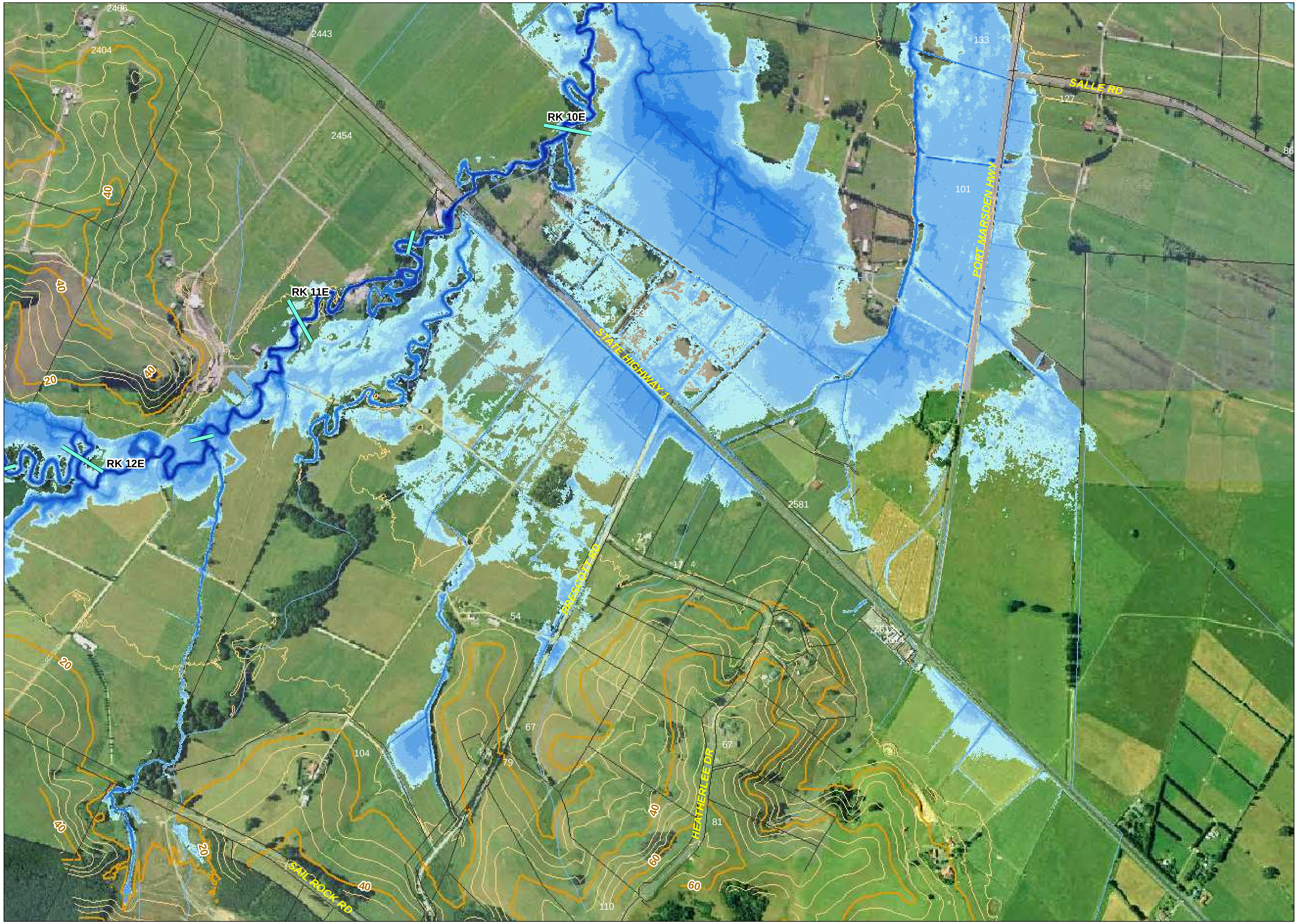

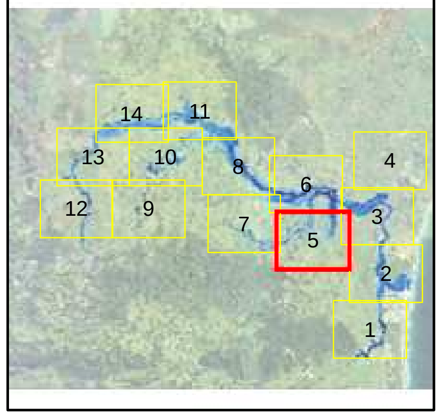

10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
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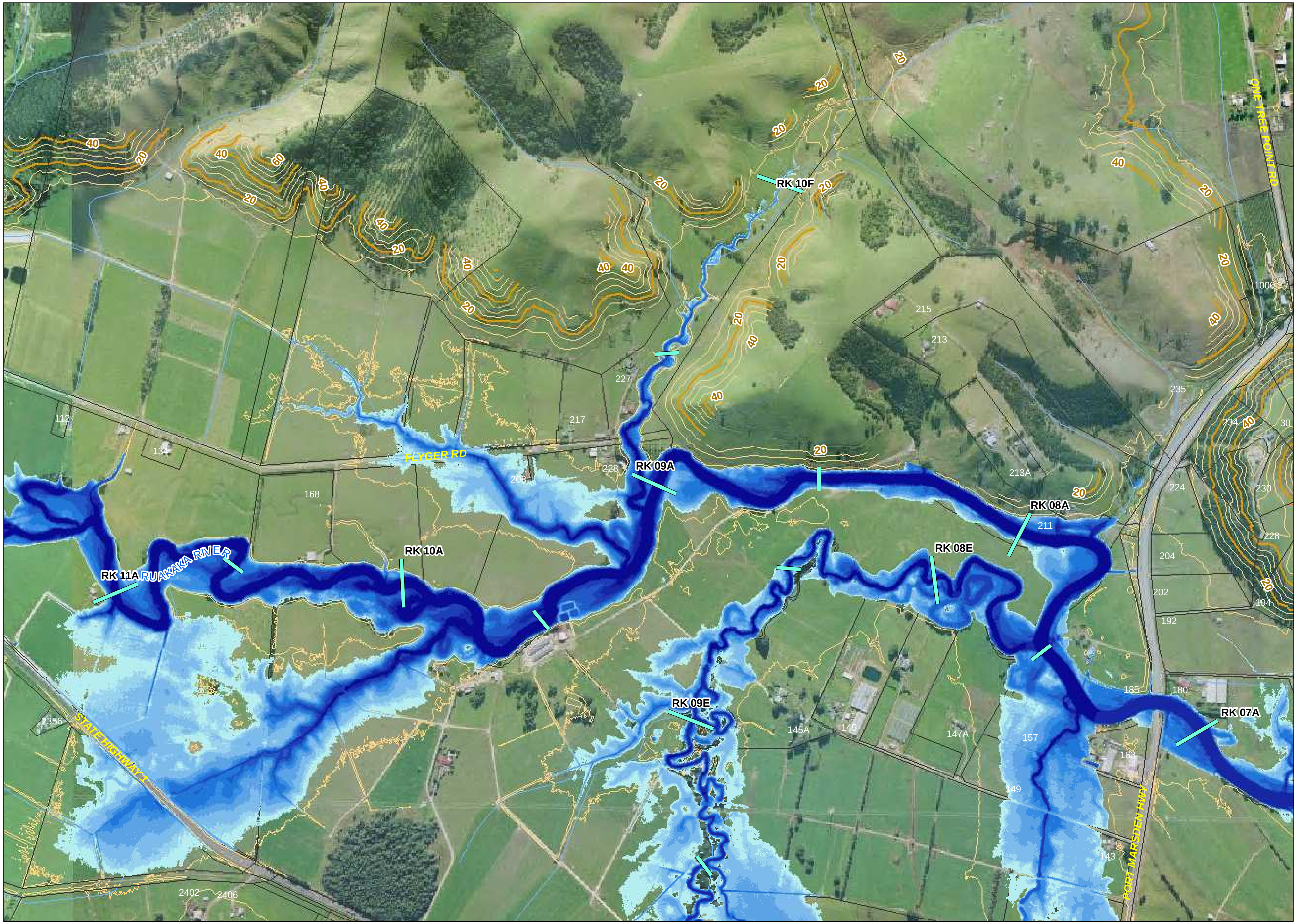

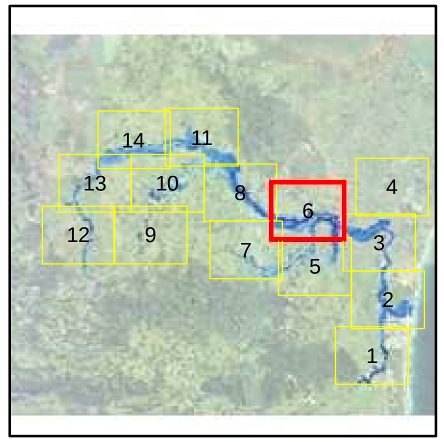

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10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
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- 2.51 - 3.00
- > 3.00

Scale 1:8,000

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RUAKAKA RIVER 10 YEAR ARI

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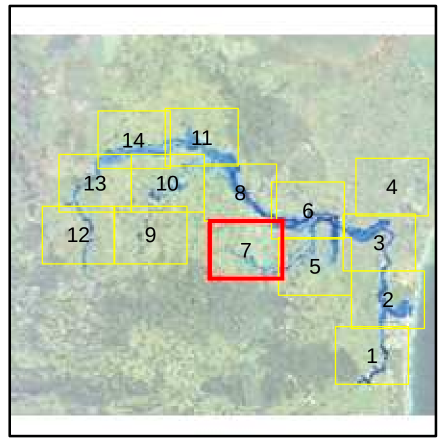

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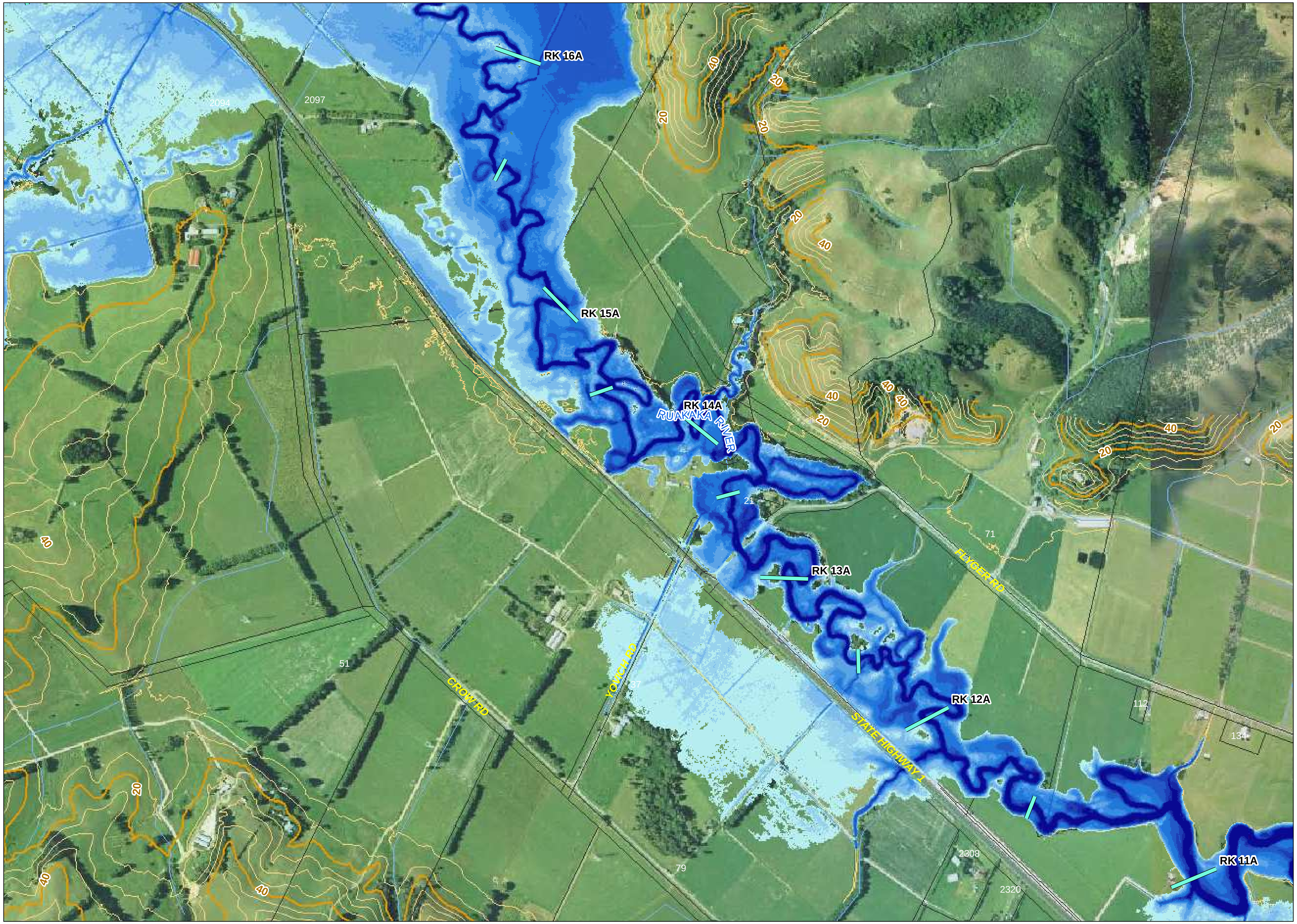

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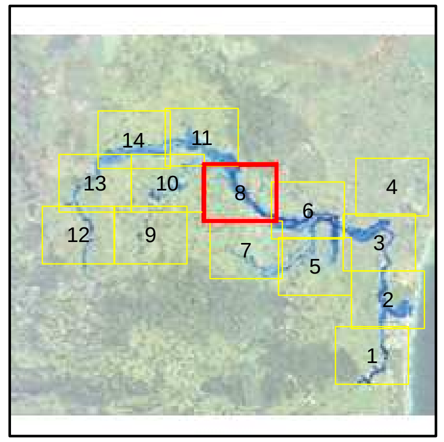

10 year ARI

Duration 12h

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 1:8,000

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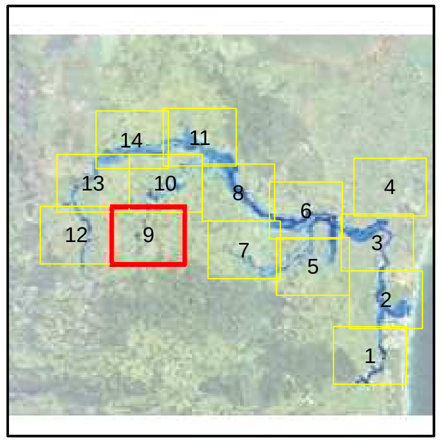

10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
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Scale 1:8,000

Manaaki Awa
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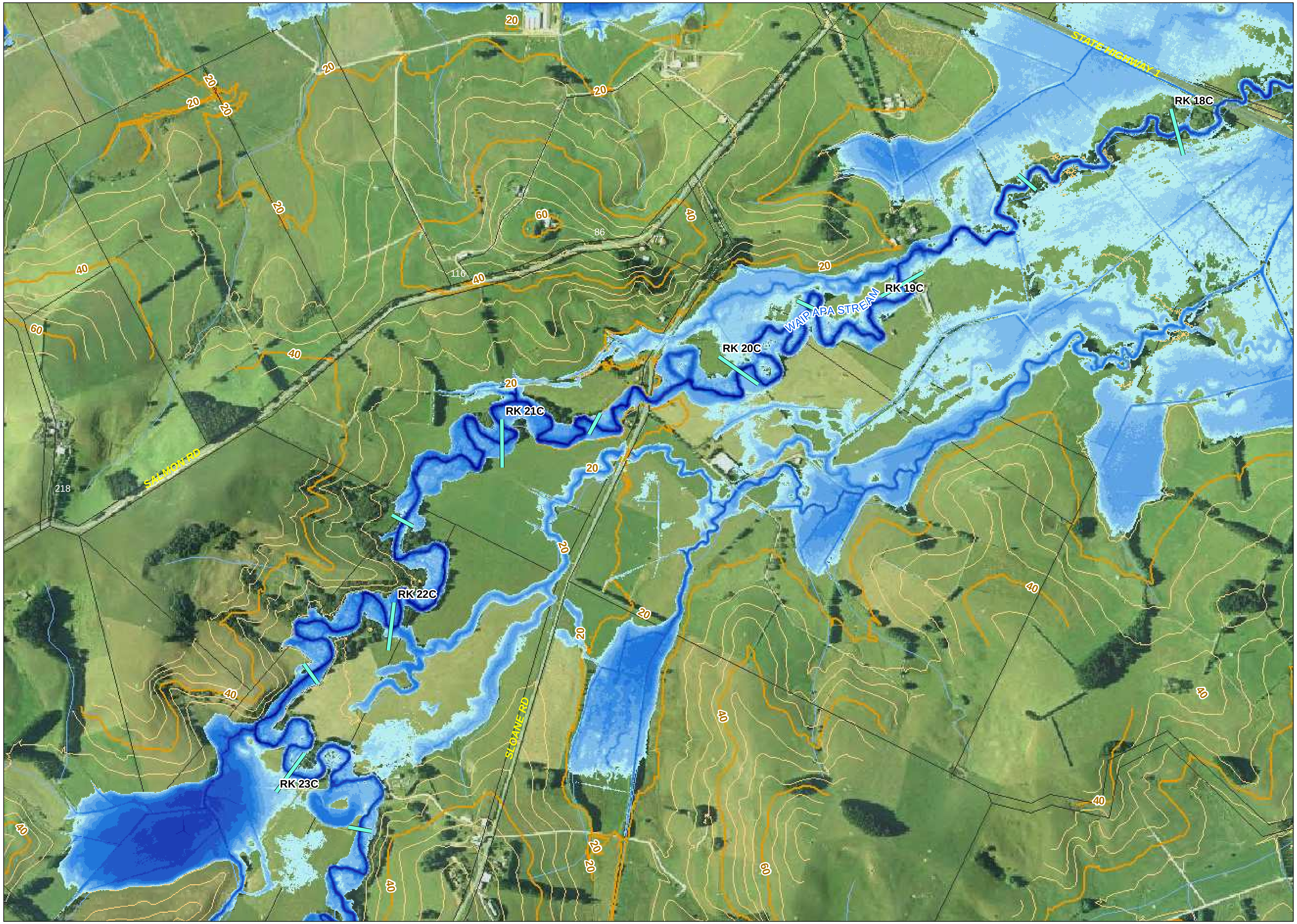
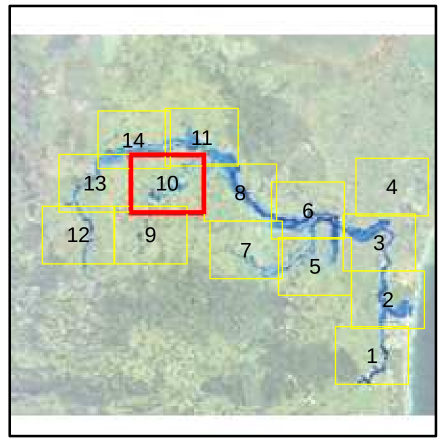
FLOOD MAPS

RUAKAKA RIVER 10 YEAR ARI

Final





10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

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Scale 1:8,000

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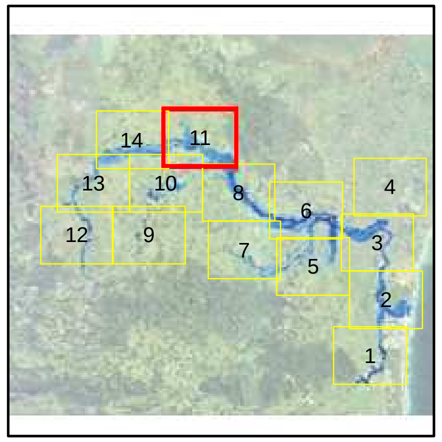

10 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

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Scale 1:8,000

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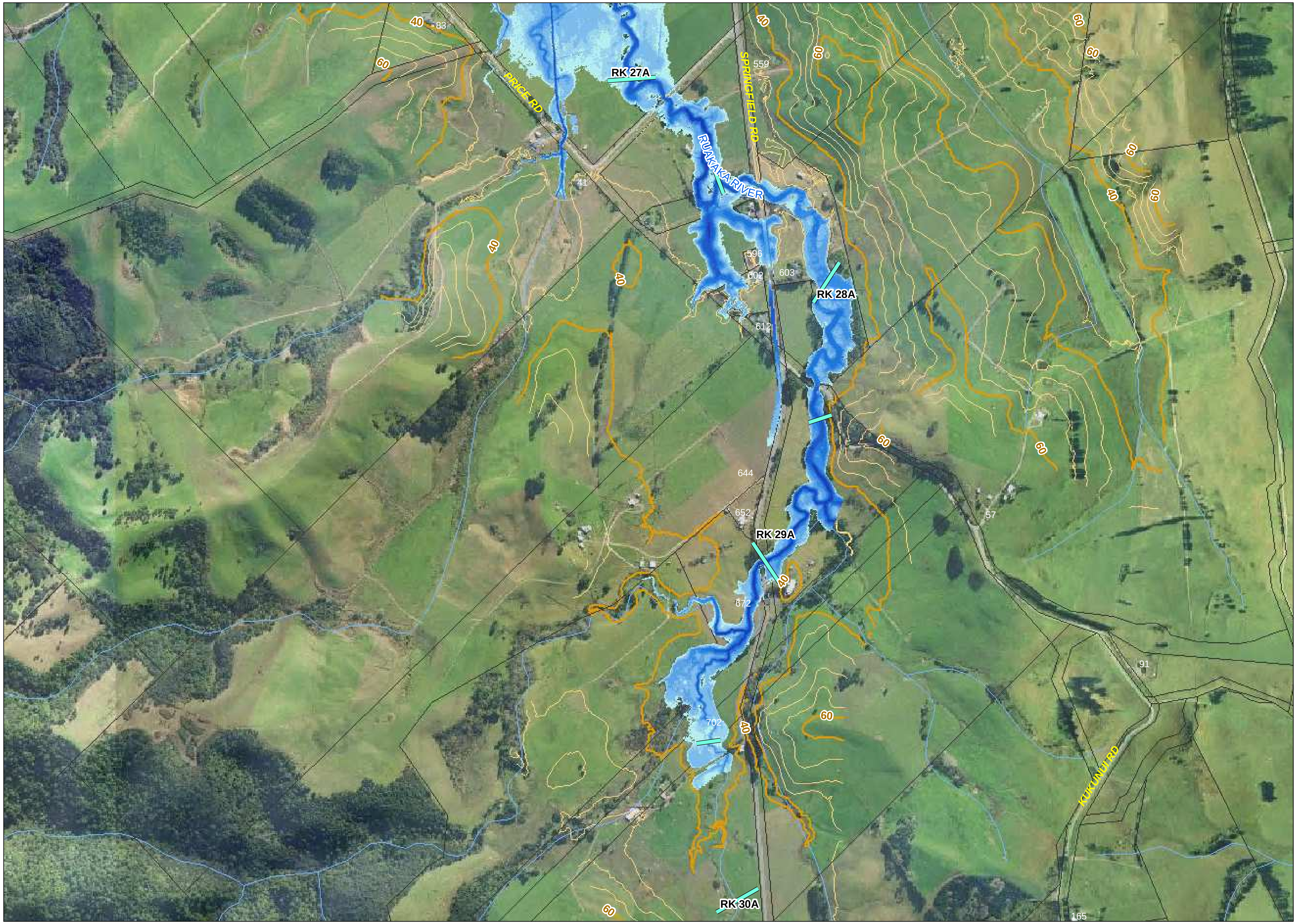

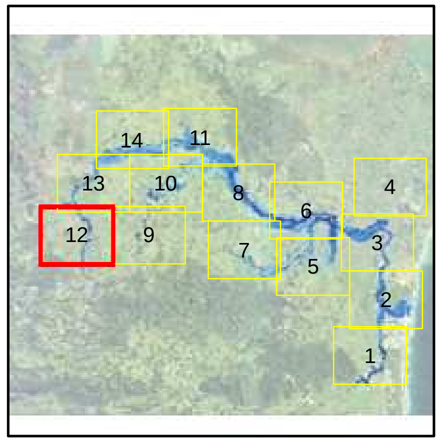

10 year ARI

Duration 12h

River Kilometre, Rk

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Scale 1:8,000

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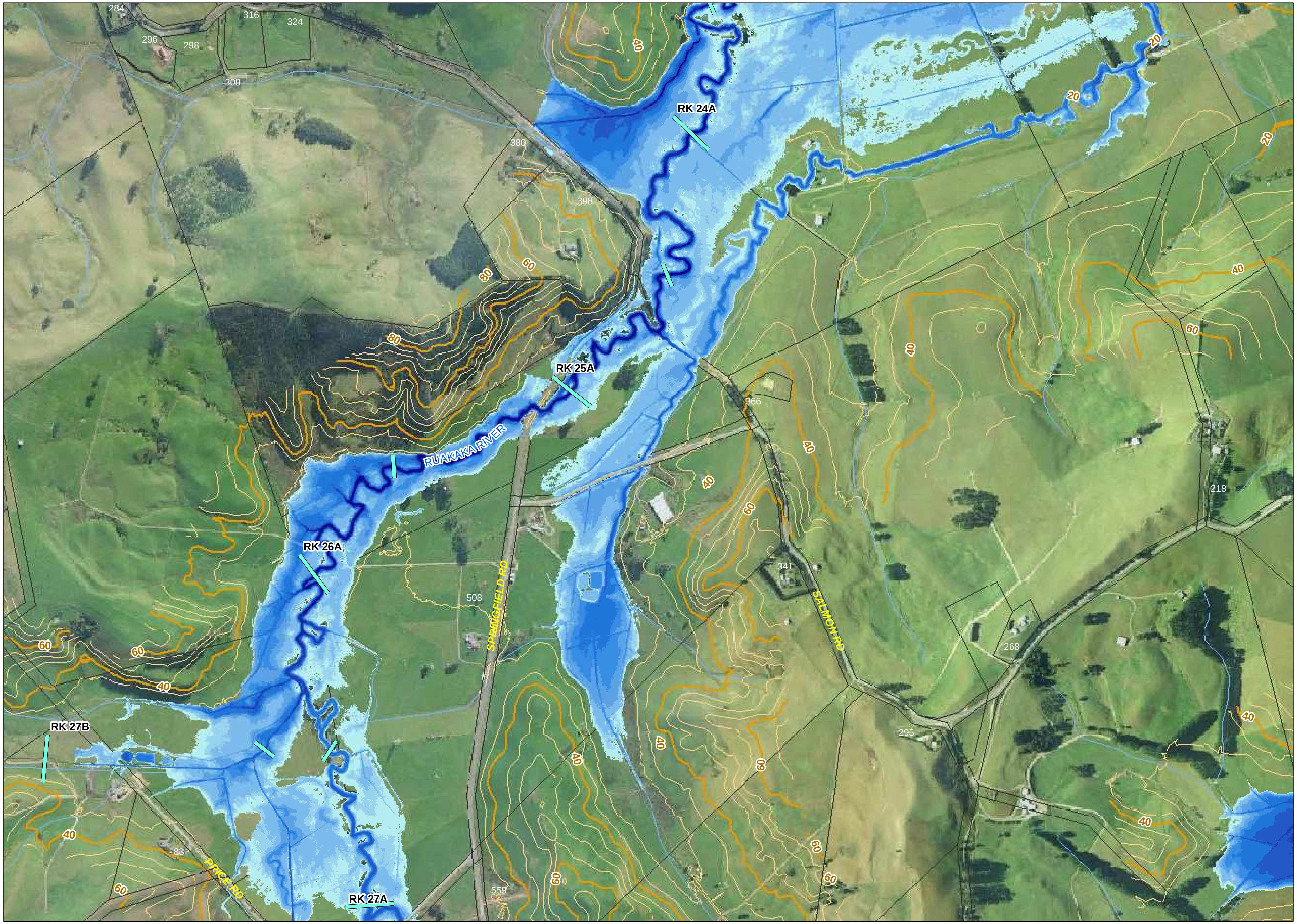

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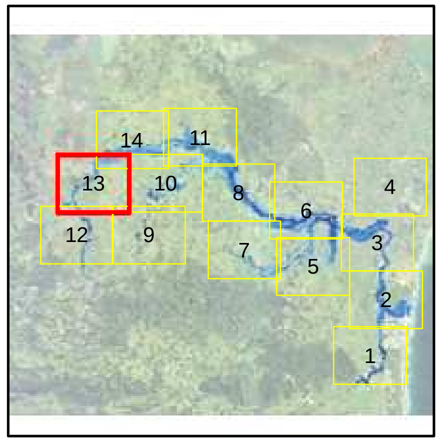

10 year ARI

Duration 12h

River Kilometre, Rk

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Scale 1:8,000

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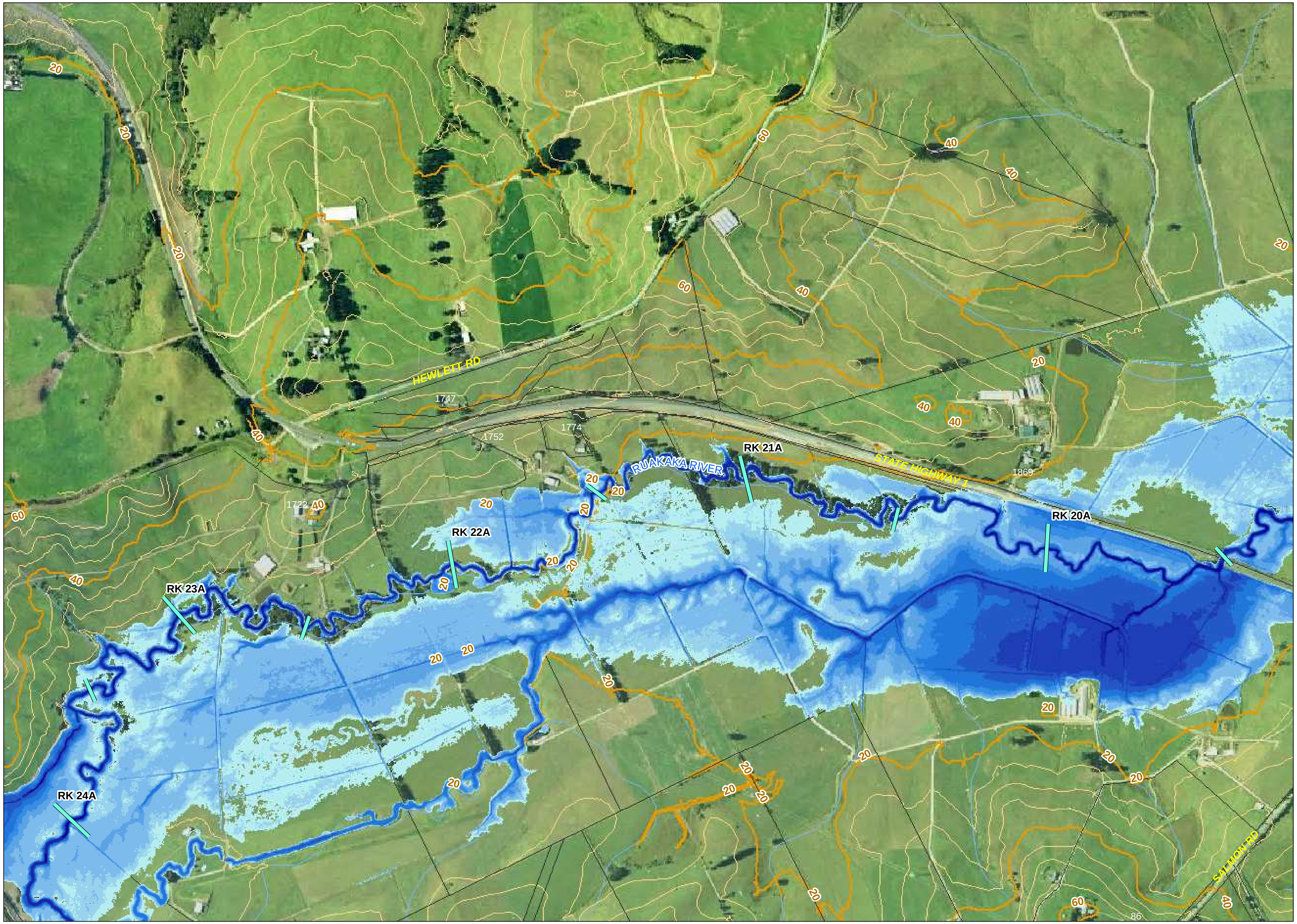

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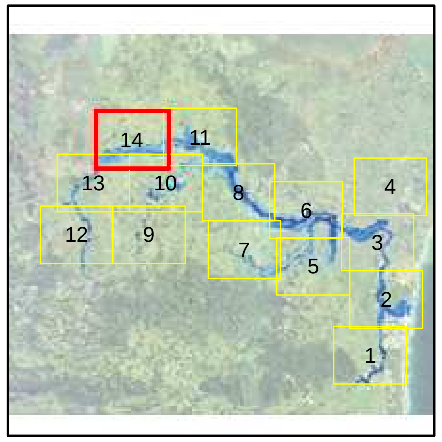

10 year ARI

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River Kilometre, Rk

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Scale 1:8,000

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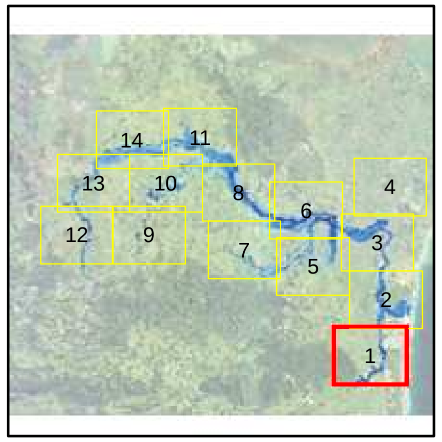

N

50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
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- > 3.00

Scale 1:8,000

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RUAKAKA RIVER 50 YEAR ARI

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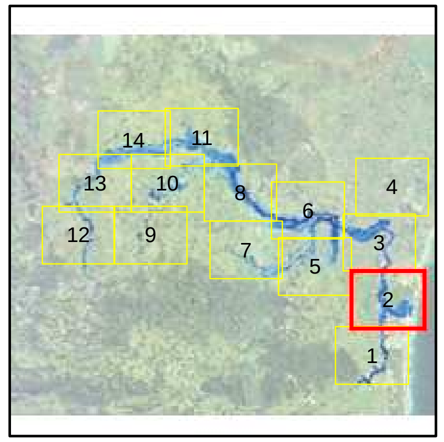

50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Final

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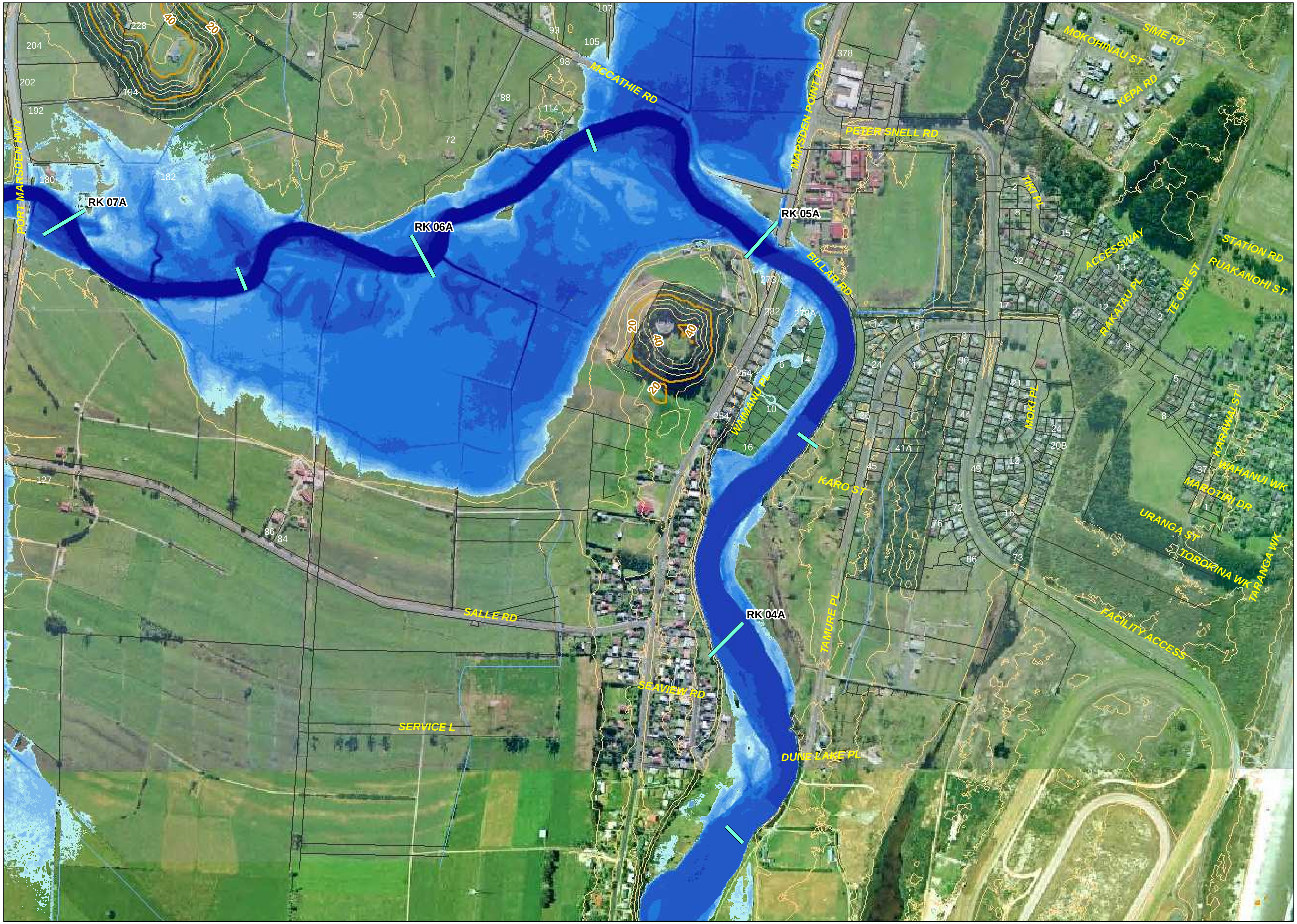

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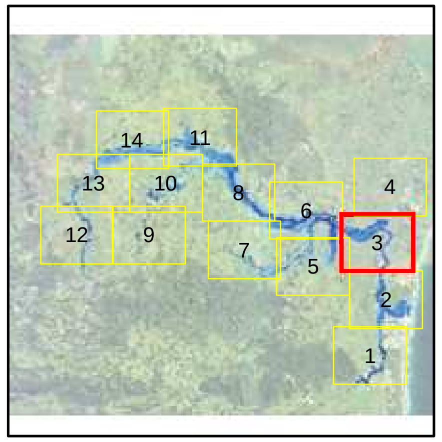

50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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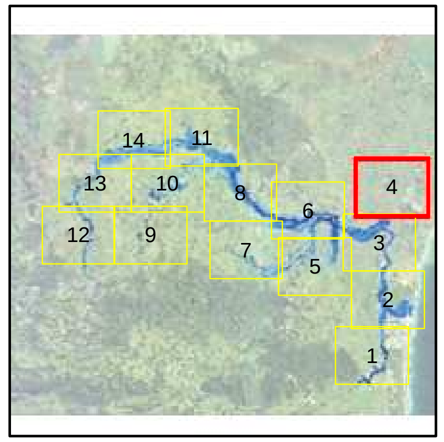

50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Final

RUAKAKA RIVER 50 YEAR ARI

URS

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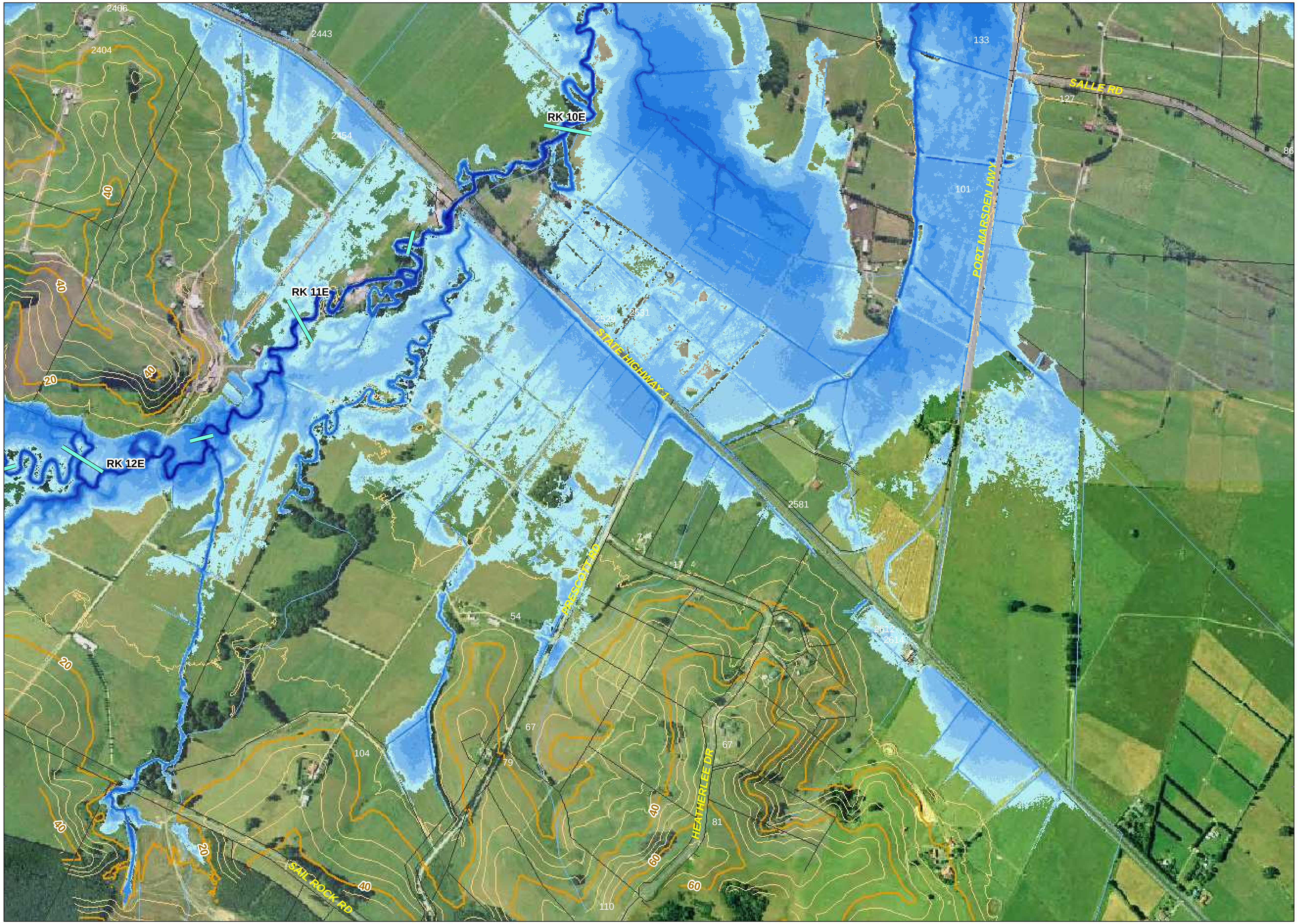

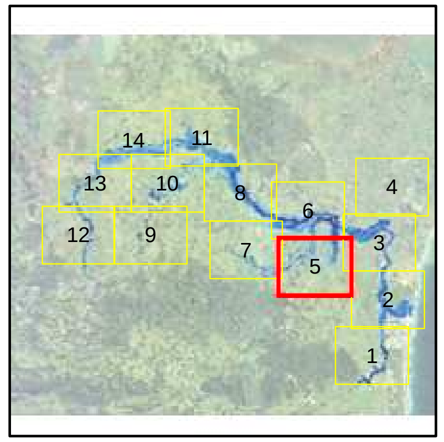

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50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
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- > 3.00

Scale 1:8,000

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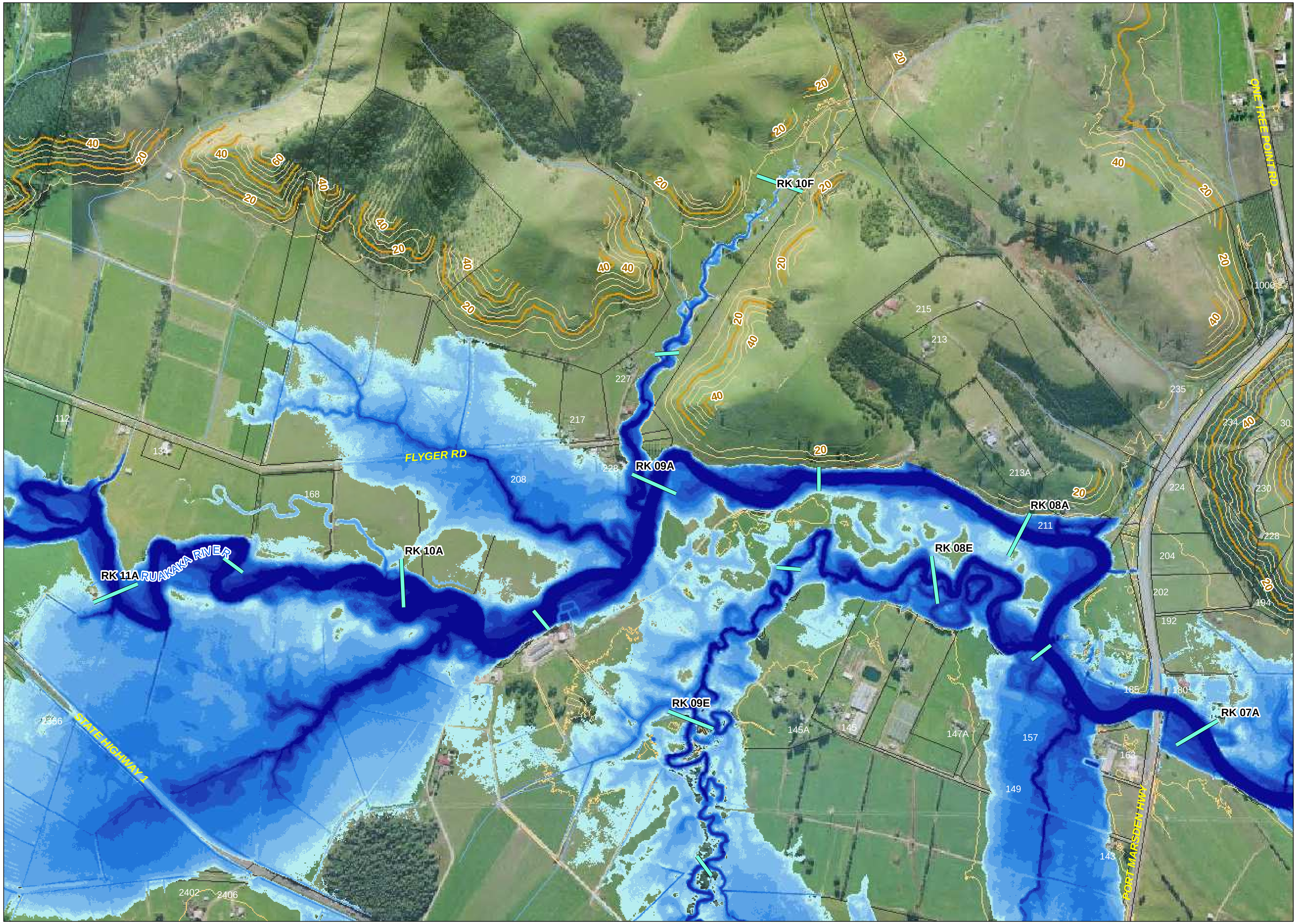

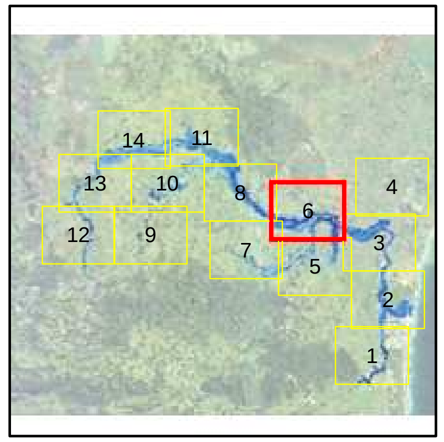

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50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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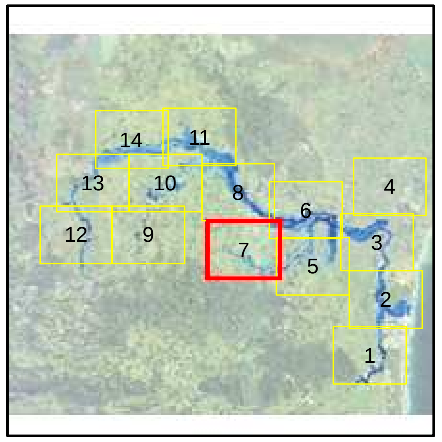

50 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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RUAKAKA RIVER 50 YEAR ARI

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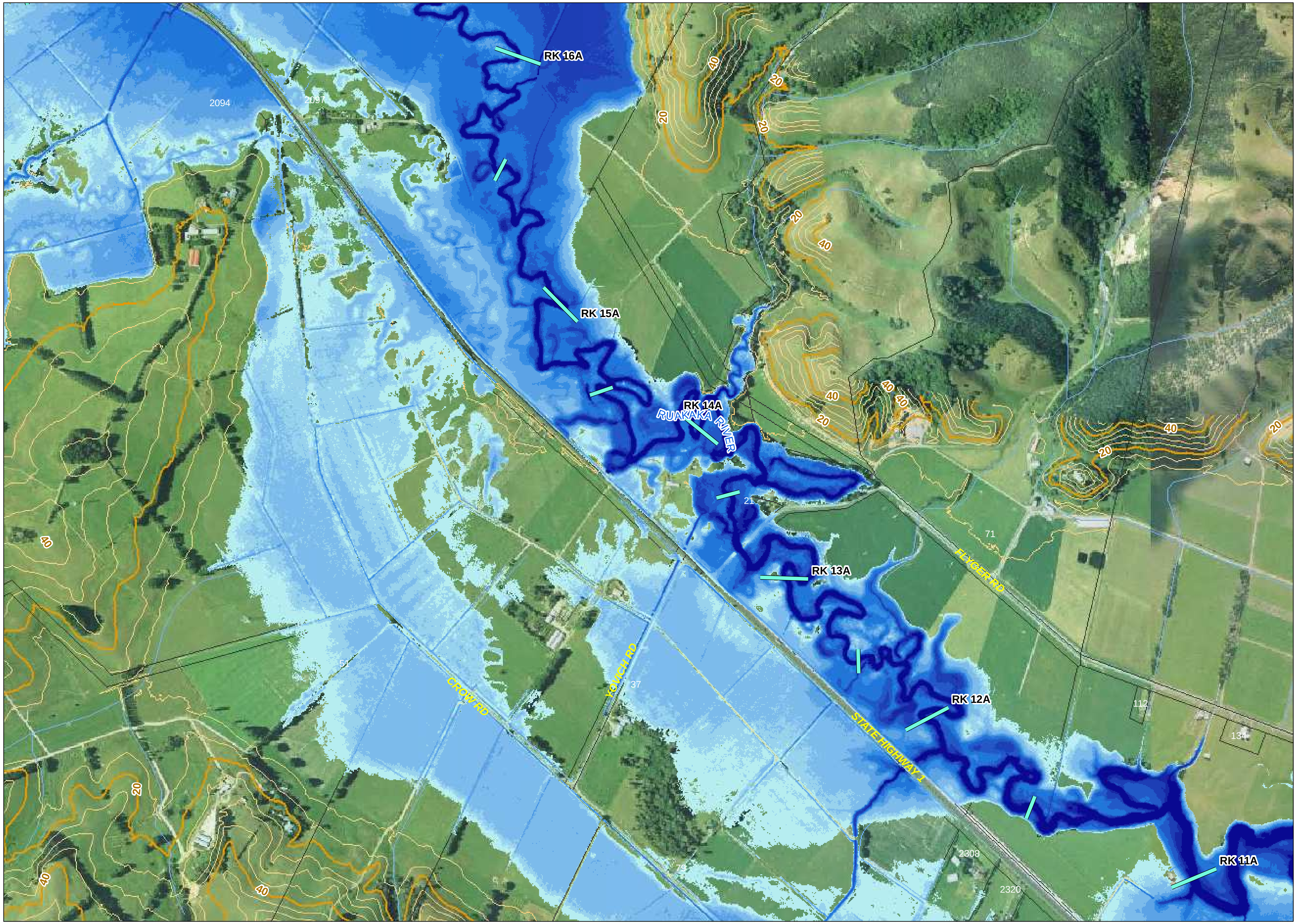

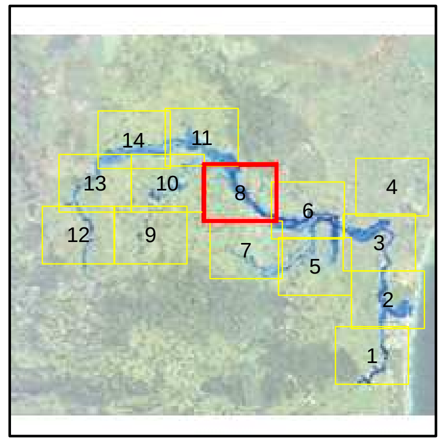

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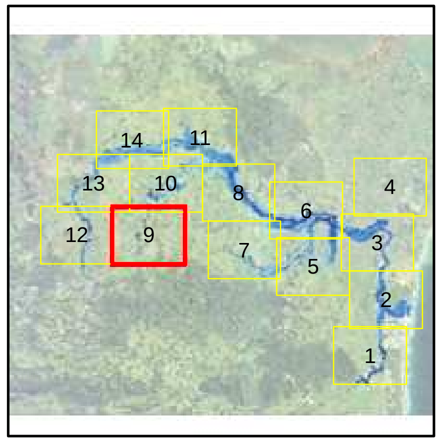

50 year ARI

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River Kilometre, Rk

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50 year ARI

Duration 12h

River Kilometre, Rk

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RUAKAKA RIVER 50 YEAR ARI

Final

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50 year ARI

Duration 12h

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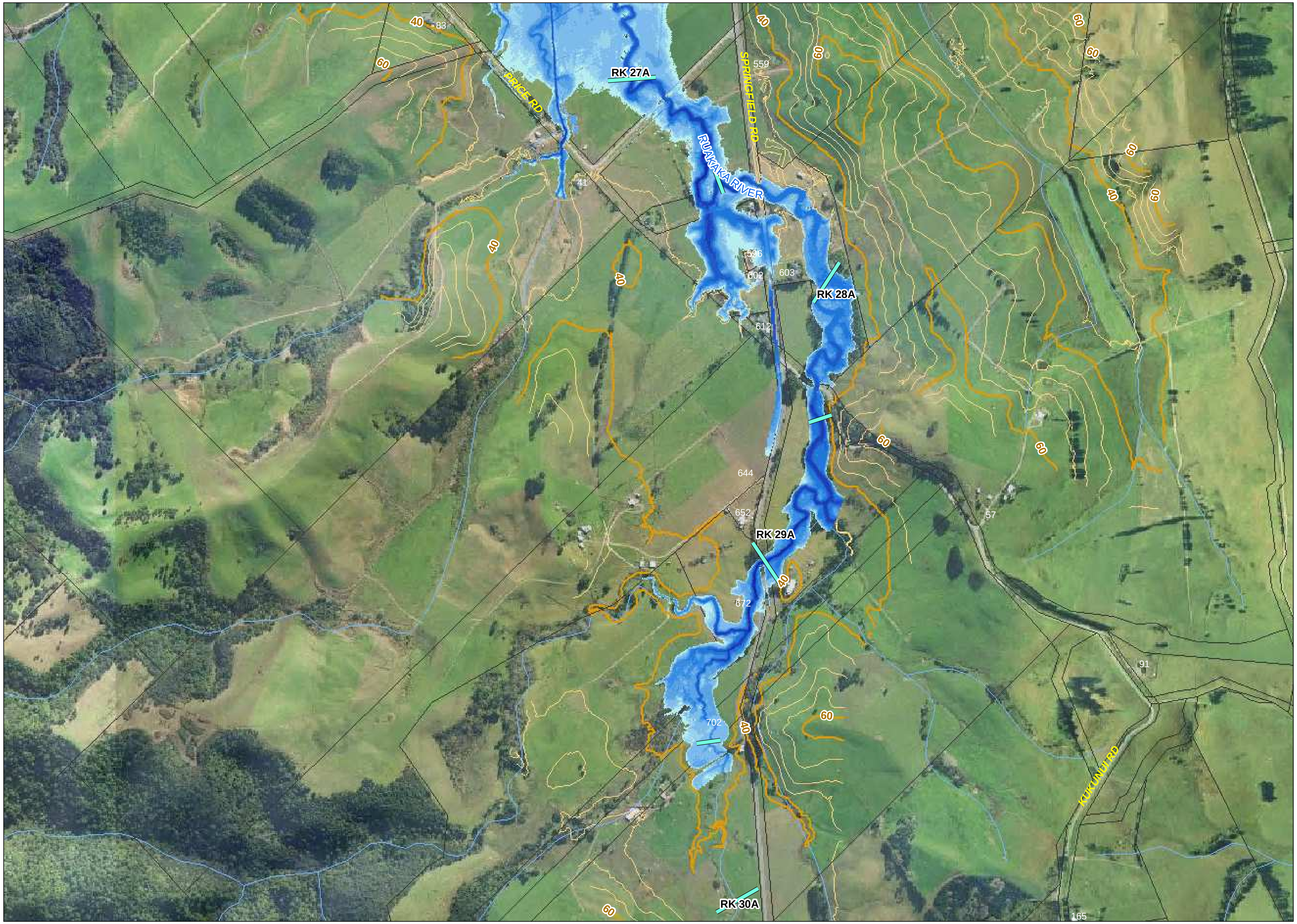

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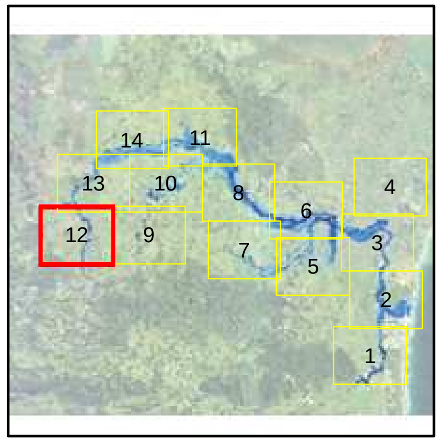

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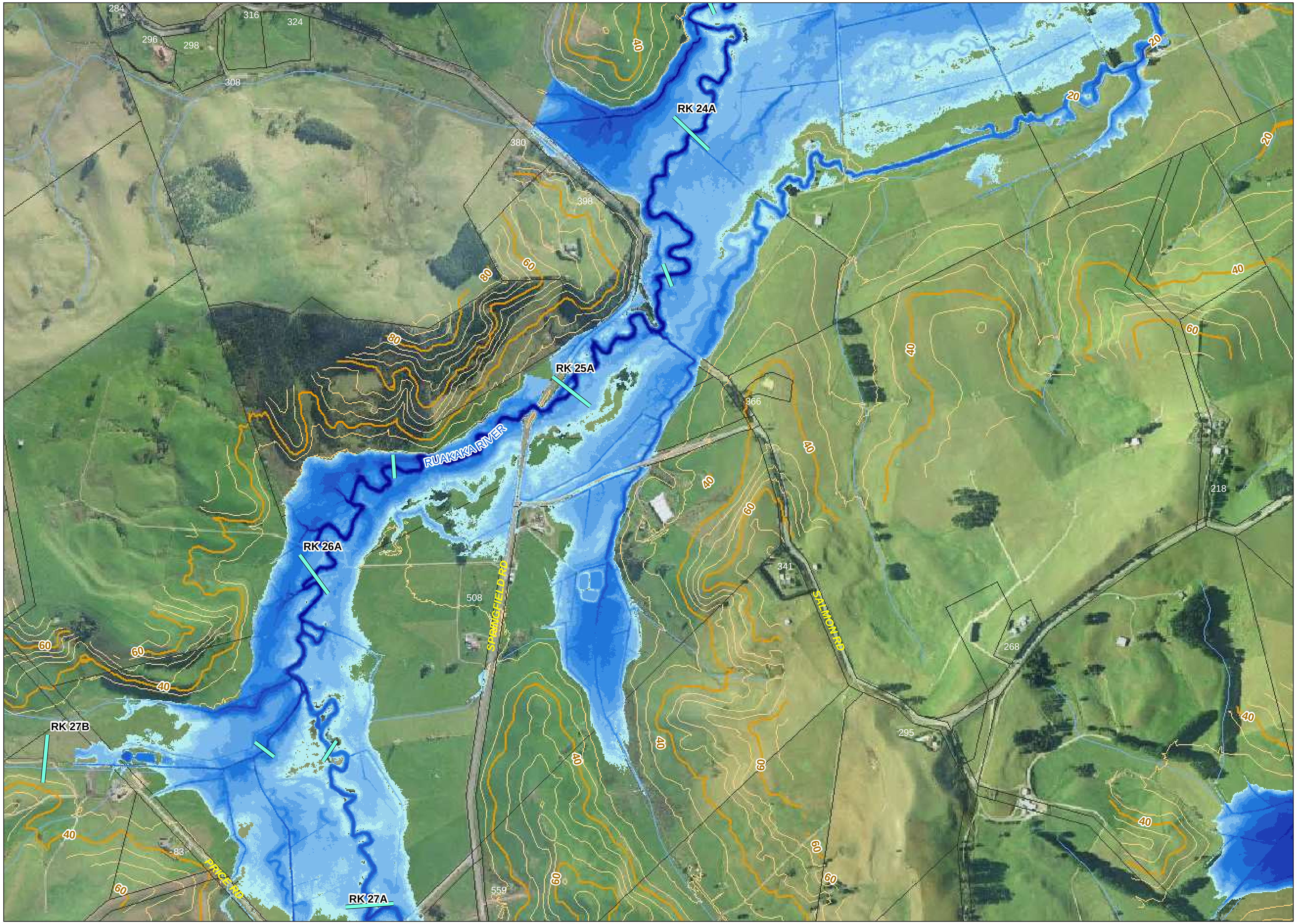

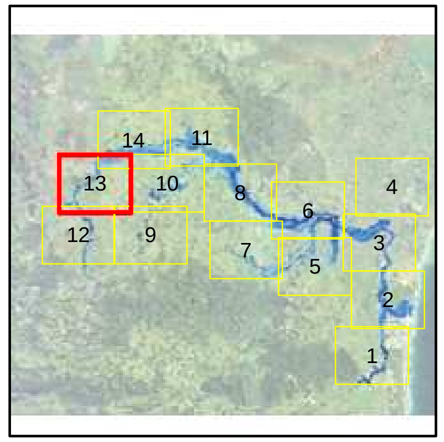

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50 year ARI

Duration 12h

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Flood Depth, m

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RUAKAKA RIVER 50 YEAR ARI

Final

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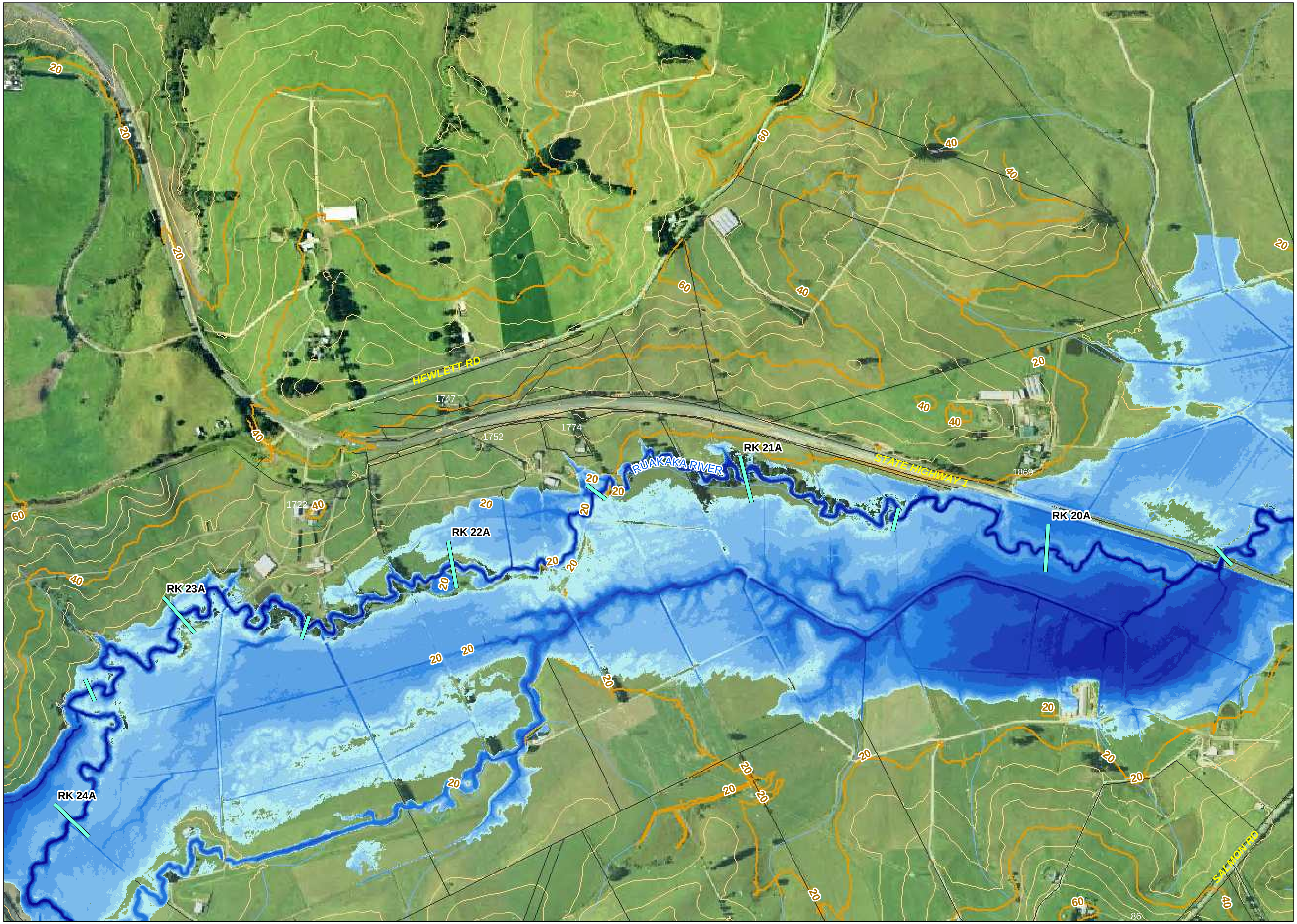

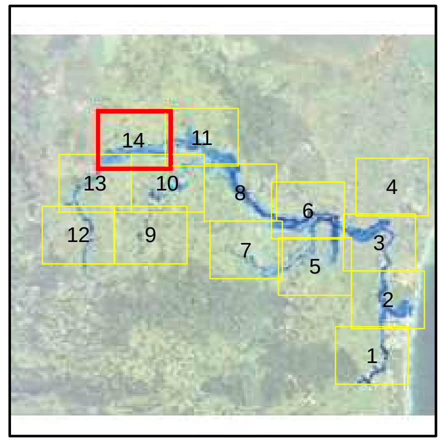

N

50 year ARI

Duration 12h

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 1:8,000

Manaaki Awa
The River Care Group
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RUAKAKA RIVER 50 YEAR ARI

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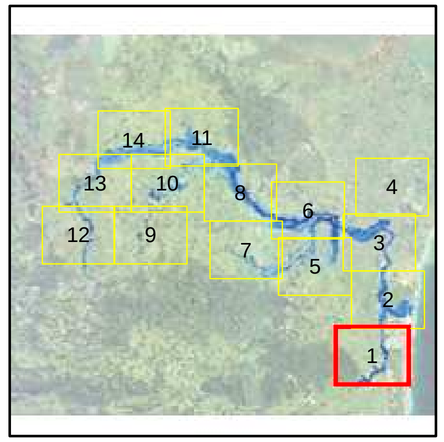

N

100 year ARI

Duration 12h

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 1:8,000

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RUAKAKA RIVER 100 YEAR ARI

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100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
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- 2.51 - 3.00
- > 3.00

Scale 1:8,000

Manaaki Awa
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Final

RUAKAKA RIVER 100 YEAR ARI

URS

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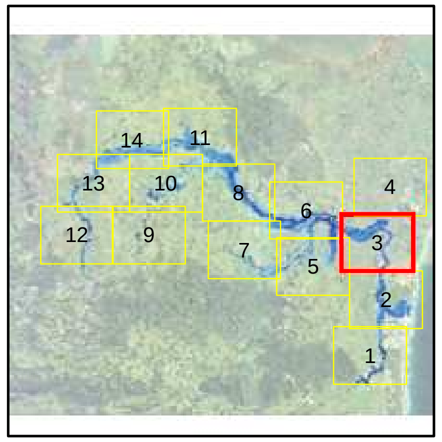

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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RUAKAKA RIVER 100 YEAR ARI

URS

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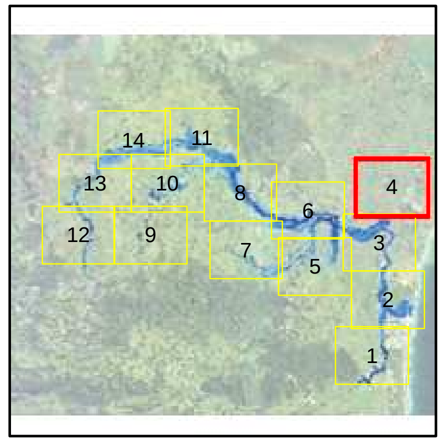

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
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Scale 1:8,000

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Final

URS

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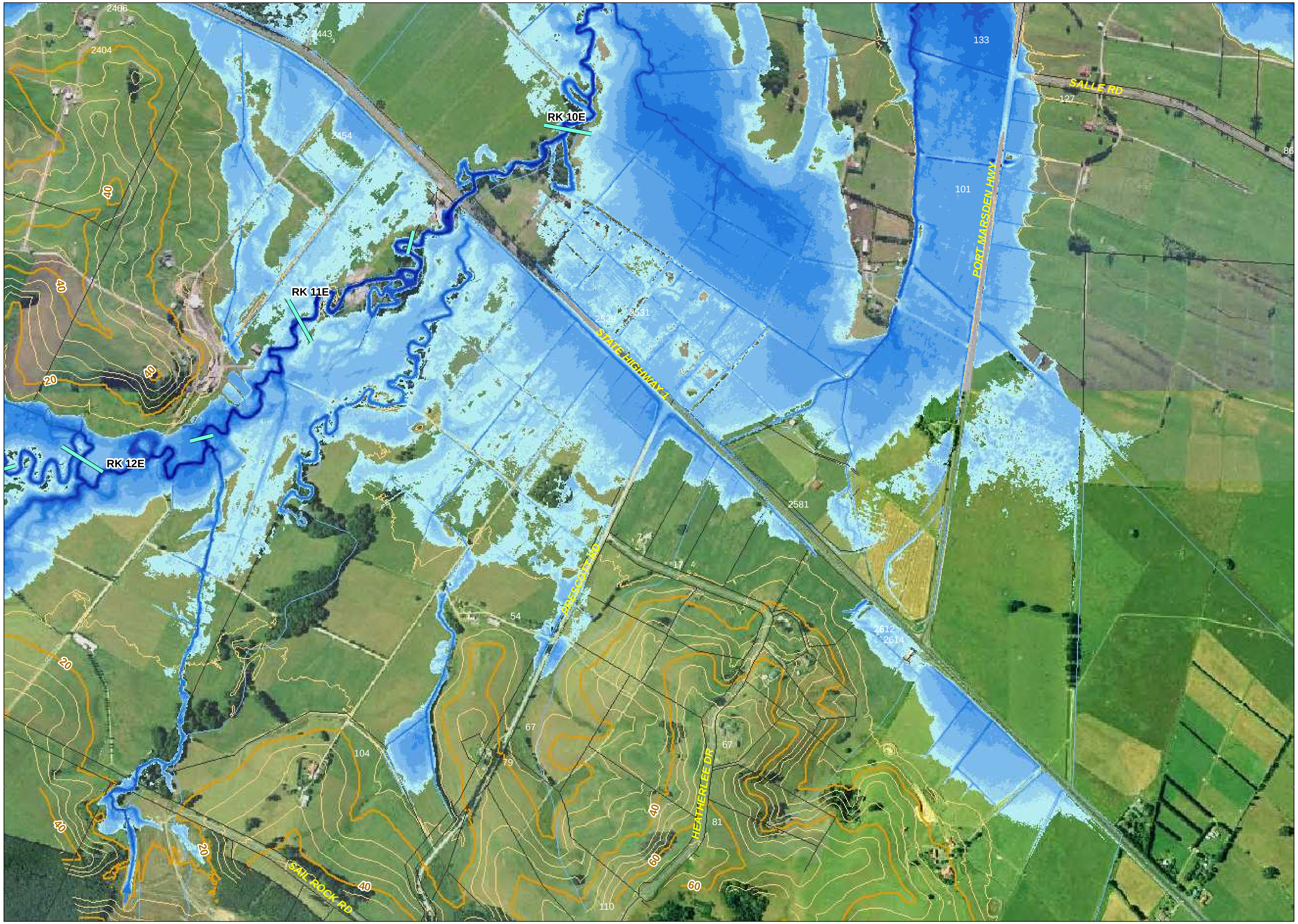

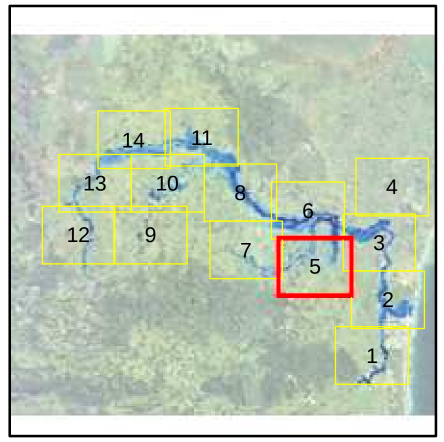

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Scale 1:8,000

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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RUAKAKA RIVER 100 YEAR ARI

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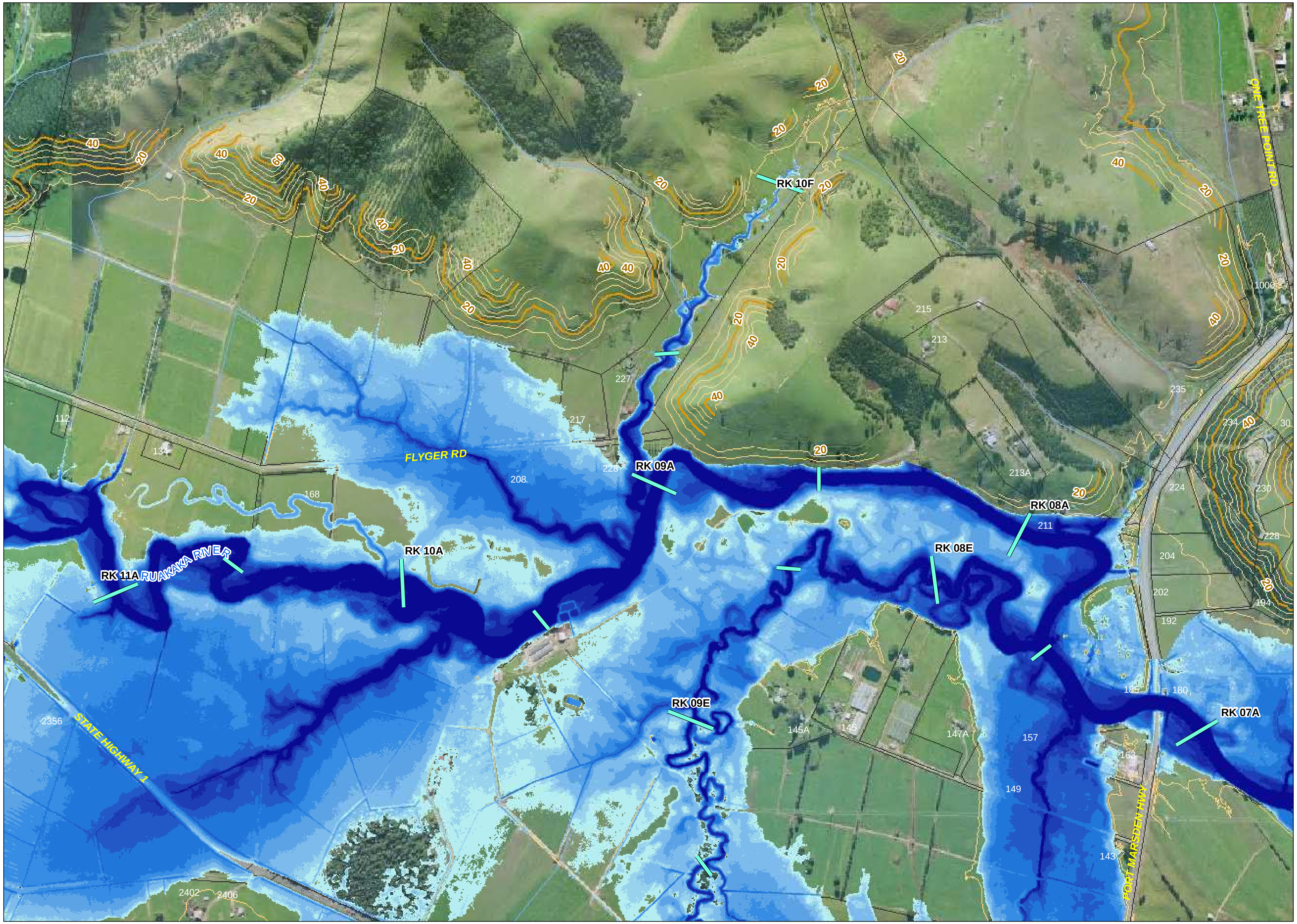

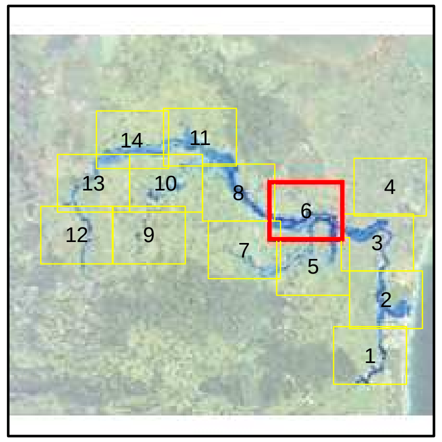

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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- > 3.00

Scale 1:8,000

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RUAKAKA RIVER 100 YEAR ARI

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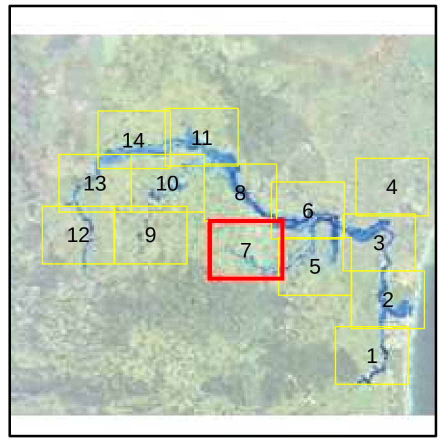

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
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Scale 1:8,000

Manaaki Awa
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RUAKAKA RIVER 100 YEAR ARI

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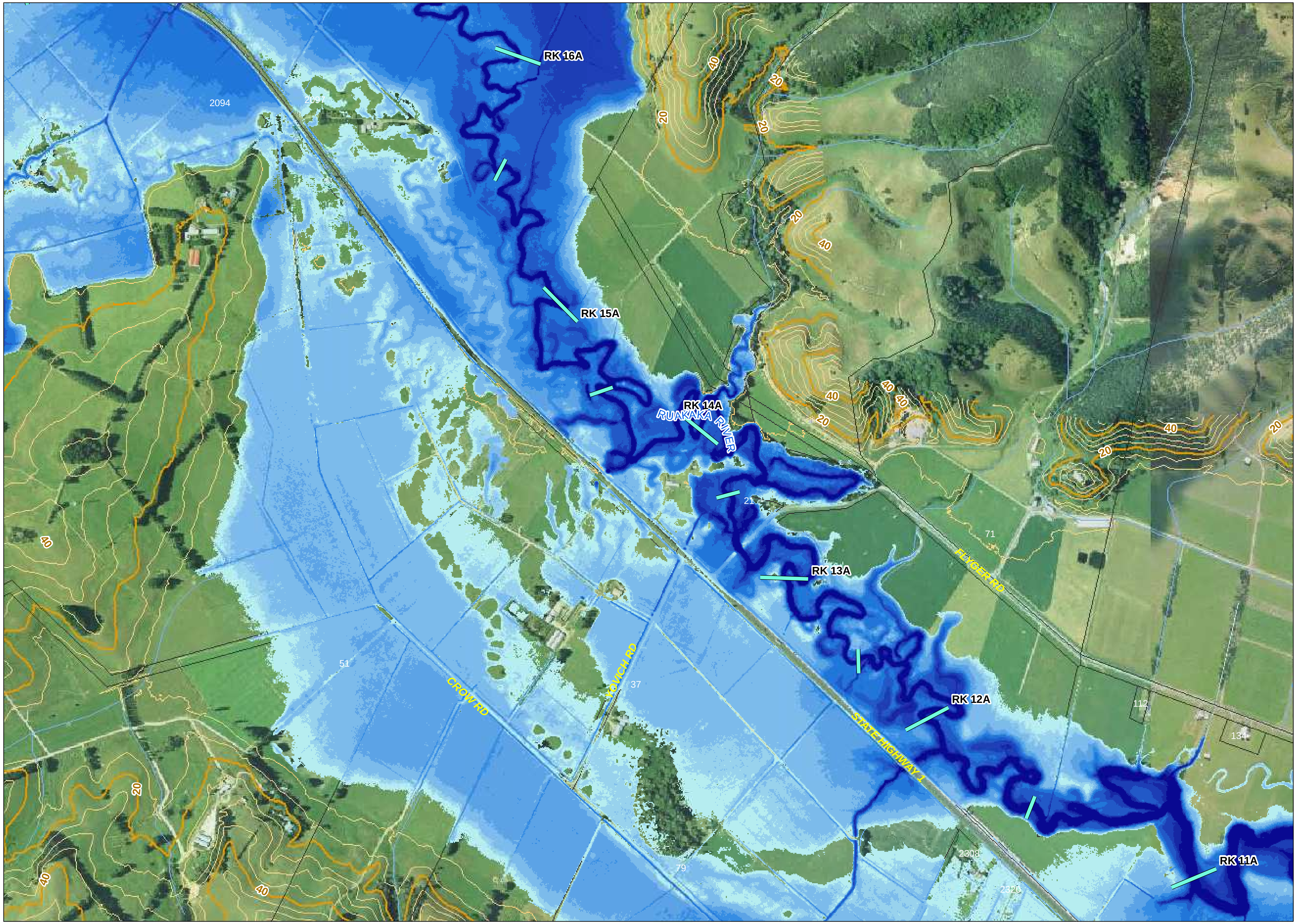

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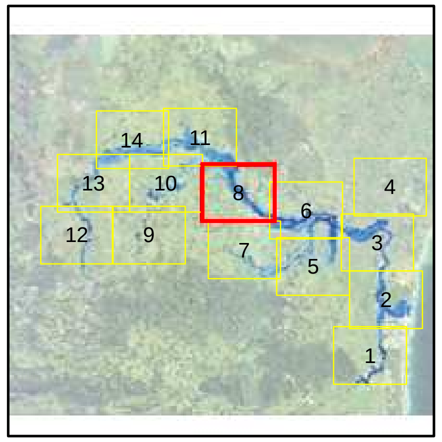

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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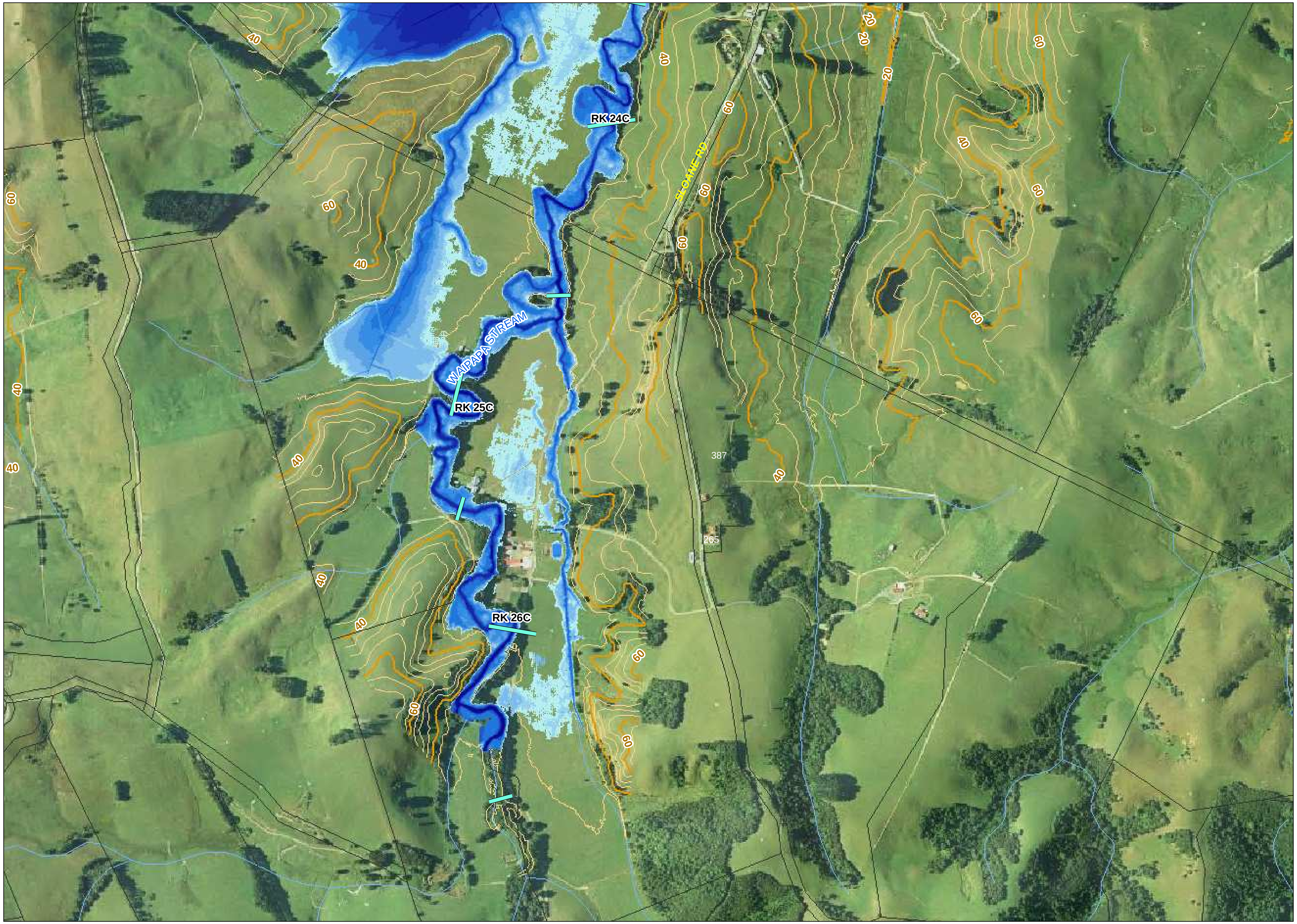

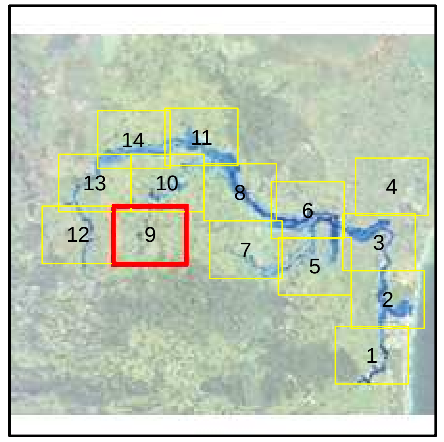

N

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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The River Care Group

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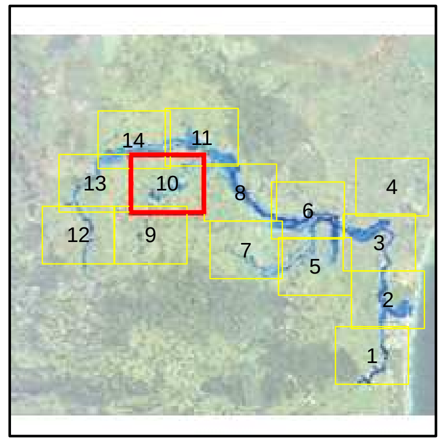

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

Manaaki Awa
The River Care Group

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Final

RUAKAKA RIVER 100 YEAR ARI

URS

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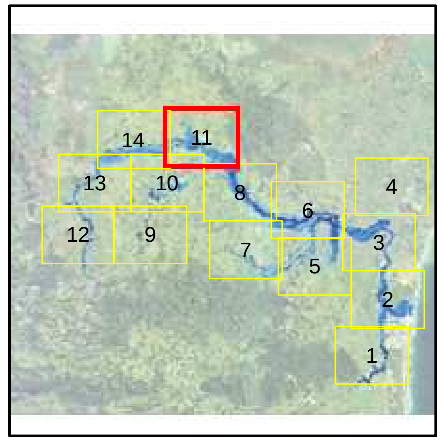

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

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Scale 1:8,000

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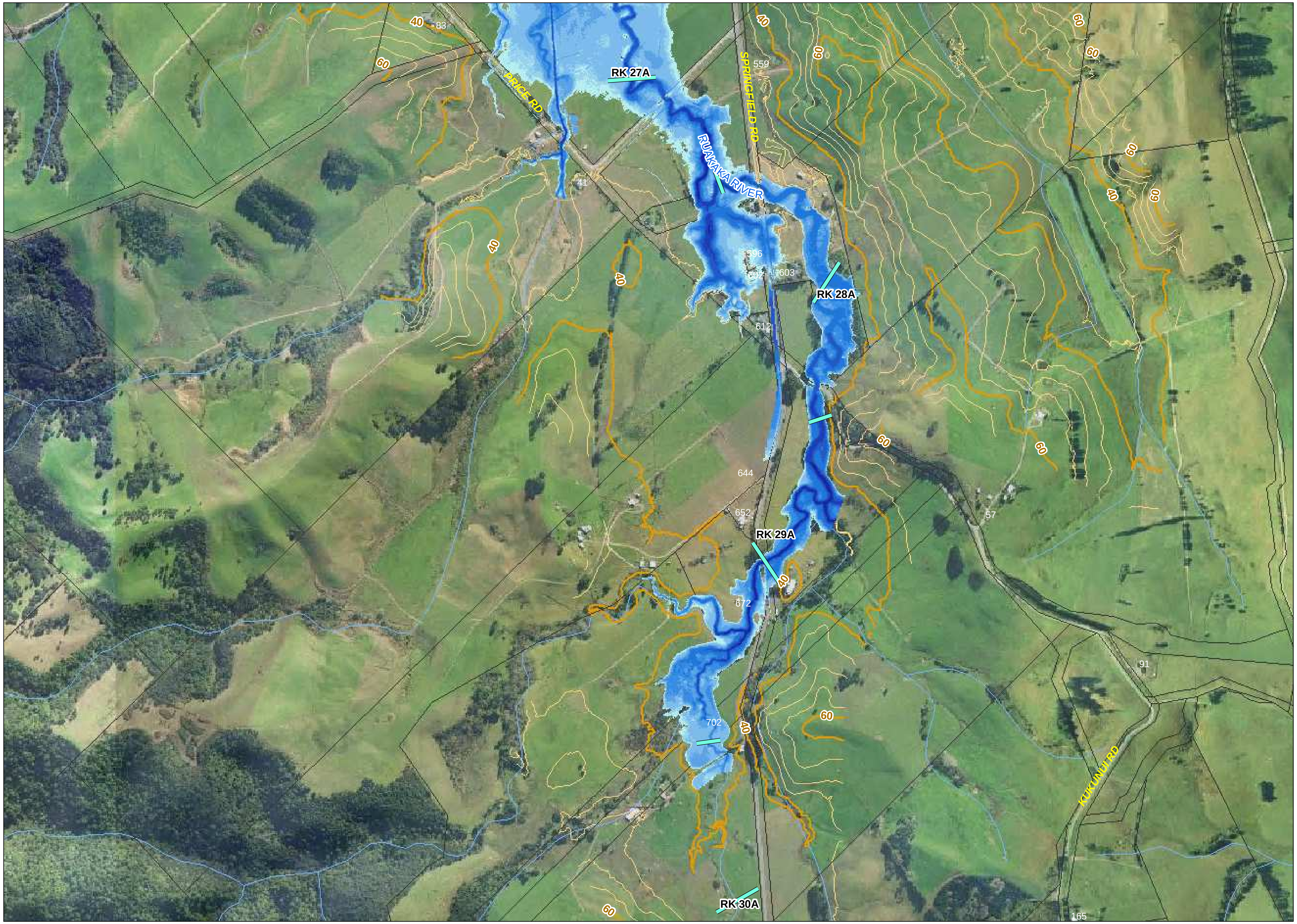

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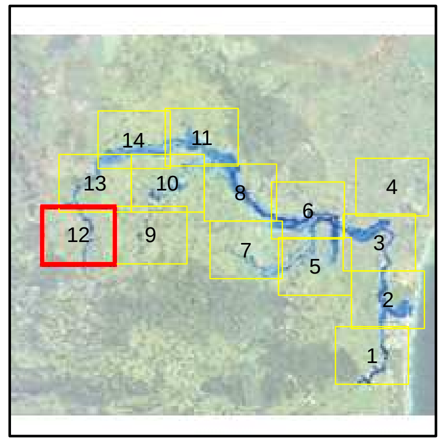

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

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- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- > 3.00

Scale 1:8,000

Manaaki Awa
The River Care Group
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RUAKAKA RIVER 100 YEAR ARI

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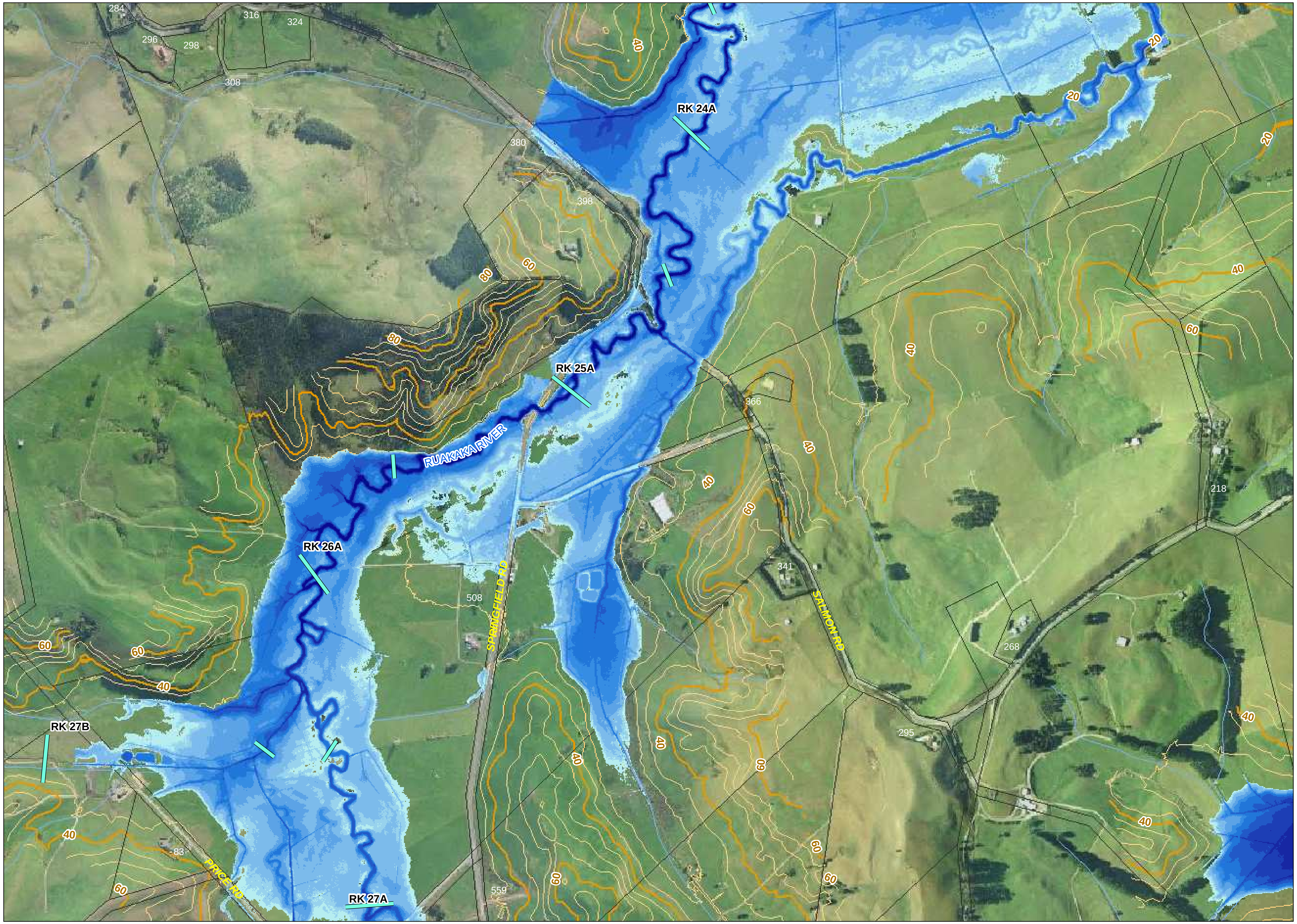

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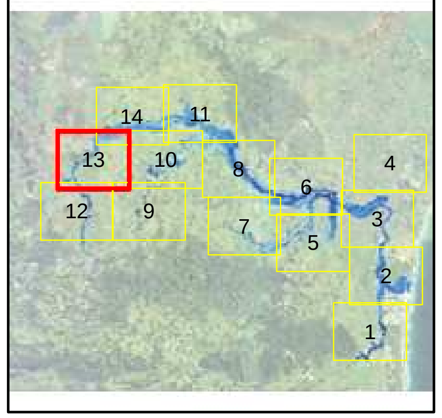

100 year ARI

Duration 12h

River Kilometre, Rk

Flood Depth, m

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Scale 1:8,000

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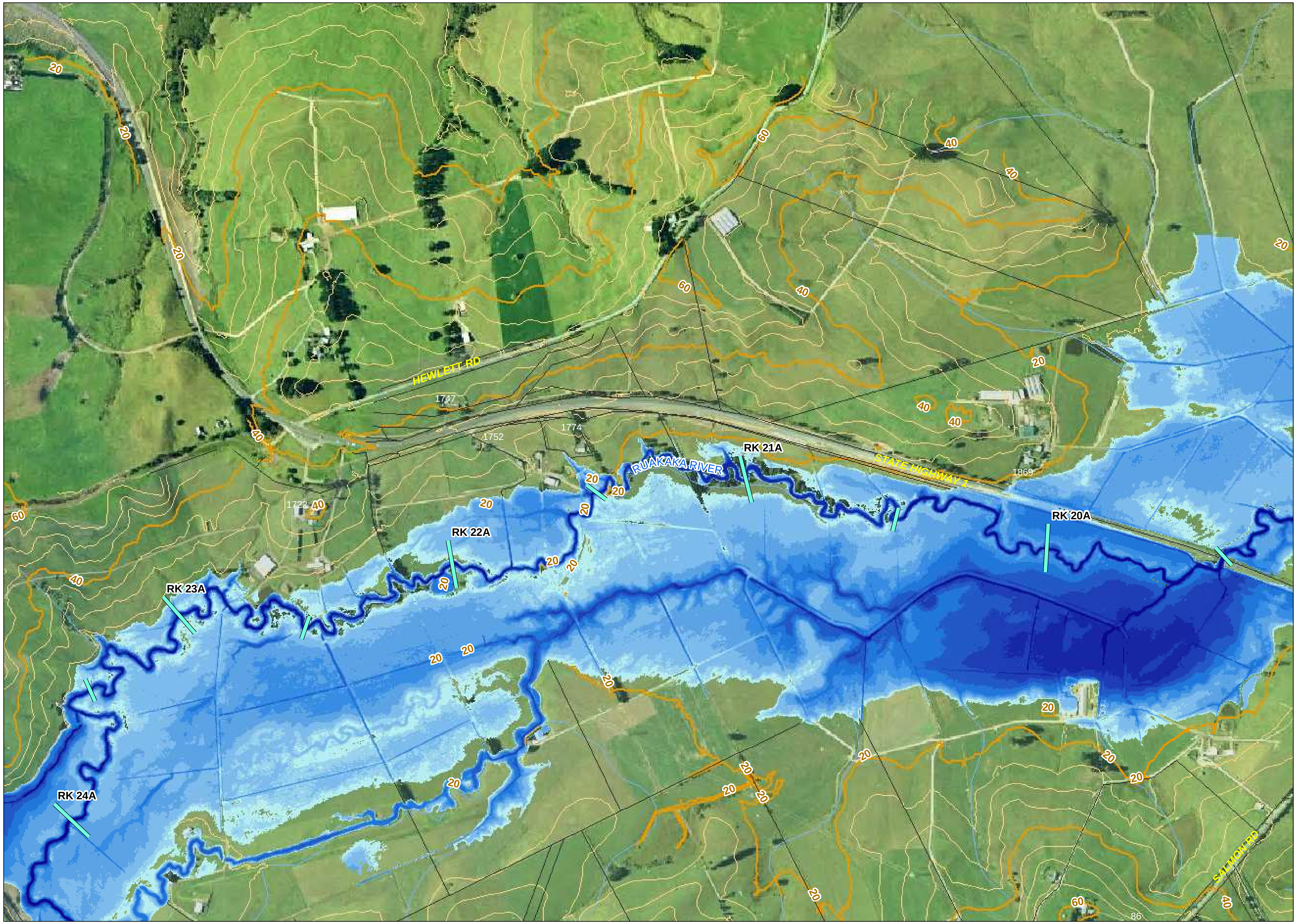

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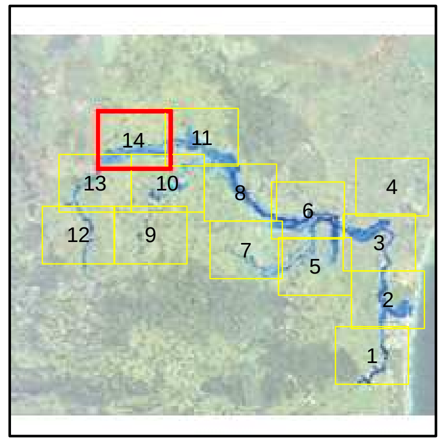

100 year ARI

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River Kilometre, Rk

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Scale 1:8,000

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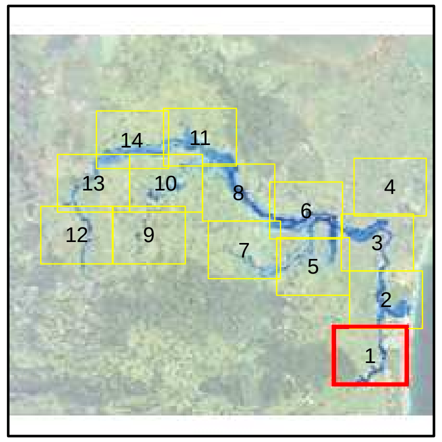

100 year ARI plus Climate Change

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
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Scale 1:8,000

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

Final

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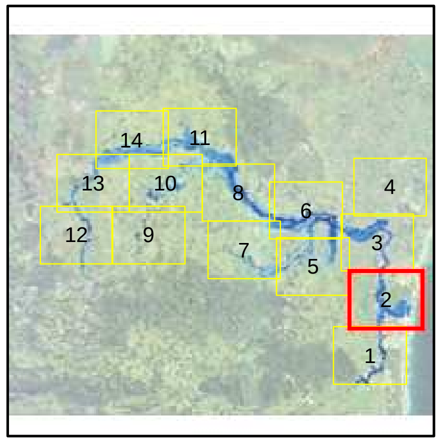

100 year ARI plus Climate Change

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Scale 1:8,000

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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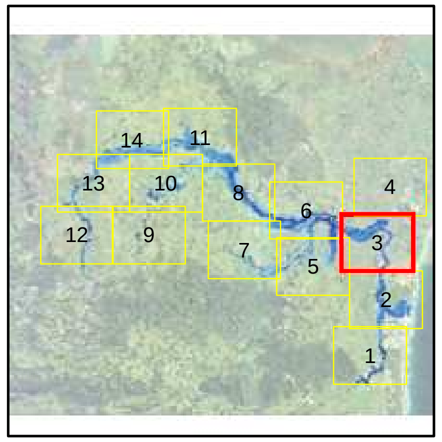

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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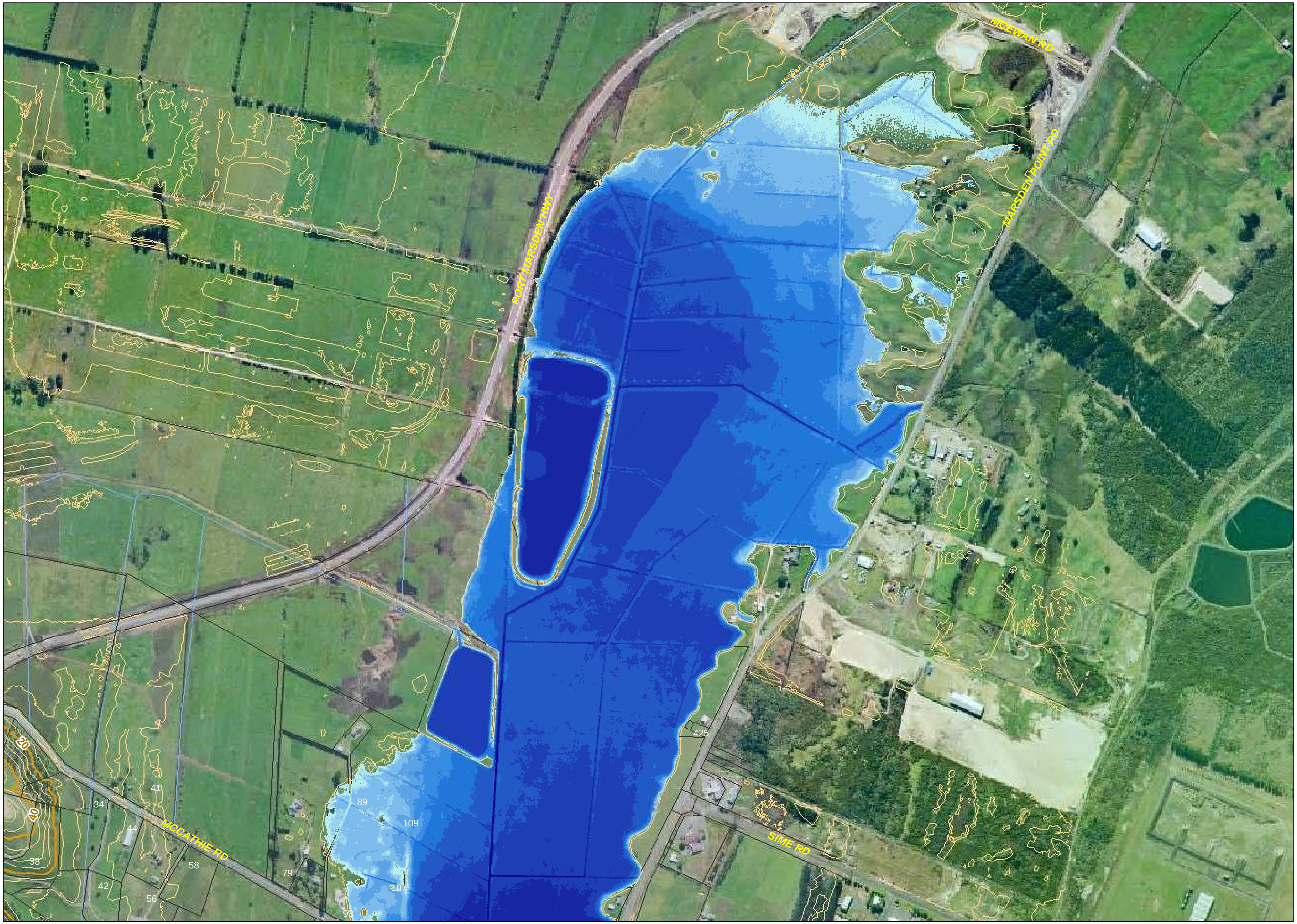

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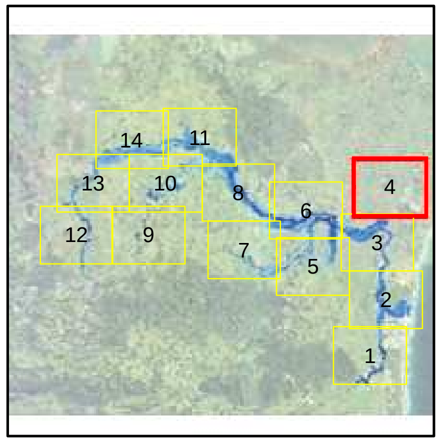

100 year ARI plus Climate Change

Duration 12h

River Kilometre, Rk

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- > 3.00

Scale 1:8,000

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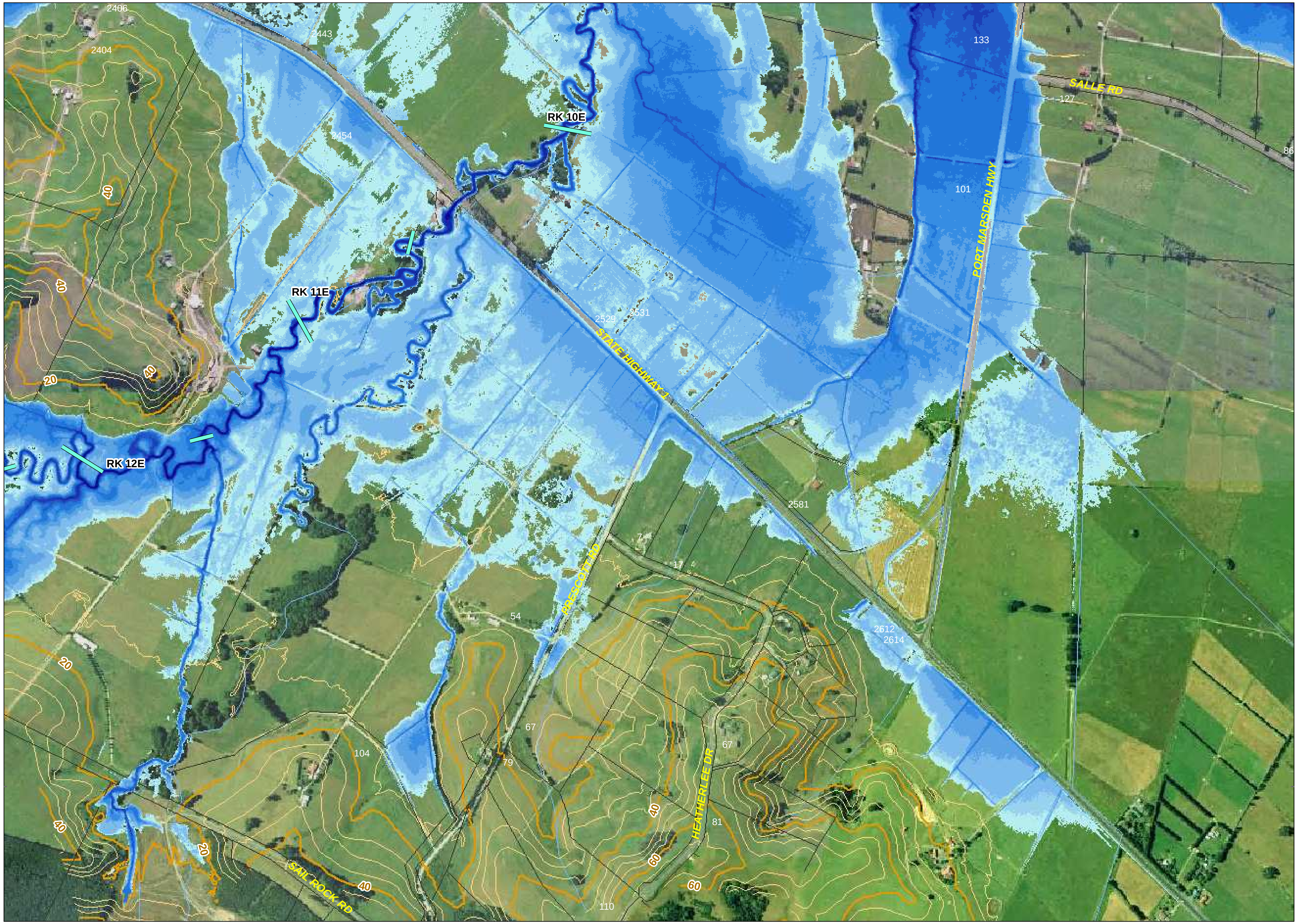

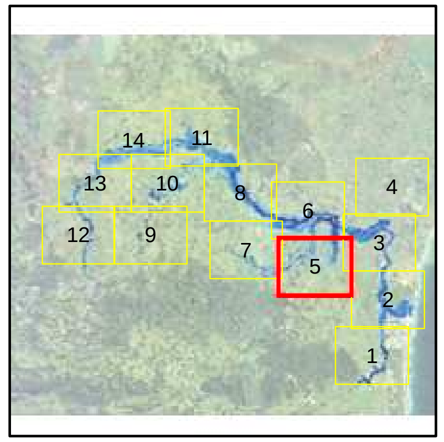

100 year ARI plus Climate Change

Duration 12h

River Kilometre, Rk

Flood Depth, m

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Scale 1:8,000

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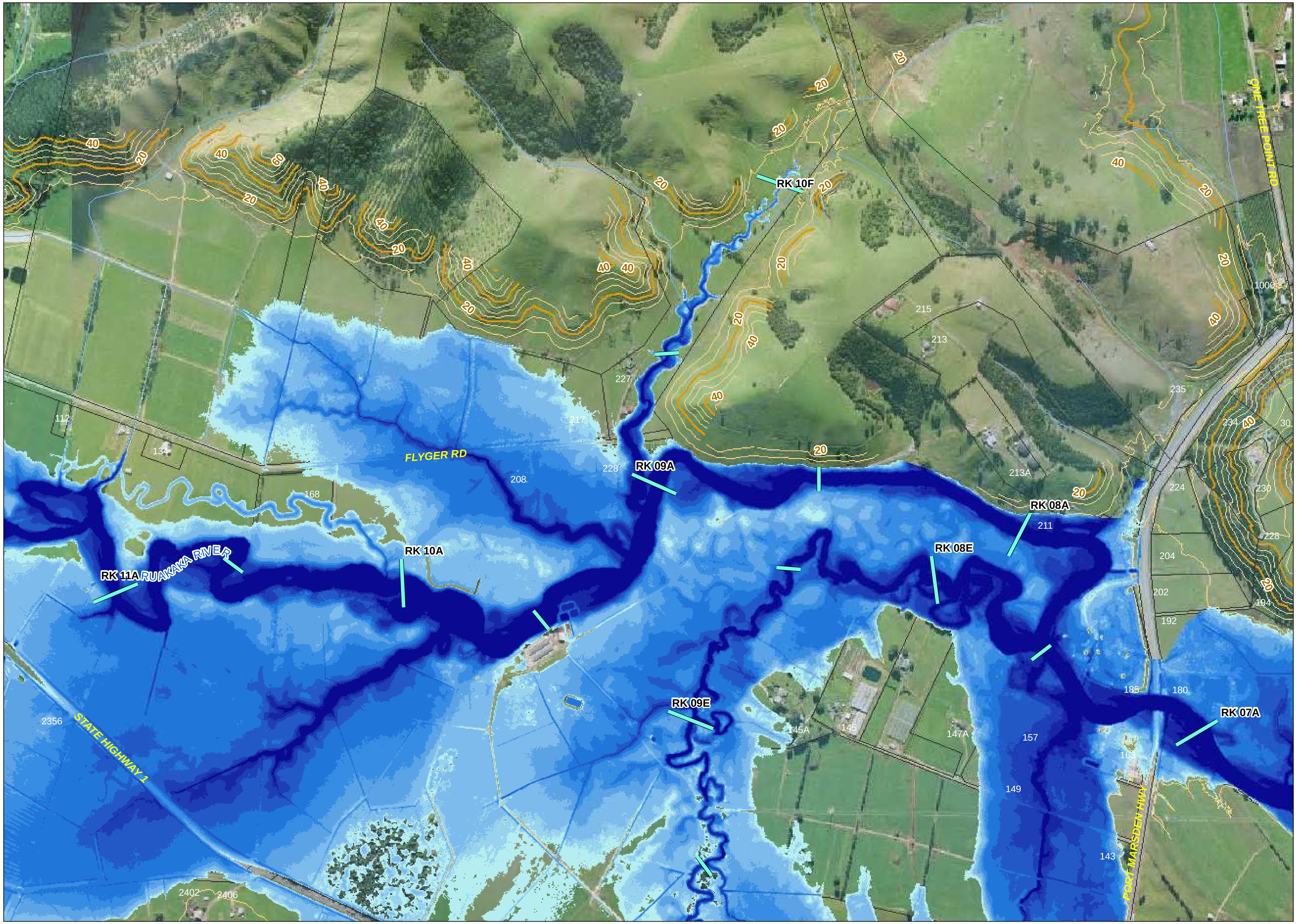

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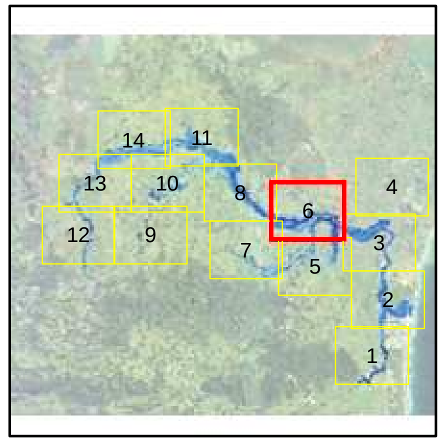

100 year ARI plus Climate Change

Duration 12h

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 1:8,000

Manaaki Awa
The River Care Group

NORTHLAND REGIONAL COUNCIL

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File: 42071138\FloodMaps\02_RUAKAKA_RIVER\Flood_Maps.mxd | Drawn: FP | Approved: JW | Date: 11/07/2012 | Rev. A | A3

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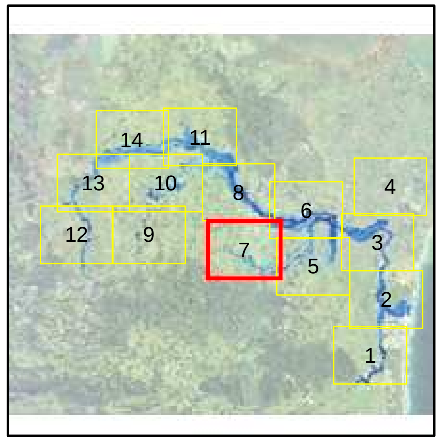

100 year ARI plus Climate Change

Duration 12h

River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
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Scale 1:8,000

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The River Care Group

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

Final

URS

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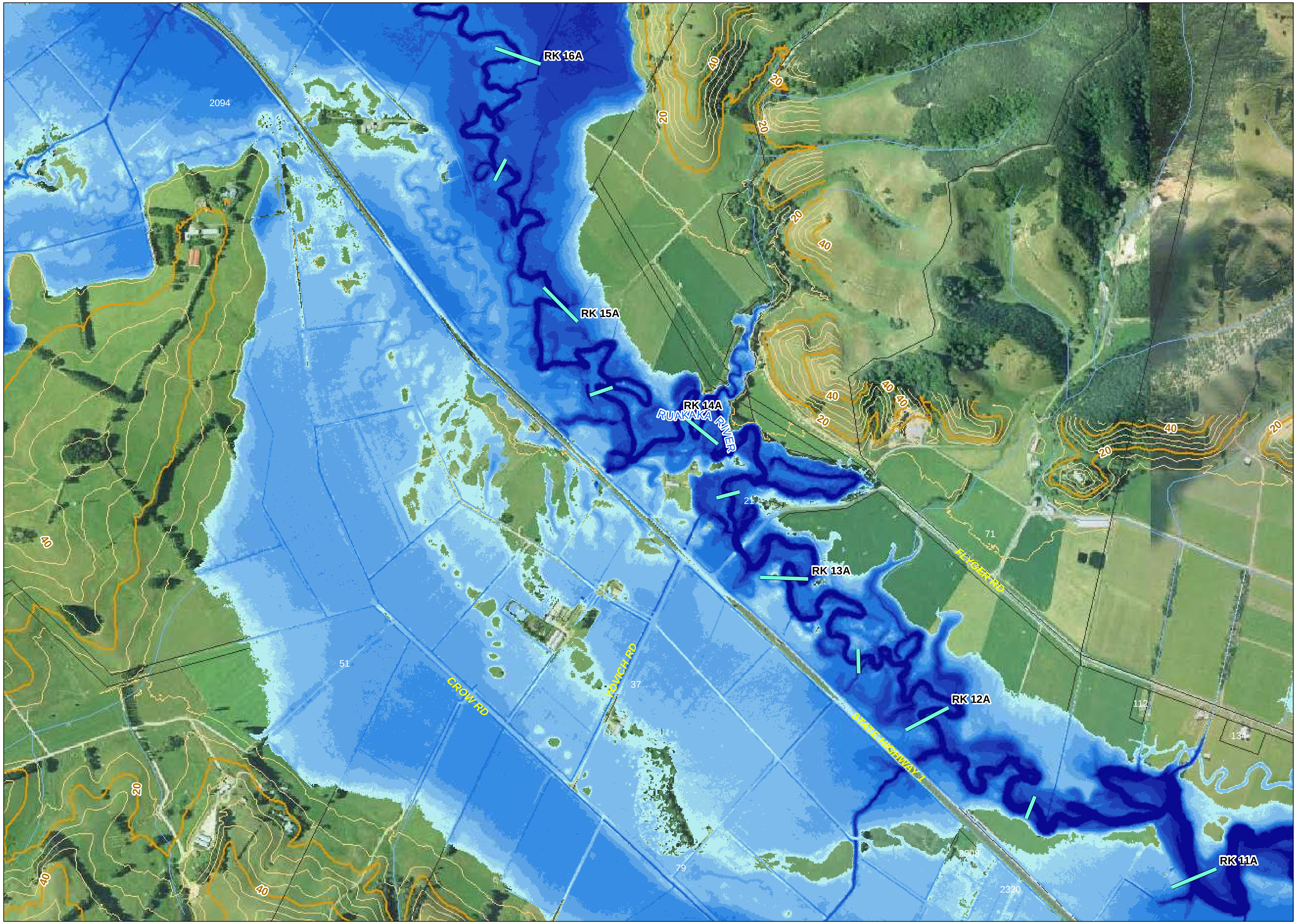

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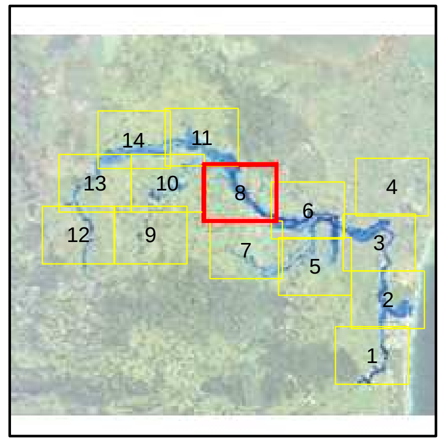

100 year ARI plus Climate Change

Duration 12h

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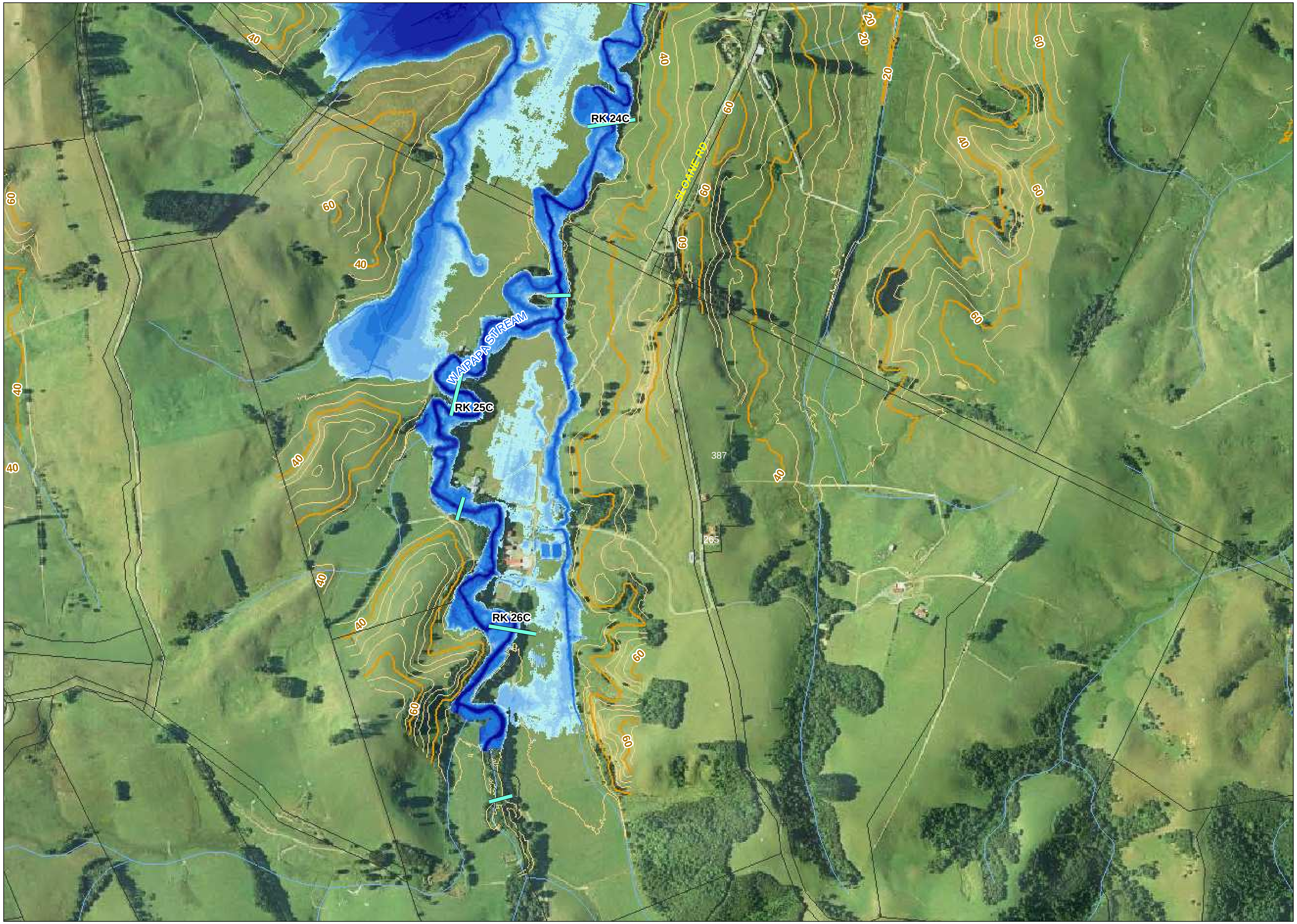

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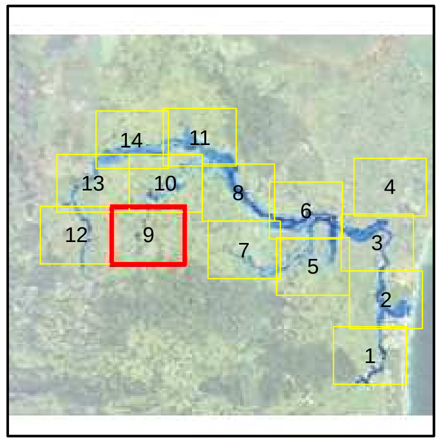

100 year ARI plus Climate Change

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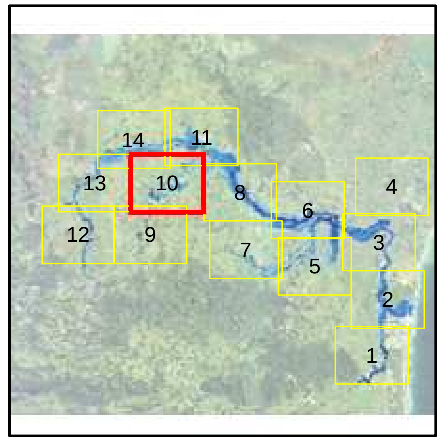

100 year ARI plus Climate Change

Duration 12h

River Kilometre, Rk

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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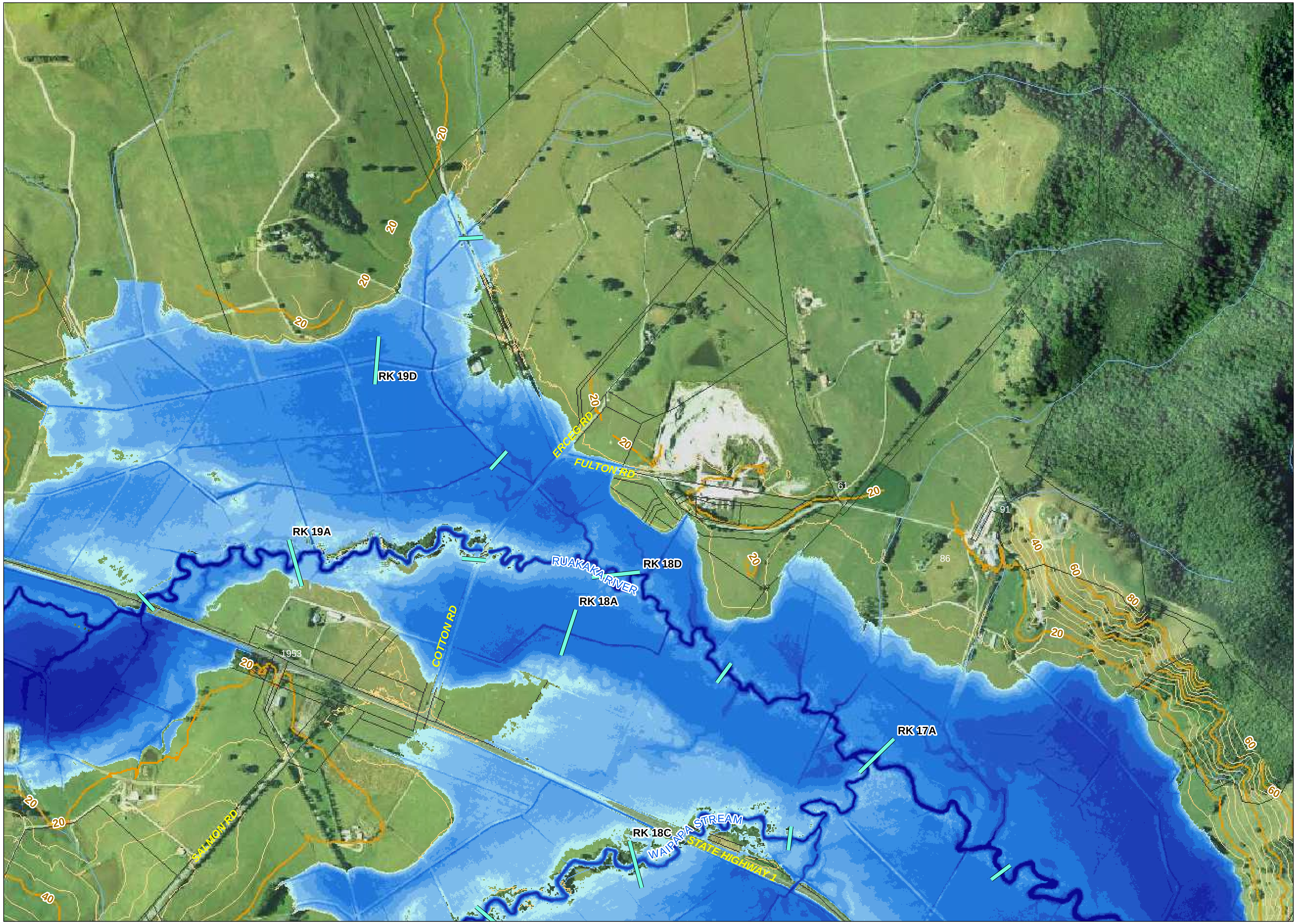

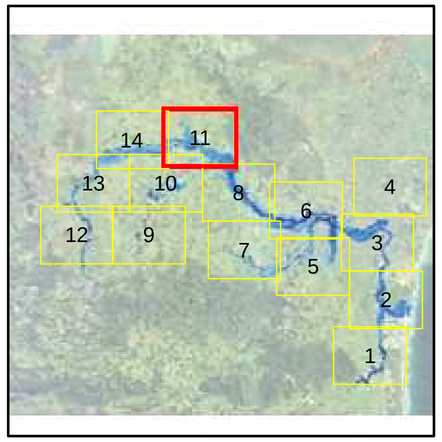

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RUAKAKA RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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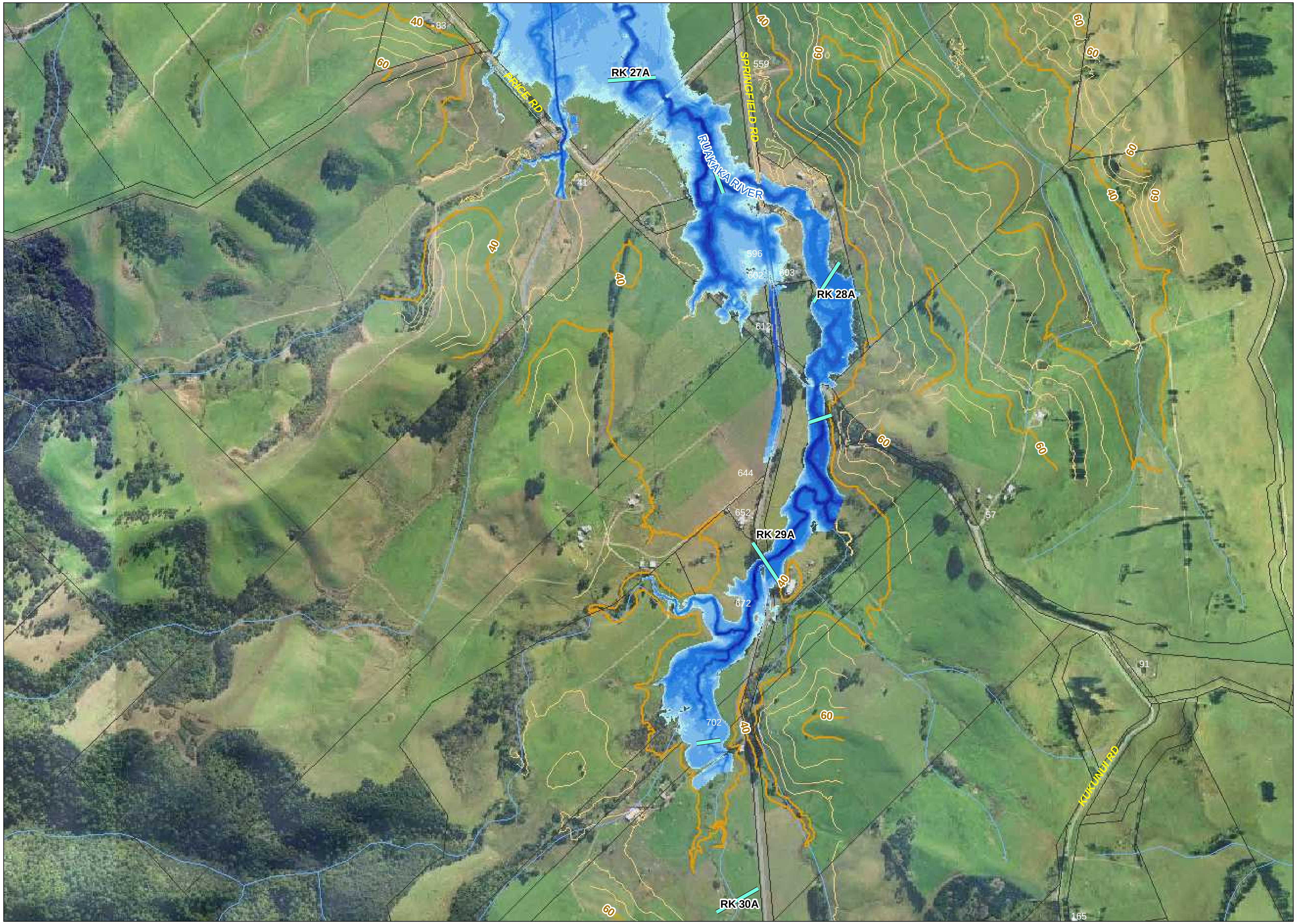

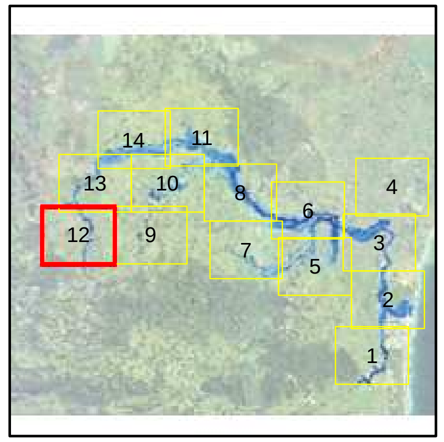

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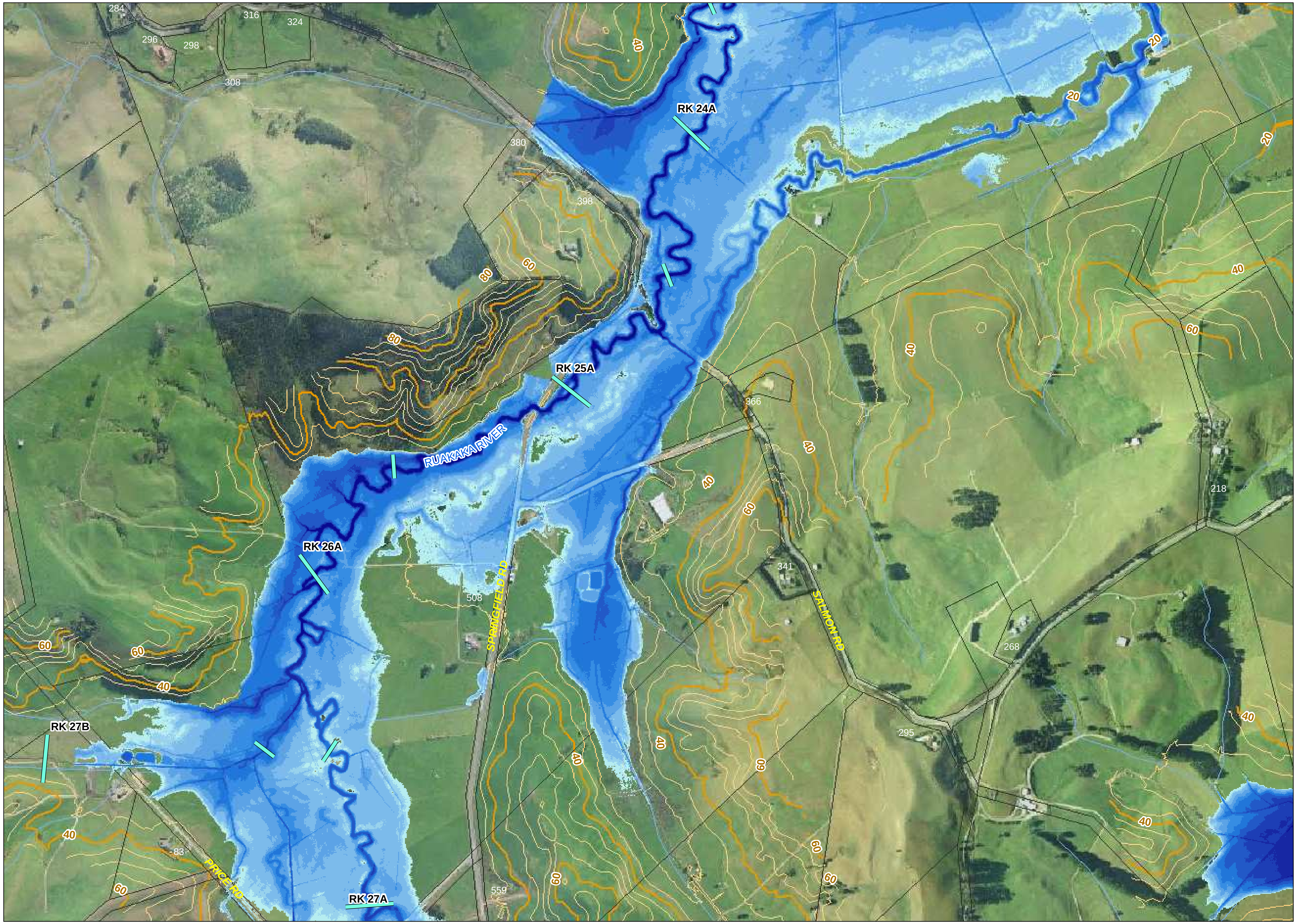

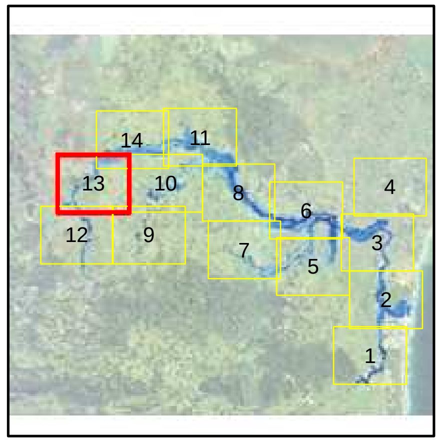

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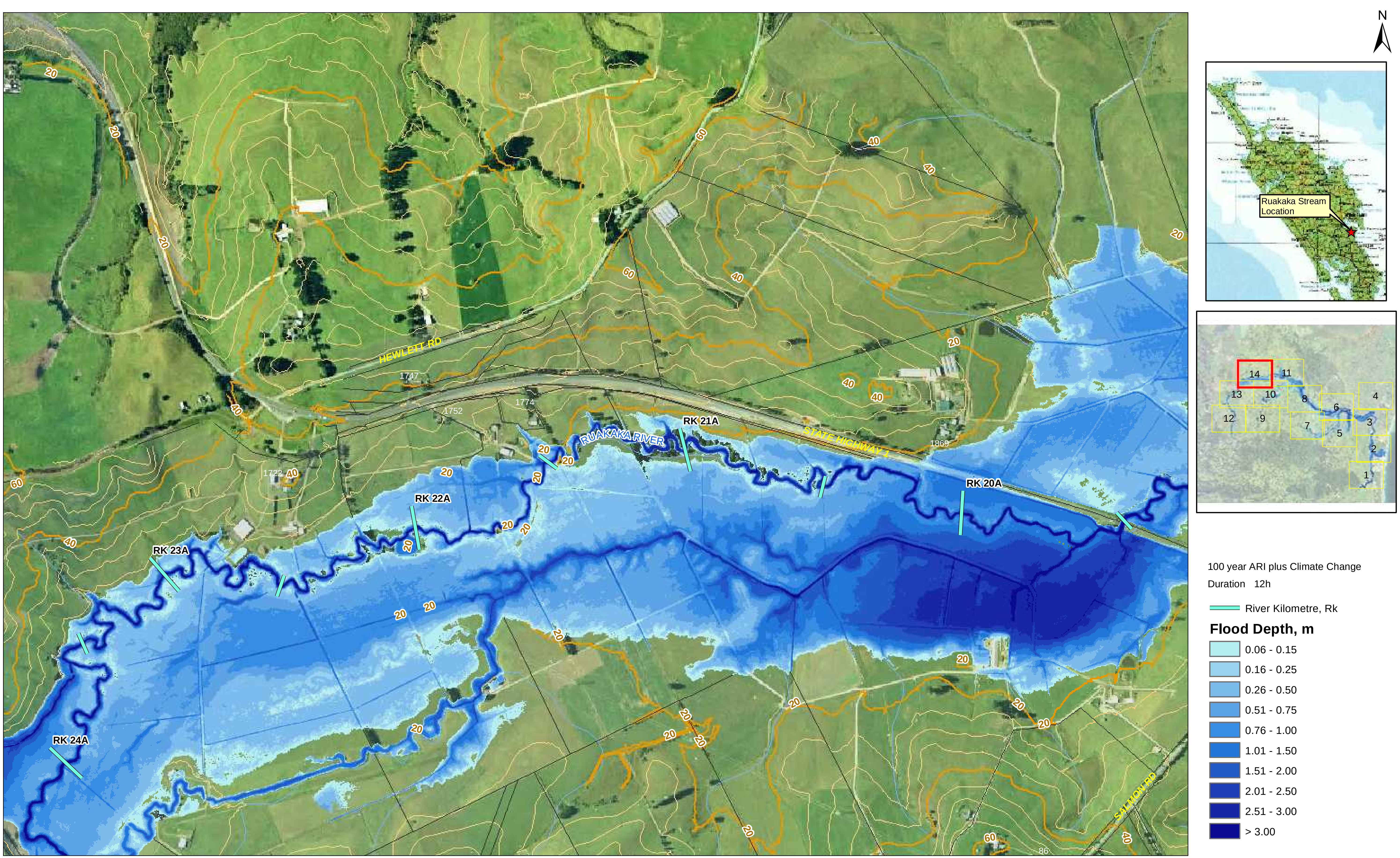

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