



Report

Hokianga Modelling Report

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Abbreviations

Abbreviation

Description

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 Hokianga model comprises of a group of four catchments discharging into the Hokianga Harbour that were found by the Northland Regional Council to be in need of improvement in order to provide confidence in the flood mapping.

The four catchments involved are listed in Table 1-1 below together with some general catchment information.

Table 1-1 Hokianga catchments

Catch ID	Catchment Name	Priority	Built by	Area (km ²)	Previous Design Storm Duration (hrs)	Time of Concentration (hrs)
10	Rotokakahi River	2	MWH	198.6	24	9.65
10	Pawarenga fans	2	MWH	7.4	24	0.65
12	Panguru Rivers	3	MWH	35.0	6	1.47
13	Awapokonui River	3	URS	10.0	6	1.18
18	Whirinaki River	3	URS	42.9	6	3.78

1.2 Catchment Description

A description of the four Hokianga catchments is provided below and their location is shown in Figure 1-1.

1.2.1 Panguru Catchment

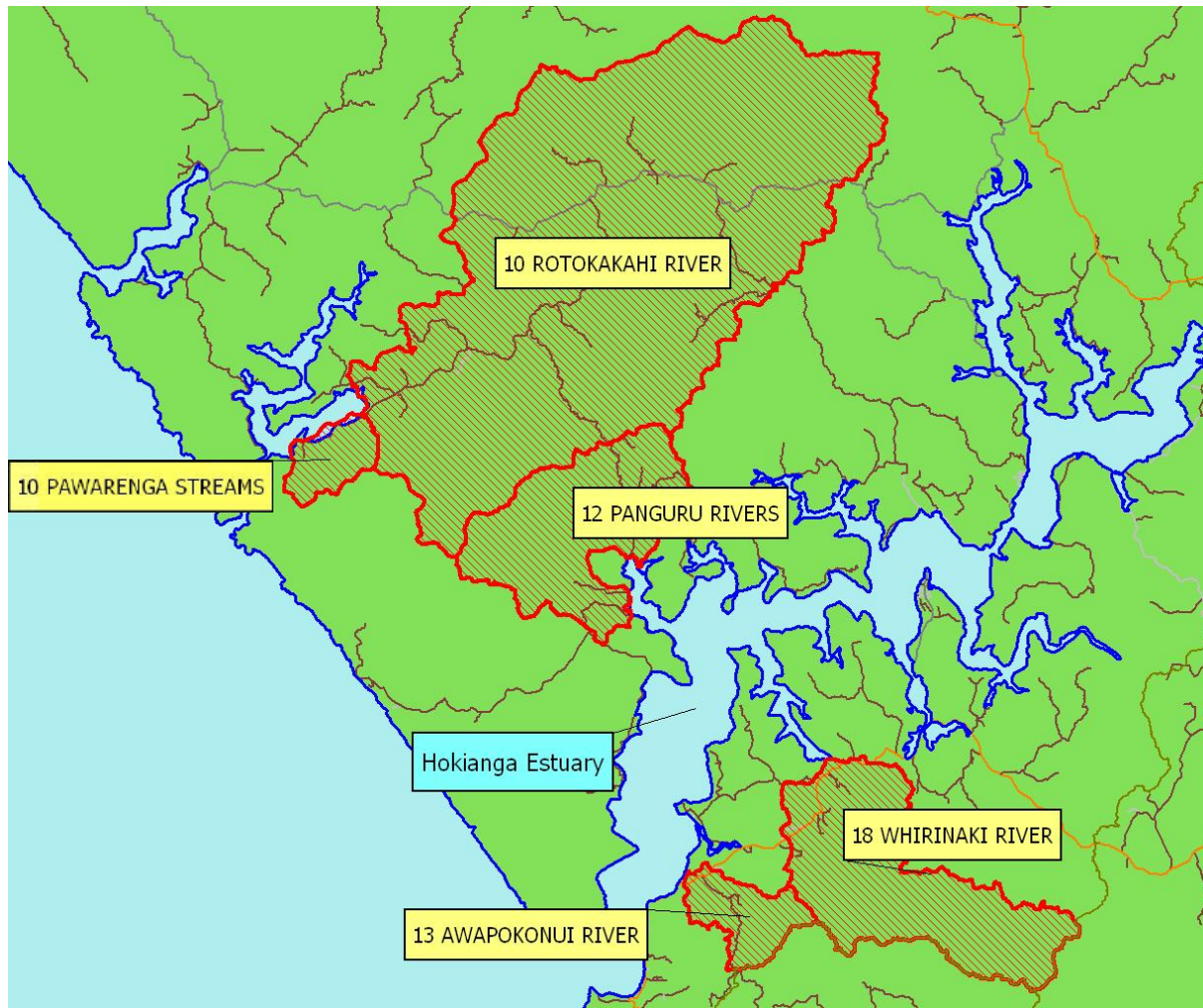
The Panguru Stream catchment is located on the western coast of the Northland region, approximately 30 km south of Kaitia. The Panguru catchment includes two watercourses that have a confluence approximately 2 km upstream of the Hokianga Harbour. These watercourses are:

- The Panguru Streams – Located on the northern side of the catchment.
- The Waihou River – Located on the southern side of the catchment.

The total catchment size is 35km², with 18.7km² for the Panguru Stream only. The whole catchment is mainly covered by indigenous forest (over 65%), with some areas of exotic grassland and other forested areas. The West Coast Road is the main road crossing through the catchment, surrounding the estuary along its northern side.

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Figure 1-1 General Location Plan of the Hokianga Catchments Models



1.2.2 Awapokonui Catchment

The Awapokonui River catchment covers an area of 10 square kilometres. It is approximately 4.5 km in length, 3.8 km at its widest point and 1.7km at its narrowest point, which is just downstream of the major tributaries. The catchment is comprised of two major tributaries the Pakanae Stream and the Matariki Stream, with both approximately 3.7 km in stream length.

The Pakanae and Matariki Streams emerge into the middle third of the catchment which has moderately sloped terrain and has been largely converted to pastureland. The Awapokonui Stream begins at the confluence of the Pakanae and Matariki streams it consists mostly of steep erodible hill country, around 46% of which is forested in mature and reverting native forest. The relatively small stream flows over a number of waterfalls in the deeply entrenched Waitemarama Gorge before emerging out of the hills immediately upstream of Pakanae.

Overall catchment land cover composition consists of 42% pasture, 6% regenerating manuka and kanuka and around 46% indigenous forest. Much of the native forest is located in the upper catchment.

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The upper portion of the catchment consists of steeply sloped terrain, whilst the lower portion of the catchment remains moderately sloped (approximately 4% stream bed slope) to the river mouth, west of Pakanae Cemetery Road.

The stream has been realigned to the western side of the valley and the SH 12 Bridge. Previously the channel had become seriously overgrown with weeds and its capacity had been reduced by a build-up of gravel on its bed. Downstream of SH12 Bridge the channel was choked by weeds, accumulated gravel and a collapsed farm bridge. Gravel accumulates immediately downstream of a ford in Cemetery Road at about the point where the stream becomes affected by the tide. Here the incoming tide swirls around the gravel deposit, eroding stream-banks, causing trees to be undercut and fall into the stream. Adjacent houses are threatened by stream-bank erosion.

Hills on the south western side of the catchment are inherently unstable with numerous slips and slumping. As most of these areas are in pasture, fine sediment loss is a problem.

Results from previous field survey indicate that the Awapokonui catchment's actual and potential erosion is moderate to severe within localised areas. Sediment from hillsides is directly discharged to the Hokianga harbour.

There is a risk that during high intensity storm events the likelihood of slips and earth movements and even debris avalanche, is high. This has the potential to affect local infrastructure, restricting access for residents. Some residential properties are at risk during extreme events.

It is for these reasons that the Awapokonui catchment ranks so highly on the NRC priority list.

1.2.3 Whirinaki River

The Whirinaki Catchment covers an area of approximately 43 square km. The catchment length is approximately 13 km and the width varies from 2km to 4km. The catchment has one main river, the Whirinaki, and three minor streams that have their confluences near the bottom of the catchment.

The upper reaches of the Whirinaki Stream are characterised by steep hillsides of native bush. The upper reaches of the stream have carved out a gorge along the valley floor, with sections of steep bed slopes and numerous waterfalls. The stream's main floodplain begins at approximately at the end of Jackson Road. The Whirinaki stream floodplain is approximately 500 metres wide with the stream meandering at the toe of the eastern hills. The lower reaches of the stream have built up natural levees from sediment deposition along the banks. The floodplain now rests below the top of the naturally formed levees. The outfall of the Whirinaki Stream is to a tidal estuary and the stream is tidally influenced to approximately 1 kilometre upstream of the SH12 Bridge on Whirinaki River.

Two of the three minor streams join the Whirinaki Stream above the tidal zone. The third stream is the largest of the minor streams and lies east of the Whirinaki Stream, joining it downstream of State Highway 12. This sub-catchment is characterised by more moderate slopes than the main Whirinaki Stream catchment and therefore has been predominantly developed for pastoral use. The floodplain for this tributary begins at about 2 kilometres upstream of SH12 and the main floodplain is generally at a lower elevation than the Whirinaki Stream floodplain. This stream has been heavily modified to drain the surrounding land.

The upper Whirinaki stream has been known to carry a mixture of boulders and softer finer sediments of Tangihua volcanic origin. Course gravel is dropped before the river emerges from the gorge, spilling out over an alluvial valley approximately two kilometres long and 0.5 kilometres wide. Further gravel is

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dropped at the top end of this section and the river then meanders on 10 to 20 metres wide bed. Here, as the river spills over its banks, it drops its silt load creating natural levees.

The river becomes tidal just downstream of the Whirinaki settlement, the State Highway 12 bridge and the alluvial flat. There is a sequence of firstly; a salt rush marsh and then a mangrove swamp. When the tide is in, an even greater proportion of flood flow can spill over the riverbanks and out towards the alluvial flats. Sediment deposited by the stream builds up and continues the natural levees out into the Hokianga harbour.

There has been historic soil conservation works along the banks with Cottonwood poplars (*Populus deltoides*) planted over 90 years ago to control stream-bank erosion. However, these trees are now mature and overdue for maintenance. In recent storms these trees have proven troublesome, with debris carried in floodwaters being caught on the logs, building dams and trapping gravel. This has resulted in reduced velocity of flow, causing more gravel accumulation and stream bed level rise. This debris dams the river resulting in gravel deposits that then divert the flow into the stream banks, causing stream-bank erosion.

High risk erosion areas within the catchment have experienced earth movements, and historic debris avalanches which can affect State Highway 12 within the Pukawa sub catchment. The Upokowhawa catchment is largely in pasture and is subject to deep seated soil movements which are difficult to manage and predict.

Results from previous field survey indicate the Whirinaki catchment's actual and potential erosion is moderate to severe within localised areas. Erosion of soils has a moderate effect on the productivity of the land and short to medium term effect on water quality due to proximity to the hydrological network.

The ranking of the Whirinaki catchment, 14th on the priority scale is largely attributed to the sheer steepness and the lack on any suitable cover to hold easily erodible soils.

1.2.4 Pawarenga Streams (Rotokakahi River)

The Rotokakahi River Catchment is located on the western coast of the Northland region in the Hokianga. It is approximately 60 km west of Kerikeri and drains to the Whangape harbour.

The headwaters of the Rotokakahi River are located along the northern boundary of the catchment, within the Maungataniwha Range. Maximum recorded elevations within this range are 744 m above Sea Level (aSL) at the Raetea Radio Mast.

Immediately to the south west of the modelled Rotokakahi Catchment are the Pawarenga Streams. A number of short streams that drain an area of the Warawara Forest to the alluvial fans of the lower reaches of the Rotokakahi River.

These watercourses are very steep and drop approximately 500 metres over a horizontal distance of 2 kilometres. These streams are characterized by very straight channels with very little meandering. The upper catchment is covered mainly by Indigenous Forest, descending to Manuka and Kanuka forest to reach exotic grassland in the low part of the catchment.

The Pawarenga Road crosses the catchment along the shore, passing over the four main streams.

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1.3 General Modelling Approach

The present project work continues with 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 provides a comprehensive model, accurate outputs and the ability to be continually upgraded.

1.4 Modelling Scope

The scope of work considered further analysis as previous 2010 models seemed to be underestimating the flood extents for the specified design events.

Each of the four sub-catchments has a tailored modelling approach dependent upon the particular catchment issues used to define the level of detail needed within the model. Additional storage, 2D polygons and cross sections were created in critical areas.

The modified models were tested against different storm profiles to evaluate which profile was more representative of the area. This analysis considered the previous NRC rainfall profile (developed during the previous Priority Rivers Project, 2010) and a rainfall profile derived by GHD for a 24 hours storm for the Far North District, in combination with different storms durations as advised by NRC.

Panguru model served as the pilot project, and it was the first to be modified and tested against the different design storms. These results were reviewed by NRC for approval of methodology and selection of the design storm profile.

Subsequent models were then improved under the same criteria used for Panguru, and the new details were reviewed and approved by NRC.

The methodology also included the setting and re-running of the Priority Rivers design storms as defined by the Priority Rivers Flood Risk Reduction project. Table 1-1 provides a summary of catchment details.

Modelling Objectives

The general objective of the model improvement is to increase the accuracy of the model results by improving the level of detail of the hydraulic features. The main objectives were as follows:

- Improve hydraulic object details (by including or improving storages, 2D meshes, cross sections, bridges, etc.).
- Incorporate new survey into the model where available.
- Test the response of the Panguru model to a set of rainfall storms to define the optimum pattern for the design event to be applied on the Hokianga model.
- Rerun design storms for the new modified model and generate new flood maps.

Issues identified in the original model

Issues identified in the previous Hokianga catchment models that have been subsequently addressed by the 2012 models are as follows:

- Flood extents seem to be underestimated
- Low level of detail in description of some flood plains and bridges

1 Introduction

- In some models, some of the sub-catchments were incorrectly connected to the river network
- Some models had significant revisions to network spills and links
- Incomplete storage areas

Data Collection and Analysis

2.1 Data Collection

NRC provided all of the data used to improve the models, extend the models and modify the hydrological models. The data received is listed and described below:

- Models delivered by MWH (Panguru and Rotokakahi-Pawarenga)
- New survey with photos (cross sections, bridges, culverts)
- GHD 24hrs rainfall profile to be tested.
- Debris level for event of 1999 (over Panguru, Awapokonui and Whirinaki catchments)

2.2 Survey

Survey data consisted in the following items:

- Survey of debris levels for the storm of April 1999.
- Survey for one bridge in Whirinaki catchment (area enclosed by the river and SH12)
- Survey for three culverts along Pawarenga Road (only culvert sizes, not inverts)
- Survey for one bridge in Awapokonui catchment (area backed up by SH12)
- Some other critical culverts in the Hokianga catchments.

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

2.3 Survey Data Processing and other GIS Tasks

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

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

2.4 Debris Level Points for Comparison

A large set of surveyed debris level points for the storm of April 1999 were available for the Panguru, Awapokonui and Whirinaki catchments. These were used to compare the model results against the surveyed levels for each of these catchments. For a proper comparison, the event of April 1999 was analysed to determine a suitable equivalent ARI storm.

Modelling Tasks

3.1 Previous IWRS Model Review

The Hokianga catchments were defined as part of the Priority River Flood Risk Reduction Project. The previous Hokianga models are listed in Table 1-1 in Section 1.

The previous Priority River models were used as the starting point for the current work. In general, they were stable, but lacked definition in a number of areas. The 2010 model presented some irregularities and deficiencies in critical areas. Improvements to the model were essential to assure a reliable representation of reality and accurate results.

In the following sections there is a description and analysis of the important aspects that were reviewed and improved in each model. Panguru River also contains the analysis of different rainfall profiles tested in the model to define the optimum design events for all Hokianga models.

3.2 Panguru River Model modifications (Catchment 12)

The Panguru model was generally in good condition considering it was a priority 3 model and some limitations were expected. Improvements were made in terms of better defining certain hydraulic features, mainly flood plains, storage areas and estuary, along with some culverts and bridges.

A summary of Panguru model improvements are listed below:

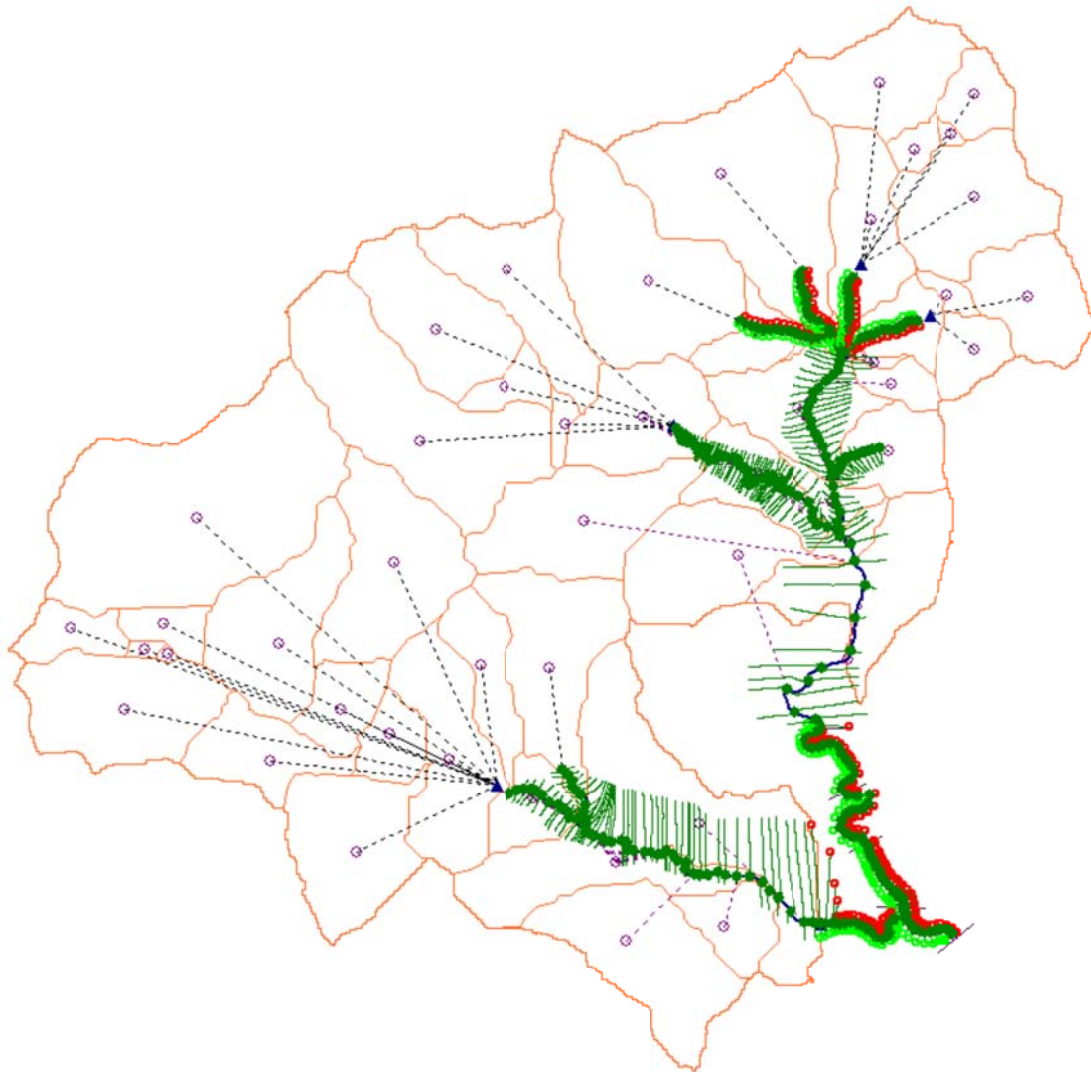
- Sub-catchment connection corrections. The drainage point for several sub-catchments was reviewed and reassigned where necessary. A delay time was added for those catchments discharging from far upstream.
- 2D polygons were added in several areas.
- Several storage areas were included for a better representation of flooded areas and volumes.
- Left and right bank lines were added to represent main channel and flood plains along cross sections. Different roughness was assigned for the main channel and flood banks.
- Additional cross sections were included in key locations such as contractions or bridges that were not included in the previous model. Some additional culverts were also included.
- Several cross sections were corrected for a better representation of volumes and parallel flow for the 1D model.
- The estuary element was rebuilt, improving representation of main channel, flood plains and tidal influence. Survey information available for this area from 2010, was useful for this task.
- Flood compartments were corrected where required.

Figures below show some of the most important improvements in the model. Figure 3-1 and Figure 3-2 provide a general overview the previous and new model layout and a description of the key refinements applied.

Figure 3-3, Figure 3-4 and Figure 3-5 provide a more detailed description of the new model modifications in three specific sections of the Panguru catchment.

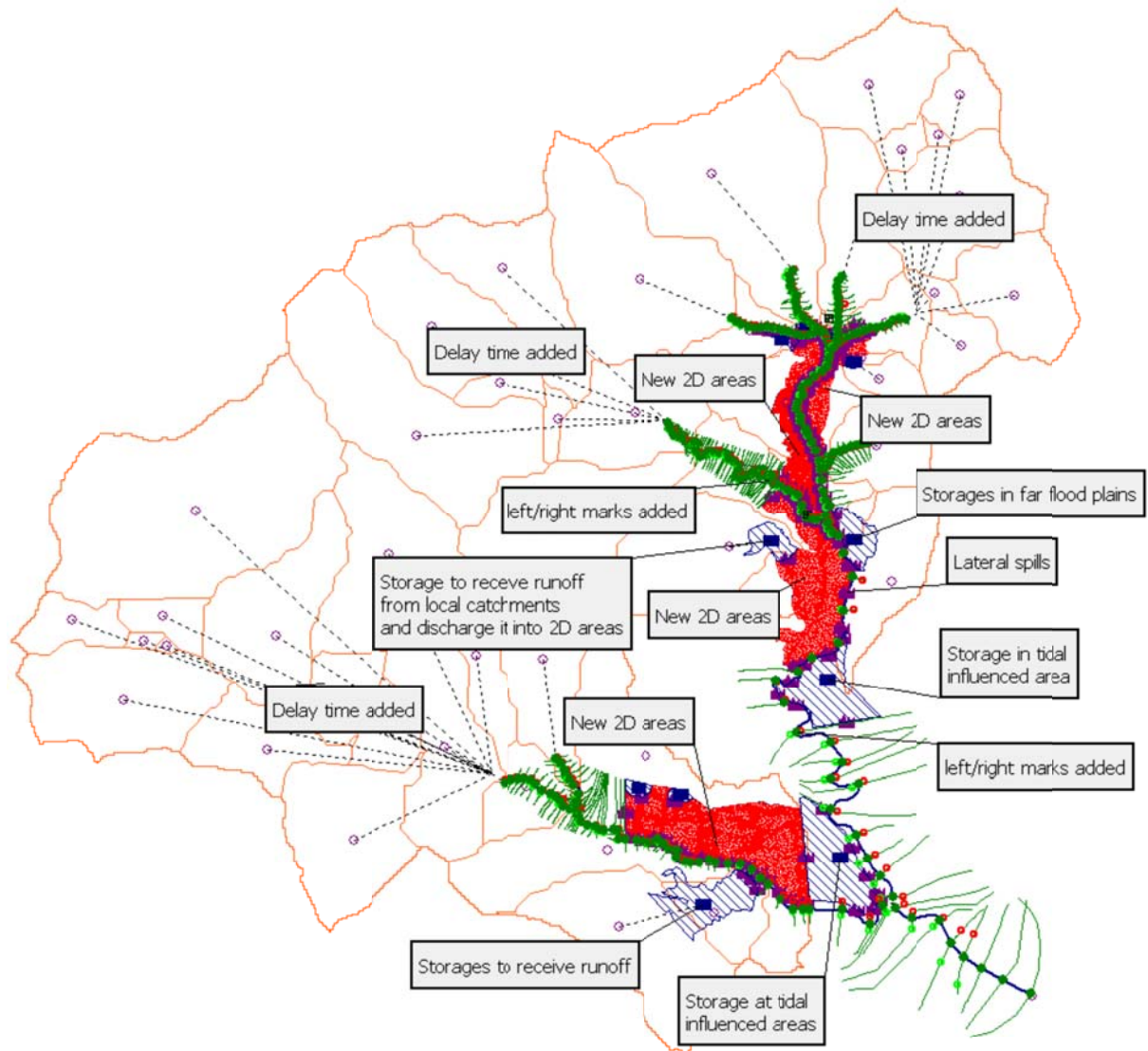
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Figure 3-1 Panguru Catchment; previous model layout



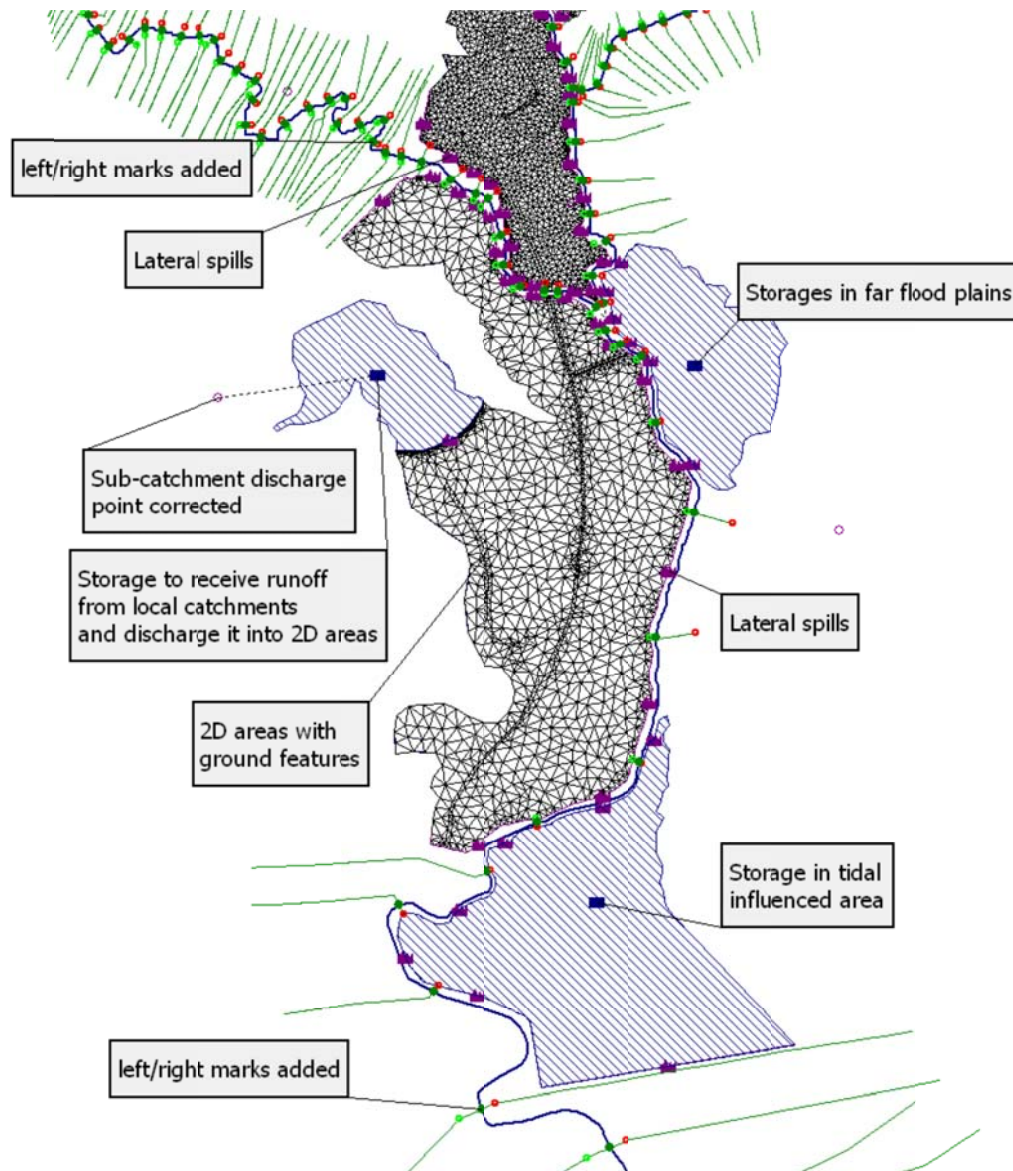
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Figure 3-2 Panguru Catchment; new model; description of main improvements



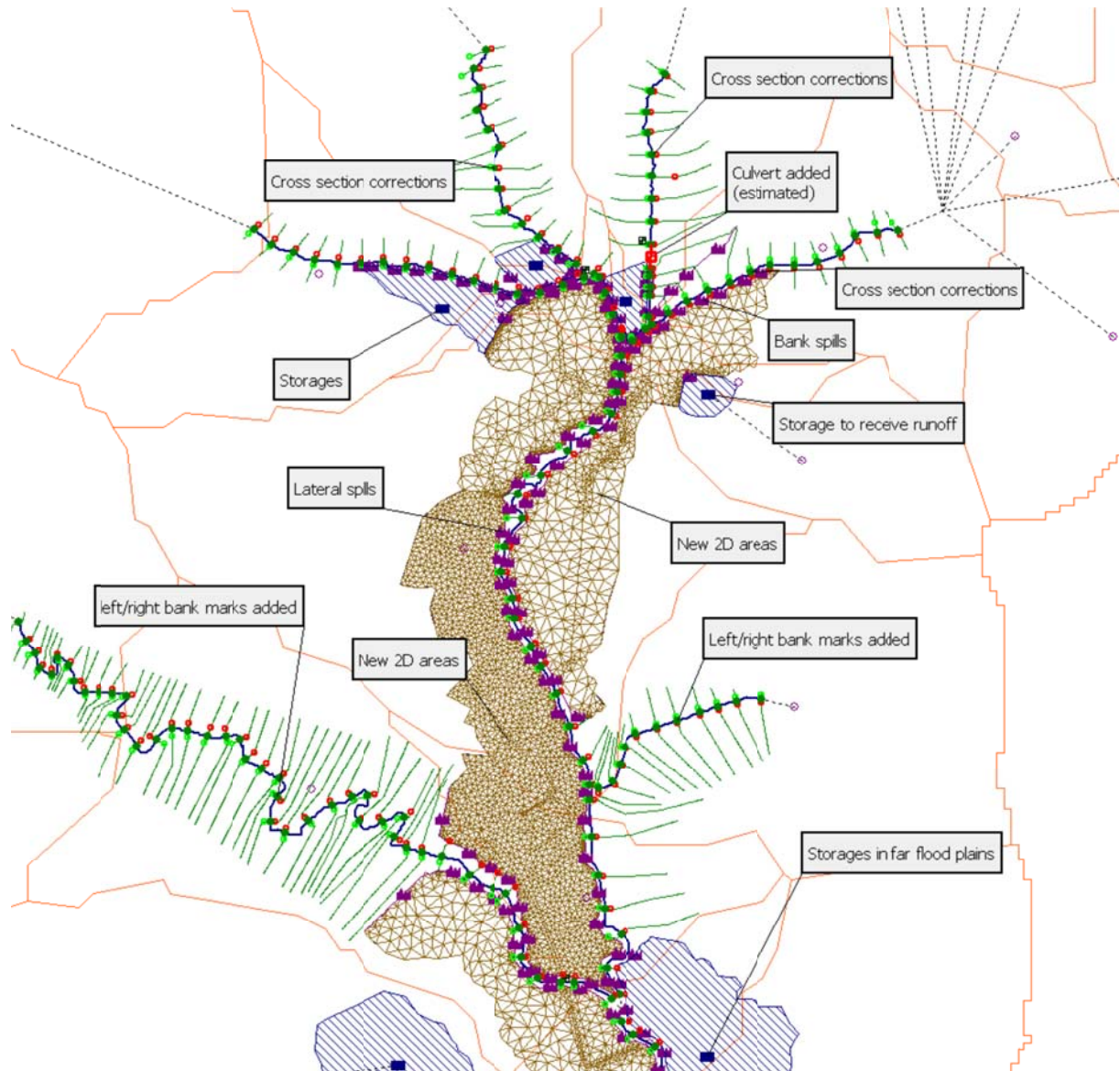
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Figure 3-3 Low catchment of Northern river in Panguru Catchment; new model details



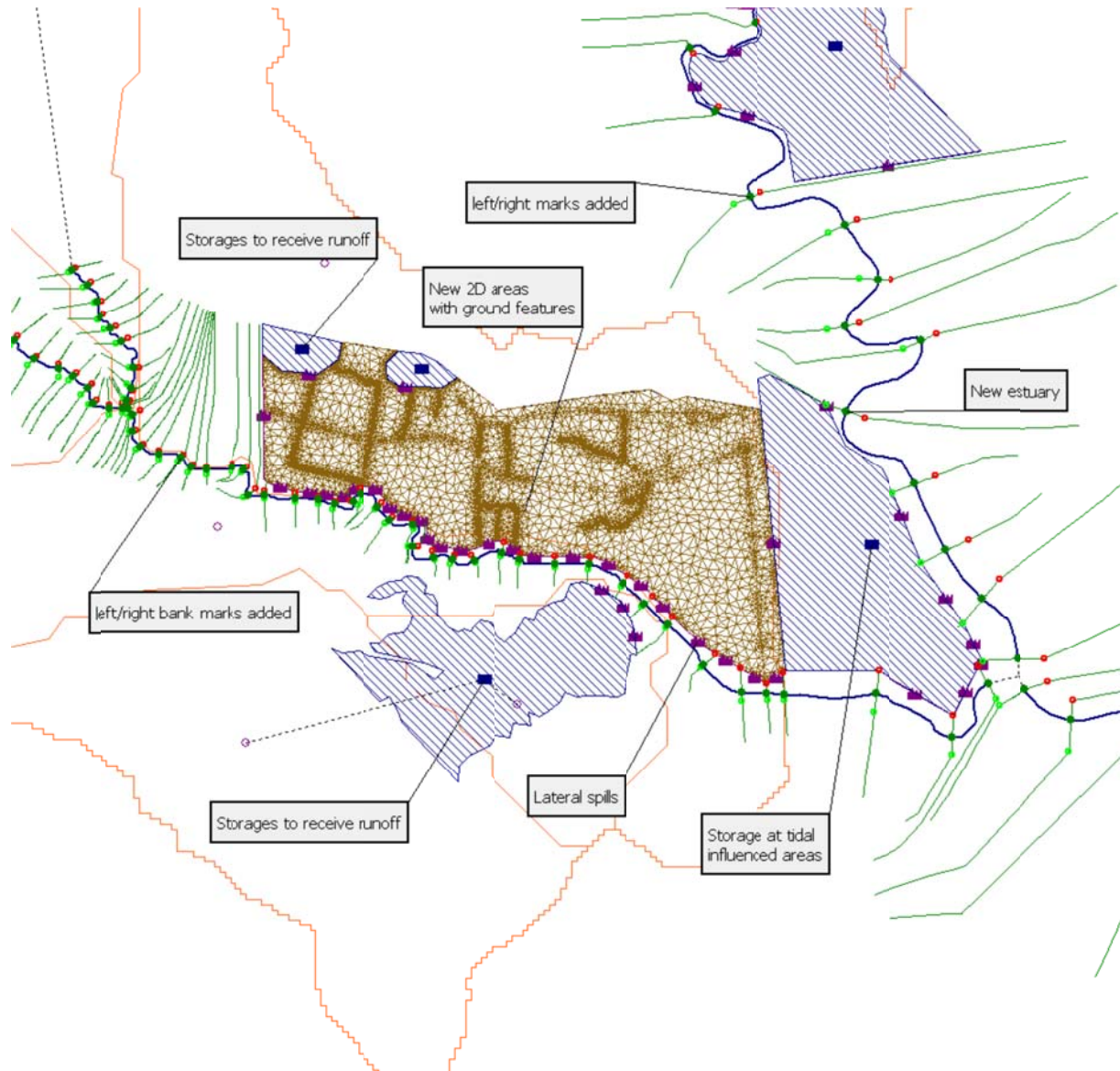
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Figure 3-4 Upper catchment of Northern river in Panguru Catchment; new model details



0 Modelling Tasks

Figure 3-5 Junction of Panguru Rivers at estuary; new model details



0 Modelling Tasks

3.3 Panguru Hydrological Analysis

The hydrological analysis considers the four scenarios summarised below and discussed in this section :

- **Scenario 1.** This scenario considers the previous NRC model developed by MWH, that ran with the previous 100yrs future and 6 hour design storm (or 150yrs and 6 hours rainfall from Hirds V3). The rainfall profile of this storm was defined on the NRC Priority Rivers Rainfall Assessment (Hydrological Report), 2010, and it was used for all previous Priority Rivers Models.
- **Scenario 2.** This scenario is the same as Scenario 1, but the initial conditions were significantly improved as in Scenario 1 they affected the accuracy of the flood extent. Revised initial conditions were chosen to make sure they were appropriate for the modelled solution (further details regarding this matter are provided below).
- **Scenario 3.** This scenario considered the new improved Panguru model, with new 2D areas, storages and more elements in the 1D model. More details regarding these improvements are explained in Section 4.1 of this document. To isolate the benefit of the new network improvements, the same design events used for Scenario 1 and Scenario 2 were run for Scenario 3 as well (previous rainfall profile, 100yrs future and 6 hour design event from Hirds V3).
- **Scenario 4.** This scenario was incorporated as the proposed rainfall profile developed for GHD for the Far North District over the new improved version of Panguru model. The rainfall profile was applied over the rainfall for a 100yrs future and 24hours storm (or 150yrs and 24 hours rainfall from Hirds V3).

The rainfall patterns, rainfall profiles and rainfall depths are summarized in the figures below.

0 Modelling Tasks

Figure 3-6 Rainfall patterns used in Hydrological Analysis

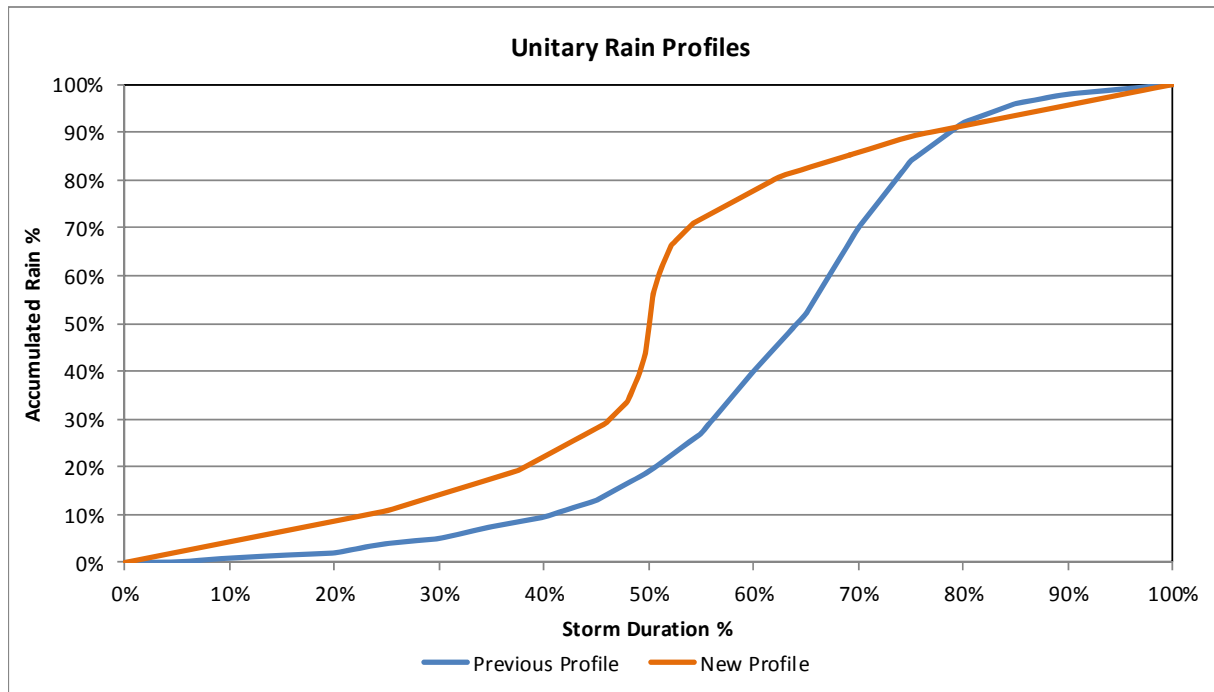
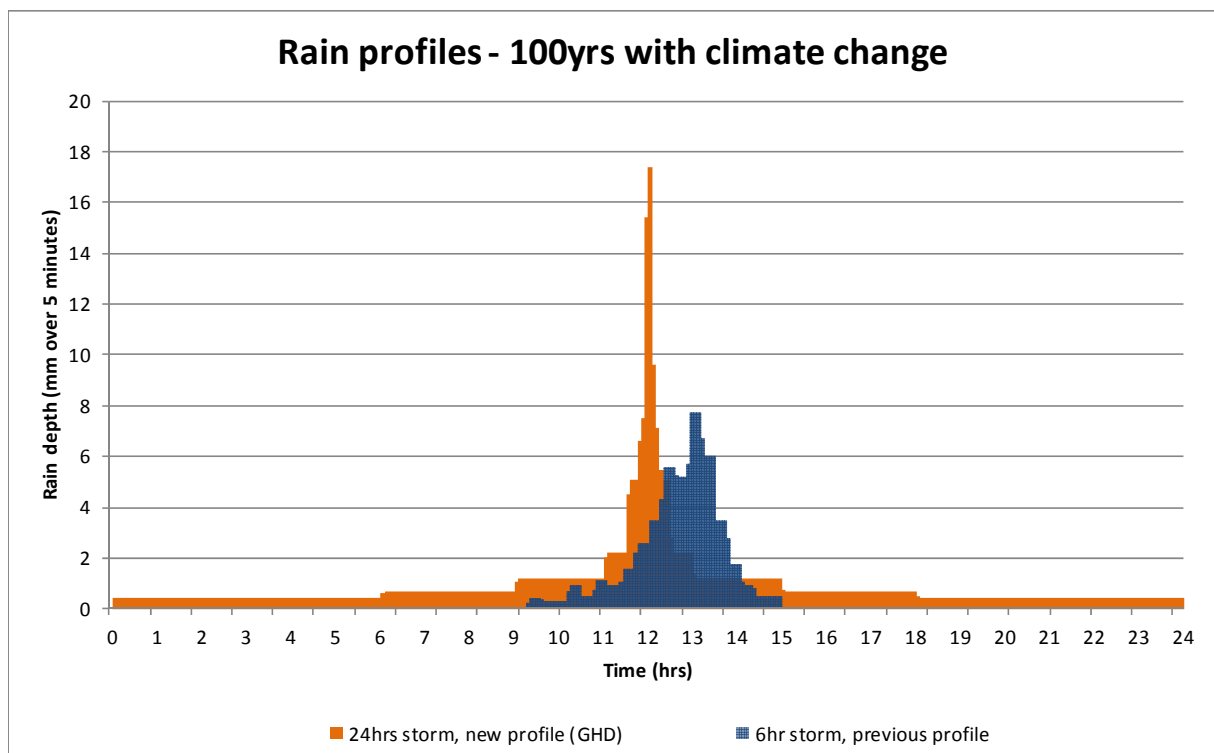


Figure 3-7 Rainfall profiles used for Panguru model tests



0 Modelling Tasks

Different locations were identified to compare the four scenarios; these locations are shown in Figure 3-8. Results showing the scenario comparisons are presented in Figure 3-9 to Figure 3-14. A short description of the main differences is explained below.

The initial conditions of Scenario 1 (previous model) indicated higher flood levels than those occurring at the peak time in some areas of the catchment. As the flood extent is defined as the maximum level occurring over the whole catchment at any time, the initial conditions would wrongly show up as part of the model solution. For that reason, in the previous modelling work the flood extent was taken for the time 05:35 which represents the flow peak time at the centre of the catchment. However, since the peak time does not occur at the same time on the whole catchment, the flood extent is underestimated in several areas. This might be one of the reasons of why the Panguru flood extent seems to be correct in some areas but underestimated in some others.

Scenario 2 (previous model with new initial conditions) is considered to provide a better base case to compare against Scenario 3 and Scenario 4. Improved initial conditions allow a more accurate flood extent taken as the maximum of the whole simulation in every place.

Scenario 3 (new model, previous rainfall profile with 6 hr storm). This scenario has a better representation of volumes and flood levels as it includes several storage areas and 2D model areas over the catchment, connected with lateral and on-line spills to the main channel modelled as 1D. It also considered an improved description of the tidal area outside of the LiDAR coverage, allowing a better representation of the tidal influence. Flood levels and flows are higher in some places and lower in others compared with Scenario 2. The same rainfall profile has been used, and any resulting differences are only result of a more detailed model built.

Scenario 4 incorporated the new 24 hour rainfall profiles modified from TP108 and developed by GHD. Both, the previous and current model use the US SCS method based in a distributed CN value along the catchment. As the storm duration is longer than the previously used 6 hour event, the soil saturation is higher in the longer storm, and the flood levels are generally higher all over the catchment.

For Scenario 4, the peak rainfall of the new profile occurs 12 hours after the storm begins. The tide series was originally set to meet the previous 6 hours storm; for that reason the tide series was corrected to match the peak flow of the new rainfall at the downstream boundary condition.

Shape files of the flood extent for all four scenarios were provided to NRC for review and analysis. As a result of this analysis it was decided that the new GHD rainfall profile, with a 24 hour storm was to be used for all Hokianga models together with a 24 hours rainfall depth from HirdsV3 for the 150yrs (or 100yrs with climate change) and 10yrs storm events.

0 Modelling Tasks

Figure 3-9 Comparison between scenarios for the River Section ID 12_04_2644617

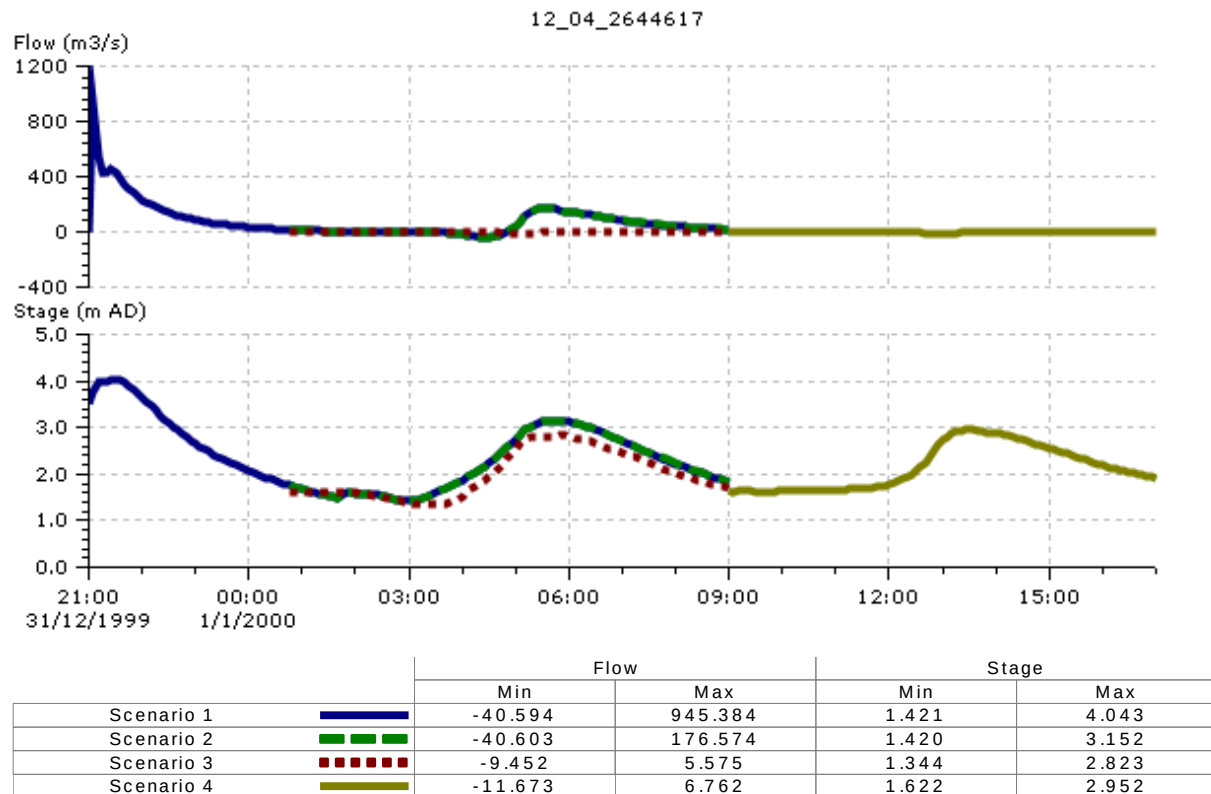
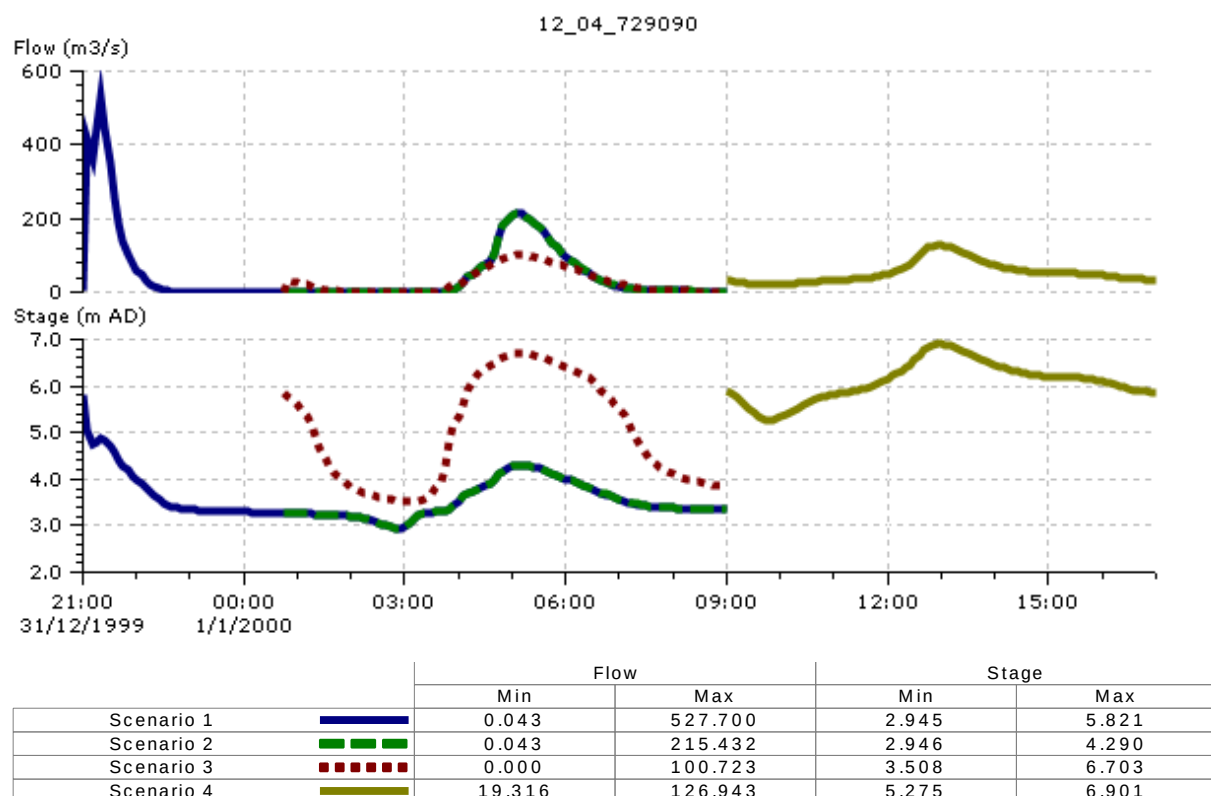


Figure 3-10 Comparison between scenarios for the River Section ID 12_04_729090



0 Modelling Tasks

Figure 3-11 Comparison between scenarios for the River Section ID 12_05_00259

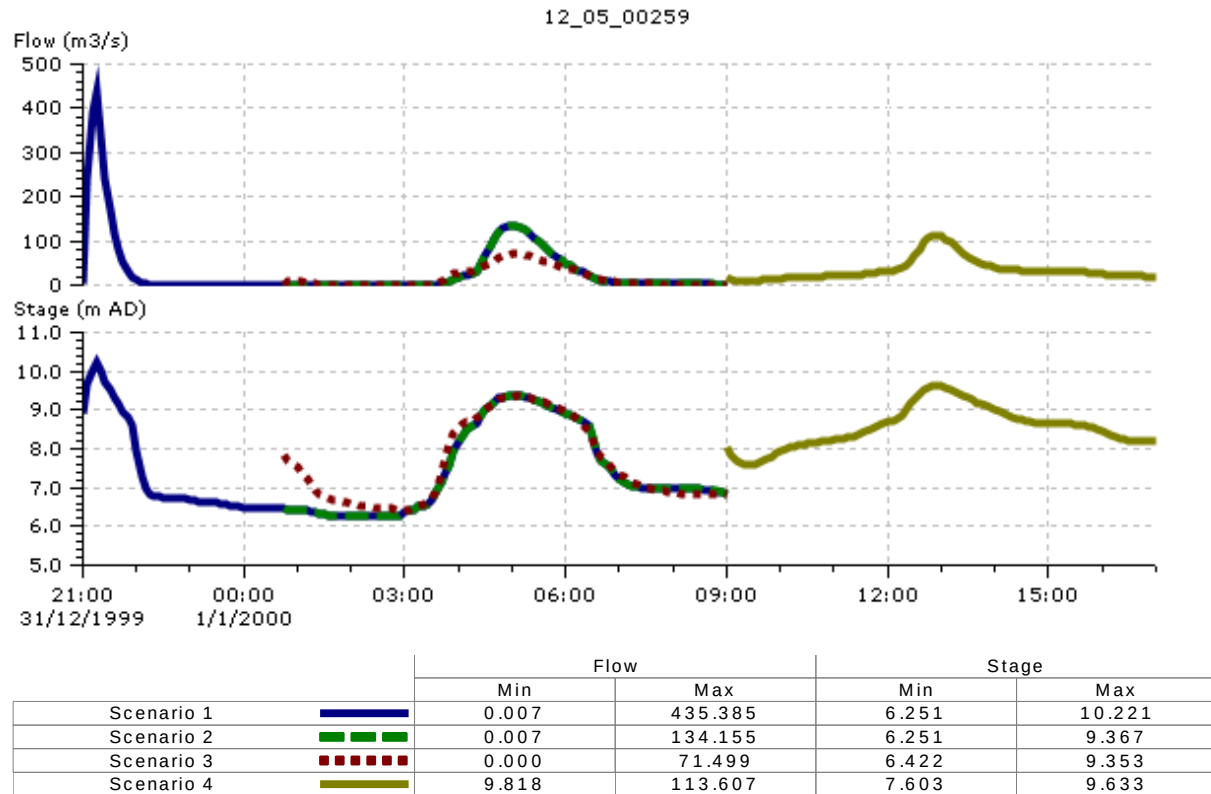
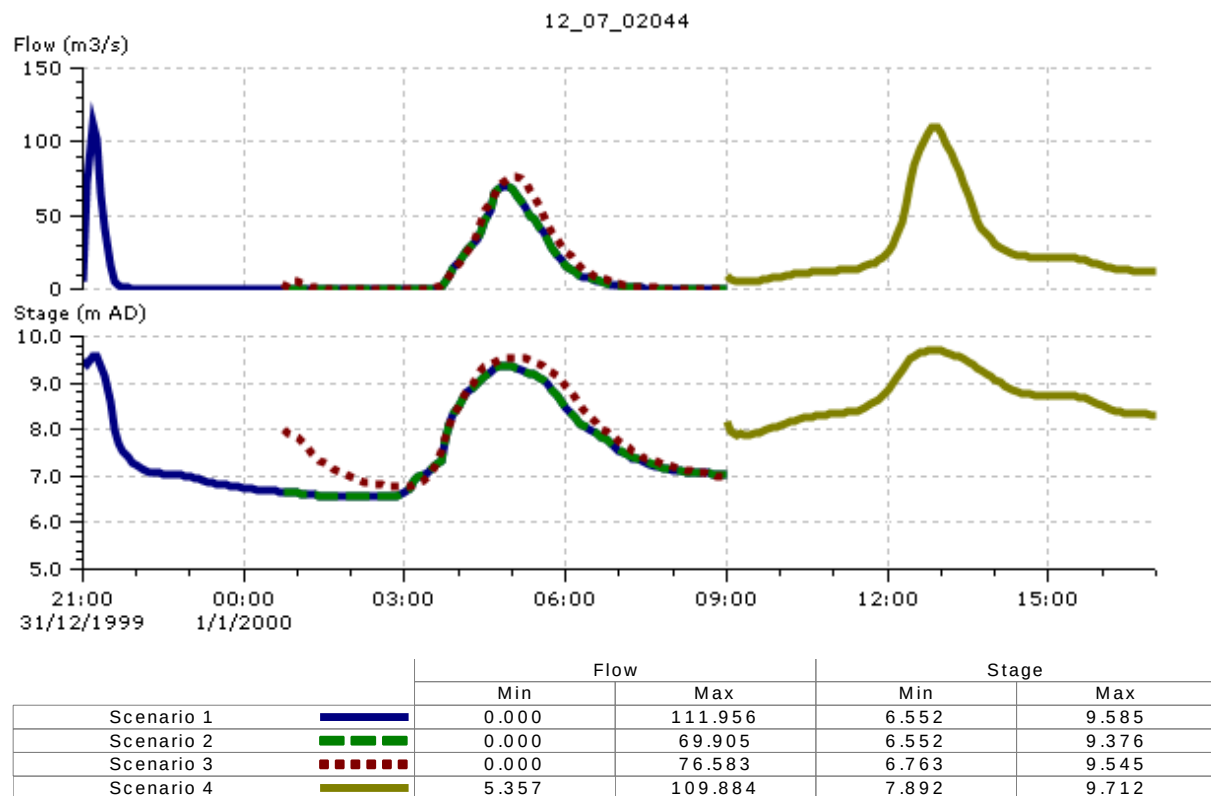


Figure 3-12 Comparison between scenarios for the River Section ID 12_07_02044



0 Modelling Tasks

Figure 3-13 Comparison between scenarios for the River Section ID 12_XS_04

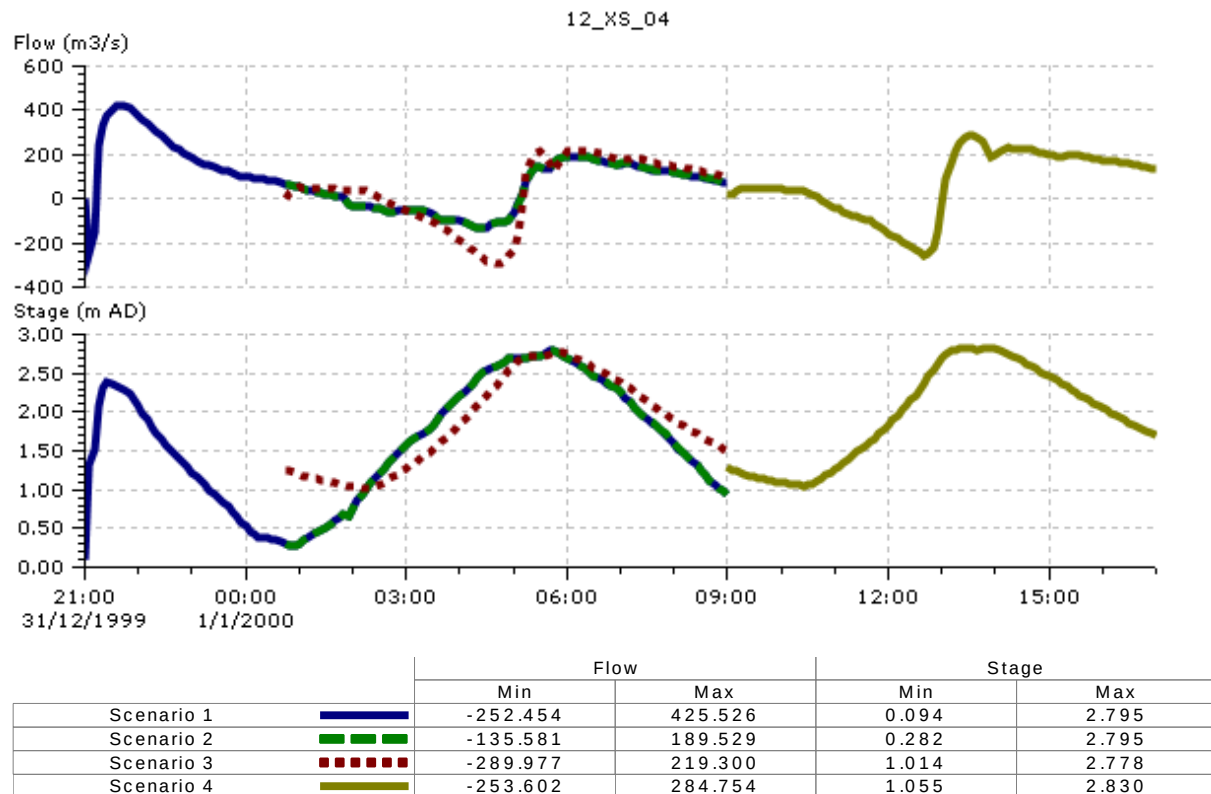
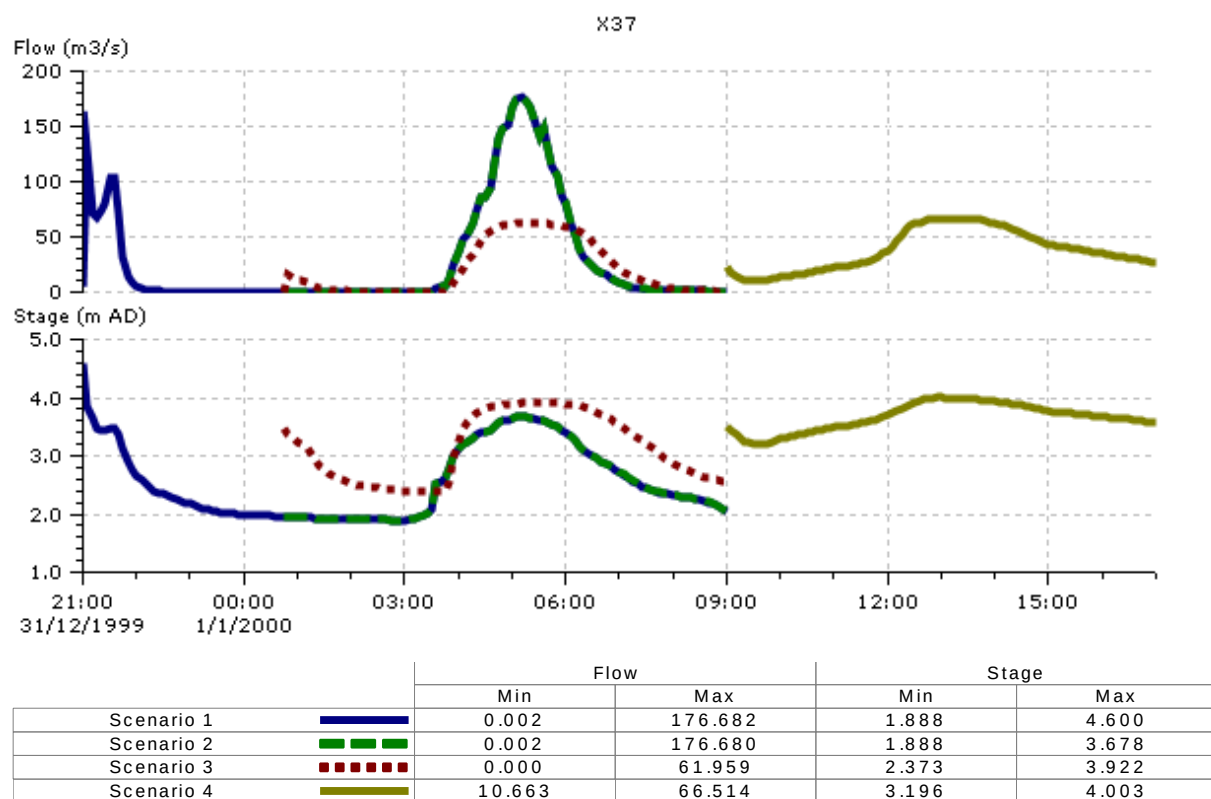


Figure 3-14 Comparison between scenarios for the River Section ID X37



0 Modelling Tasks

3.4 Awapokonui River Model modifications (Catchment 13)

The Awapokonui model was generally in good condition considering it was a priority 3 model and limitations were expected. Improvements were made in terms of a better definition of certain hydraulic features, mainly flood plains, storage areas and some critical bridges and culverts.

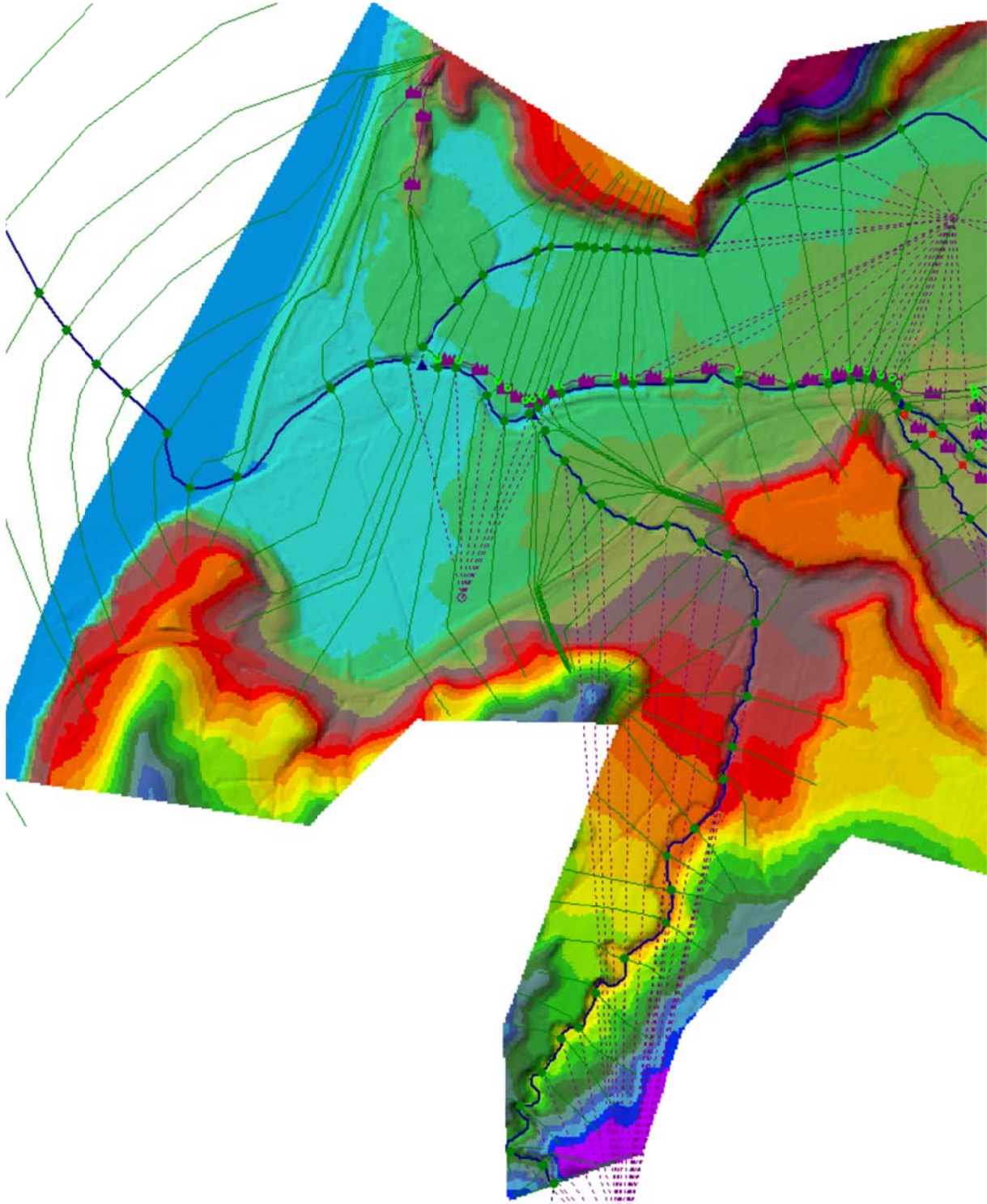
A summary of Awapokonui model Improvements are listed below:

- 2D polygons were added in several areas, especially in the lower catchment.
- 2D representation of overflows over SH12, together with the flood plains at the upstream and downstream side of it.
- Several storage areas included for a better representation of flooded areas and volumes.
- Several new spill objects created along most river and streams banks to connect 1D river model to storages and 2D meshes. Levels were based on LiDAR information.
- Improvement in the distribution of runoff over the streams and flood plains, especially on the lower catchment.
- Left and right bank lines were added in main rivers to represent main rivers and flood plains along cross sections. Different roughness was assigned for the main channel and flood plains.
- Additional cross sections were included in key locations such as contractions or bridges that were not included in the previous model. Some critical culverts and one bridge link also were included.
- Flood compartments were corrected were required.

The Figures below show some of the most important improvements in the model. Figure 3-15 and Figure 3-17 show the previous model in the lower and middle areas of the catchment respectively. Figures 3-16 and 3-18 show the revised model with a description of the improvements for the same respective areas. Later Figure 3-19 provides details of the model improvements made in the vicinity of the SH12 Bridge.

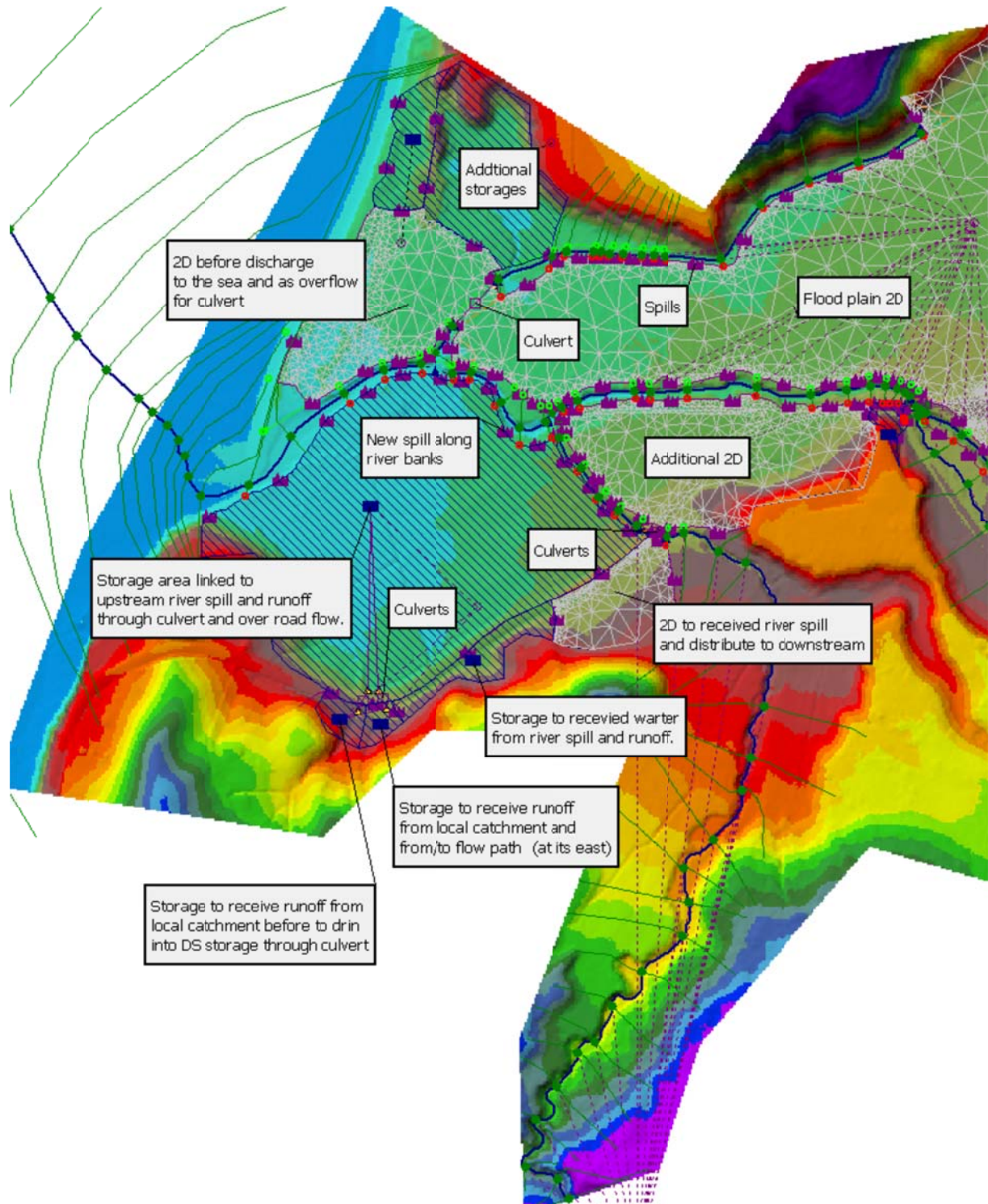
0 Modelling Tasks

Figure 3-15 Previous Awapokonui model; lower catchment



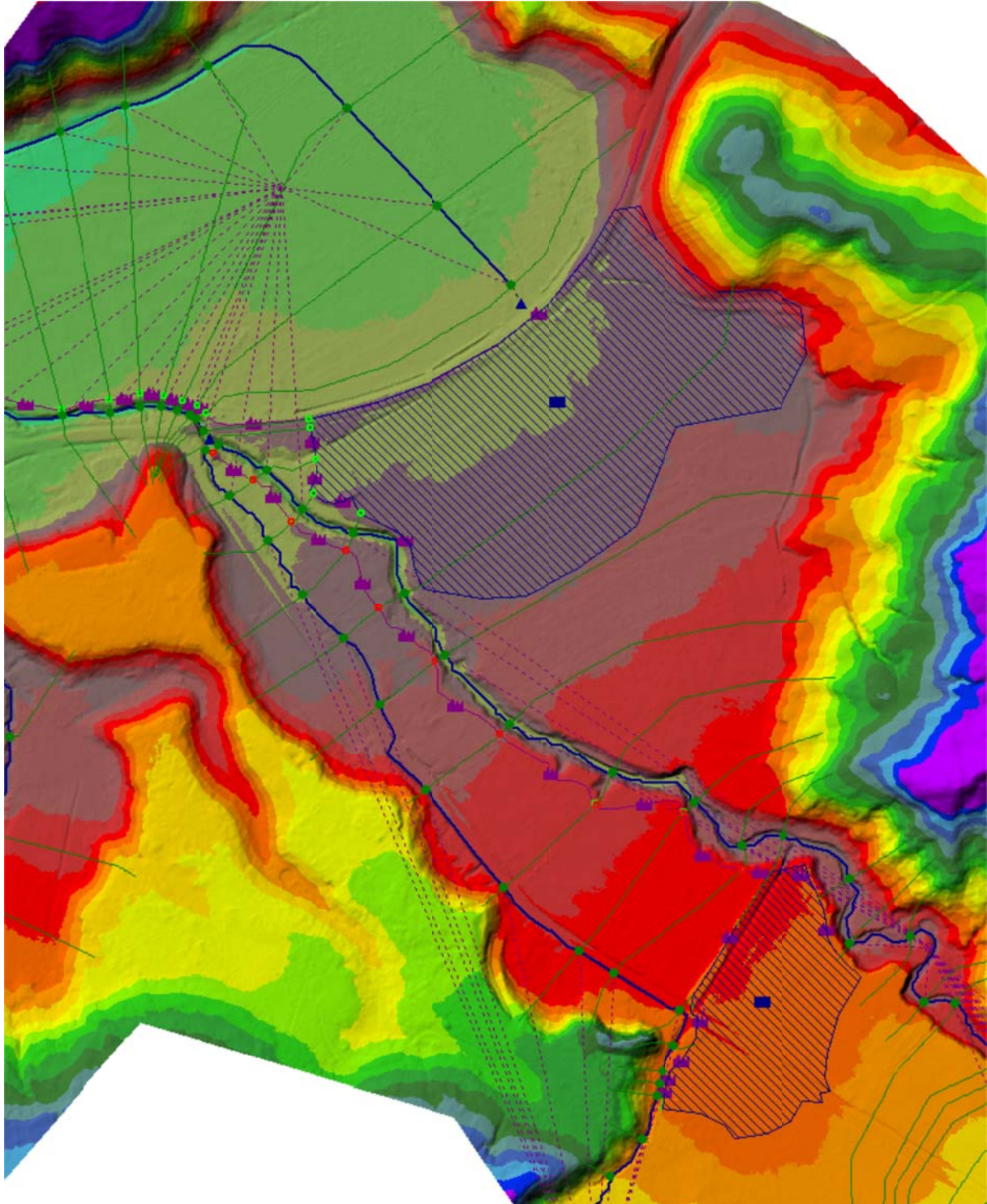
0 Modelling Tasks

Figure 3-16 Improved Awapokonui model; lower catchment



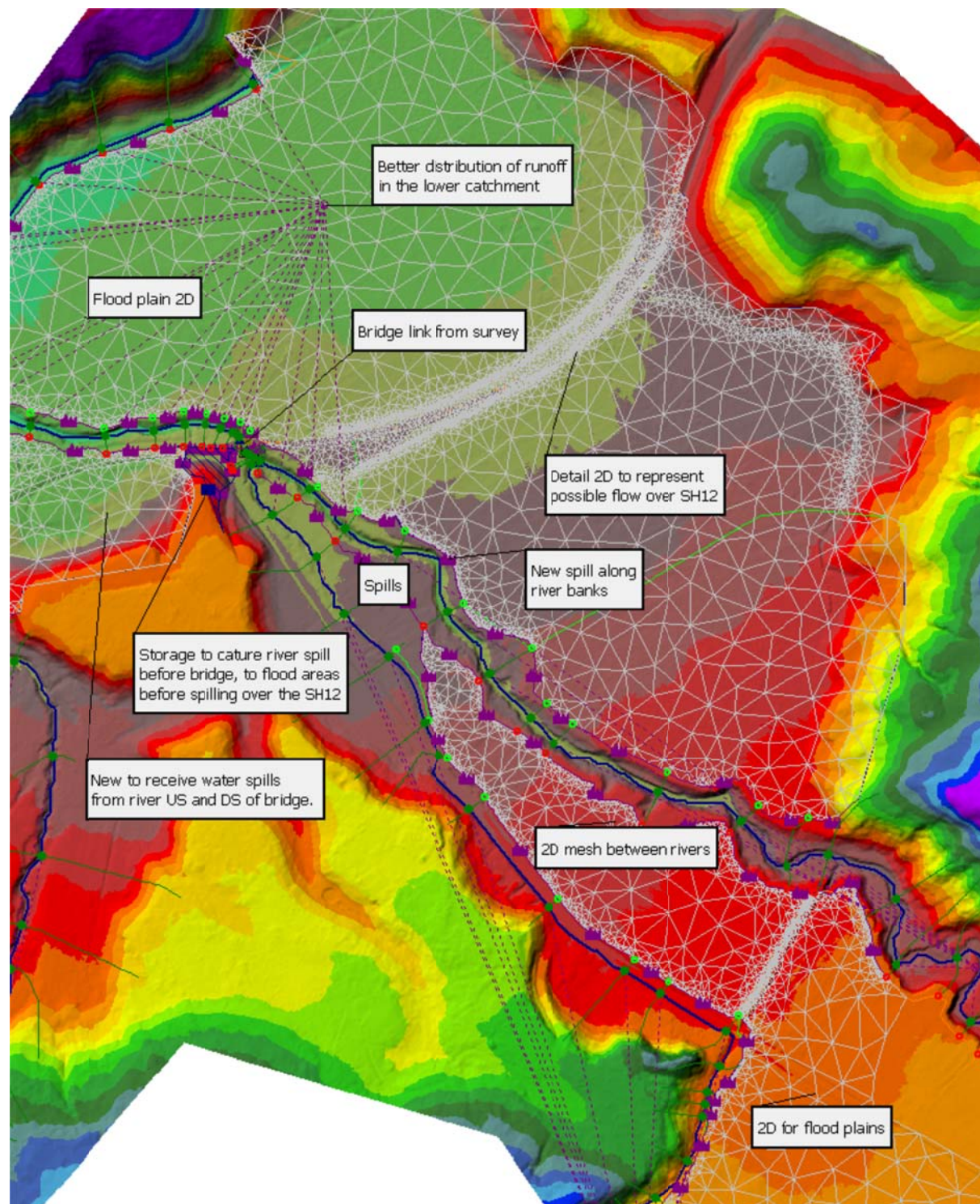
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Figure 3-17 Previous Awapokonui model; middle catchment



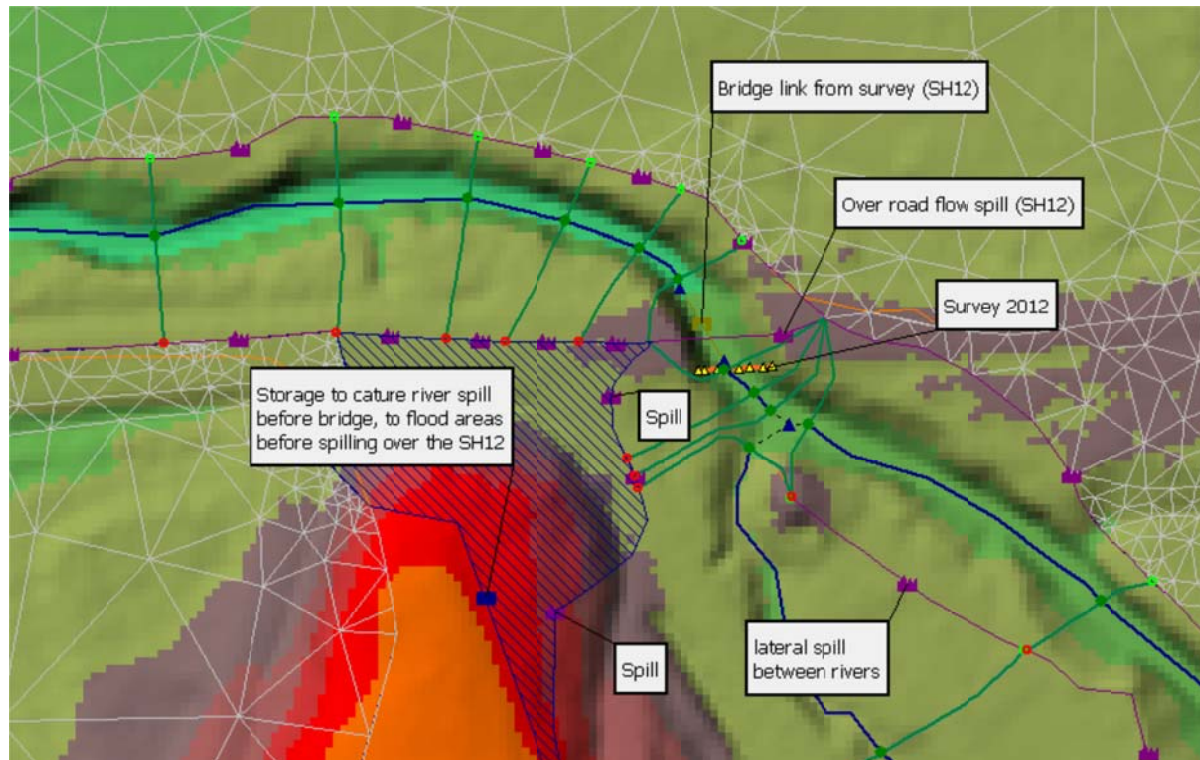
0 Modelling Tasks

Figure 3-18 Improved Awapokonui model; middle catchment



0 Modelling Tasks

Figure 3-19 Improved Awapokonui model; SH12 bridge details



0 Modelling Tasks

3.5 Whirinaki River Model modifications (Catchment 18)

The Whirinaki model was generally in good condition considering it was a priority 3 model and limitations were expected. Improvements were done in terms of a better definition of certain hydraulic features, mainly flood plains, storage areas and some critical sections.

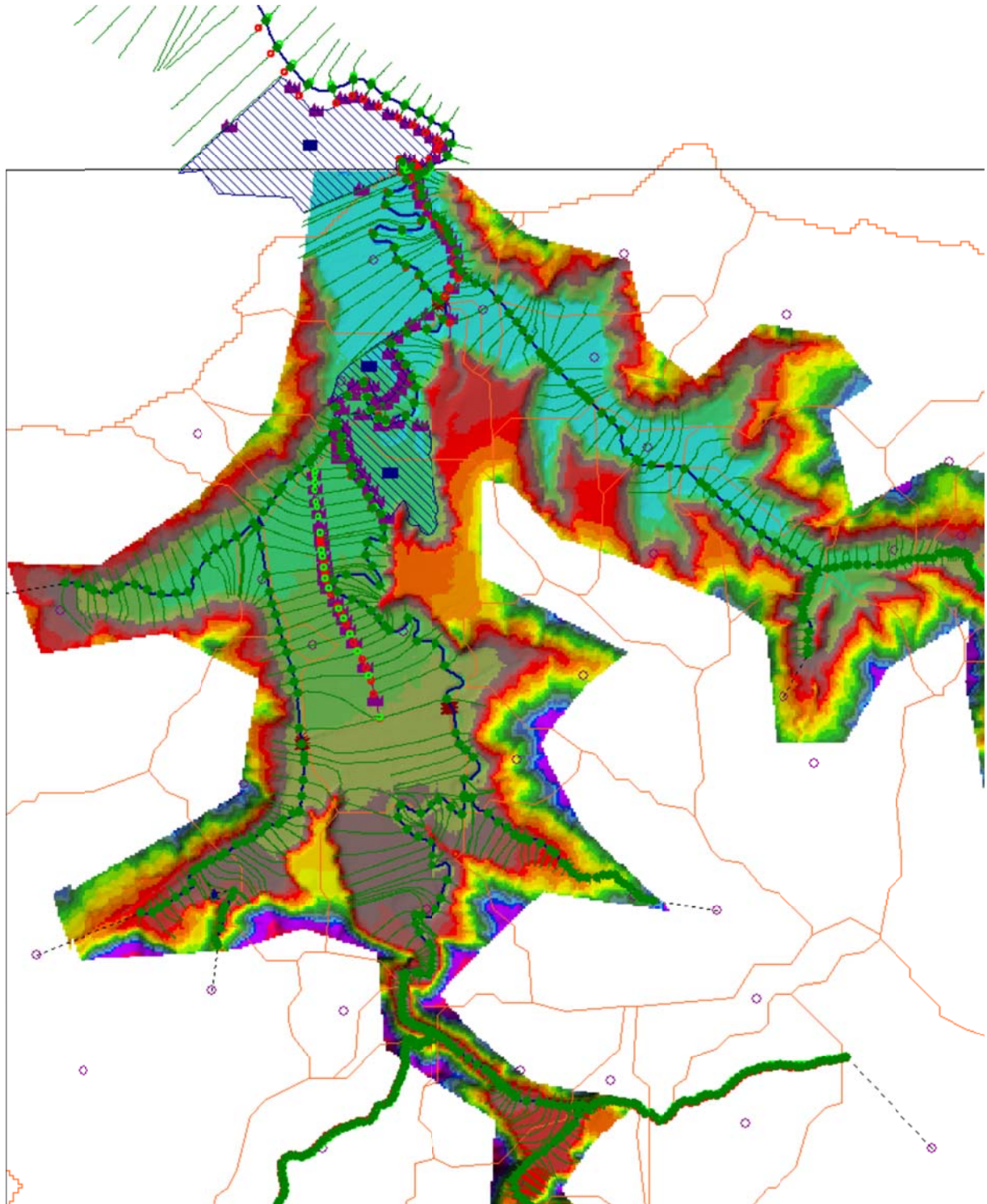
A summary of Whirinaki model Improvements are listed below :

- 2D polygons were added in several areas, especially in the lower catchment.
- Storage areas included around some river junctions for a better representation of flooded areas, volumes and exchange of water.
- Several new spill objects created along most river and streams banks to connect the 1D river model to storages and 2D meshes. Levels are based on LiDAR information.
- Left and right bank lines were added in main rivers to represent main rivers and flood plains along cross sections. Different roughness was assigned for the main channel and flood plains.
- Additional cross sections were included in key locations such as contractions or bridges that were not included in the previous model.
- New bridges and culverts survey was included in the model.
- Flood compartments were corrected were required.

The figures below show some of key improvements made to the model. Figure 3-20 and Figure 3-21 show the previous and revised model details, with a general description of the improvements made. Figure 3-22 and Figure 3-23 provide a more detailed description of the new model modifications in the lower and middle areas of the catchment respectively.

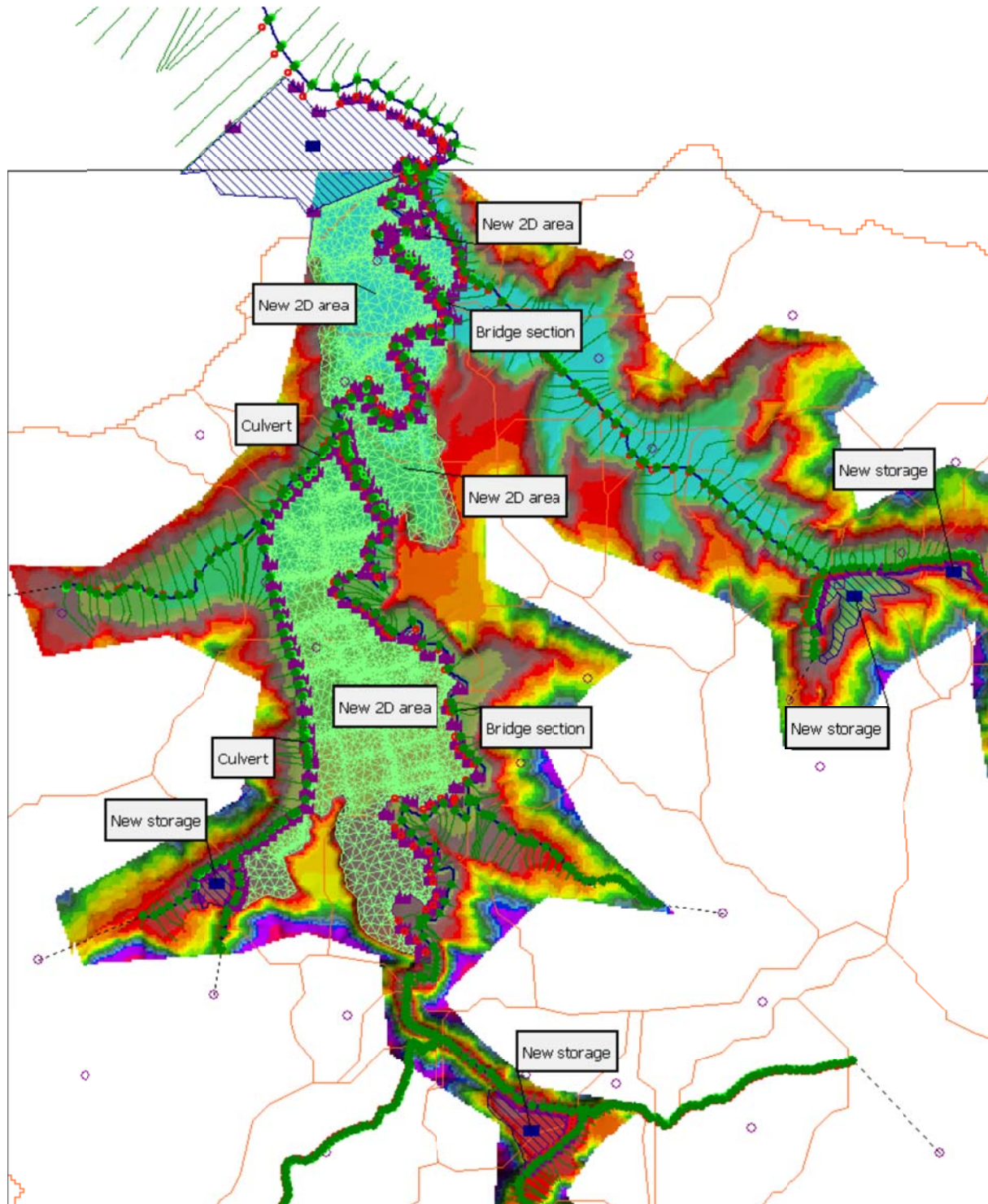
0 Modelling Tasks

Figure 3-20 Previous Whirinaki model; general view



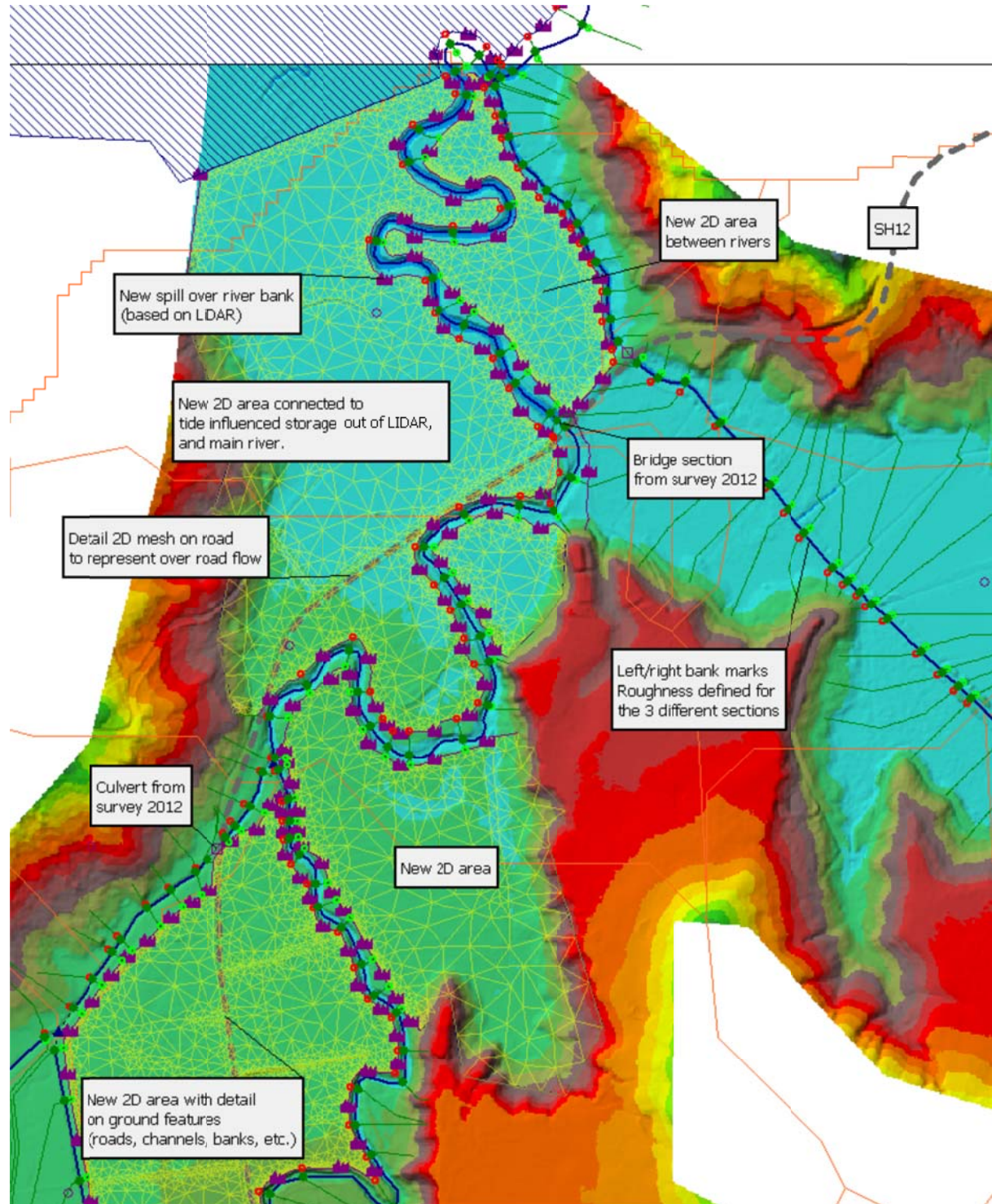
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Figure 3-21 Improved Whirinaki model; general view and description of main changes



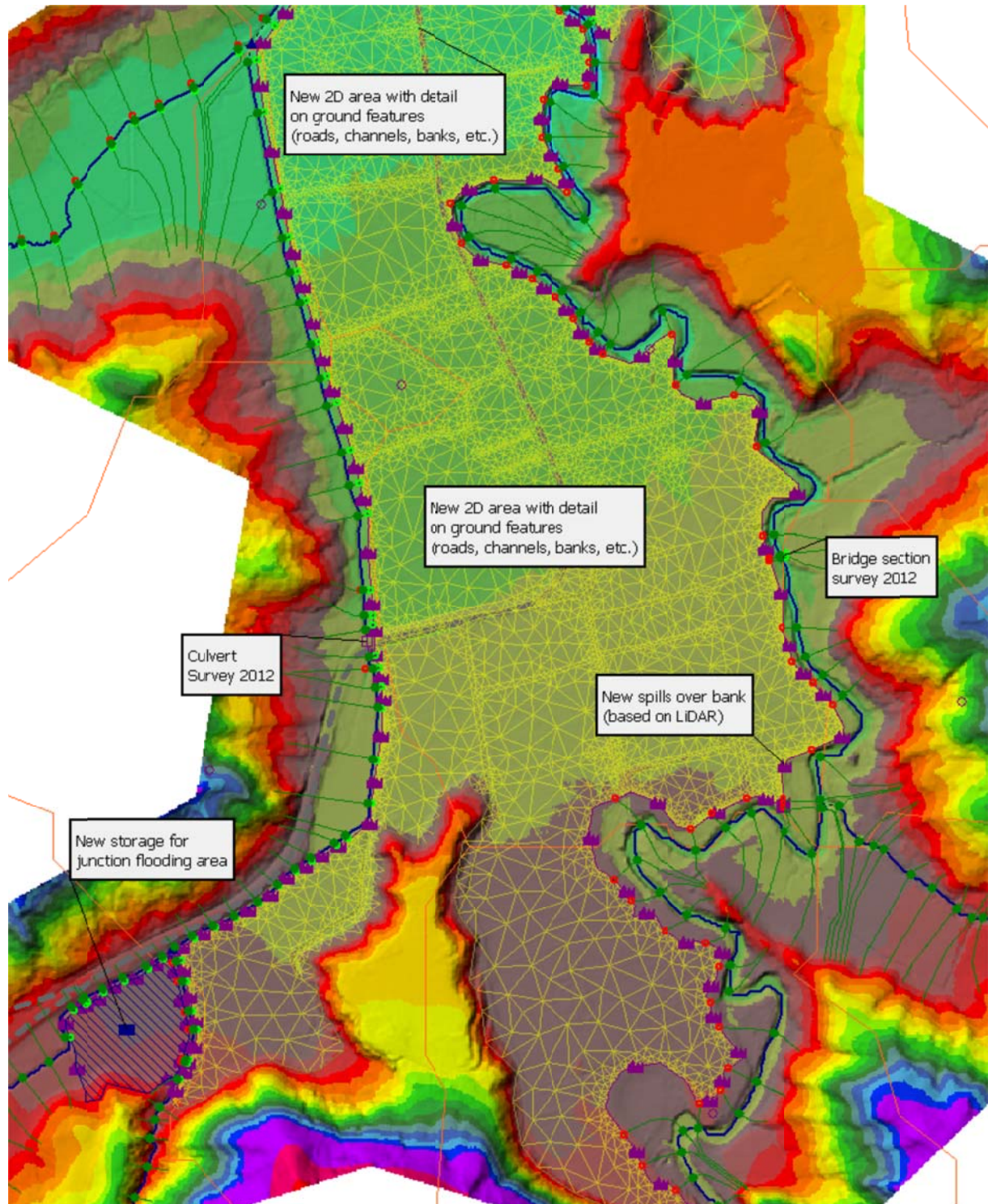
0 Modelling Tasks

Figure 3-22 Improved Whirinaki model; lower catchment and description of main changes



0 Modelling Tasks

Figure 3-23 Improved Whirinaki model; middle catchment and description of main changes



0 Modelling Tasks

3.6 Pawarenga Fans Model modifications (Catchment 10)

The Pawarenga Fans model was generally in poor condition considering it was a priority 2 model and a more detailed output was expected. Improvements were made in terms of a better definition of certain hydraulic features, mainly through incorporation of a 2D mesh for the fans, further details for culverts under the Pawarenga road, and a more detailed distribution of the runoff over the flooding areas.

A summary of the Pawarenga Fans model improvements are listed below:

- The model was almost completely re-built as the old model was showing very little of the flooding on the fans. The new model considered all the upper catchment as 1D model, draining into a 2D mesh of the lower catchment and the main 1D streams (four Pawarenga streams as in the previous model).
- The four 1D streams have more detail, with more river cross sections.
- The lower catchment was considered as a full 2D mesh with a rainfall on cell. This allows a better definition of the small flooding areas, and not only around the 1D streams.
- Several spill sections were defined over the stream banks around the 1D streams. The elevation for these spills was taken from the LiDAR ground model.
- The rainfall hyetograph on the 2D areas was defined to be the same as in the upper catchment but times 0.9. This factor comes from the HirdsV3 distribution of the 100yrs with climate change rainfall depth, the same as was used to define the rainfall distribution for all NRC models.
- Only the effective rainfall was applied on the 2D area. The effective rainfall was calculated using US SCS method as in the rest of the catchment 10. The CN value was 75; that is a conservative average of the CN in the lower catchment calculated with the same methodology used in previous NRC models.
- The resolution of the mesh was refined on the streams, roads and special ground features. The resolution for flood plains and high hills was relatively rough as it is only intended to catch and distribute the rainfall. These big cells on the hills won't be used for 2D mapping as the interpolation of the flooding surface is not sufficiently accurate.
- One 1.5m x 1.5m box culvert was included for each of the two Pawarenga streams. The invert levels were estimate to be 2.0m under the road level. The estimated invert levels were 0.4mOTP and 0.8mOTP that are under the LiDAR levels in that area. For that reason, the bottom level of the 1D river sections were reduced from a few metres upstream of the bridges to the sea. These box culverts were modelled with an obstruction of 50% of the capacity, to take into account possible debris blocking the flow during big events. Over the road spill was also included for these two locations.
- For the other two streams (western and eastern streams on the fans), the Pawarenga Road was modelled as an open river section with a rectangular shape with 1.5m width, and a invert level also 2m under the LiDAR road level.

Figure 3-24 provides a general overview of the all new features in the new Pawarenga model. Figure 3-25, Figure 3-26 and Figure 3-27 provide a set of comparisons between the previous model and new model details.

0 Modelling Tasks

Figure 3-24 New Pawarenga model; general description

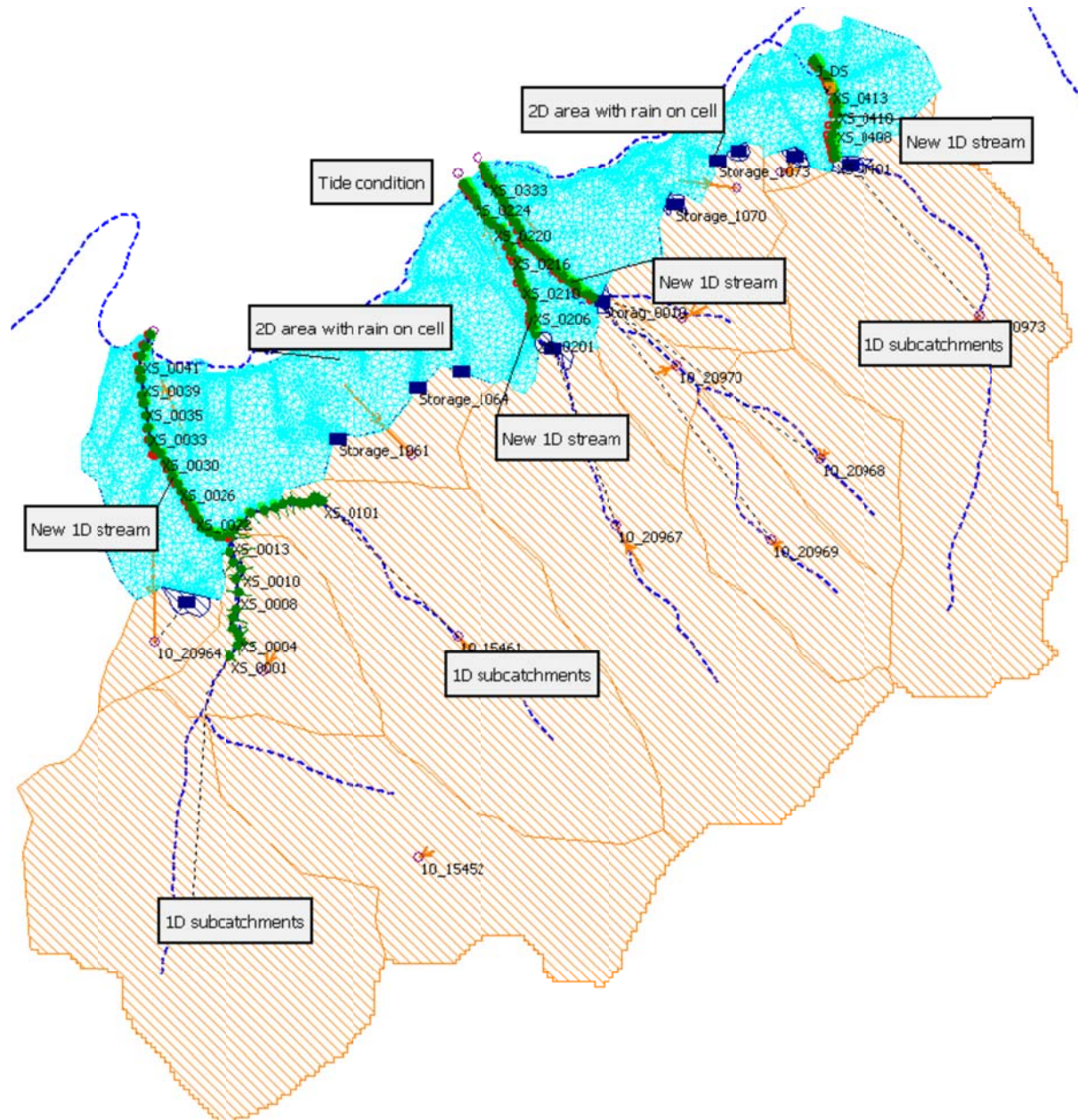
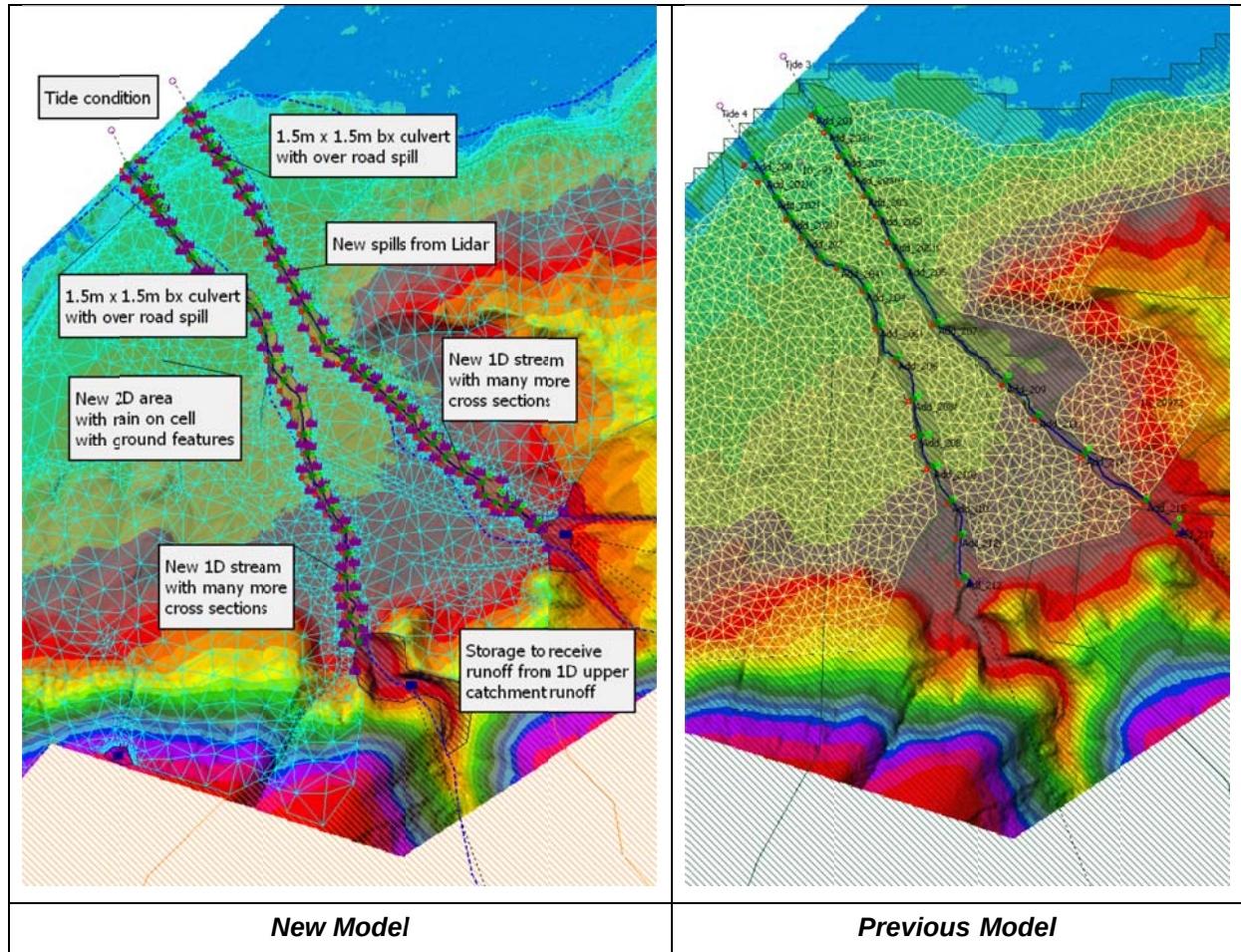


Figure 3-25 New Pawarenga model against previous model; western side stream



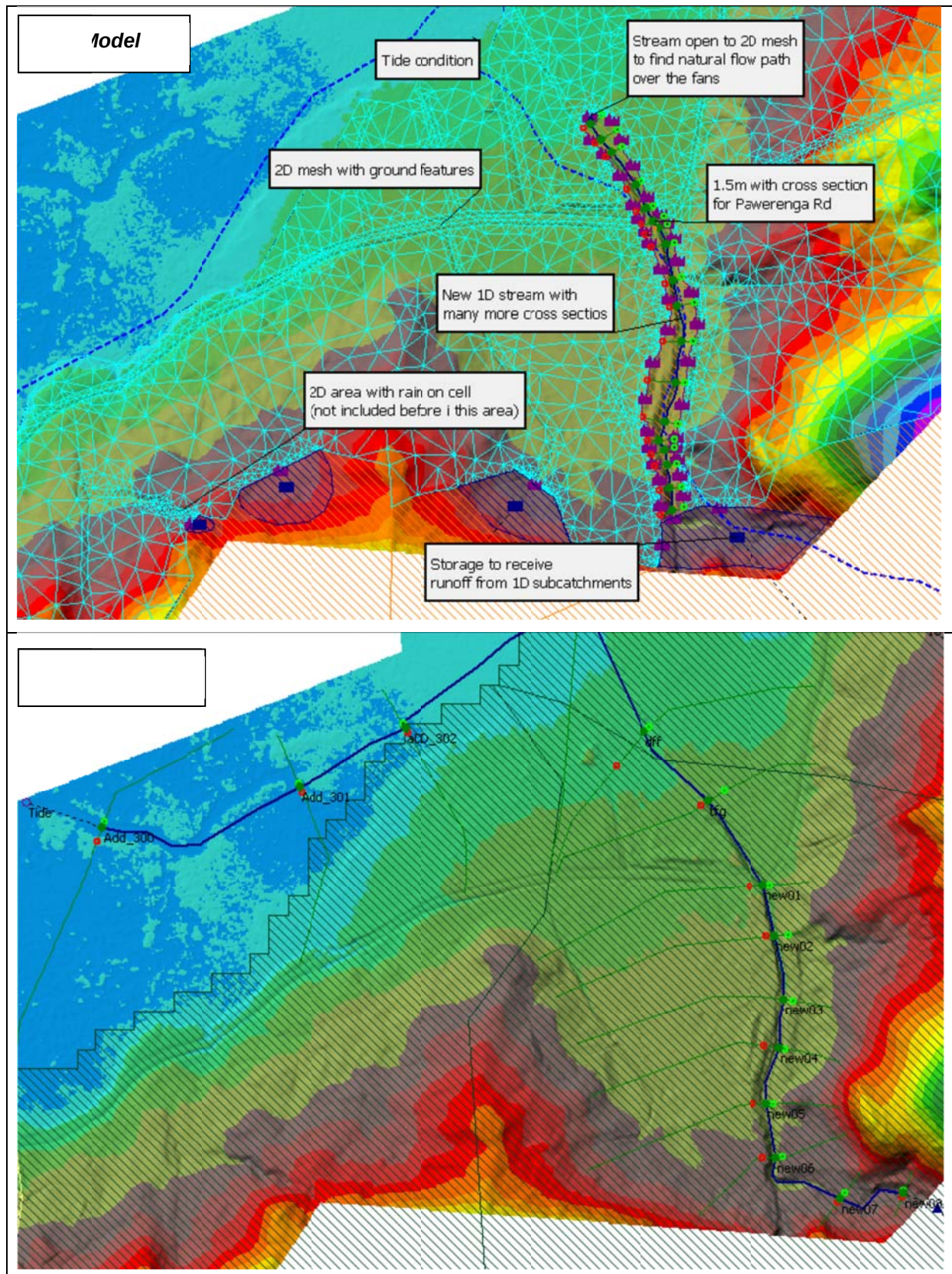
0 Modelling Tasks

Figure 3-26 New Pawarenga model against previous model; Pawarenga streams



0 Modelling Tasks

Figure 3-27 New Pawarenga model against previous model; Ngaue stream (eastern side)



0 Modelling Tasks

3.7 Rotokakahi River Model modifications (Catchment 10)

The Rotokakahi River model was initially intended to be run with no modification, however some critical deficiencies were identified in the model and some improvements were made before re-running it with the design events.

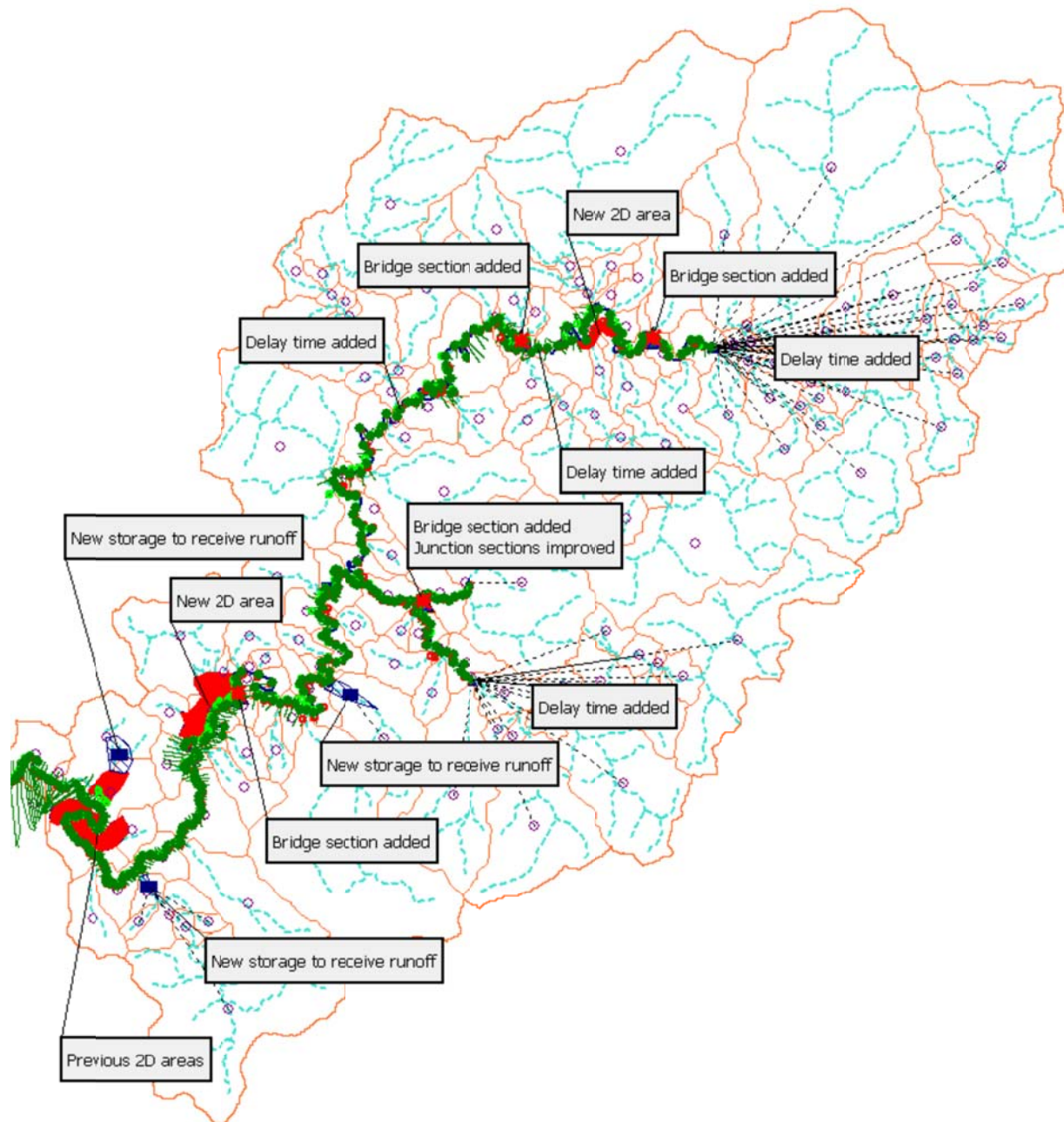
A summary of the Rotokakahi River model Improvements are listed below:

- Sub-catchment connection corrections. Several sub-catchments were draining into wrong areas. Also a delay time was missing for those catchments discharging from far upstream.
- 2D polygons were added in key areas, together with spill units created along the river banks and based on LiDAR ground model.
- Some storage areas were included for a better representation of flooded areas and volumes.
- Additional cross sections were included in key locations such as contractions or bridges that were not included in the previous model.
- Flood compartments were corrected were required.

Figure 3-28 below summarizes the key improvements in the model.

0 Modelling Tasks

Figure 3-28 New Rotokakahi model; description of main improvements



Design Events

Table 4-1 summarizes the design event criteria for all Hokianga models

Table 4-1 Hokianga catchments design events details

Catch ID	Name	Design Storm Duration (hrs.)	Rainfall profile	Rainfall depths
10.1	Rotokakahi River	24	Previous Priority Rivers profile	Previous model
10.2	Pawarenga fans	24	Far North District (GHD)	Hirds V3 24hrs
12	Panguru Rivers	24	Far North District (GHD)	Hirds V3 24hrs
13	Awapokonui River	24	Far North District (GHD)	Hirds V3 24hrs
18	Whirinaki River	24	Far North District (GHD)	Hirds V3 24hrs

All models were run for two events:

- 10yrs 24hrs (from HirdsV3)
- 100yrs 24hrs with climate change (or 150yrs 24hrs from HirdsV3)

No areal reduction factor was applied over the Hokianga catchments, except for Rotokakahi catchment where a standard Shamseldin ARF was applied, in this case ARF=0.94.

The respective rainfall depths for each model are summarized in the table below. Note that there is a distribution factor applied over each sub-catchment, with a factor of 1.0 the maximum rainfall depth inside each of the Hokianga catchment. A weighted average rainfall depth is also shown in Table 4-2, as well as the areal reduction factor.

Table 4-2 Hokianga catchments design events rainfall depths

Catch ID	ARF	Max Rain depth (mm) [x ARF]		Weighted factor over catchment	Weighted average (mm)	
		10yrs	100yrs Future		10yrs	100yrs Future
10.1	0.94	178.8	335.3	0.92	164.6	308.5
10.2	1.00	190.1	356.6	0.98	186.9	350.5
12	1.00	151.3	289.3	0.94	142.1	271.7
13	1.00	148.5	284.0	0.79	116.8	223.4
18	1.00	166.6	314.2	0.73	121.4	229.1

The final flood maps are included in the Appendix A of this report.

Debris level comparison

5.1 Data Analysis

A large set of surveyed debris level points for the storm of April 1999 were available for in the Panguru, Awapokonui and Whirinaki catchments.

Even though there were several points outside of the LiDAR coverage area or outside of the model extent, there were still a large number of points that could be used to compare the design events' flood extent with the surveyed points for the storm of 1999. It's not clear though what equivalent duration and storm period corresponds to the event of 1999 for each of the three mentioned catchments. However, by looking at information available in other NRC catchments (Waiarohia catchment) it seems it was close to a 6hr 10yrs ARI event.

The time of concentration for those Hokianga catchments that have available surveyed flood levels for the storm of 1999 is less than 4 hours, so it was presumed that the survey points should be distributed close to the respective 10yr 24hr GHD event (asymmetrical distributed HIRDS dataset).

On the other hand, the survey levels were taken using the Mean Sea Level (MSL) as datum and all NRC Priority River models use a One Tree Point datum (OTP). Even though the OTP datum is a local MSL datum, there is not clear relationship between the two datums and there are also some differences between the surveyed levels and the respective LiDAR levels. Furthermore, the set of April 1999 data points does not include a unique ID or description to enable determination of the type of data point. It is likely that not all points are debris levels, but also some control points or ground features.

As there is no clear relationship established between the set of survey points and the design events for each catchment (likely close to the 10yrs events), the comparison was only subjective and focussed on defining whether the survey points were inside the area covered by the 10yr flood extent.

To enable any future analysis, the whole list of points is provided together with the surveyed level (in MSL), the respective LiDAR elevation (in OTP), the model flood elevation (OTP) and flood depth for the 10yr and 100yr events. This should provide enough information for further analysis if needed.

These are provided in Appendix B.

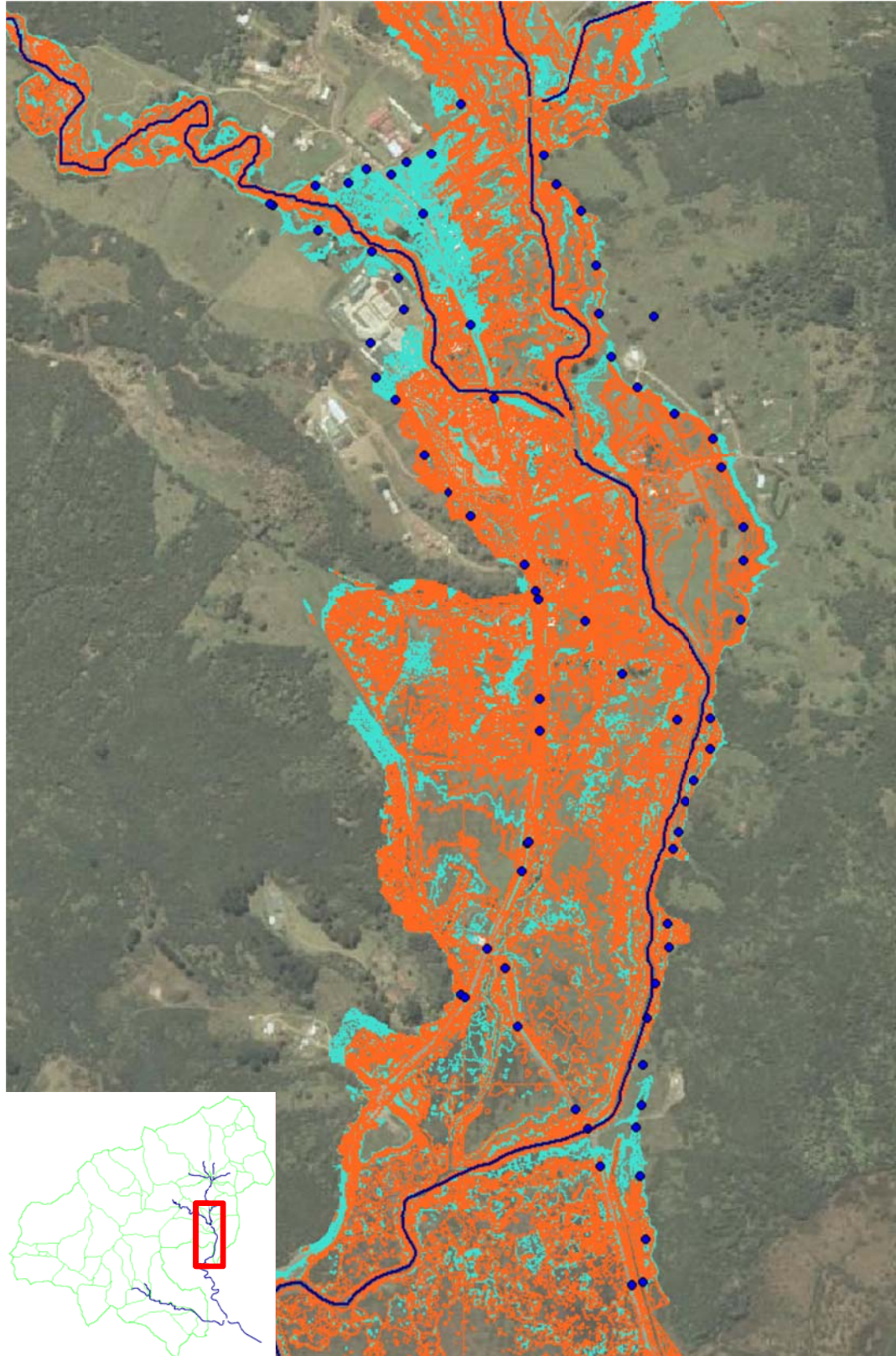
5.2 Model Results

Figure 5-1 to **Error! Reference source not found.** show the flood extents for the 10yr event and the 100yr event with climate change together with the flood levels at the surveyed points for the three catchments that contain additional debris survey (Panguru, Awapokonui and Whirinaki). In these figures, the shapes in light blue represent the 100yr with climate change flood extent, the orange shape is the 10yr flood extent, and the blue dots are the survey points.

As can be seen in the figures, the survey points are mainly concentrated around the 10yr flood extent edges. The storm of April 1999 was estimated to be close to a 10yr ARI event and this analysis confirms that this event was very similar in extent to the modelled 10yr design event. This outcome supports the model results and provides more confidence in the models.

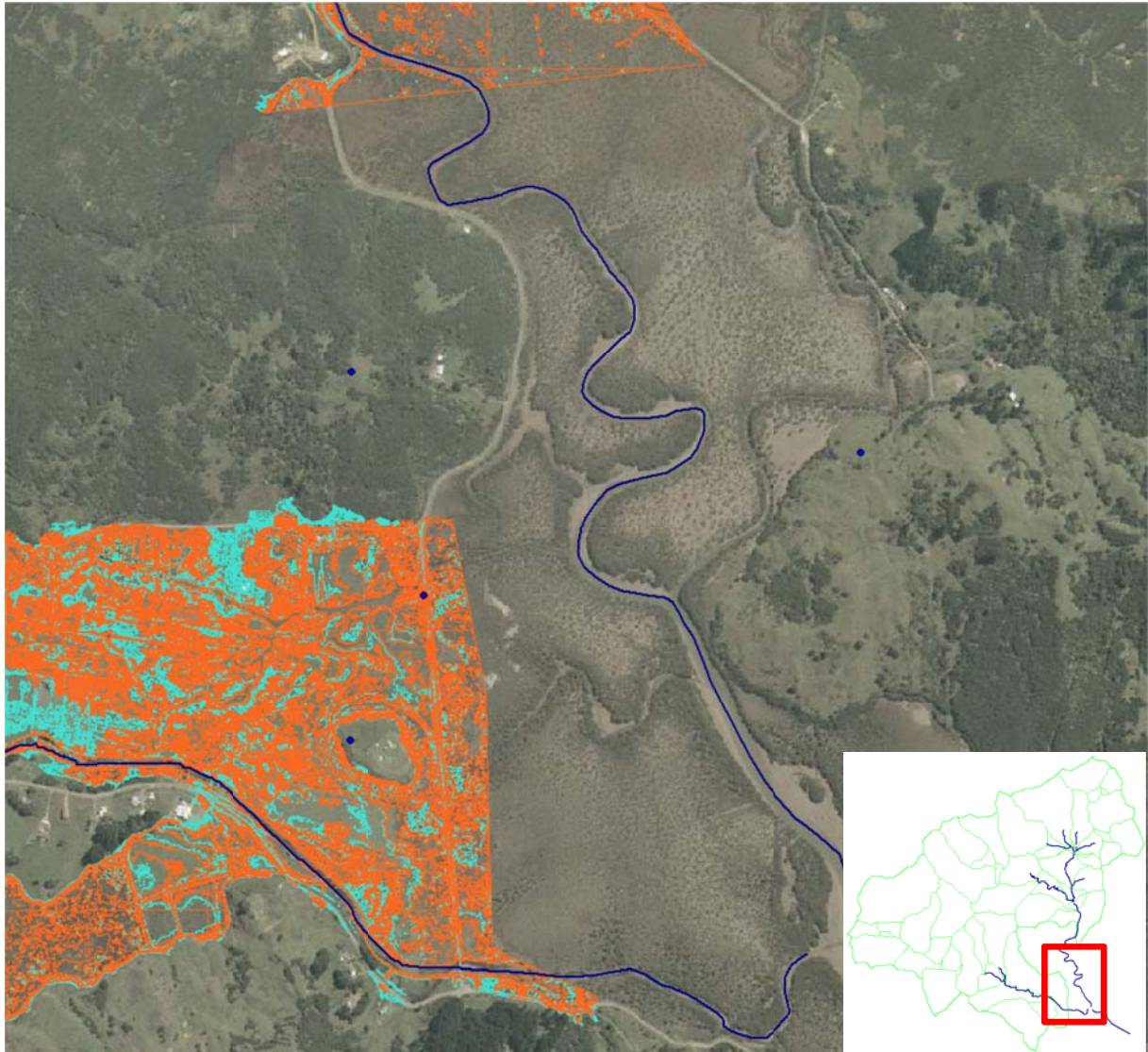
5 Debris level comparison

Figure 5-1 Panguru model; flood extent against survey levels; northern branch



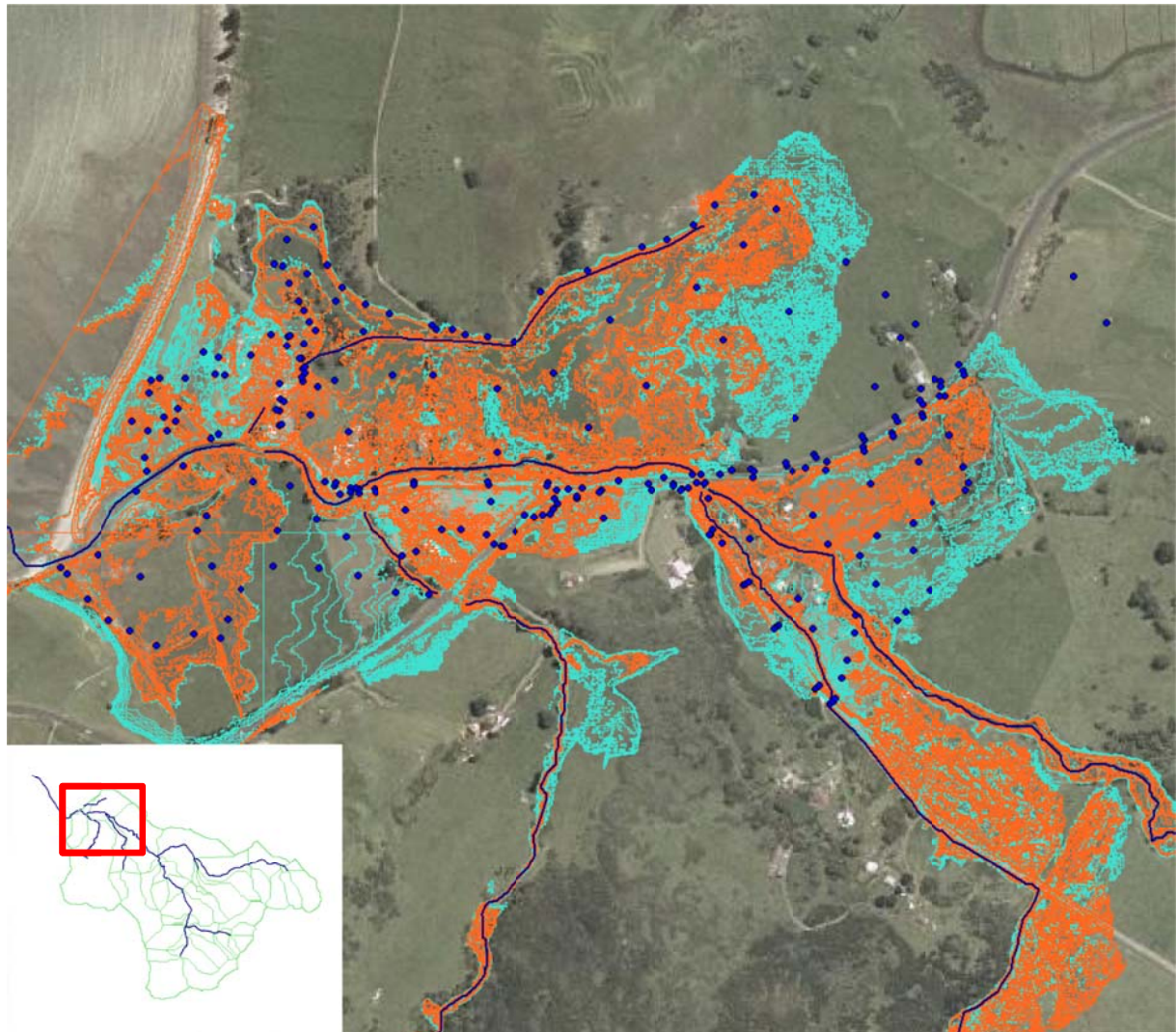
5 Debris level comparison

Figure 5-2 Panguru model; flood extent against survey levels; river junction at estuary



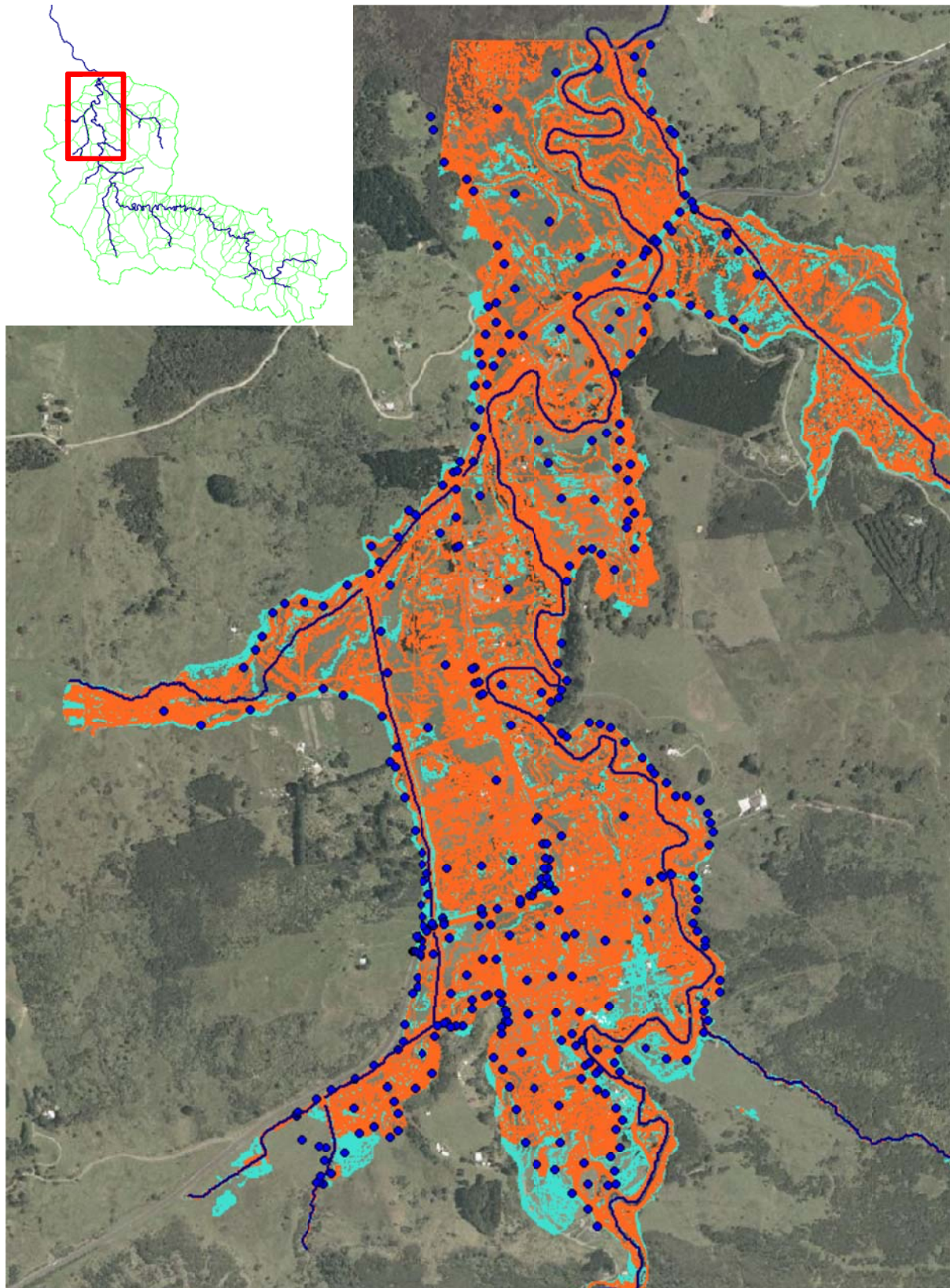
5 Debris level comparison

Figure 5-3 Awapokonui model; flood extent against survey levels; lower catchment



5 Debris level comparison

Figure 5-4 Whirinaki model; flood extent against survey levels; lower catchment



Discussion and Conclusion

Critical improvements in the models hydraulic performance allowed good outcomes from the models. Many important modifications were made to the modelling elements in order to achieve these results, mainly incorporating new critical river sections, bridges, culverts, 2D areas, storages and a large set of new spills to interconnect all the new objects which were generally delimited by banks, roads or other geographic features.

The previous hydrological set up was retained in all models, using a US SCS method to calculate runoff based on sub-catchment features such time of concentration, CN values and sub-catchment area. These parameters are included in the delivered 2010 InfoWorks RS models.

A spatial distribution factor was applied over each sub-catchment to take into account the variability of the storm over the whole area. This factor was also retained from the previous model, as it was defined for all previous NRC Priority Rivers models.

The areal reduction factor was 1.0 for all Hokianga models, except for Rotokakahi catchment that used a standard Shamseldin ARF=0.94.

The preliminary hydrological analysis carried out using the Panguru model led to the use of a GHD type rainfall profile, for all design events with 24 hours storm duration. 10yr event and 100yr event with climate change were simulated. Rotokakahi again was the exception using the same rainfall profile as in its previous version (Priority Rivers Project profile).

Table 6-1 summarizes the main features of each Hokianga model.

The results of this modelling work are mainly based on a theoretical approach supported by the experience gained in other NRC catchments with similar features. Calibration or validation data was not available for any Hokianga models. In that context, the model results have some limitation and uncertainties related to limited data and they need to be treated as such. However, the improvements in the hydraulic performance of the models, as a result of the enhancements made, are important and the results present a better quality compared with the previous 2010 models. This is supported by a more detailed hydraulic performance. Furthermore, the survey flood levels for the storm of April 1999 appear to match with the 10yr design event that was considered to be the estimated comparable event.

The final flood extents for the 10yr event and the 100yr event plus climate change for each catchment are included in the Appendix A of this report.

Table 6-1 Hokianga models; general features

Catch ID	Priority	Catch Name	Storm Duration (hrs)	ARF	Rain profile	Hydrological Model
10.1	2	ROKOKAKAHI RIVER	24	0.940	NRC	US SCS
10.2	2	PAWARENGA STREAMS	24	1.000	GHD	US SCS
12	3	PANGURU RIVERS	24	1.000	GHD	US SCS
13	3	AWAPOKONUI RIVER	24	1.000	GHD	US SCS
18	3	WHIRINAKI RIVER	24	1.000	GHD	US SCS

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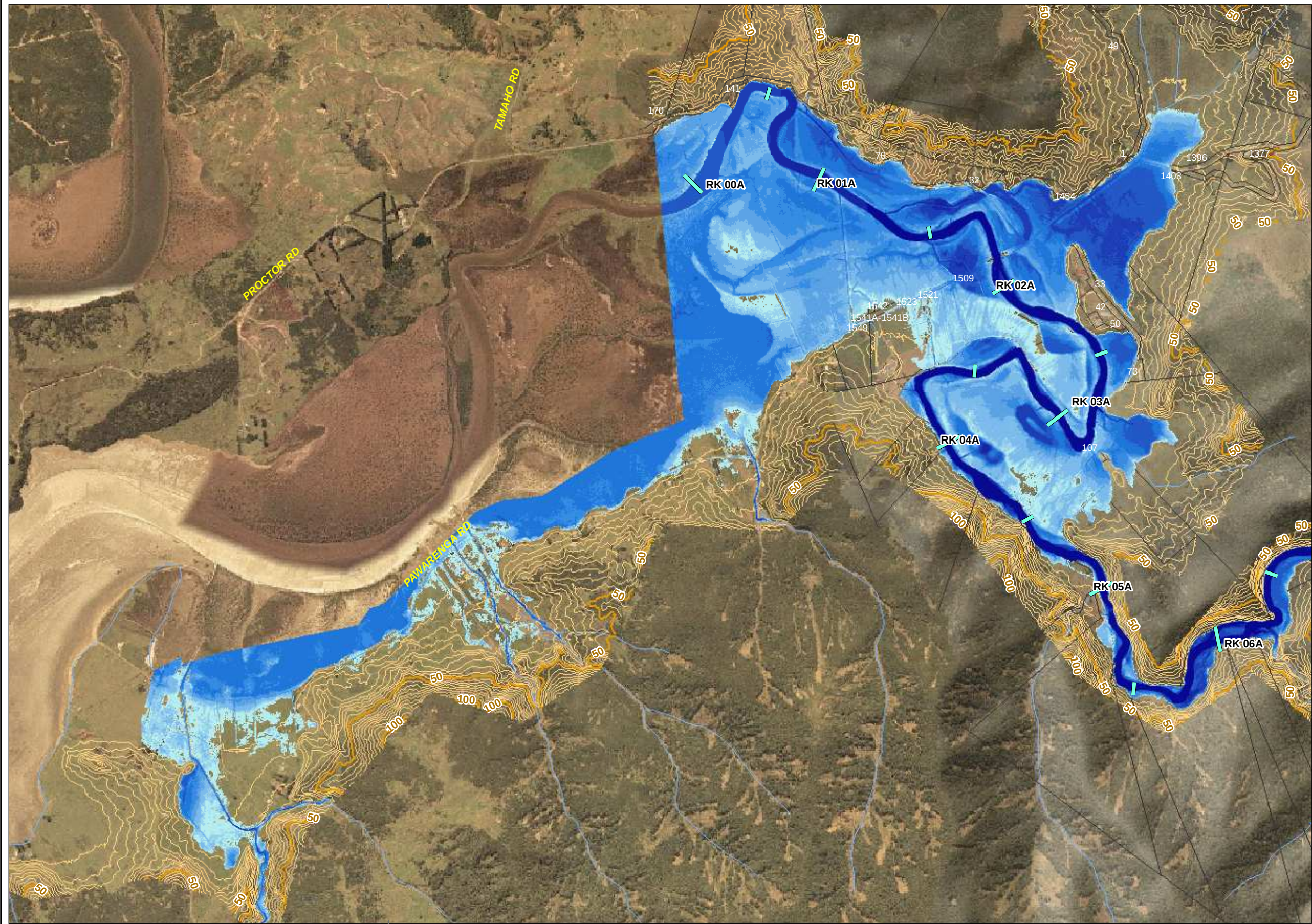
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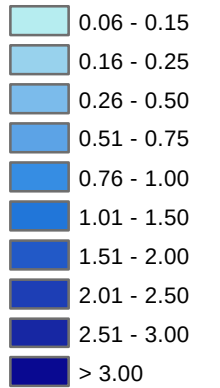
Appendix A Flood Maps



10 year ARI
Duration 24h

— River Kilometre, Rk

Flood Depth, m

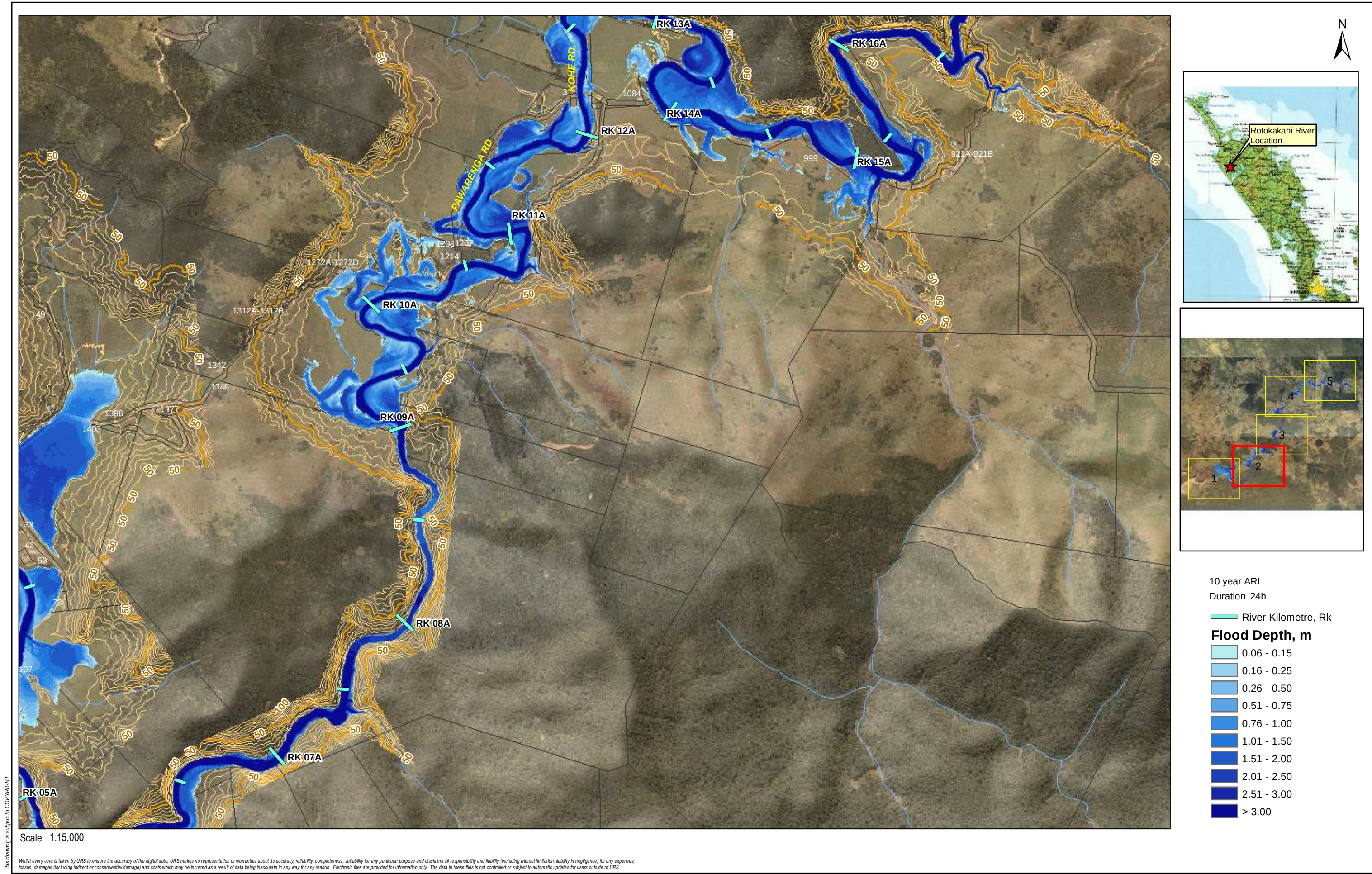


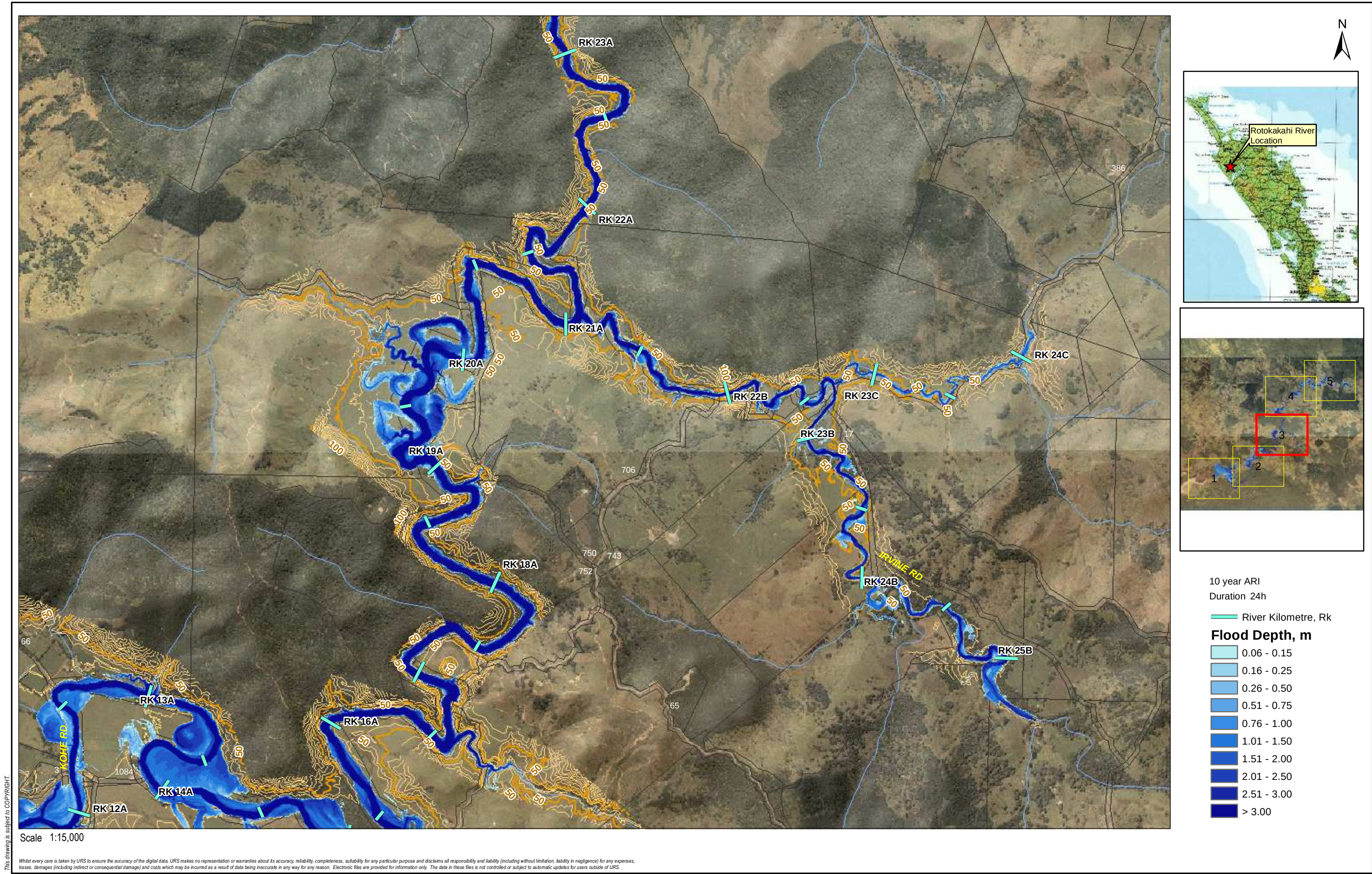
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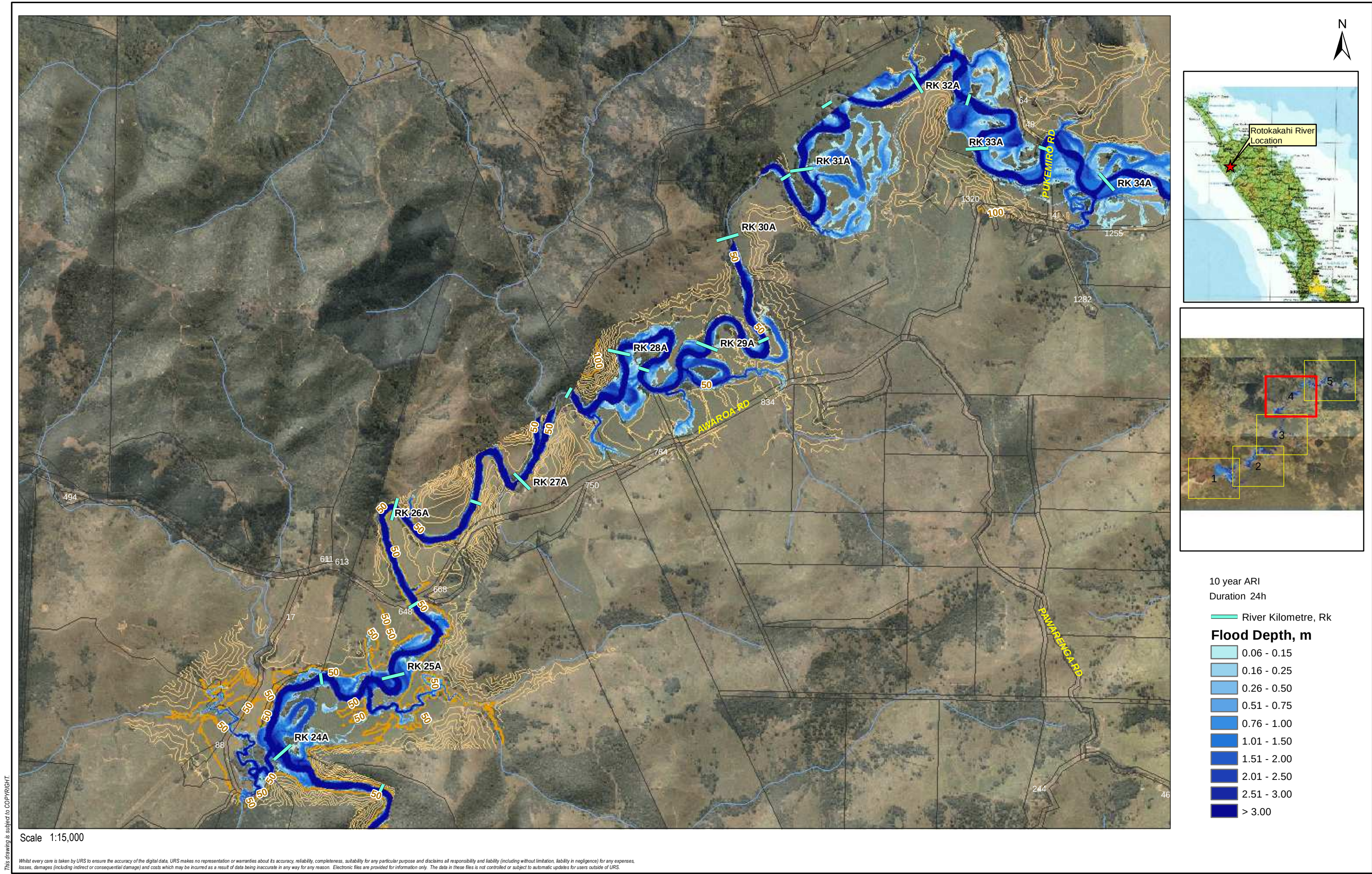
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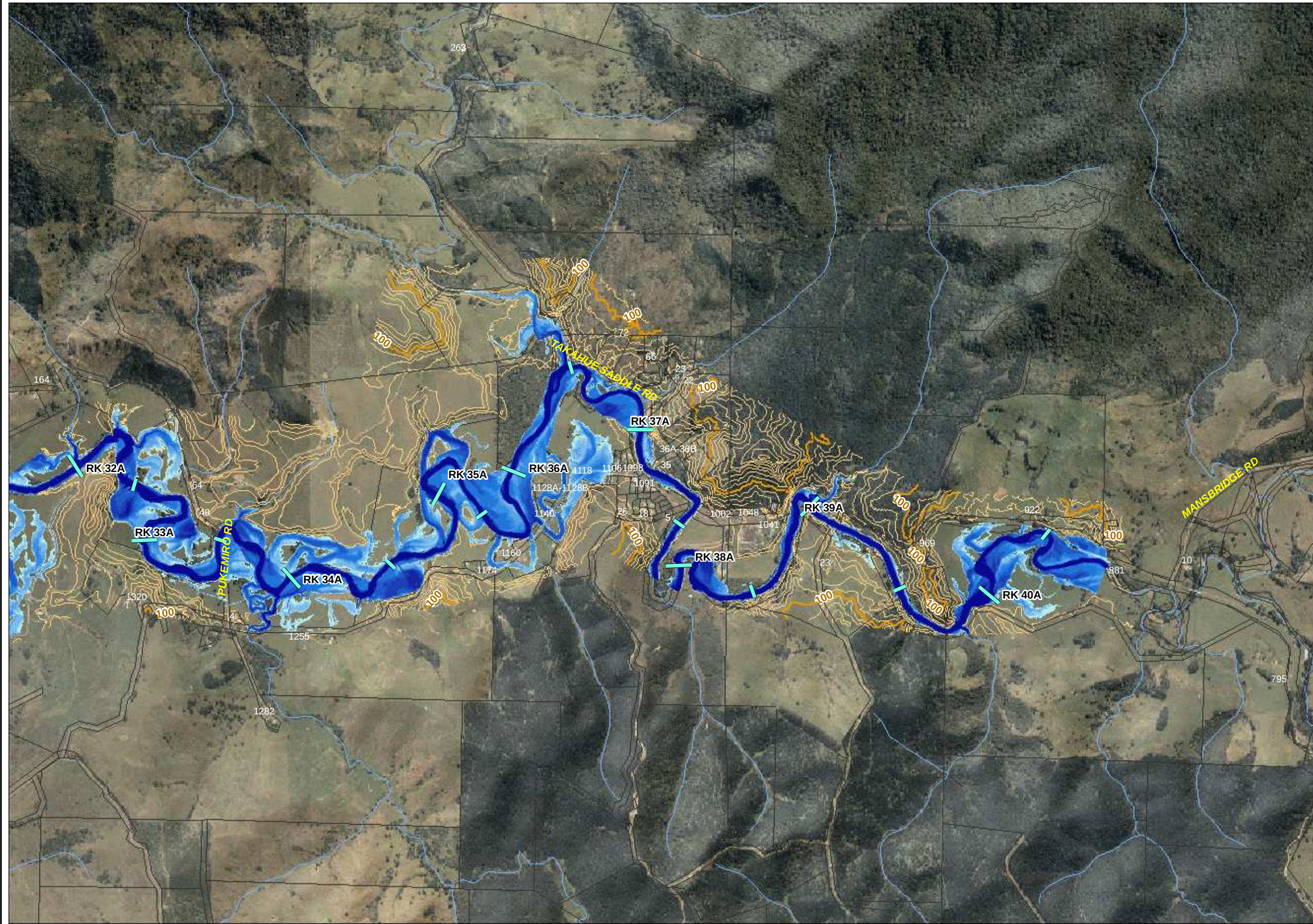
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- 10 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00

Scale 1:15,000

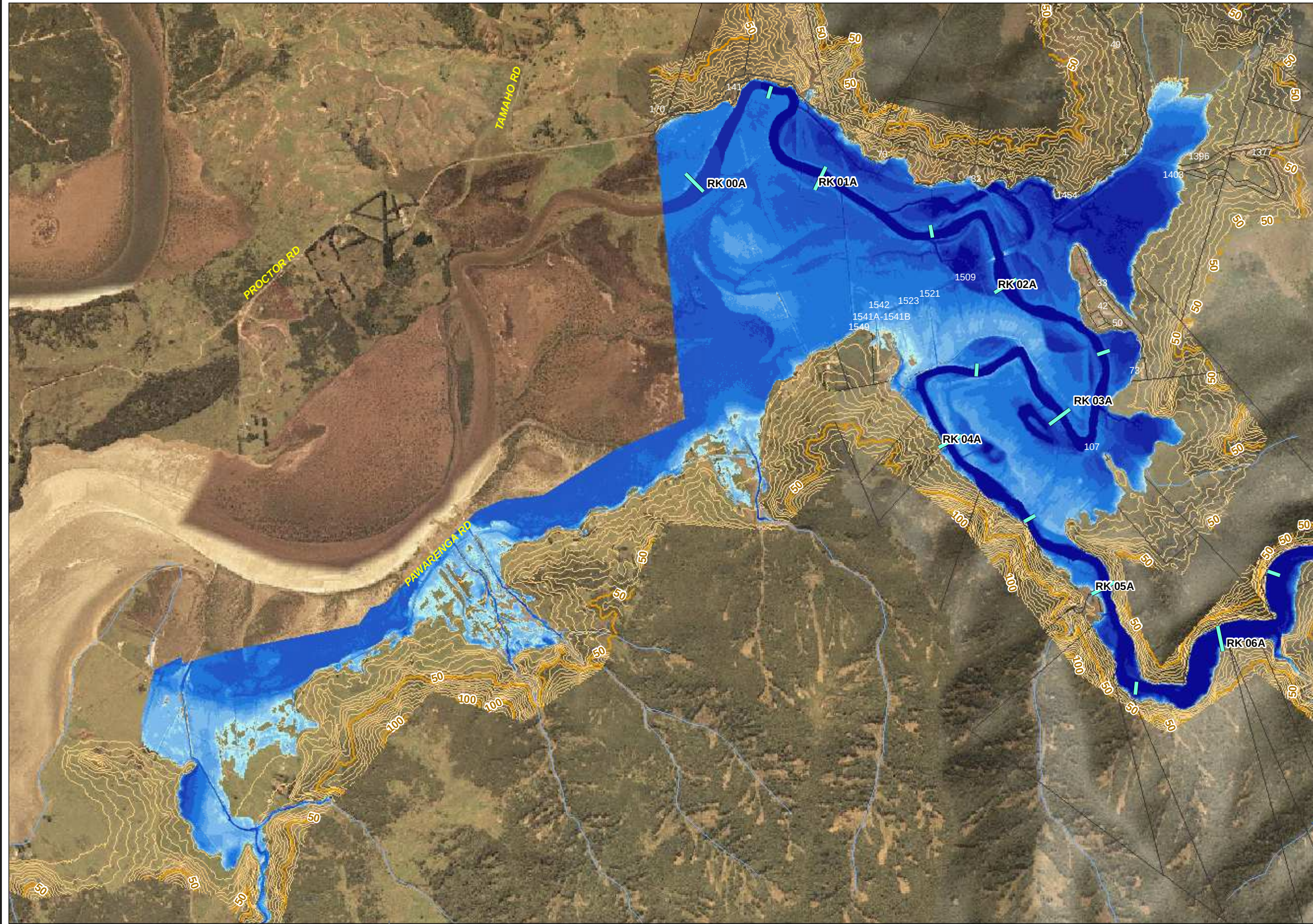
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FLOOD MAPS

Final
ROKAKAKAHI RIVER 10 YEAR ARI



100 year ARI plus Climate Change
Duration 24h

— River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- > 3.00

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FLOOD MAPS

ROKAKAKAHI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE

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Drawn: FP

Approved: JW

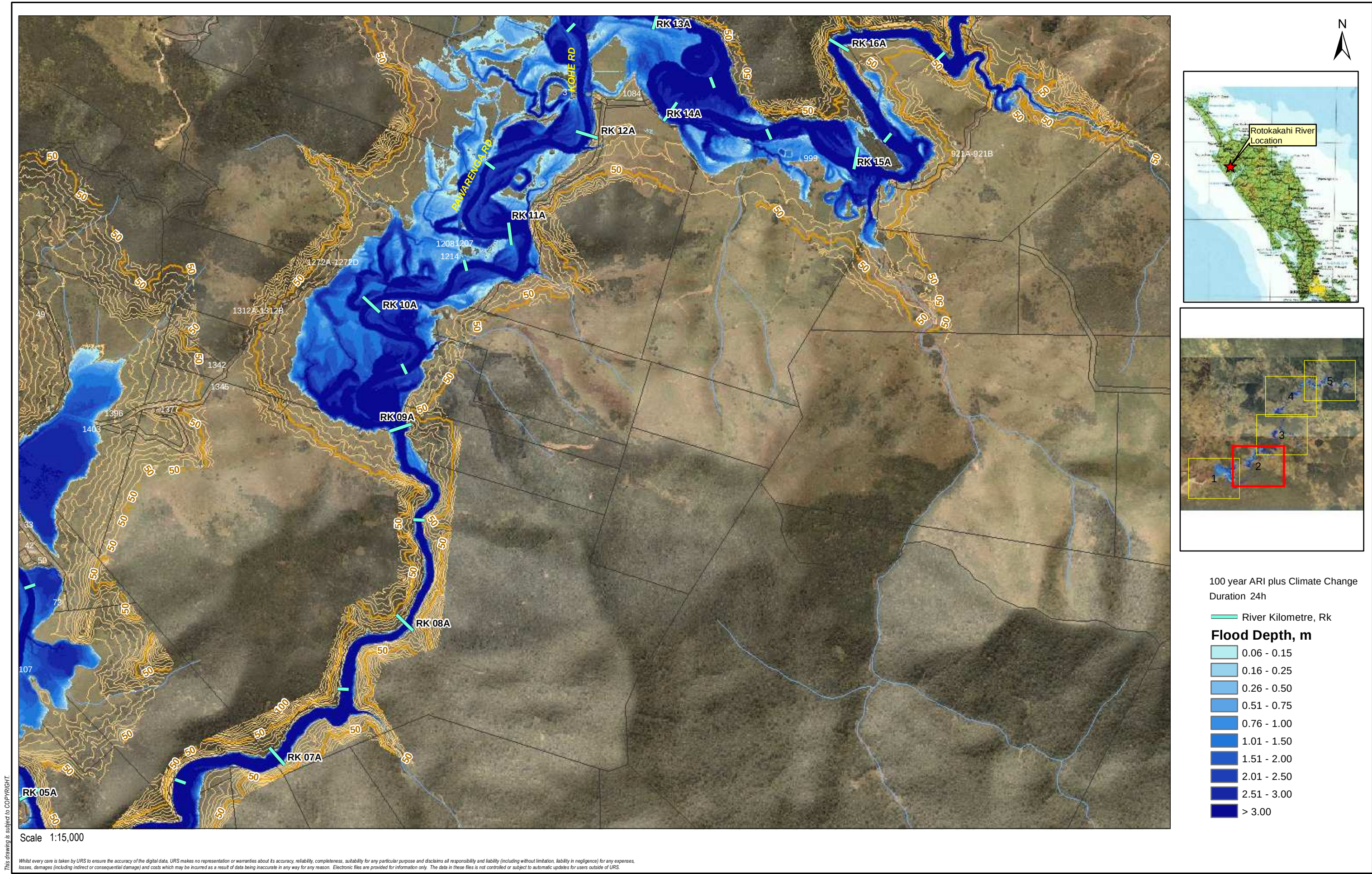
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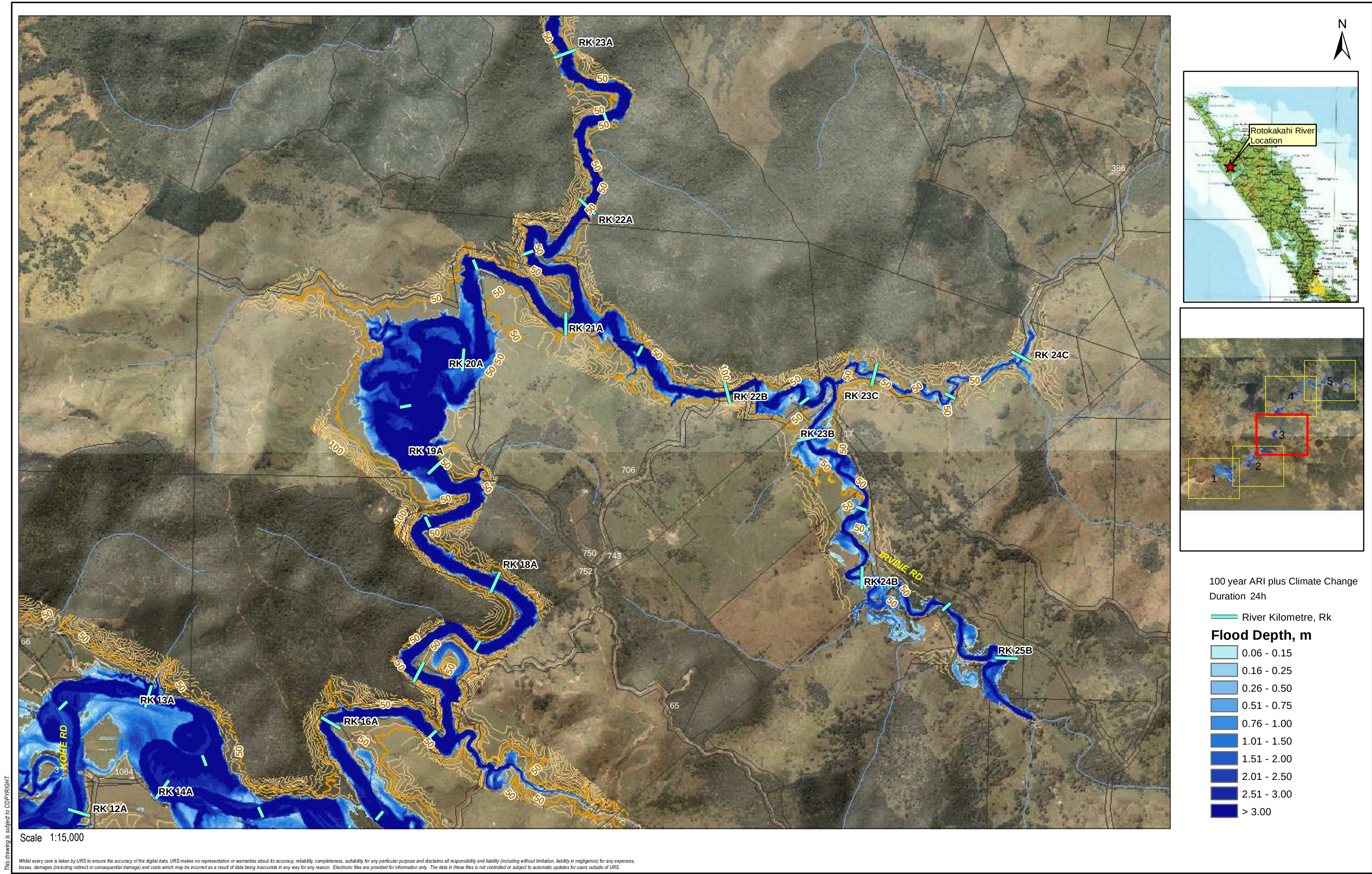
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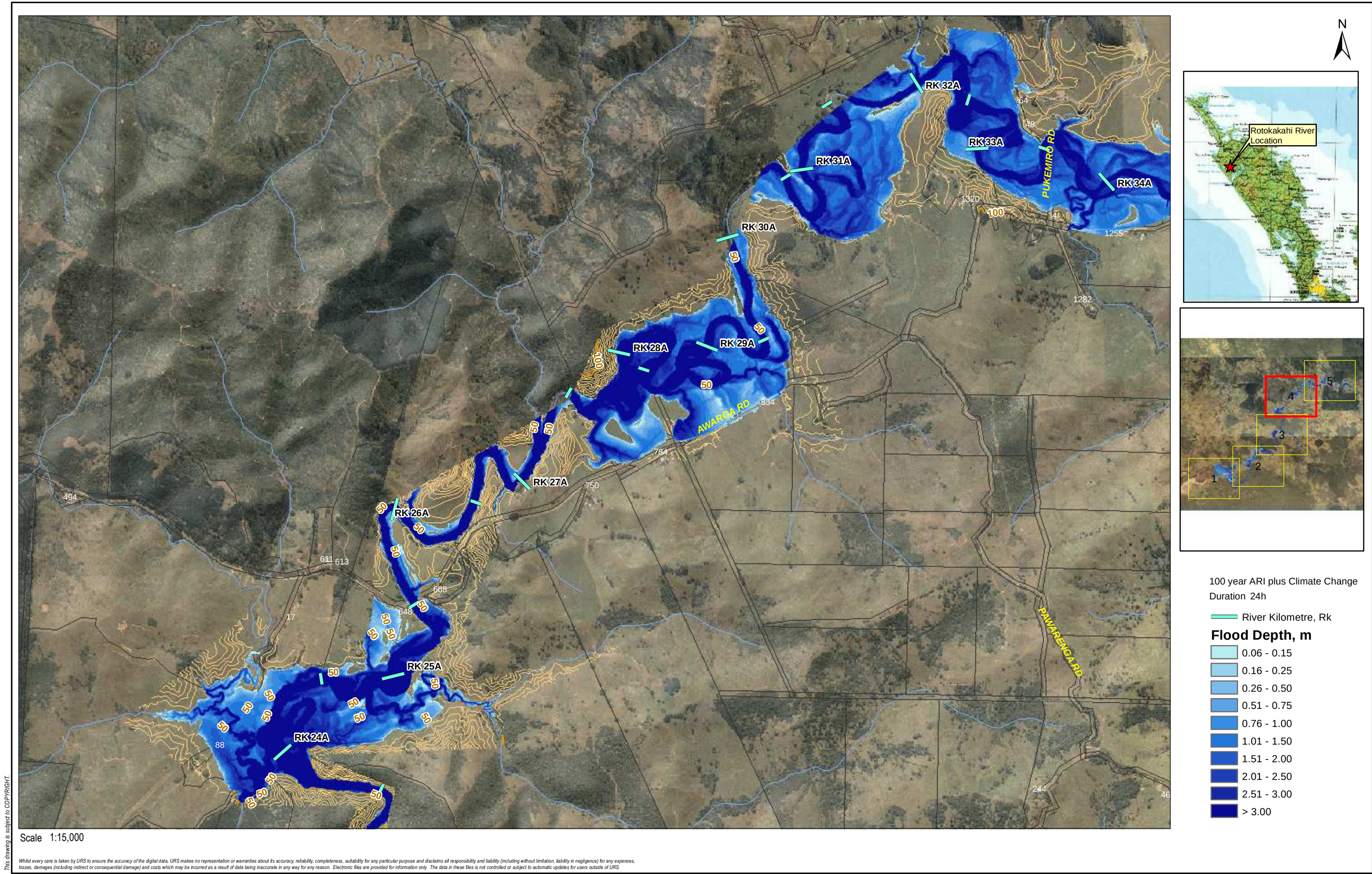
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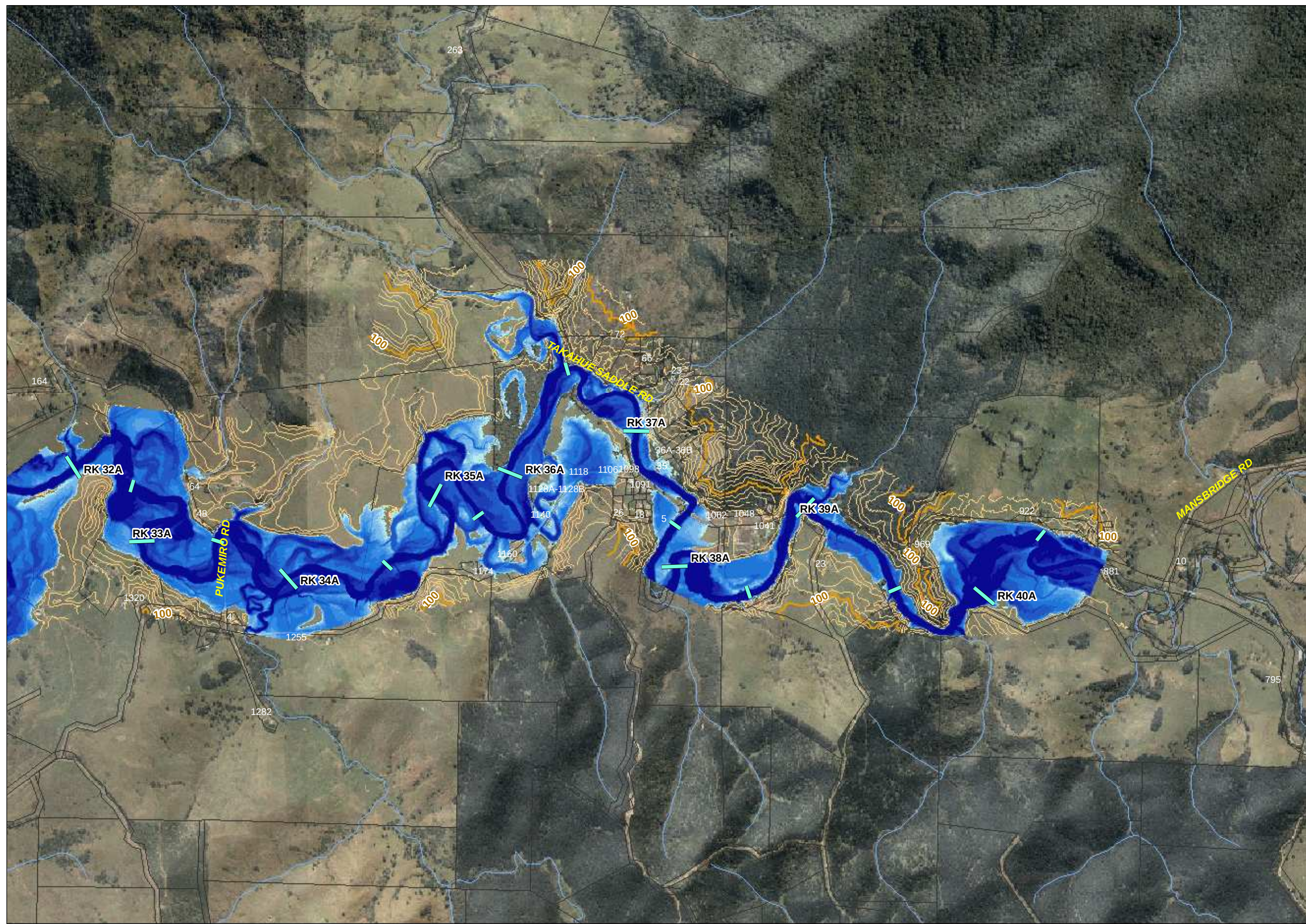
FLOOD MAPS

ROTOKAKAHI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE



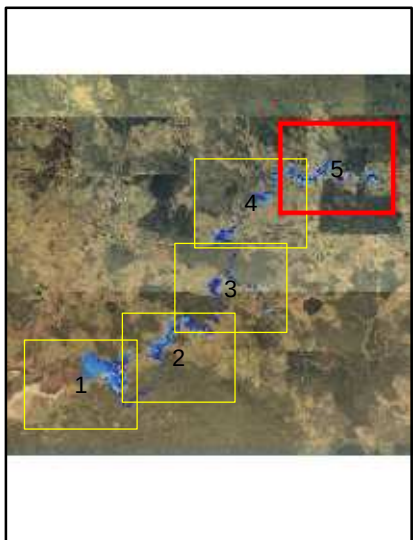


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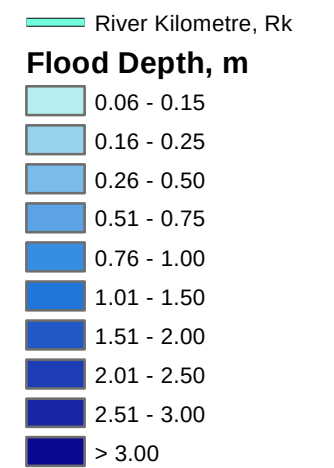


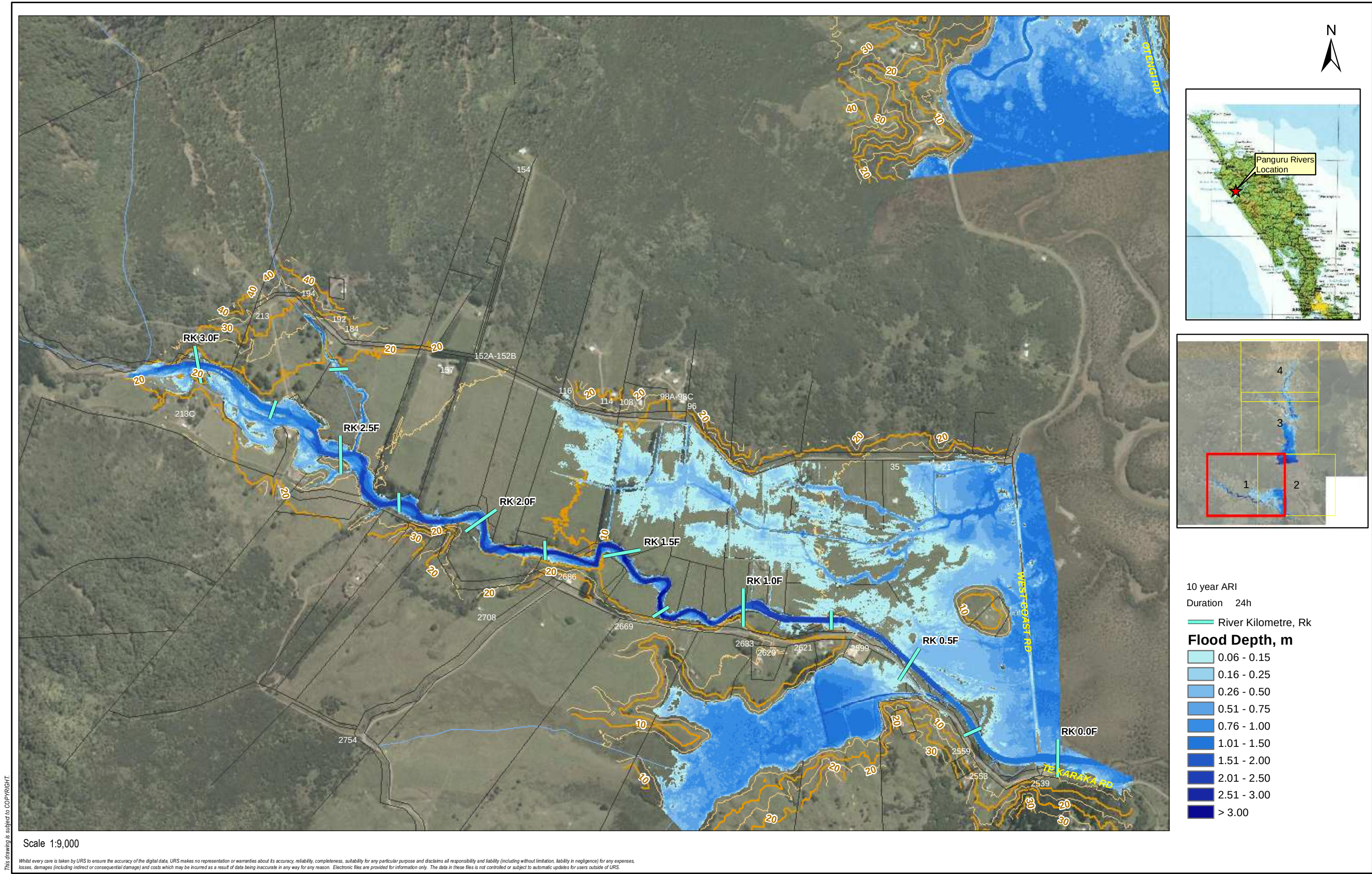
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100 year ARI plus Climate Change
Duration 24h





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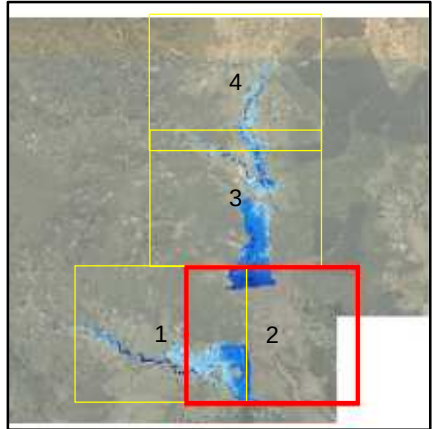
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10 year ARI
Duration 24h
River Kilometre, Rk
Flood Depth, m
0.06 - 0.15
0.16 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
> 3.00

Manaaki Awa



FLOOD MAPS

PANGURU RIVERS 10 YEAR ARI

URS

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Drawn: FP

Approved: JW

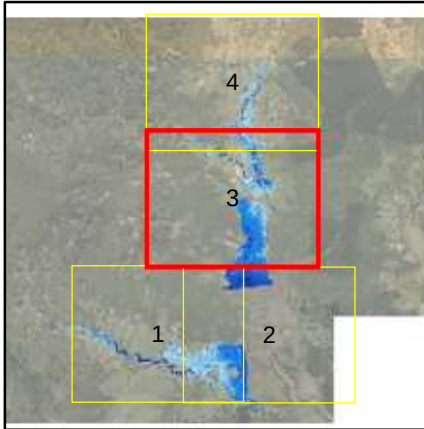
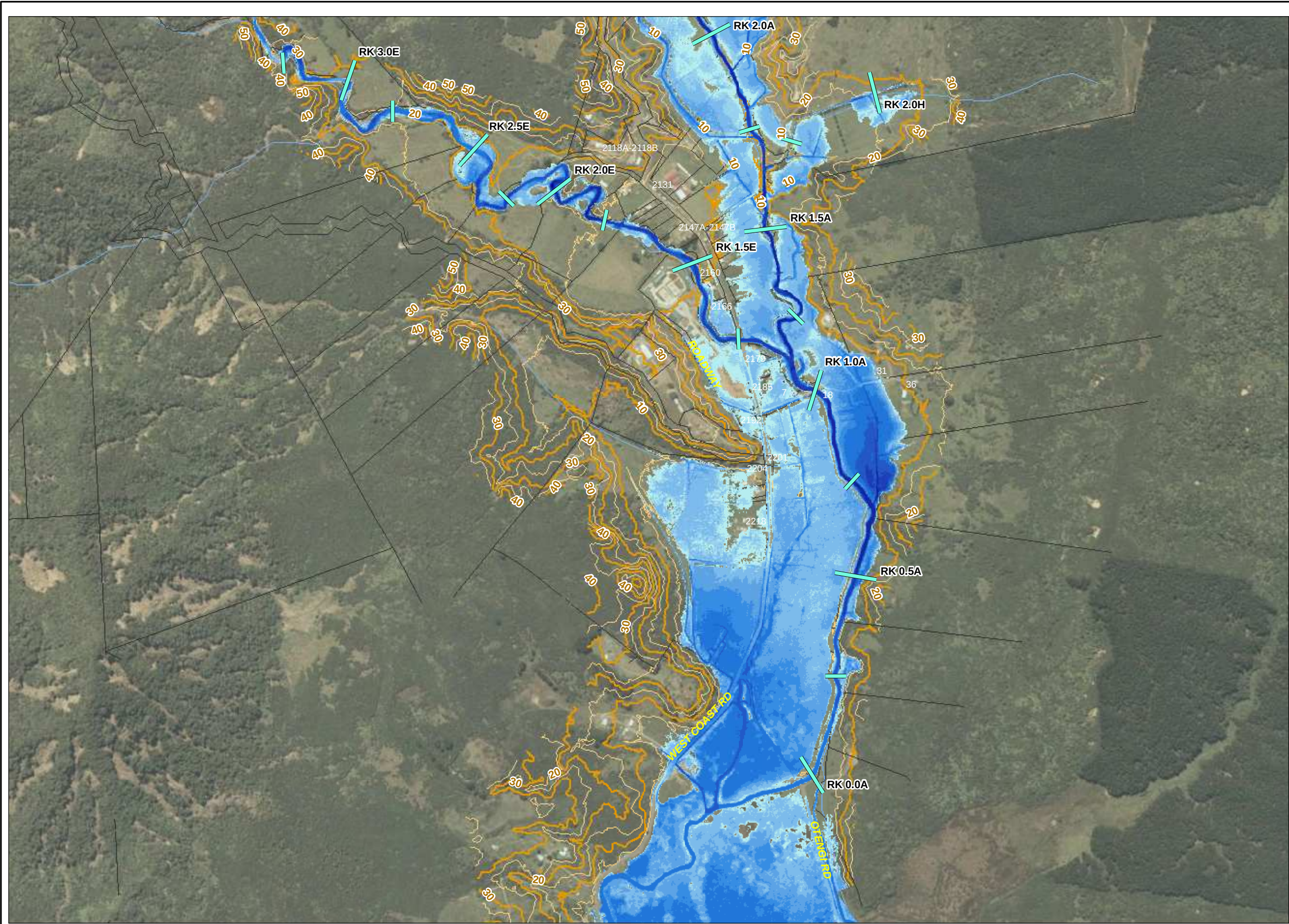
Date: 13/07/2012

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A3





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

Scale 1:9,000

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FLOOD MAPS

PANGURU RIVERS 10 YEAR ARI

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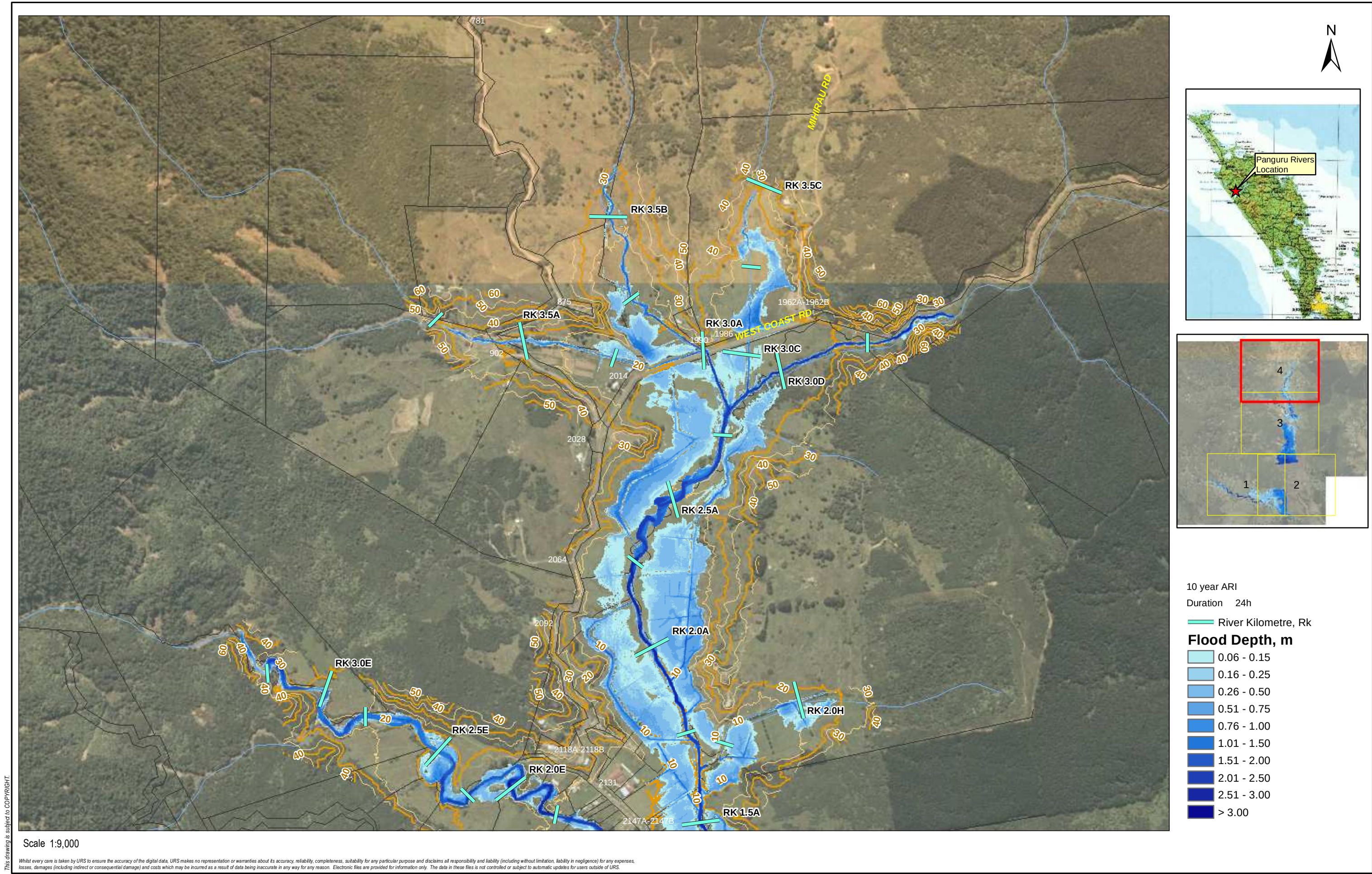
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Sheet 3 of 4

Rev. A

A3



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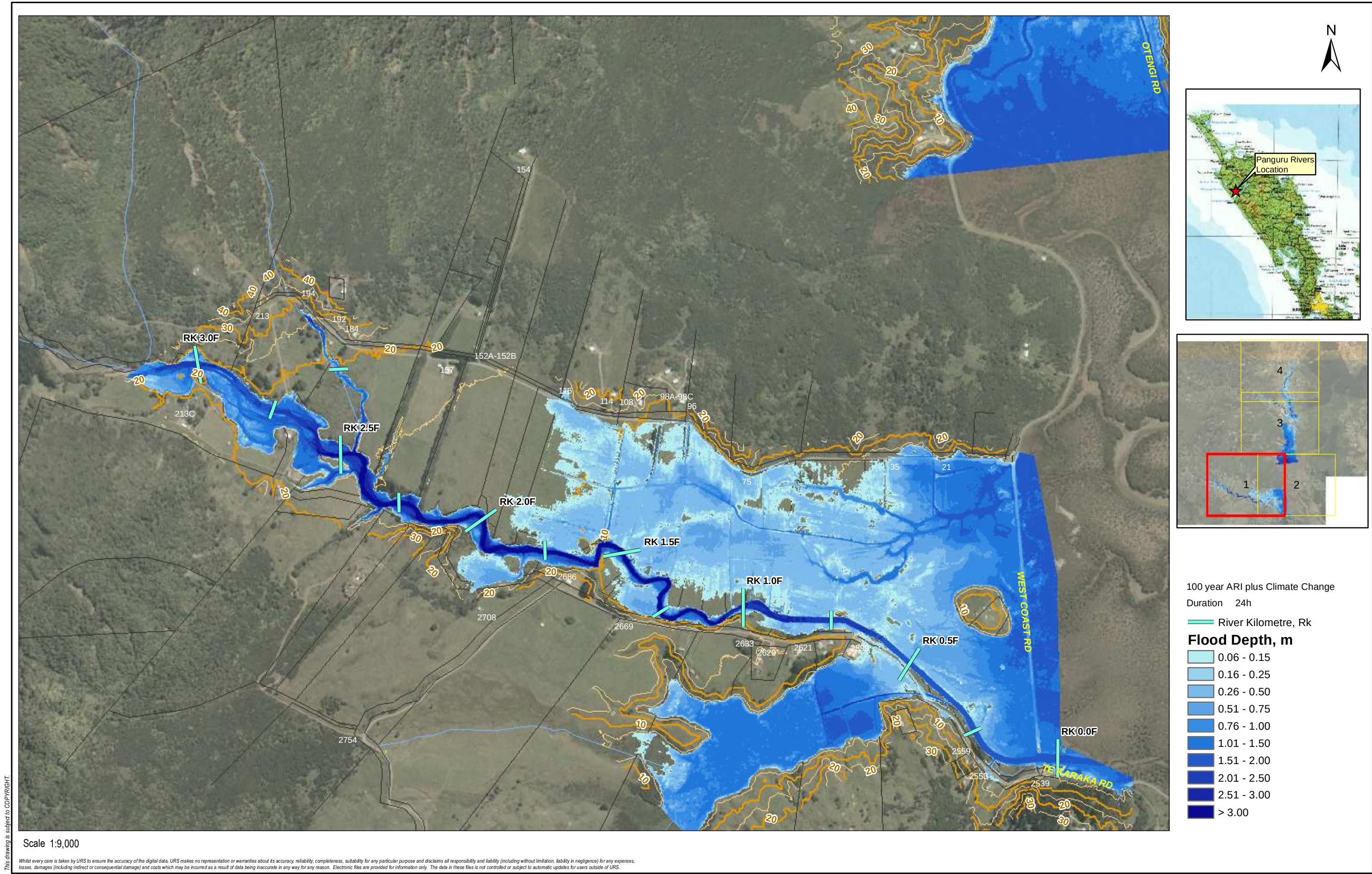
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- 10 year ARI
Duration 24h
- River Kilometre, Rk
- Flood Depth, m**
- 0.06 - 0.15
 - 0.16 - 0.25
 - 0.26 - 0.50
 - 0.51 - 0.75
 - 0.76 - 1.00
 - 1.01 - 1.50
 - 1.51 - 2.00
 - 2.01 - 2.50
 - 2.51 - 3.00
 - > 3.00



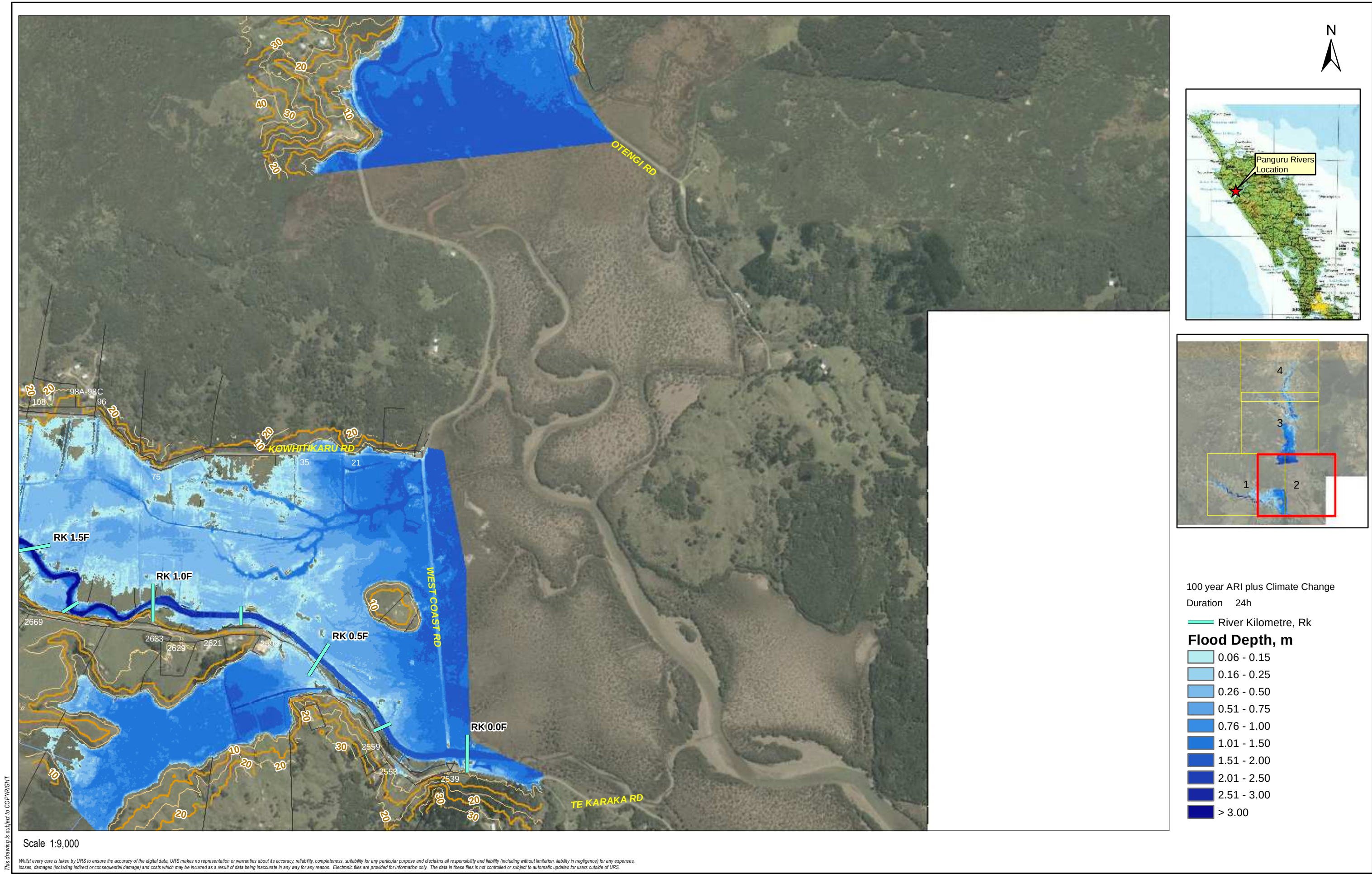
FLOOD MAPS

PANGURU RIVERS 10 YEAR ARI



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FLOOD MAPS

PANGURU RIVERS 100 YEAR ARI PLUS CLIMATE CHANGE



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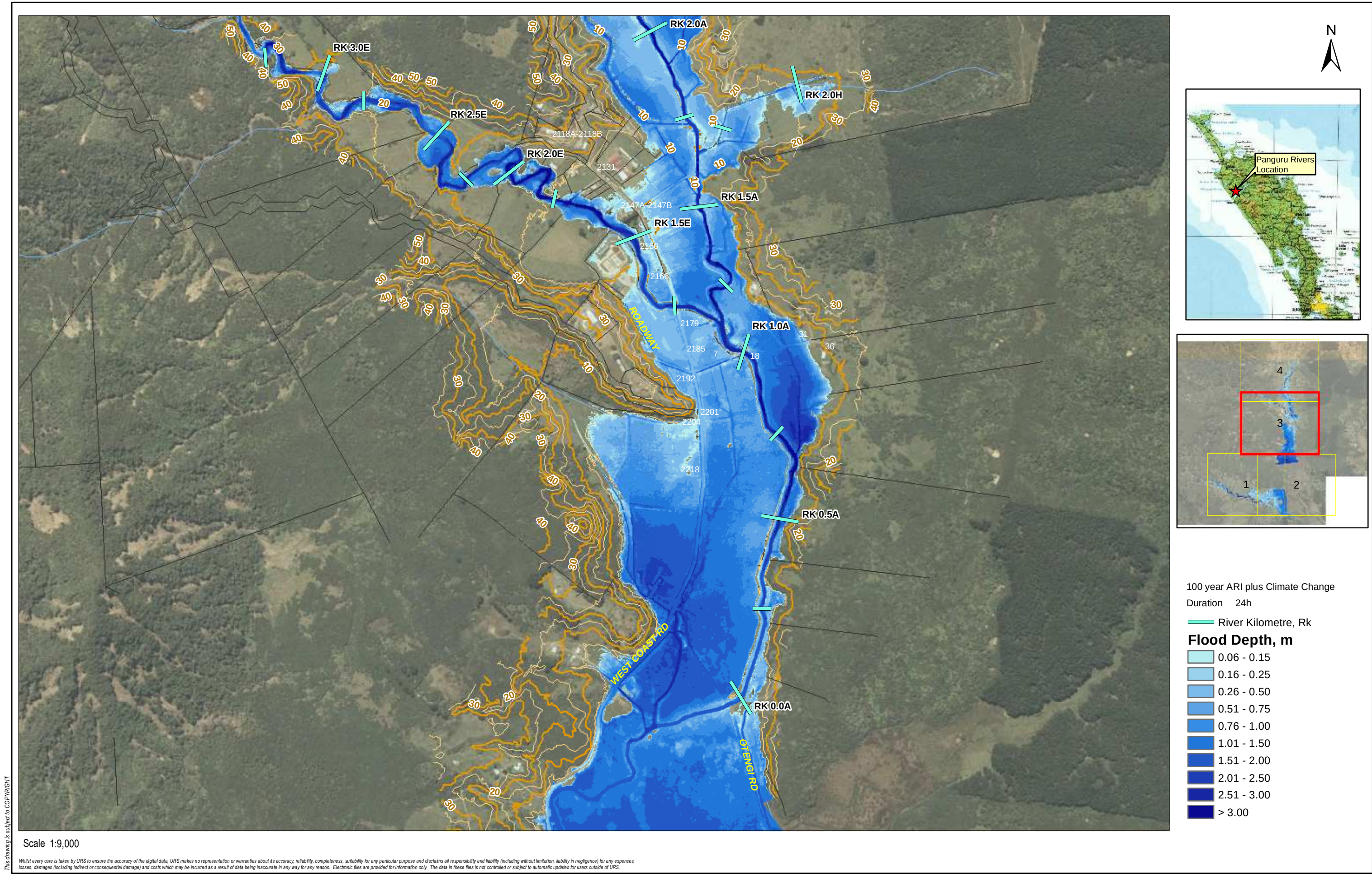
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Sheet 2 of 4

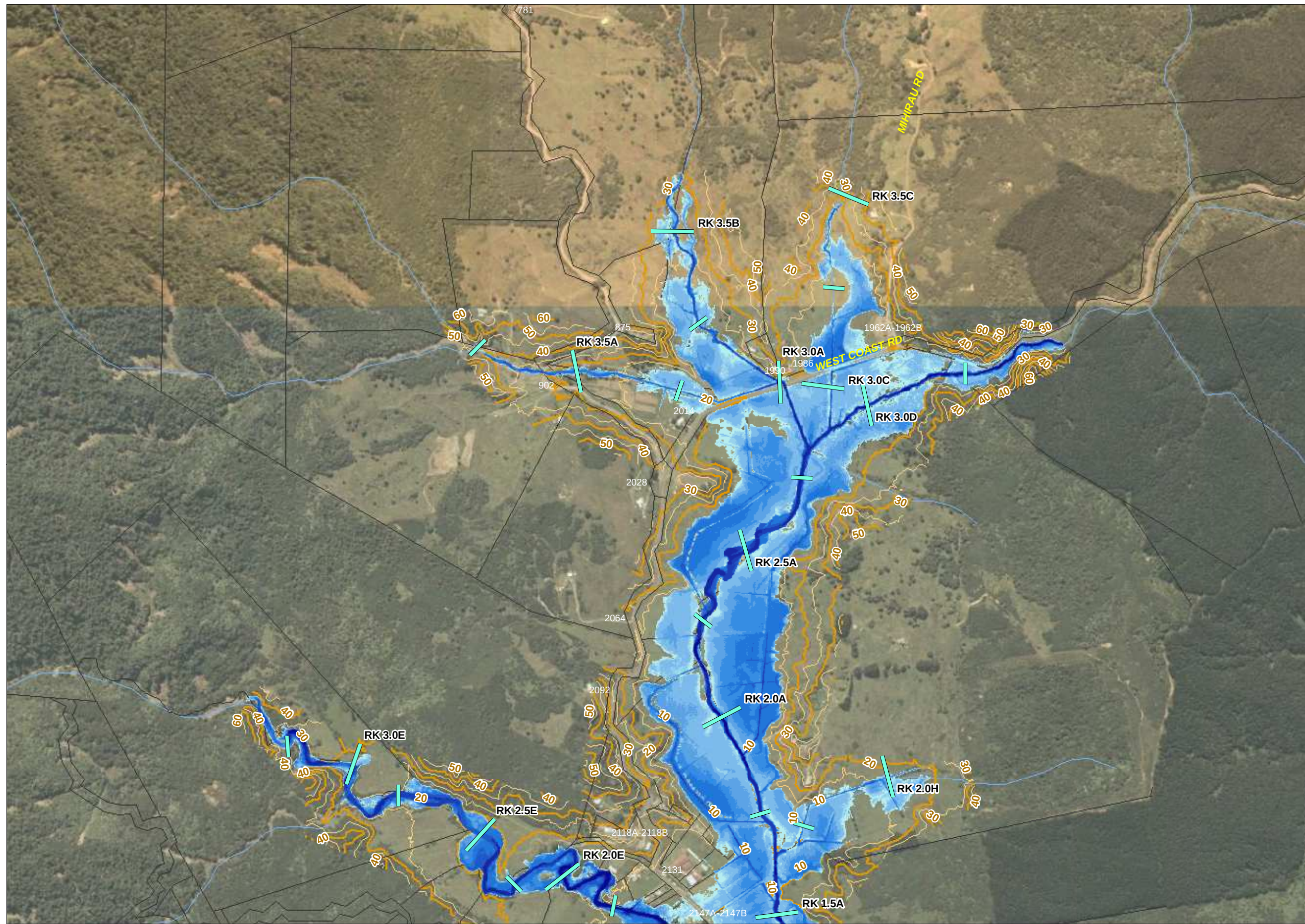
Rev. A

A3



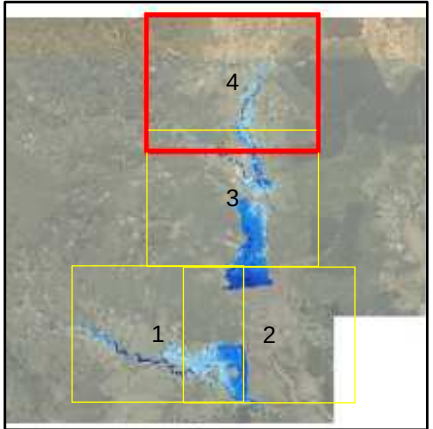


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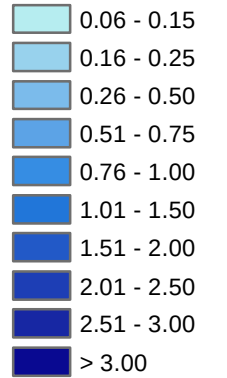
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100 year ARI plus Climate Change
Duration 24h

— River Kilometre, RK

Flood Depth, m



Manaaki Awa



FLOOD MAPS

PANGURU RIVERS 100 YEAR ARI PLUS CLIMATE CHANGE

URS

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Approved: JW

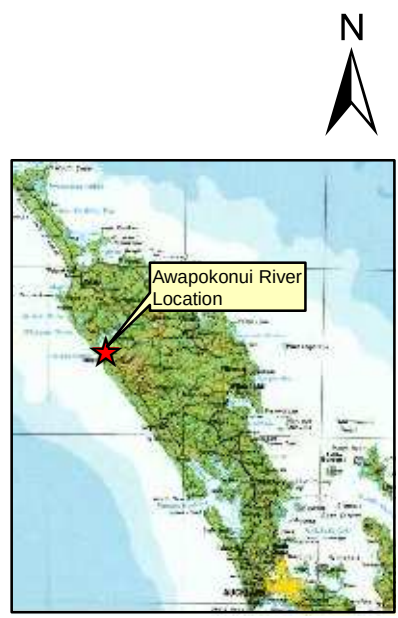
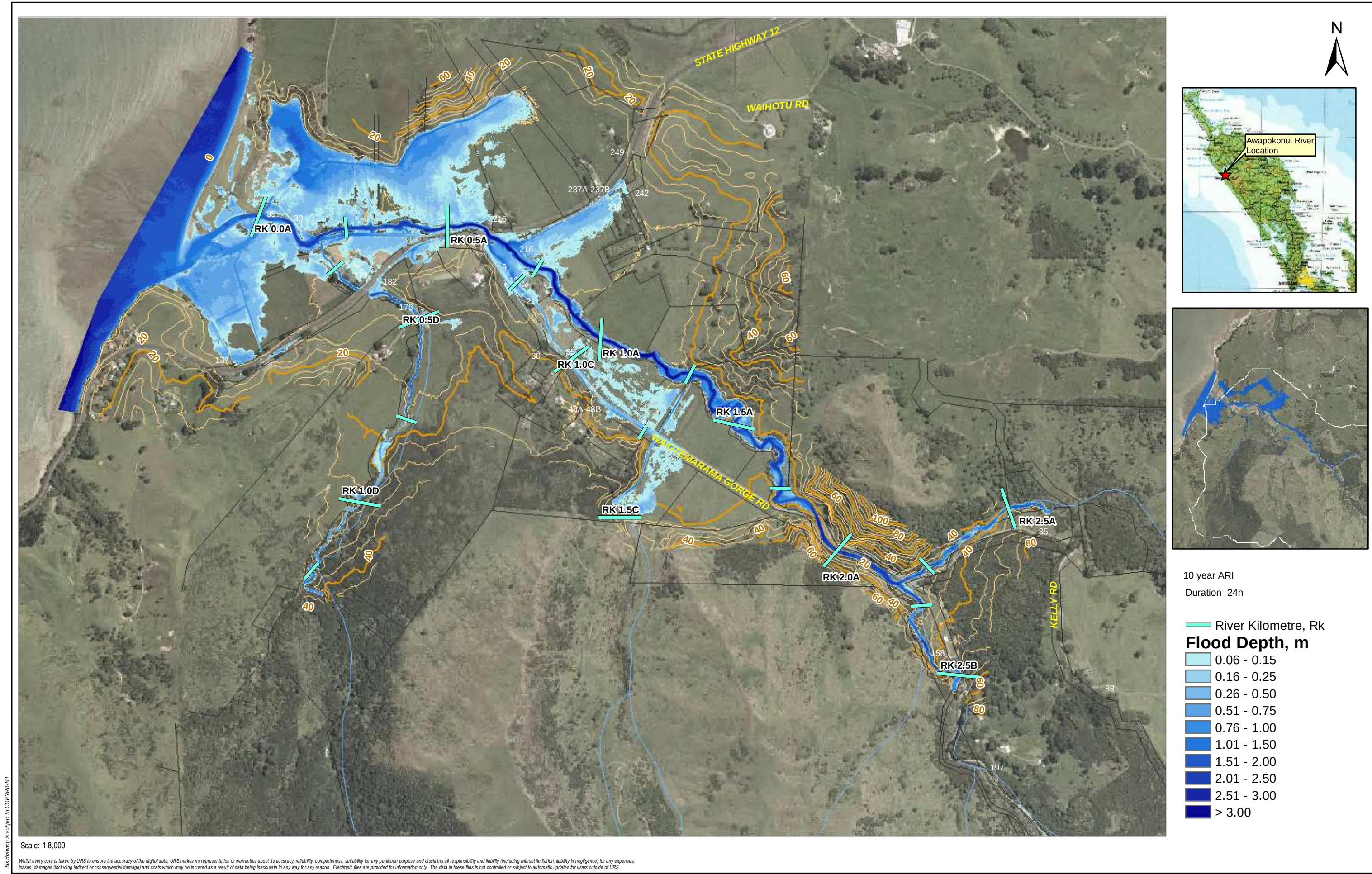
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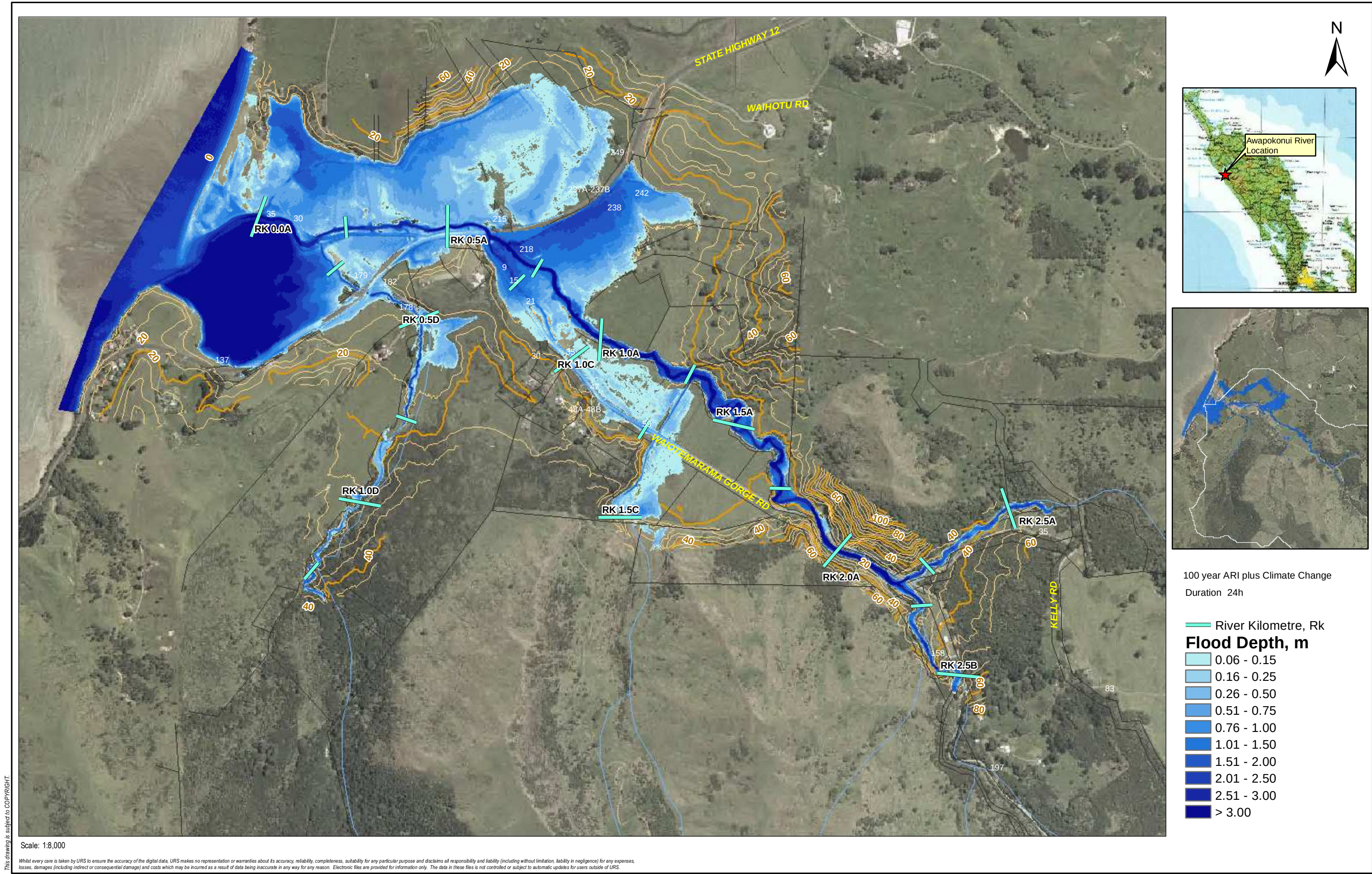
Sheet 4 of 4

Rev. A

A3



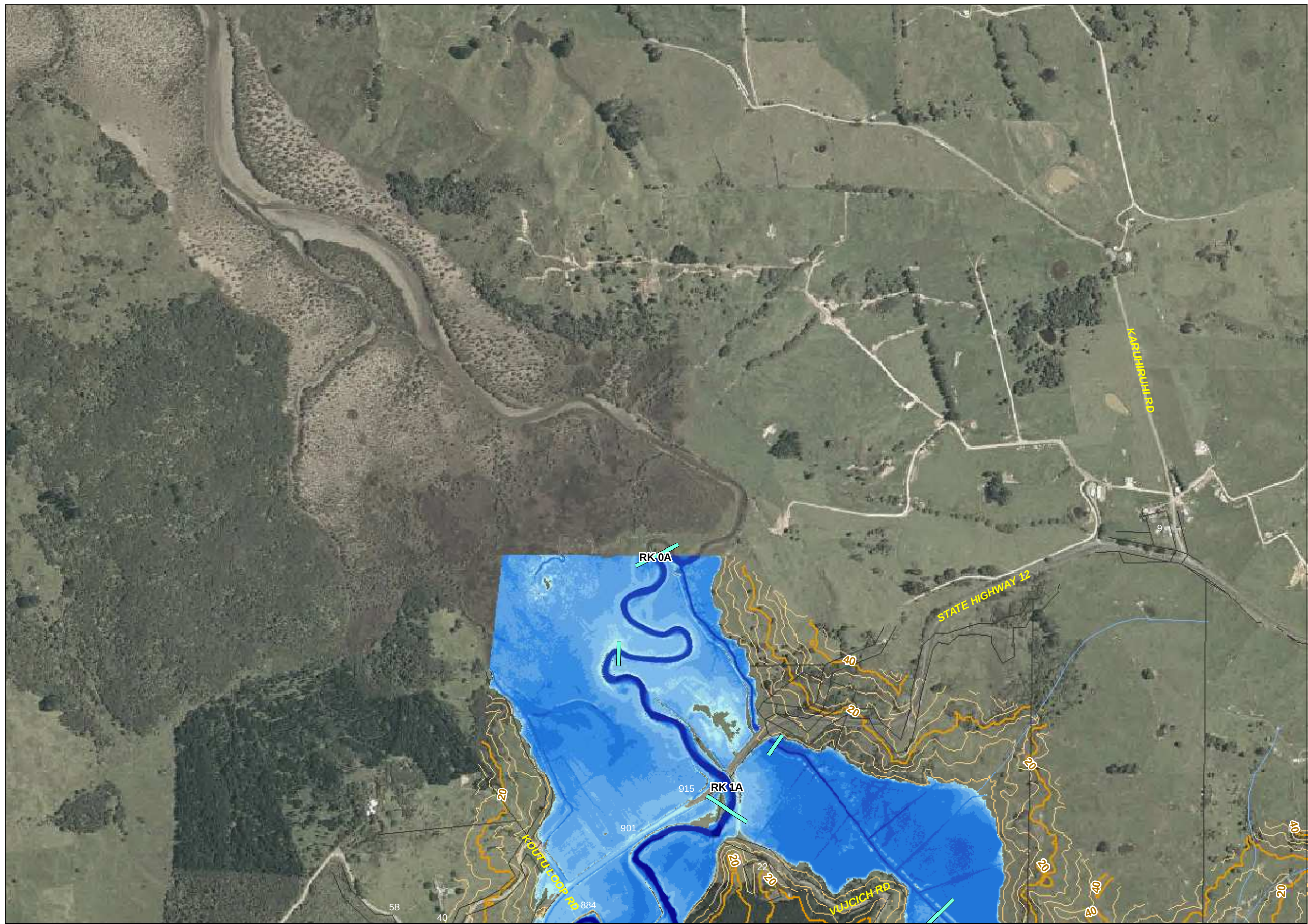




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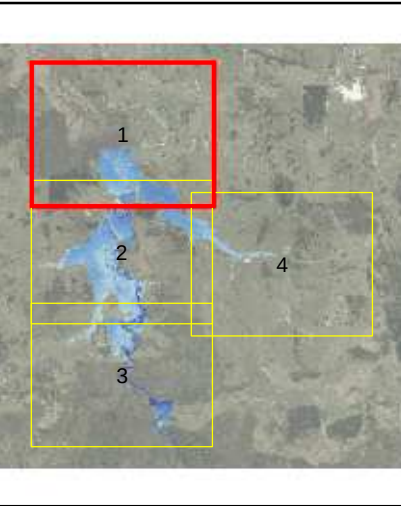
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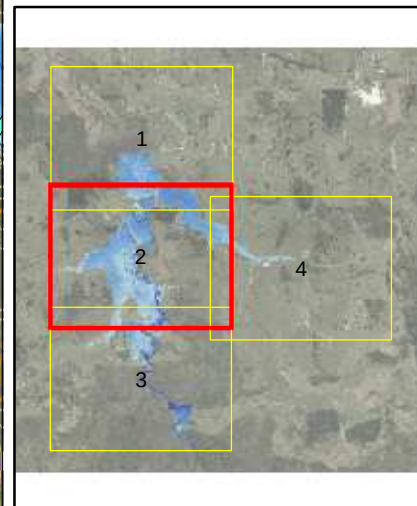
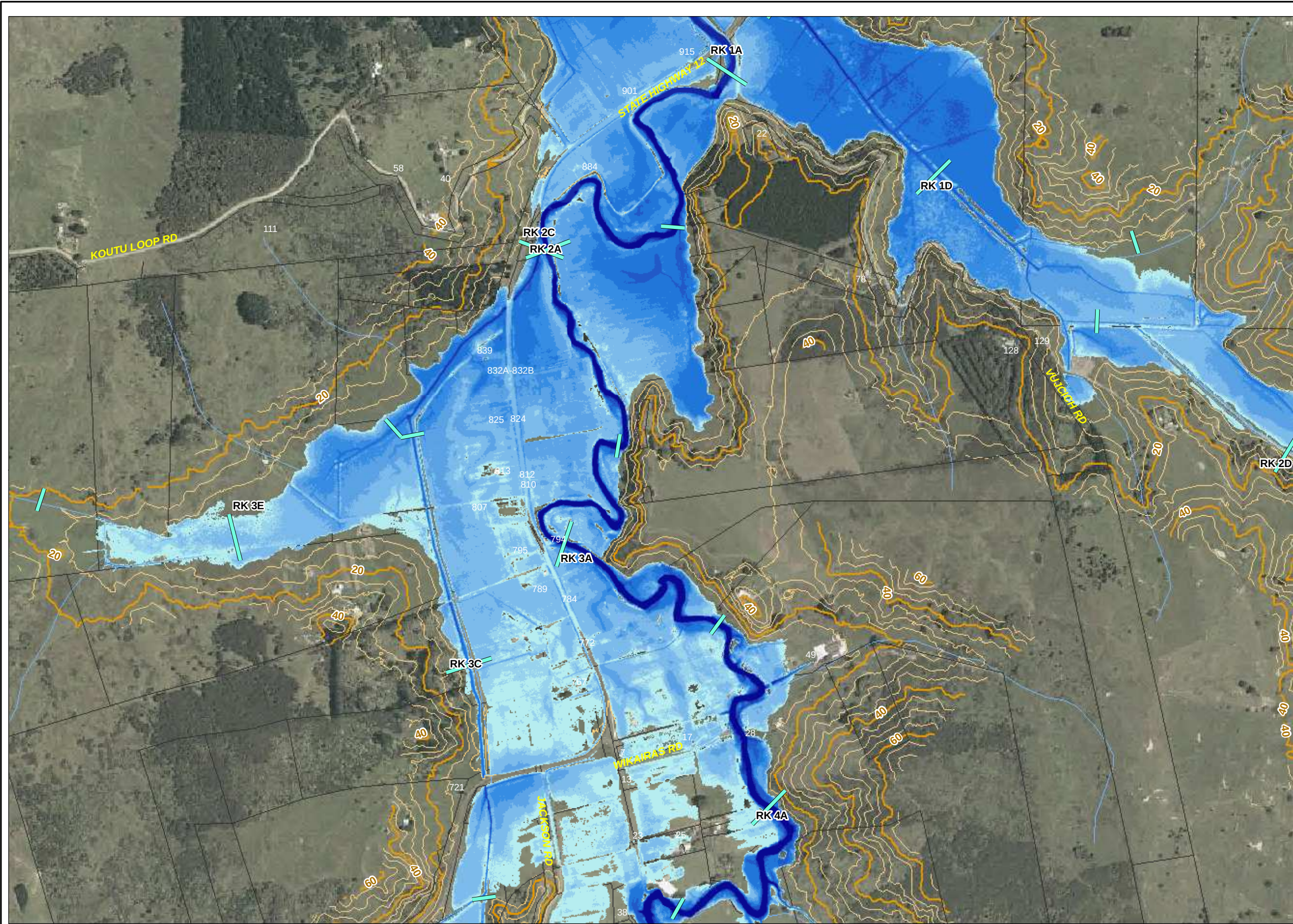


Scale 1:8,000

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



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

Scale 1:8,000

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FLOOD MAPS

Final
WHIRINAKI RIVER 10 YEAR ARI

URS

File: 42071138\FloodMaps18_WHIRINAKI_RIVER\Flood_Maps.mxd

Drawn: FP

Approved: JW

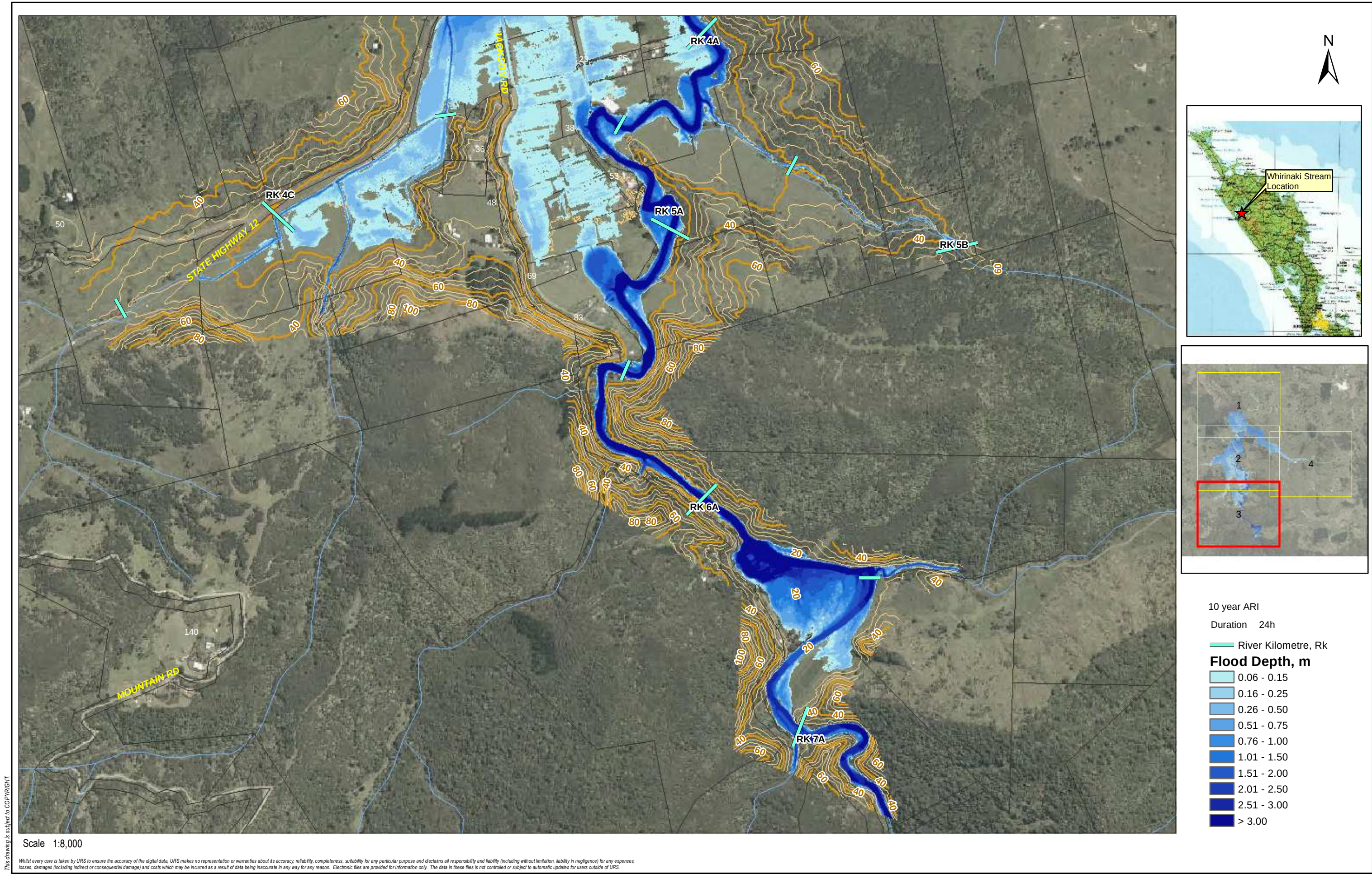
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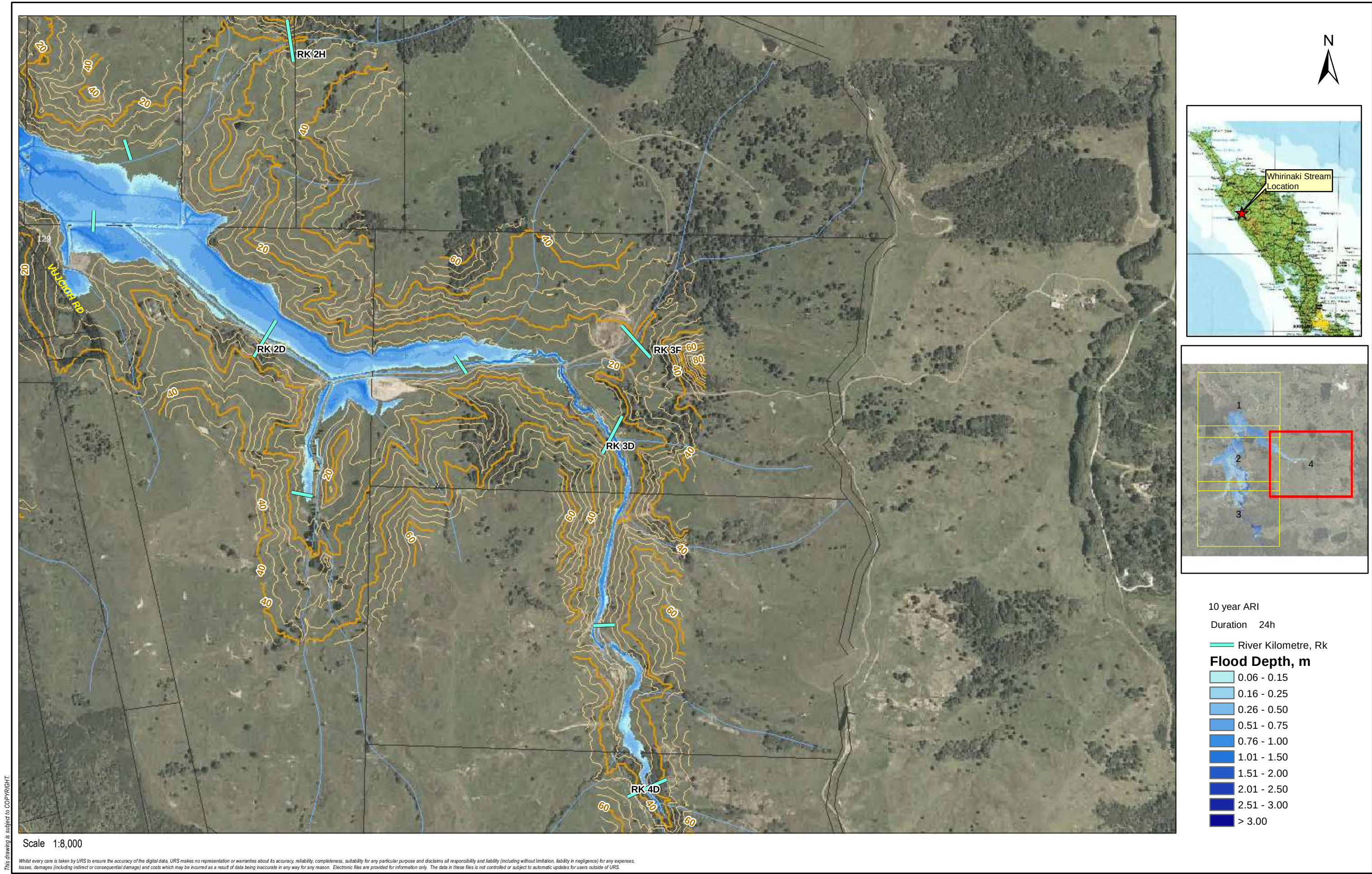
Sheet 2 of 4

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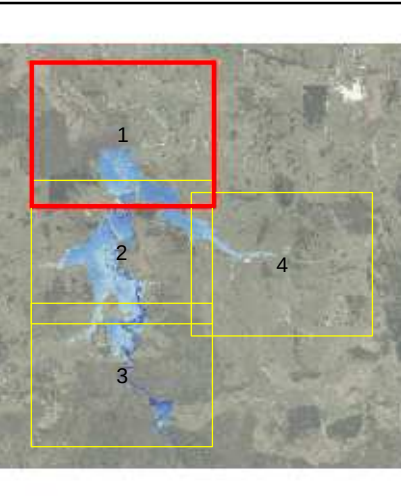
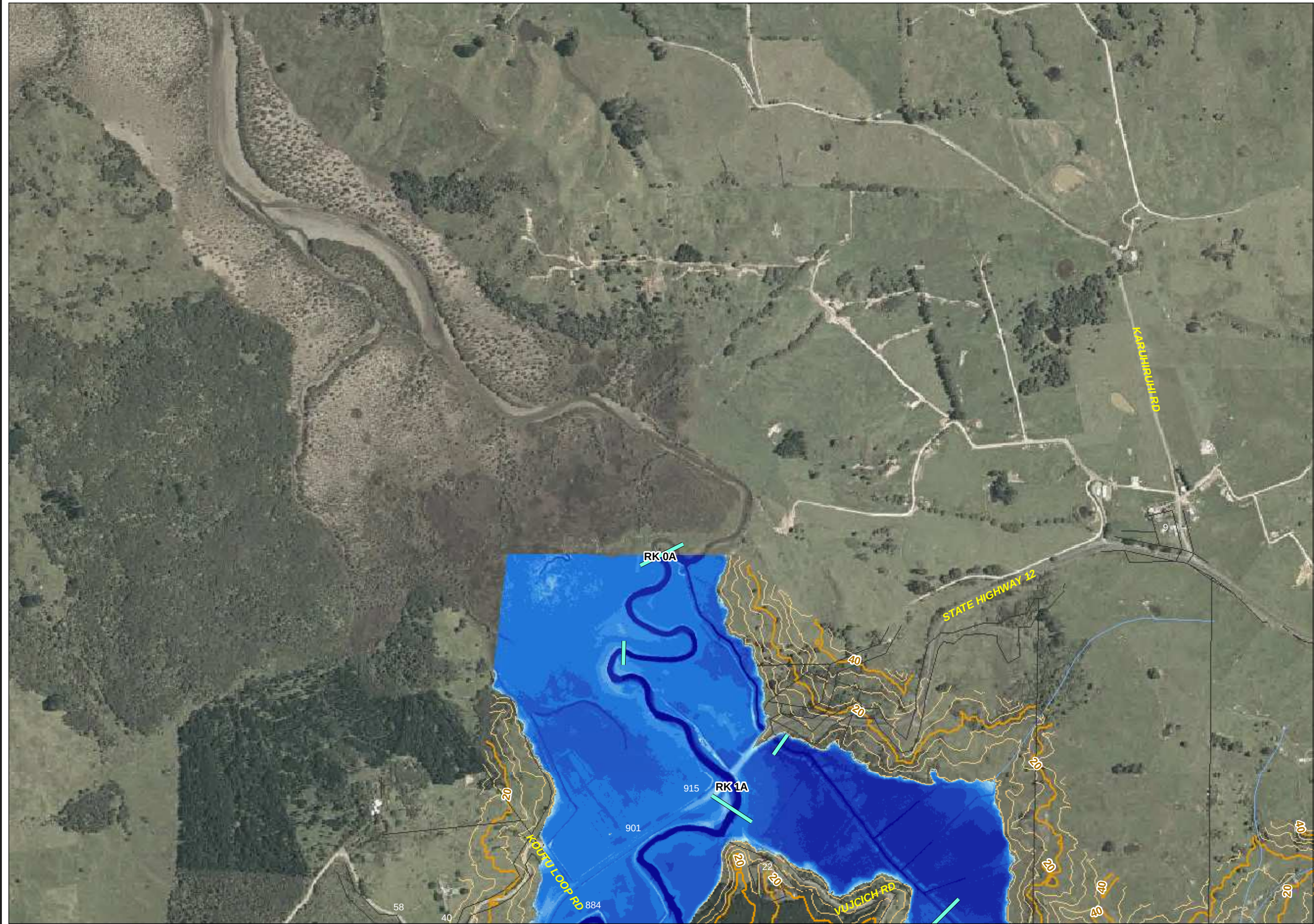




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100 year ARI plus Climate Change
Duration 24h

— River Kilometre, Rk

Flood Depth, m

- 0.06 - 0.15
- 0.16 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- > 3.00

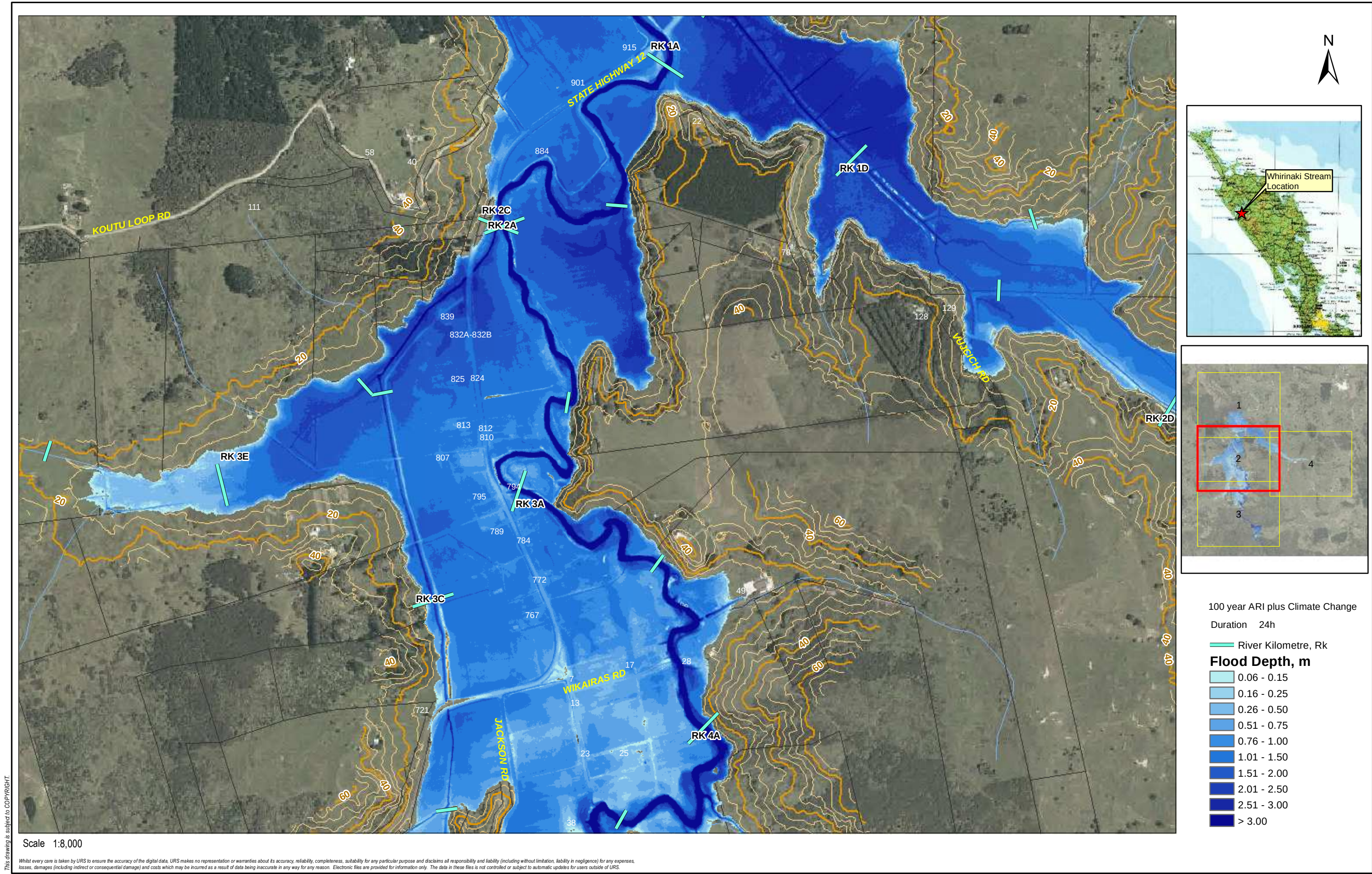
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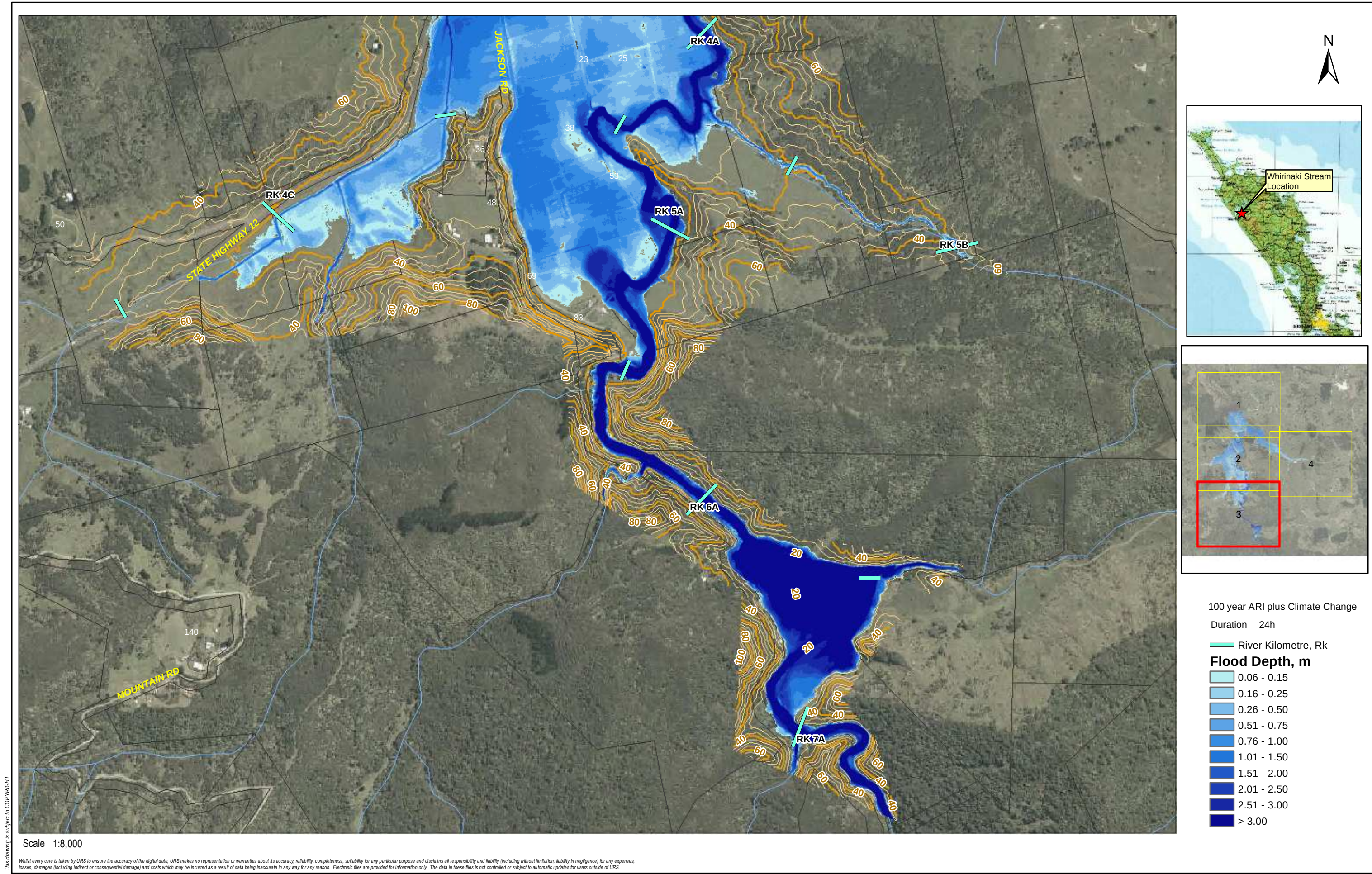
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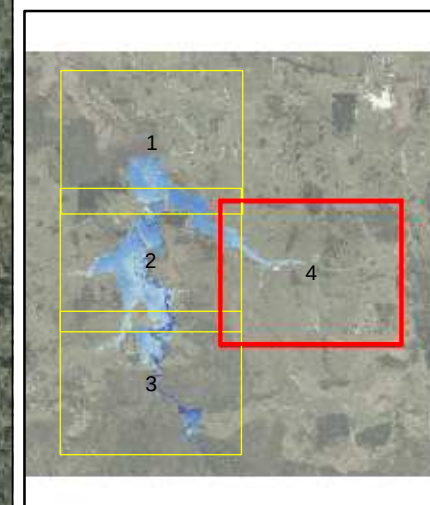
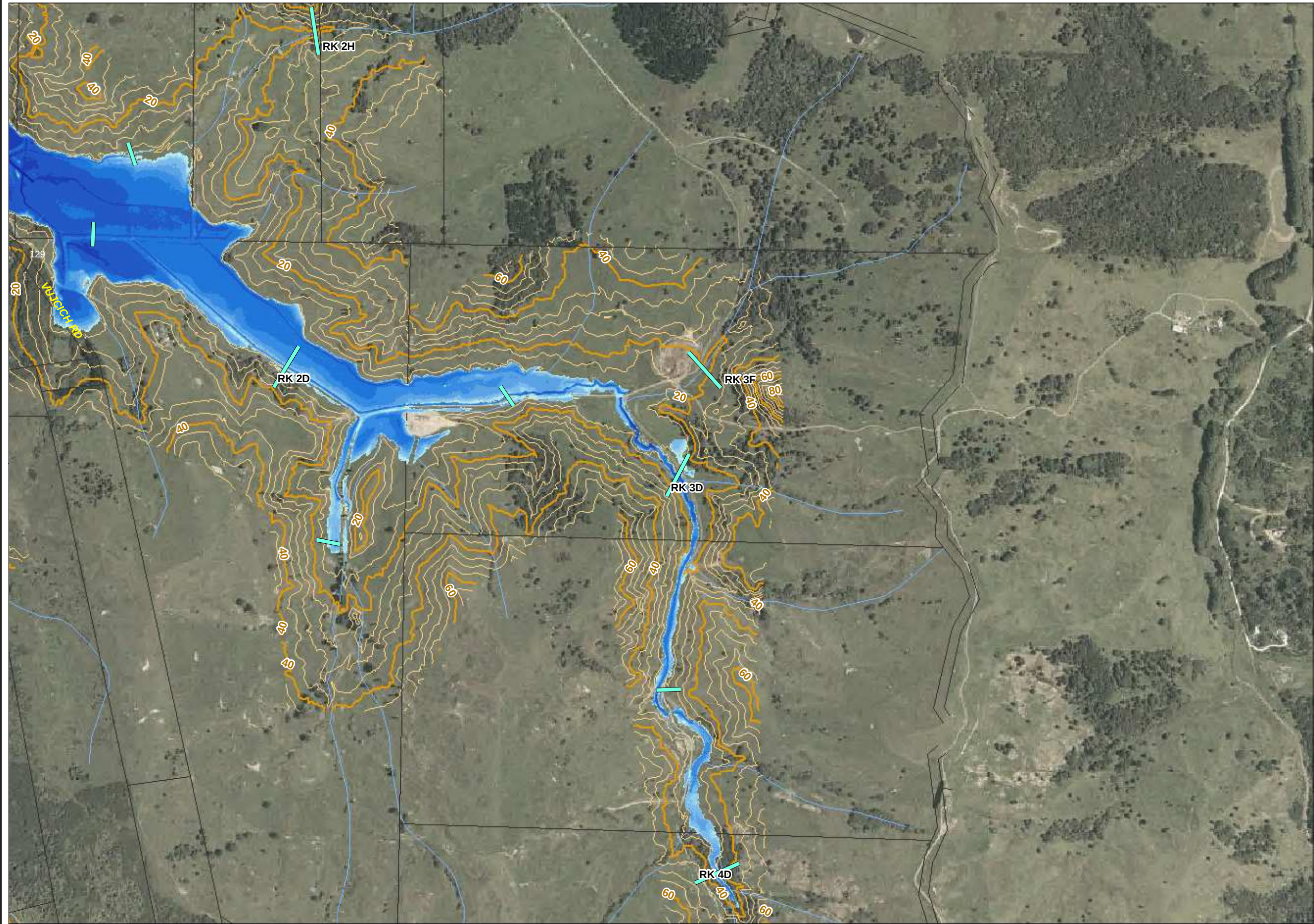


FLOOD MAPS

WHIRINAKI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE







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

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FLOOD MAPS

WHIRINAKI RIVER 100 YEAR ARI PLUS CLIMATE CHANGE



Appendix B Survey Points Results

Table 7-1 Flood survey points; survey and model results

Included in excel table.



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