Design Modelling

Whangapae Ahipara Catchment (M04)

Northland Regional Council

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1 PROJECT OVERVIEW

Overview

Water Technology was commissioned by Northland Regional Council (NRC) to undertake a region-wide flood modelling study. The study area encompassed the entire Northland Regional Council area which covers an area of over 12,500 km^2, with the exclusion offshore islands. The aim of this project was to map riverine flood hazard zones across the entire Northland region and update existing flood intelligence.

Modelling approach

This project used a 2D Direct Rainfall (also known as Rain on Grid) approach for hydraulic modelling and has provided flood extents for a defined range of design storms. The hydraulic modelling software TUFLOW was used. TUFLOW is a widely used software package suitable for the analysis of flooding. TUFLOW routes overland flow across a topographic surface (2D domain) to create flood extent, depth, velocity and flood hazard outputs that can be used for planning, intelligence and emergency response. The latest release of TUFLOW offers several recent advanced modelling techniques to improve modelling accuracy which where practical, were tested and adopted in this project.

This study delineated and modelled 19 catchments, shown in Figure 1-1. To validate the adopted methodology and model parameters used in the design modelling, 9 catchments were calibrated against recent (and historic) flood events. The calibration/validation methodology is documented in a standalone report *NRC Riverine Flood Mapping - Calibration Report – R01* and is referred to throughout this document as the *Calibration Report*.

This report documents the design modelling methodology for Whangapae Ahipara Catchment (M04), noting that this catchment was not calibrated however, model parameters reflected regional parameters and assumptions relied upon for Catchments M03, M06 & M07, located within close proximity to Catchment M04 which was calibrated.

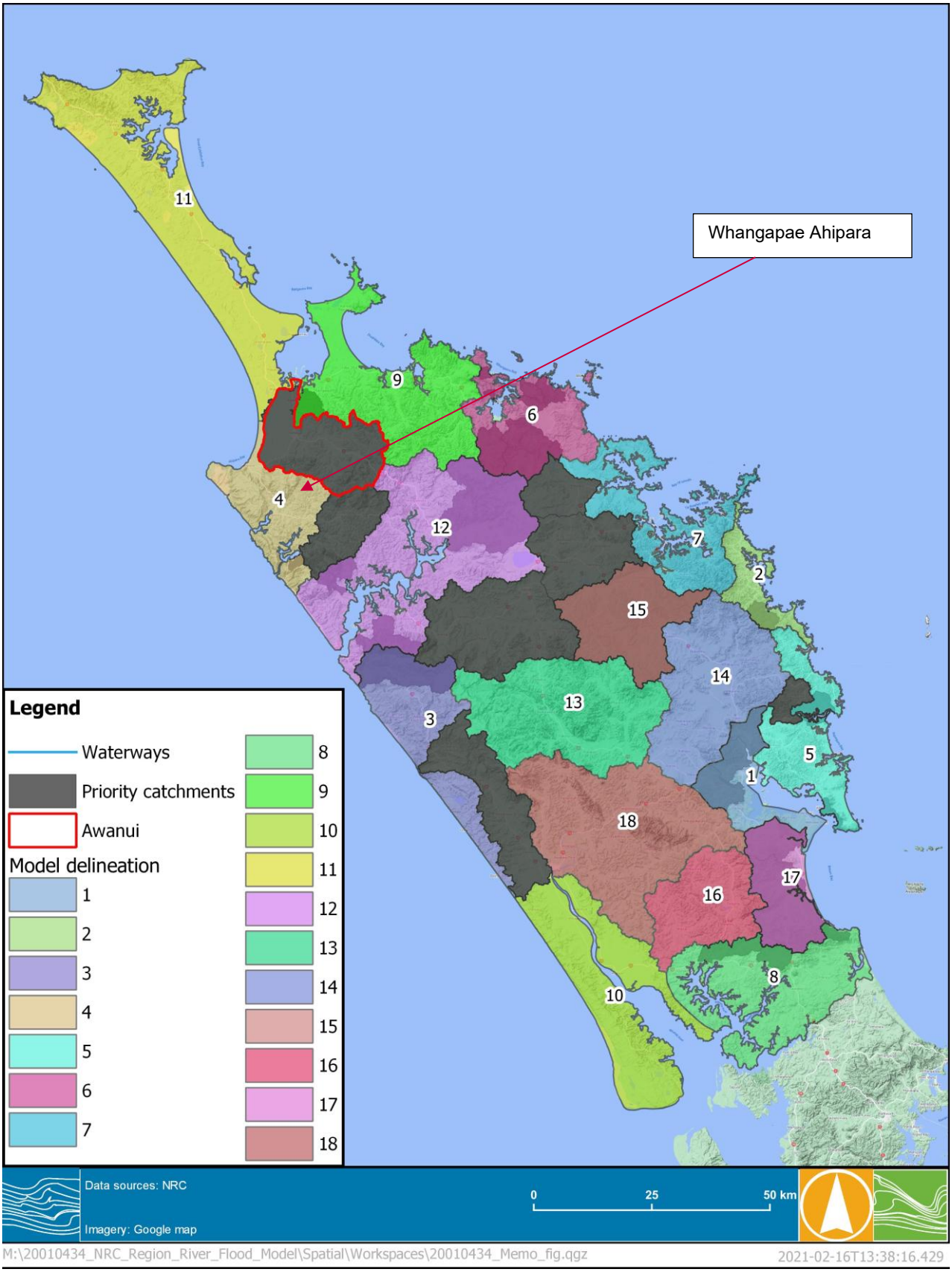

FIGURE 1-1 MODEL DELINEATION

2 STUDY AREA

The Model 04 catchment is a coastal catchment, covering a total area of approximately 361 km^2. The Awaroa River is the major waterway within the catchment and it joins the Rotokakahi River before discharging into the ocean. Figure 2-1 displays the study area of the catchment Model 04.

FIGURE 2-1 STUDY AREA

3 DESIGN MODELLING

3.1 Overview

A hydraulic model (TUFLOW) of the Whangapae Ahipara catchment (M04) was constructed to model overland flooding. A range of storm durations were run and results for each Annual Exceedance Probability (AEP) event were enveloped to ensure the critical duration was well represented across each part of the study area. The merged results captured the maximum flood level and depth of the range of design event durations modelled.

Table 3-1 and the following sections detail the key modelling information used in the development of the hydraulic model.

TABLE 3-1 KEY MODELLING INFORMATION

Terrain data	NRC 1m LiDAR without filling of sinks but includes the "burning of creek alignments' through embankments
Model type	Direct rainfall model
Model build	Build: 2020-10-AA-iSP-w64
Rainfall	See Sections 3.2.1 and 3.2.4
Losses	See Section 3.2.3
Boundaries	See Section 3.2.4
Modelling solution scheme	TUFLOW HPC (adaptive timestep)
Modelling hardware	GPU
Modelling technique	Sub-grid-sampling (SGS)
Model grid size	10m with 1m SGS

3.2 Model Parameters

A range of model parameters were adopted, based on the calibration of catchments (i.e. M03, M06 and M07) in the Far North region. Details of these are outlined below.

3.2.1 Rainfall Intensity-Duration-Frequency

Intensity-Duration-Frequency (IDF) tables were developed by NIWA through the High Intensity Rainfall Design System (HIRDSV4)[1]. Design rainfall totals for durations from 10 minute up to 120 hours were developed for design modelling and were developed at 179 rainfall gauge sites across the wider study area. The IDF tables cover a range of magnitude events from 1 in 1.58 ARI through to 1 in 250 ARI along with climate change predictions (Representative Concentration Pathway 4.6, 6 & 8.5) up to the year 2100. For this catchment, seven rainfall gauges were used with a spatially weighted grid of rainfall totals created for design modelling. Figure 3-1 shows the 12-hour cumulative rainfall grid for the 1% AEP event along with the rainfall gauge locations used to create the grid.

[1] Accessed via https://hirds.niwa.co.nz/

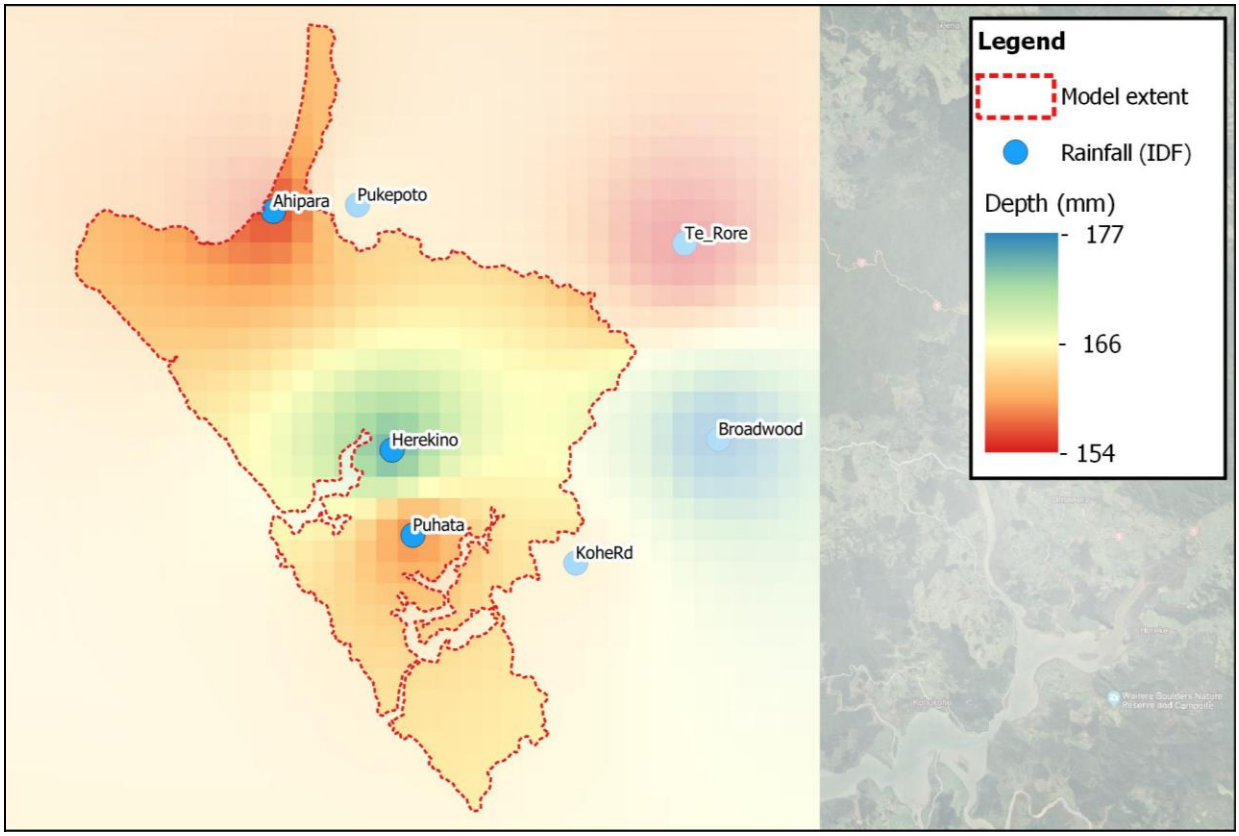

FIGURE 3-1 EXAMPLE OF DESIGN RAINFALL GRID (12-HOUR, 1% AEP RAINFALL) FOR M04

3.2.2 Design Rainfall Temporal Patterns

Design temporal patterns (rainfall hyetographs) were provided by NRC for design modelling. These were developed as part of a previous project undertaken by Macky & Shamseldin (2020)[2]. The project aimed to provide multiple design hyetographs and a better representation of rainfall variability across the Northland region, replacing the single set of design hyetographs previously developed.

The HIRDS design temporal pattern is recommended for design modelling of Northland catchments[2]. Hence, the design hyetographs for the rainfall gauges were developed using the rainfall IDF data at available rainfall gauges for the catchment. Although a 12-hour hyetograph is suitable for design modelling for most Northland catchments as suggested[2], a range of durations were selected; including 1-hour, 6-hour, 12-hour and 24-hour for each of the following AEPs: 10%, 2% and 1% AEP to ensure that the event critical duration was identified across the catchment. The shorter durations were critical in the upper parts of the catchment, while the longer 24-hour durations were critical in the lower catchment, where flood volumes are generally the predominant factor in generating peak flood levels.

Table 3-2 summarises the 1% AEP rainfall depth (based on IDF from HIRDSV4) for different event durations at each rainfall gauge and Figure 3-2 shows the design cumulative rainfall across the different gauges for the 12-hour duration event. Considering a single temporal pattern is assigned (i.e. HIRDS hyetograph), the proportional amount of rainfall applied through time for a given duration (e.g., 6-hour) is generally consistent (as shown in Figure 3-2) across the catchment area.

[2] Macky & Shamseldin (2020) - Northland Region-wide Hyetograph review

TABLE 3-2 1% AEP DESIGN RAINFALL DEPTH

Gauge location	1% AEP (mm)			
	1-hour	6-hour	12-hour	24-hour
Ahipara_A53111	60	126	157	190
Broadwood_A53242	56	133	178	229
Herekino_A53222	58	133	174	218
Puhata_A53321	55	122	160	200
Pukepoto_A53129	59	128	164	205
Rotokakahi at KoheRd_533302	54	126	164	208
Takahue at Te Rore_531313	59	121	155	193

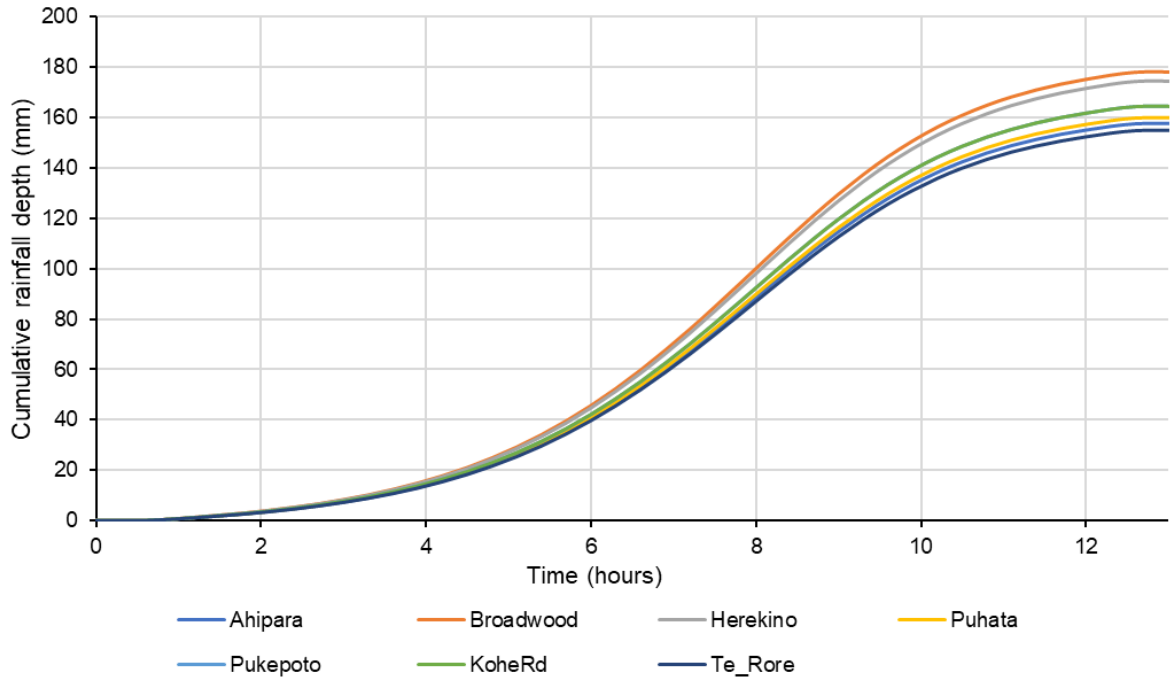

FIGURE 3-2 TEMPORAL PATTERN FOR DESIGN RAINFALL OF 12-HOUR, 1% AEP EVENT

A climate change scenario (for the 1% AEP events) was modelled for the 2081-2100 timeframe, for the RCP 8.5. This is based on the increases in rainfall intensity of 35%, 30%, 26% and 22% respectively for 1-hour, 6-hour, 12-hour and 24-hour duration events.

3.2.3 Losses

Model cells were assigned a Manning's "*n*" (surface roughness), initial loss and a continuing loss based on land use types and hydrologically important characteristics. Table 3-3 summarises the adopted roughness and loss parameters. It should be noted these parameters were adopted based on the calibration to a historic event where streamflow gauges were present in other Far North catchments (i.e. M03, M06 and M07). Figure 3-3 displays the roughness layer based on the land use type, showing most land use is forest and grassland.

TABLE 3-3 DESIGN MODEL PARAMETERS

Hydrological areas	Land use types	Manning's n	Initial loss (IL) – mm	Continuing loss (CL) – mm/hr
Entire M04 catchment	Forest	0.09	9	6
	Grassland	0.05	9	4.5
	Cropland – perennial	0.04	17	2
	Cropland – annual	0.04	17	2
	Wetland – open water	0.04	0	0
	Wetland – vegetated	0.05	10	1
	Urban areas	0.10	5	1.5
	Waterways	0.05	0	0
	Other	0.06	15	1.5

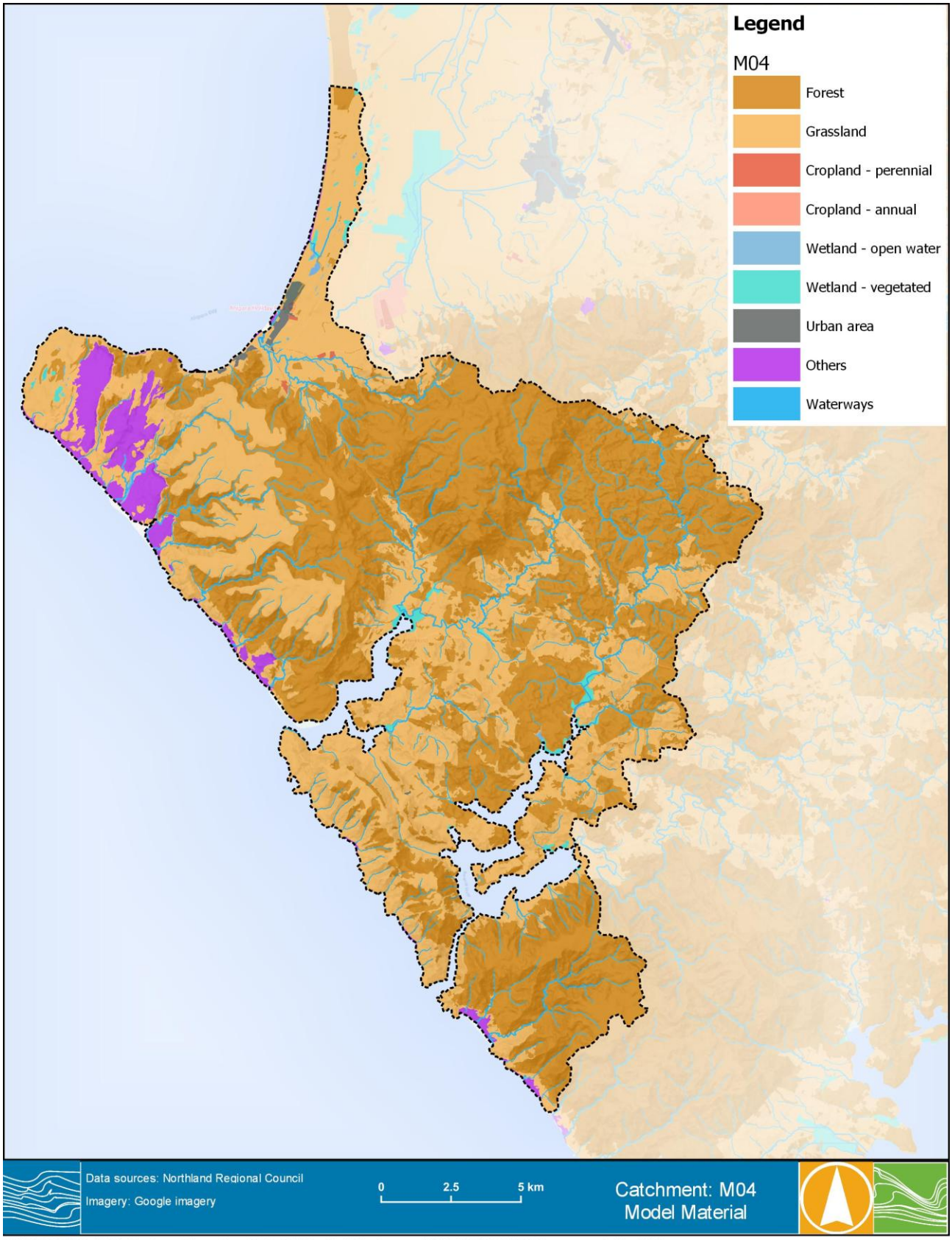

FIGURE 3-3 HYDRAULIC MODEL MATERIAL LAYER

3.2.4 Boundaries

As the Whangapae Ahipara catchment is a coastal catchment, a static tail-water (i.e. 2161 mm OTP) outflow boundary based on the 2 year ARI tide level[3] at Pouto Point was used for the design modelling. A 1.2 m sea level rise was adopted for climate change runs based on the project brief.

There is no upstream inflow coming from upstream catchments applied in this catchment model.

[3] MWH, 2010 *Priority Rivers – Flow Assessment, Sea Level Rise and Storm Surge*, prepared for Norhland Regional Council

4 MODELLING RESULTS

4.1 Modelled Result Processing/Filtering

Design modelling consisted of running the model for four storm durations (1-hour, 6-hour, 12-hour and 24-hour) with the results enveloped for each design event (i.e. 1%, 2% and 10% AEP) to ensure the critical duration was well represented across each part of the catchment. Each model run produced gridded results, including depth, water surface elevation (WSE), flood hazard (Z0) and velocity. Several post-processing steps were required to produce the final design modelling outputs. These are described as follows:

Step 1:

- The modelling results are firstly merged to produce a single data set for each AEP from the storm durations modelled. For example, the flood depth output is produced by merging the depth results of the four different durations within each AEP. This allows for the critical storm duration across each part of the catchment to be represented (i.e. the short intense storms in upper reaches and longer duration storms in the lower parts of the catchment).

Step 2:

- The maximum gridded results are then remapped to a finer DEM grid using LiDAR data resampled to a 5-m grid resolution. This allows the flood extent to be more accurately displayed on the map and the higher resolution gridded results (i.e. same resolution as the 5-m DEM) to be produced.

Step 3:

- Finally, the remapped results are post-processed by filtering out depths below 100mm and puddle areas less than 2000m^2 as agreed with NRC.

Figure 4-1, Figure 4-2 and Figure 4-3 respectively show the final post-processed flood depths, velocity and hazard of the 1% AEP design event modelled for M04. Figure 4-4 shows the flood depth map zoomed in at Manukau as an example. It is noted that the hazard classification is based on the following criteria:

TABLE 4-1 FLOOD HAZARD CLASSIFICATION

Hazard classification	Hazard – VxD (m^2/s)
Low	< 0.2
Low to Moderate	0.2 to 0.4
Moderate	0.4 to 0.6
Moderate to High	0.6 to 0.84
High	> 0.84

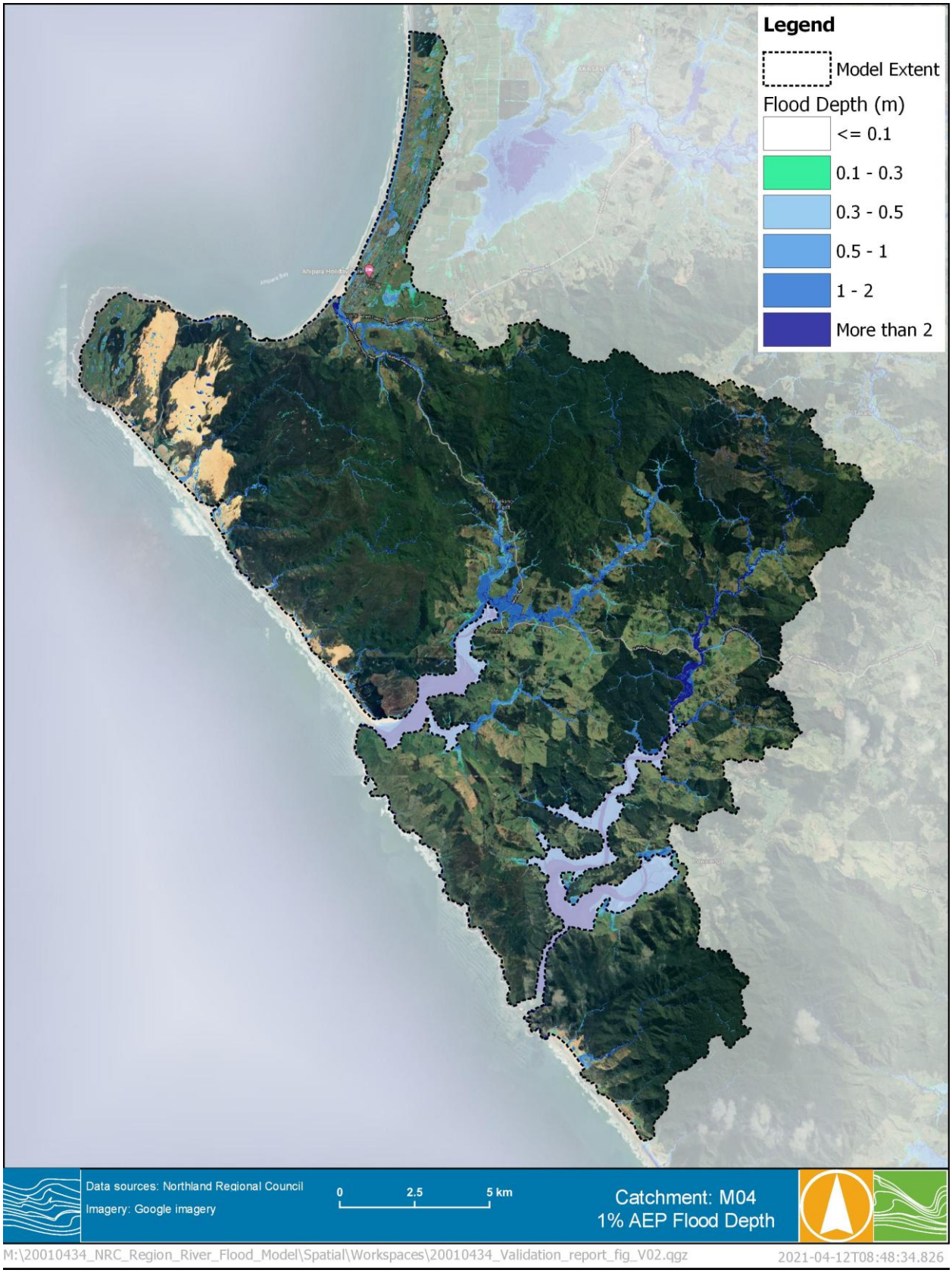

FIGURE 4-1 DESIGN MODELLING OF 1% FLOOD DEPTH

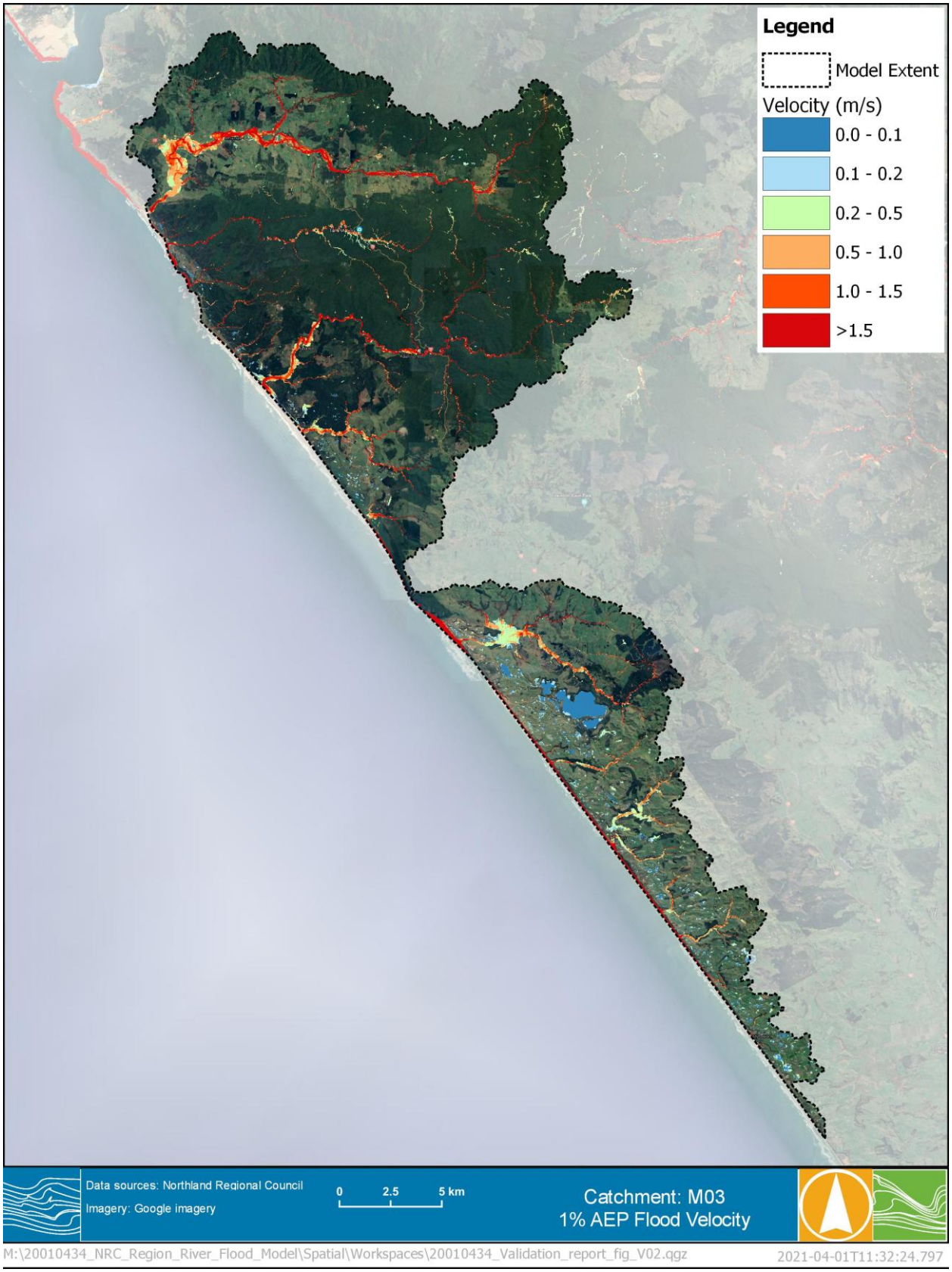

FIGURE 4-2 DESIGN MODELLING OF 1% AEP FLOOD VELOCITY

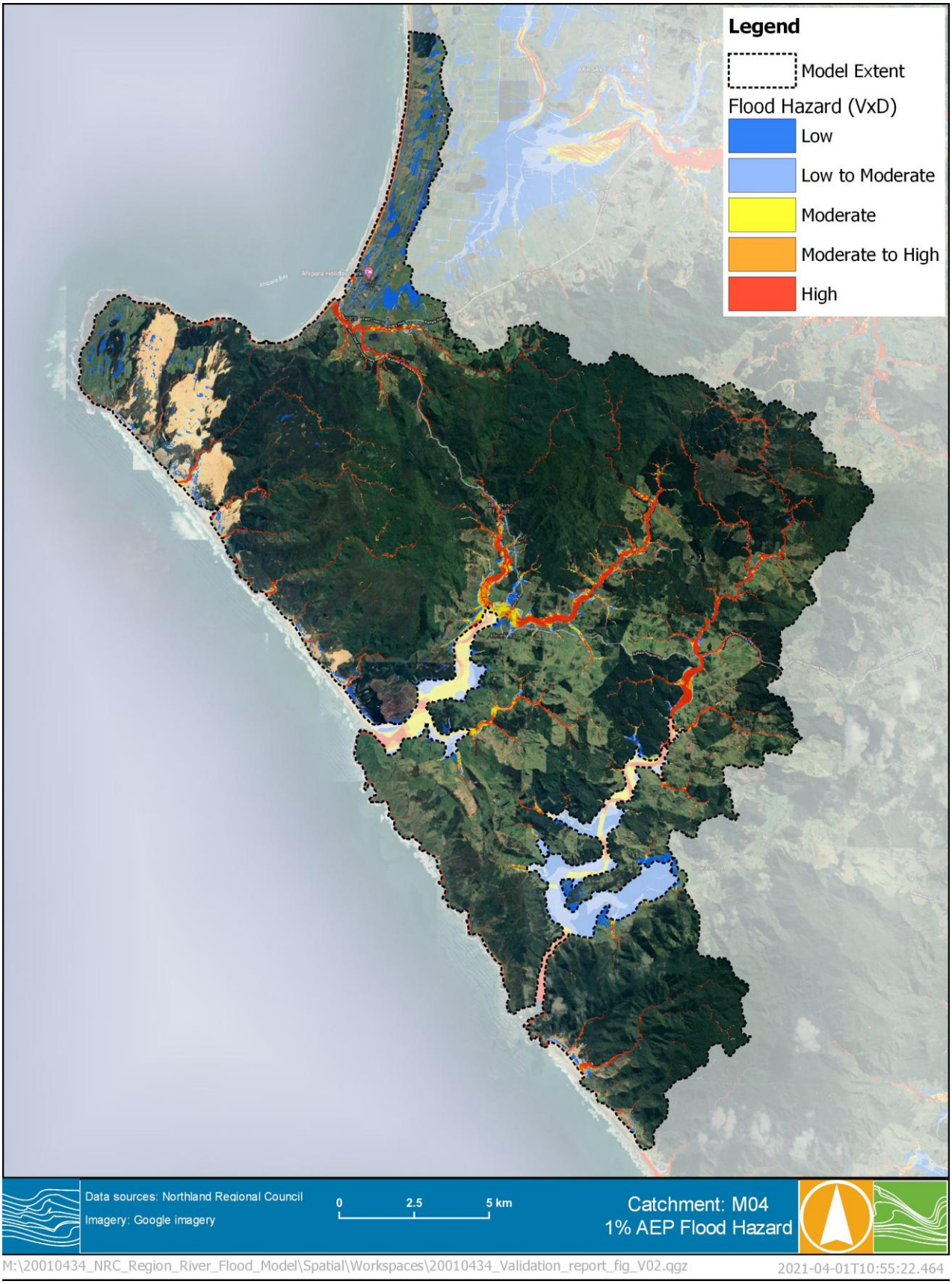
Legend
Model Extent
Flood Hazard (VxD)
Low
Low to Moderate
Moderate
Moderate to High
High
Data sources: Northland Regional Council
Imagery: Google imagery
0
2.5
5 km
Catchment: M04
1% AEP Flood Hazard
M:\20010434_NRC_Region_River_Flood_Model\Spatial\Workspaces\20010434_Validation_report_fig_V02.qgz
2021-04-01T10:55:22.464

FIGURE 4-3 DESIGN MODELLING OF 1% AEP FLOOD HAZARD

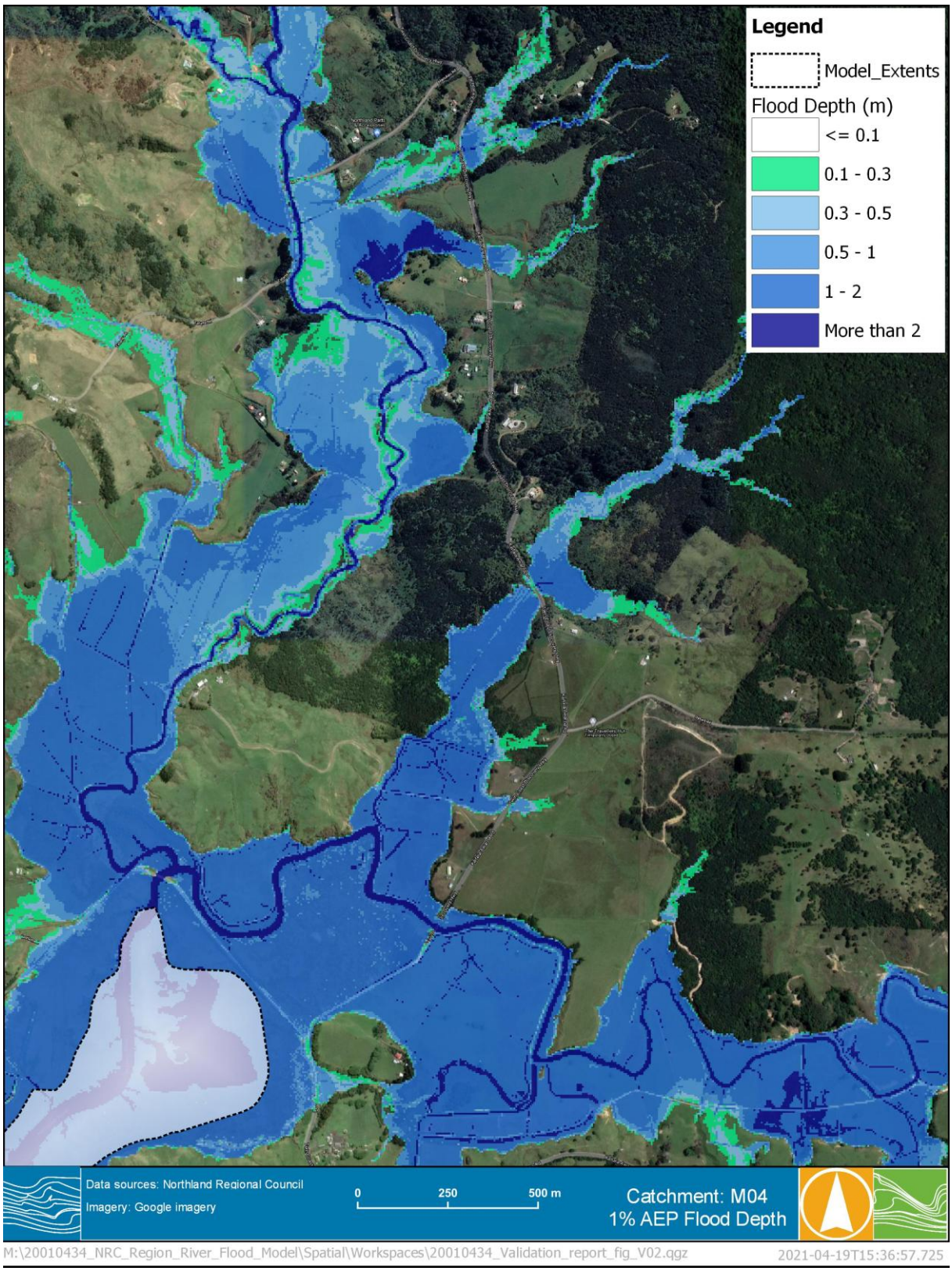

FIGURE 4-4 DESIGN MODELLING OF 1% AEP FLOOD DEPTH ZOOMED AT MANUKAU

5 VERIFICATION OF DESIGN FLOWS

Flow lines were included at several waterways in the hydraulic model as 2D Plot Output (2D PO) for design events. This allows flow hydrographs and peak flows to be extracted at these locations. Figure 5-1 displays the PO line locations and shows that there is no streamflow gauge found within the Whangapae Ahipara catchment.

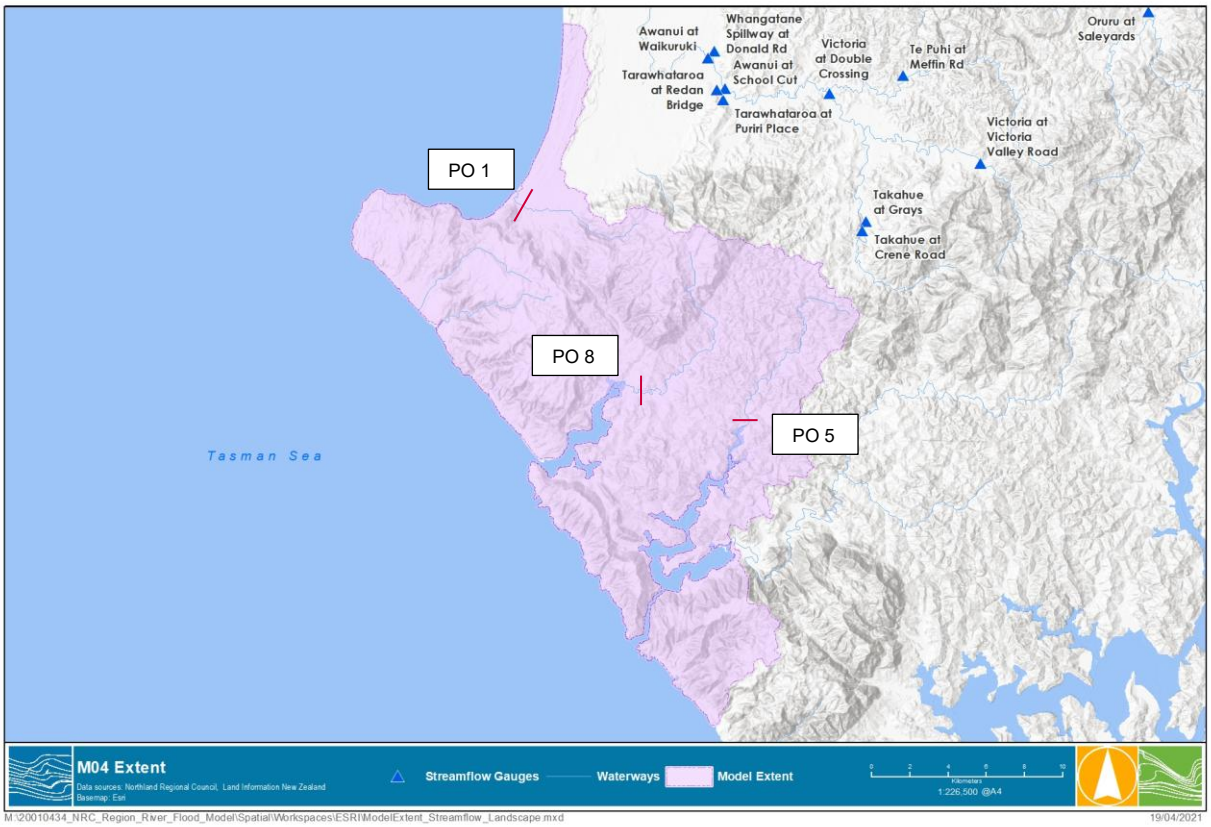

FIGURE 5-1 AVAILABLE STREAMFLOW GAUGES WITHIN WHANGAPAE AHIPARA CATCHMENT

The modelled peak flow for the 1% AEP design flood was compared with hydrological estimates, including the Rational Method and SCS Method.

5.1 Regional Estimation Methods

For catchments where a suitable streamflow gauge record was not available, additional estimation methods were used to provide design flow verification. These methods are based on empirical estimations using catchment area and design rainfall totals to estimate peak design flows. These methods were checked for each Flow Line location within the study area and are described below.

5.1.1 NIWA New Zealand River Flood Statistics Portal

The New Zealand River Flood Statistics portal[4] provides peak flood estimation at streamflow gauging stations and the entire river system in New Zealand completed in 2018. The design estimates can be extracted from the portal are:

- Flood Frequency estimates, noted as Henderson & Collins 2018 (at river reach).
- Rational Method HIRDS V3 (at river reach).

The flood frequency estimates given by the portal are determined using the Mean Annual Flow method developed by Henderson & Collins (2018)[5].

5.1.2 SCS method

The SCS method, first developed by the U.S. Department of Agriculture's Soil Conservation Service, calculates peak flood flow based on rainfall and land-cover-related parameters. It is the recommended method for stormwater design in the Auckland region, providing a useful comparison. The peak flow equation is:

$Q = (P – Ia)^2 / (P – Ia + S)$

where:

- Q is run-off depth (millimetres).
- P is rainfall depth (millimetres)
- S is the potential maximum retention after run-off begins (millimetres).
- Ia is initial abstraction (millimetres), which is 5 millimetres for permeable areas and zero otherwise.

The retention parameter S (measured in millimetres) is related to catchment characteristics through:

$S = (1000/CN – 10)\ 25.4.$

The value of the curve number (CN) represents the run-off from 0 (no run-off) to 100 (full run-off) and it is influenced by soil group and land use. A CN value of 50 was used for the SCS estimation of this catchment.

The run-off depth (Q) is then converted to a peak flow rate using the SCS unit hydrograph.

5.1.3 Rational Method

The Rational Method is widely used across both New Zealand and Australia. The equation is based on catchment area and design rainfall. The equation is:

$Q = C\ i\ A\ /3.6$

where:

- Q is the estimate of the peak design discharge in cubic metres per second
- C is the run-off coefficient
- i is rainfall intensity in mm/hr hour, for the time of concentration
- A is the catchment area in km^2.

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[4] NIWA Flood Frequency tool, accessed via: https://niwa.co.nz/natural-hazards/hazards/floods
[5]Henderson, R.D., Collins, D.B.G., Doyle, M., Watson, J. (2018) *Regional Flood Estimation Tool for New Zealand Final Report Part 2*. NIWA Client Report

5.2 Verification Results

Table 5-1 summarises the comparison of 1% AEP peak flow estimates with the modelled values at three PO line locations in the Whangapae Ahipara catchment and the differences between the estimation methods and modelled results can be visualised in Figure 5-2.

The Rational Method and the SCS method across all the locations tend to underestimate the design flows across these PO locations.. It is noted that both these methods are only applicable for relatively small catchments, with the SCS method limited to 12 km². The catchment sizes for the three PO line locations within this study area range from 30 to 55 km². These equations are also subject to great uncertainty in summarising catchment characteristics.

At PO 1 and PO 8 locations, the modelled design flows are significantly greater than the empirical estimates. In contrast, the modelled design flow at PO 5 has a good match to the NIWA H&C2018 estimate.

The verification of the modelled design flows heavily relied on the use of empirical method estimations. With the absence of streamflow gauge, this catchment model was not able to be calibrated and its results were not verified against any historic record, however are fit for purpose of mapping riverine flood hazard zones across the entire Northland region and to update existing flood intelligence.

TABLE 5-1 SUMMARY OF 1% AEP PEAK FLOW COMPARISON

PO line location	Hydraulic model (m^3/s)		Empirical estimates (m^3/s)		NIWA Flood Frequency Tool 2018 (m^3/s)
	Critical duration	Modelled peak	SCS	Rational method	NIWA – H&C 2018
PO1	6 hr	253.8	70.6	77.7	81
PO8	6 hr	250.2	76.3	84.2	153
PO5	6 hr	298.6	112.6	128.5	317

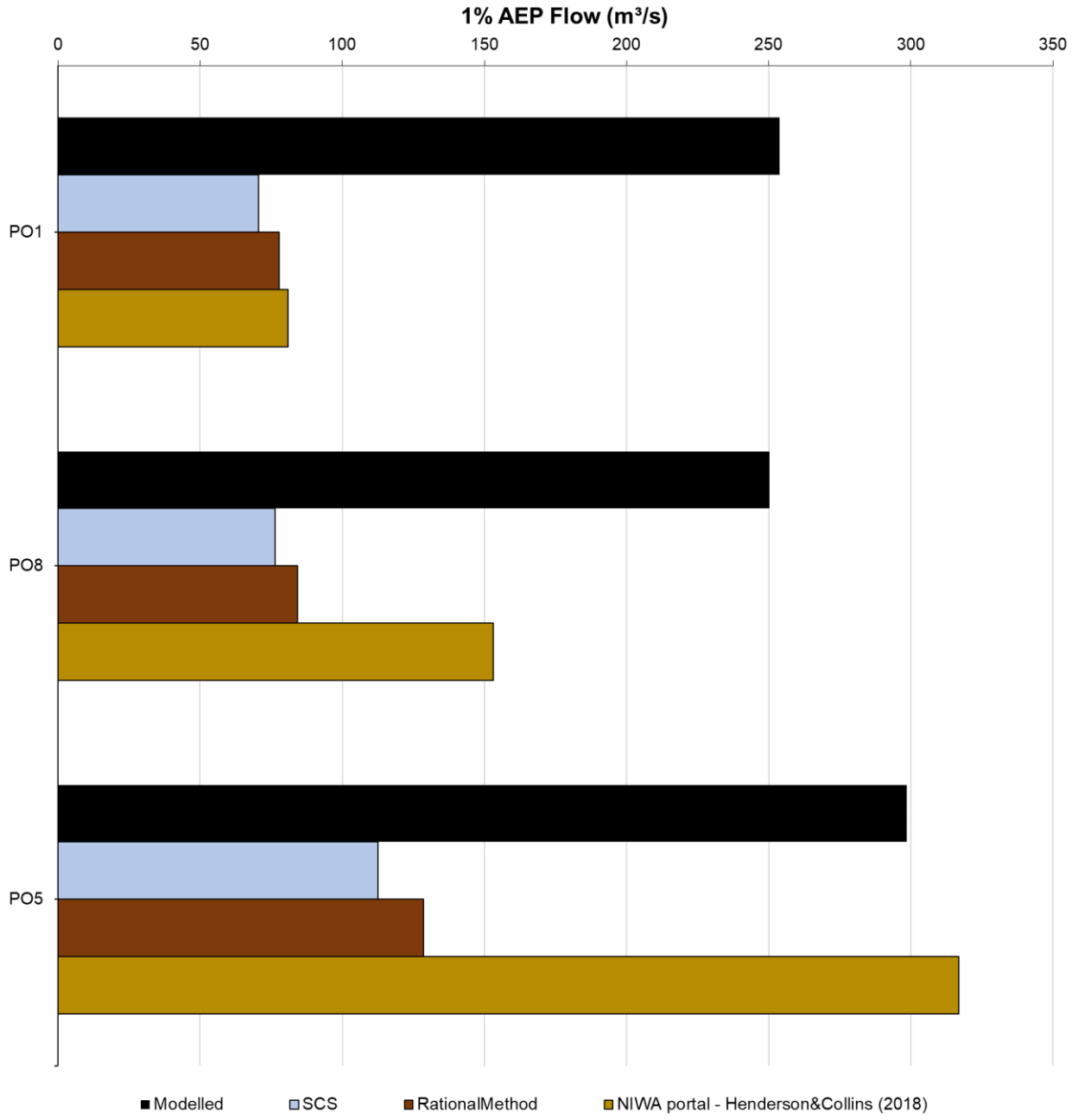

FIGURE 5-2 VERIFICATION OF DESIGN MODELLING RESULTS AGAINST HYDROLOGICAL ESTIMATES

6 SUMMARY

The Whangapae Ahipara catchment model (M04) was not calibrated and its model parameters were adopted based on calibrated catchments nearby in the Far North region. The design modelling of this catchment consisted of four storm durations (1-hour, 6-hour, 12-hour and 24-hour) for each design AEP (i.e. 1%, 2% and 10% AEP). Design flood extents and gridded results, including depth, water surface elevation, velocity and hazard were produced and delivered to NRC.

The modelled 1% AEP design flows were verified against limited design flood estimation methods at three PO line locations but these estimation methods are subject to uncertainty in summarising the catchment characteristics. Given the absence of historic records and the general limitation with empirical design estimates, the reliability of the modelled design flows is uncertain in this catchment.

When considering the scope and the scale of this project, the current modelling results are considered fit for use. Modelling outputs can be used to identify flood hazard and potential flood risk. It can also inform planning decisions, infill flood mapping between detailed flood studies and provide a basis for broad emergency management exercises.