Design Modelling

Manganui Catchment (M16)

Northland Regional Council

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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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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 Manganui Catchment (M16), noting that this catchment was not calibrated however, model parameters reflected regional parameters and assumptions relied upon for Catchments M01, M13, M14 and M15, located within close proximity to Catchment M16 and which were calibrated.

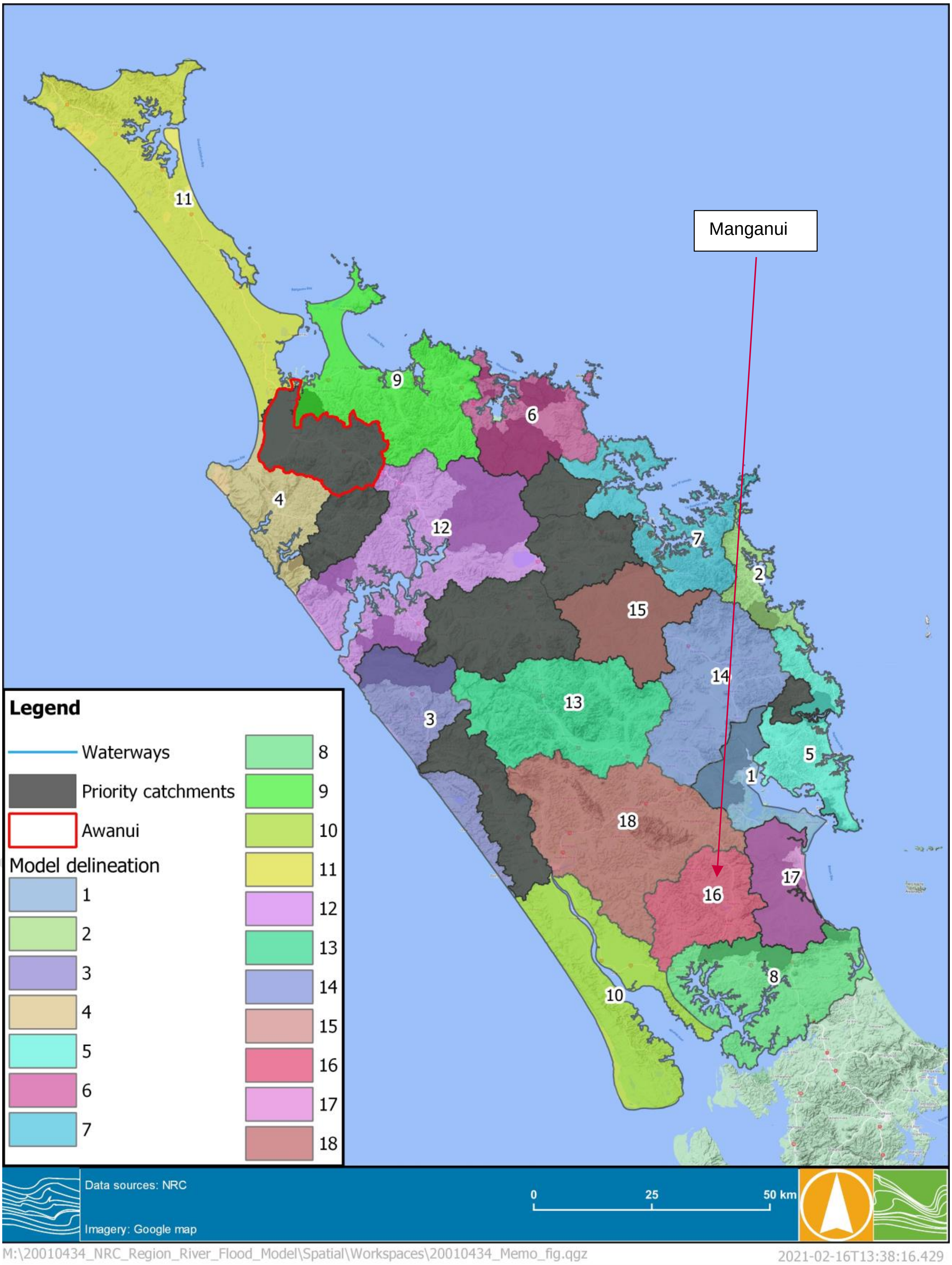

FIGURE 1-1 MODEL DELINEATION

2 STUDY AREA

The model 16 catchment is an inland and mountainous catchment, covering a total area of approximately 409 km^2. Manganui River is the largest waterway within the catchment flowing from east to west. Figure 2-1 displays the study area of the catchment model 16.

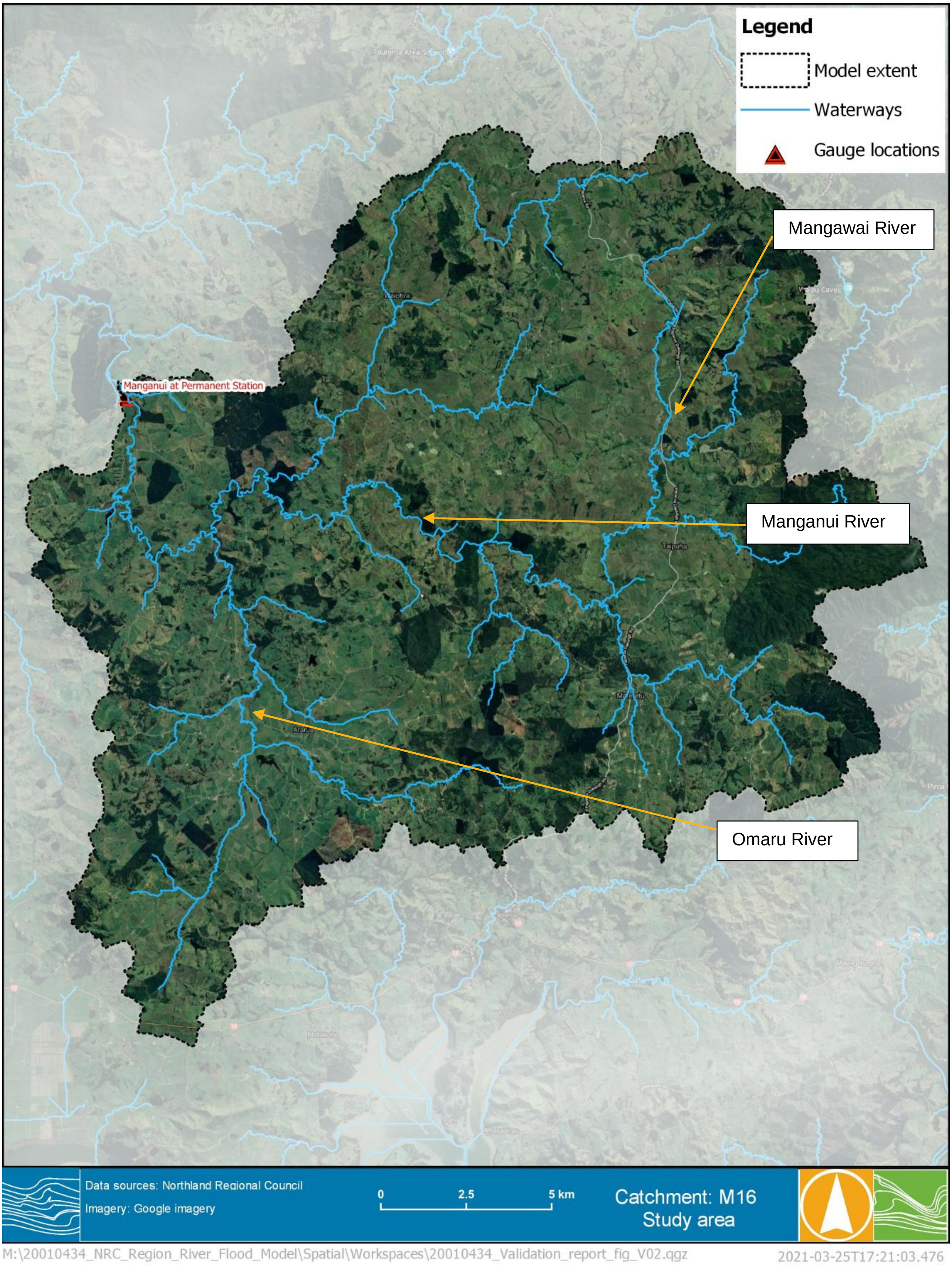

FIGURE 2-1 STUDY AREA

3 DESIGN MODELLING

3.1 Overview

A hydraulic model (TUFLOW) of the Manganui catchment (M16) 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. M01, M13, M14 and M15) in the Whangarei District. 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, five 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/

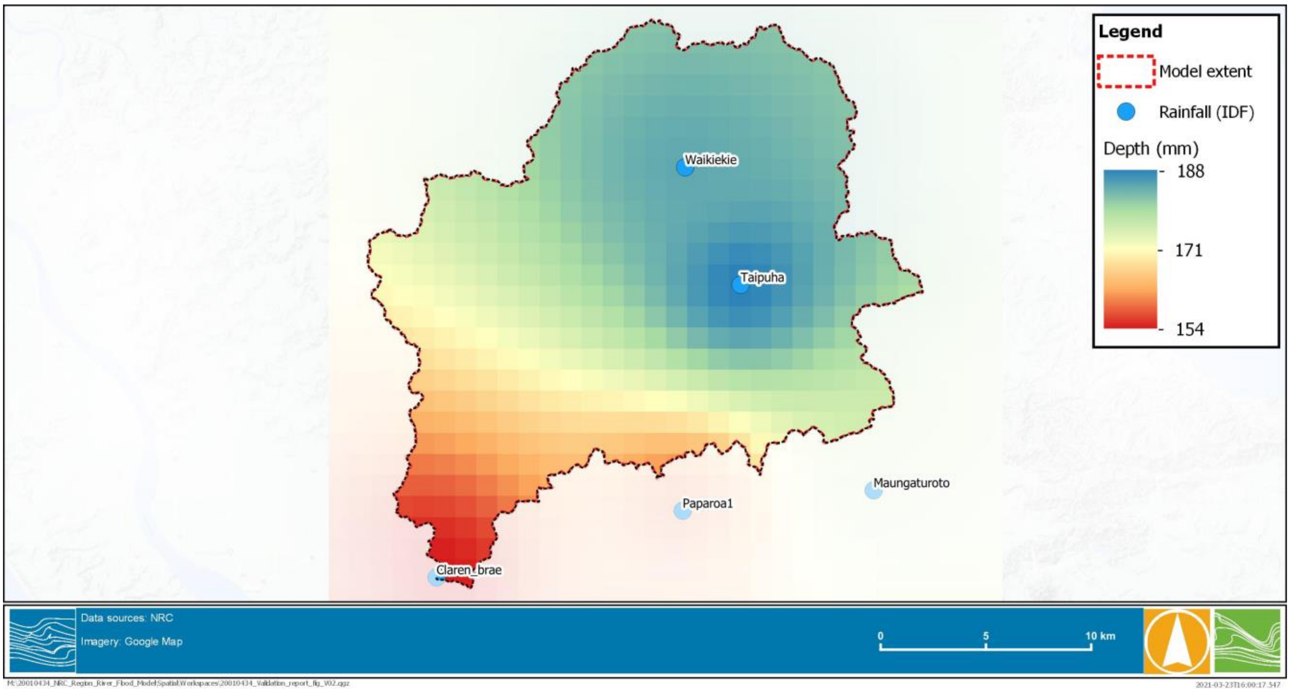

FIGURE 3-1 EXAMPLE OF DESIGN RAINFALL GRID (12-HOUR, 1% AEP RAINFALL) FOR M16

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 AEP's, including 10%, 2% and 1% AEP events 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
Paparoa1_A64121	57.8	124.2	159.6	198.96
Paparoa_at_Maungaturoto_641213	61.2	138	176.4	218.4
RUAWAI_Claren_bare_A64112	54.8	120.6	154.8	192.24
TAIPUHA_A64021	57.8	139.2	188.4	247.2
WAIKIEKIE_A54921	57.1	136.2	184.8	244.8

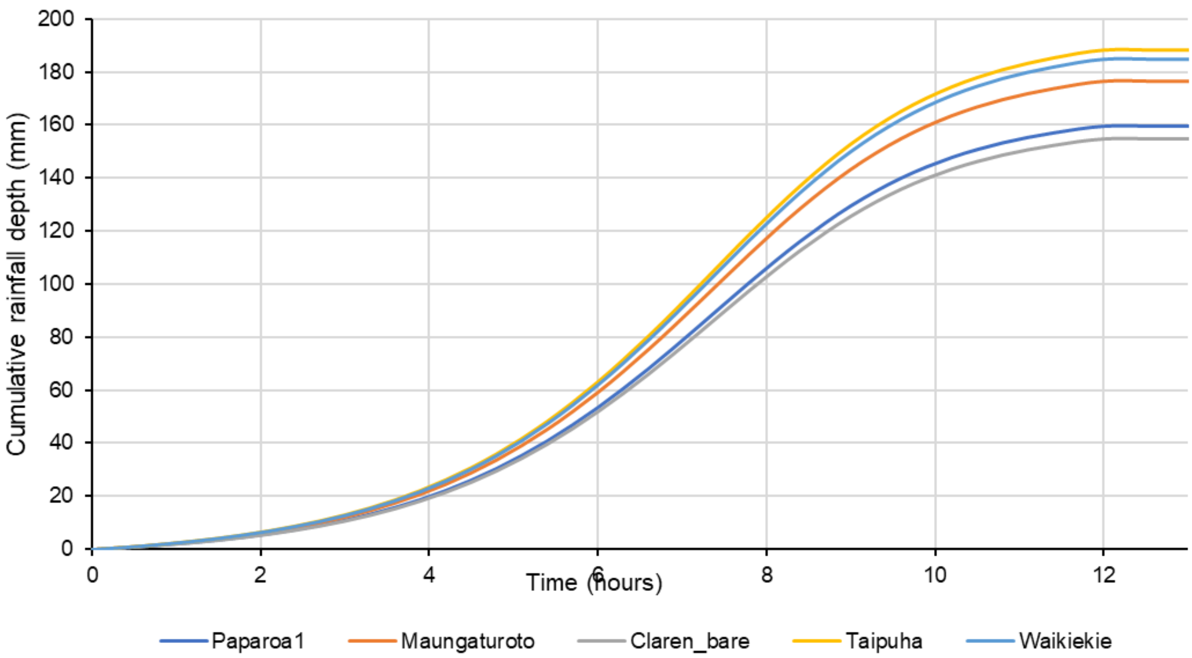

FIGURE 3-2 TEMPORAL PATTERN FOR DESIGN RAINFALL OF 12-HOUR, 1% AEP EVENT

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 Whangarei District catchments (i.e. M01, M13, M14 and M15). 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 M16 catchment	Forest	0.08	34	5.3
	Grassland	0.06	34	5.3
	Cropland – perennial	0.04	20	2
	Cropland – annual	0.04	20	2
	Wetland – open water	0.04	0	0
	Wetland – vegetated	0.05	10	1
	Urban areas	0.10	5	1.5
	Waterways	0.06	0	0
	Other	0.06	15	1.5

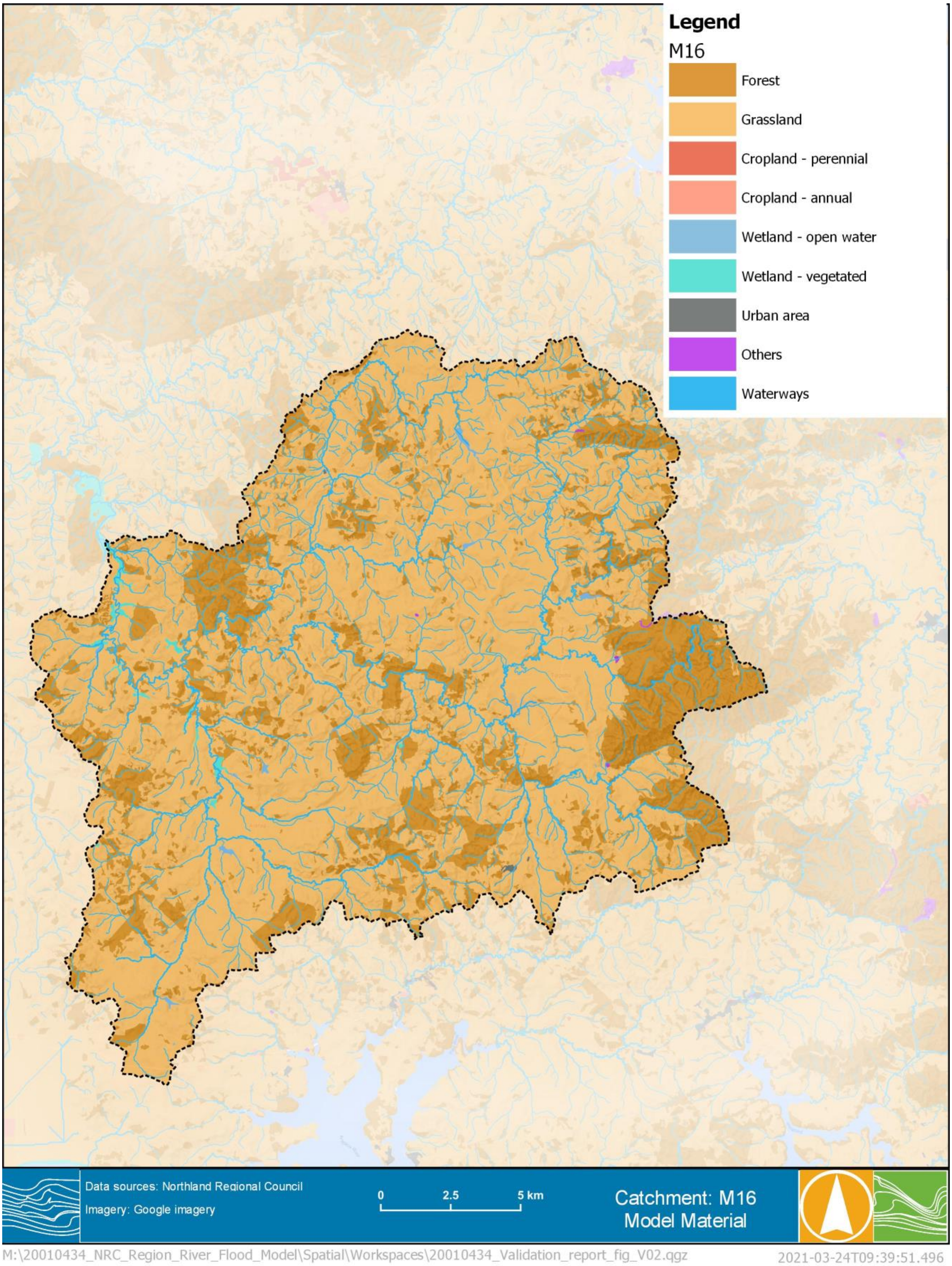

FIGURE 3-3 HYDRAULIC MODEL MATERIAL LAYER

3.2.4 Boundaries

As the Manganui catchment is an inland, a stage and discharge (i.e. HQ) outflow boundary based on the floodplain slope was used at the immediately downstream of the Mangaui at Permanent Station gauge for the design modelling. It should be noted that the flowrates at the outflow boundary were recorded in the model and they were used as inflows for catchment M18 in design modelling (refer to validation report for M18).

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

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), 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 the maximum outputs of the range of 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). Effectively, a map of the worst-case scenario at each location (based on the modelled scenarios) is generated across the whole area.

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 M13. Figure 4-4 shows the flood depth map zoomed in at a township 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

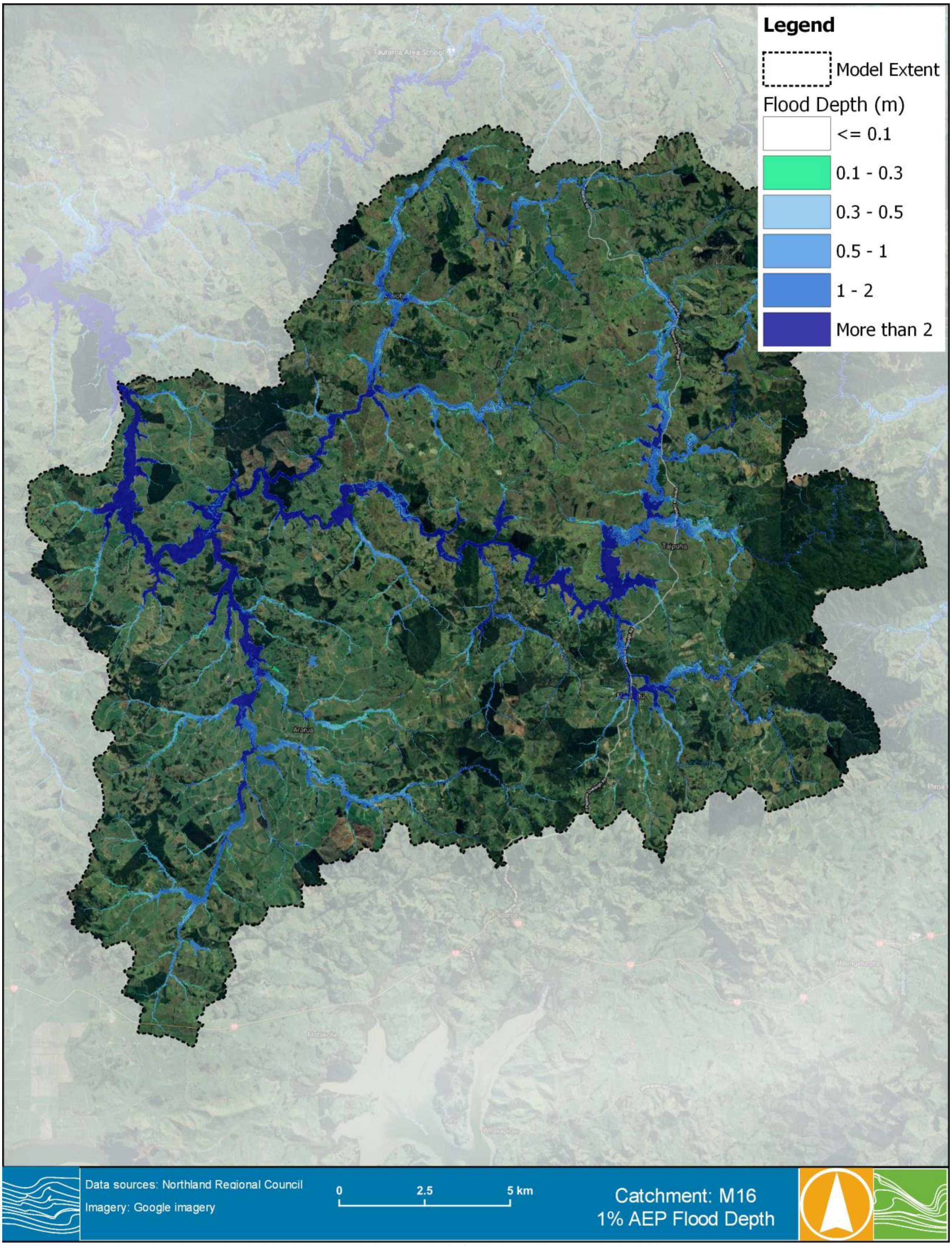

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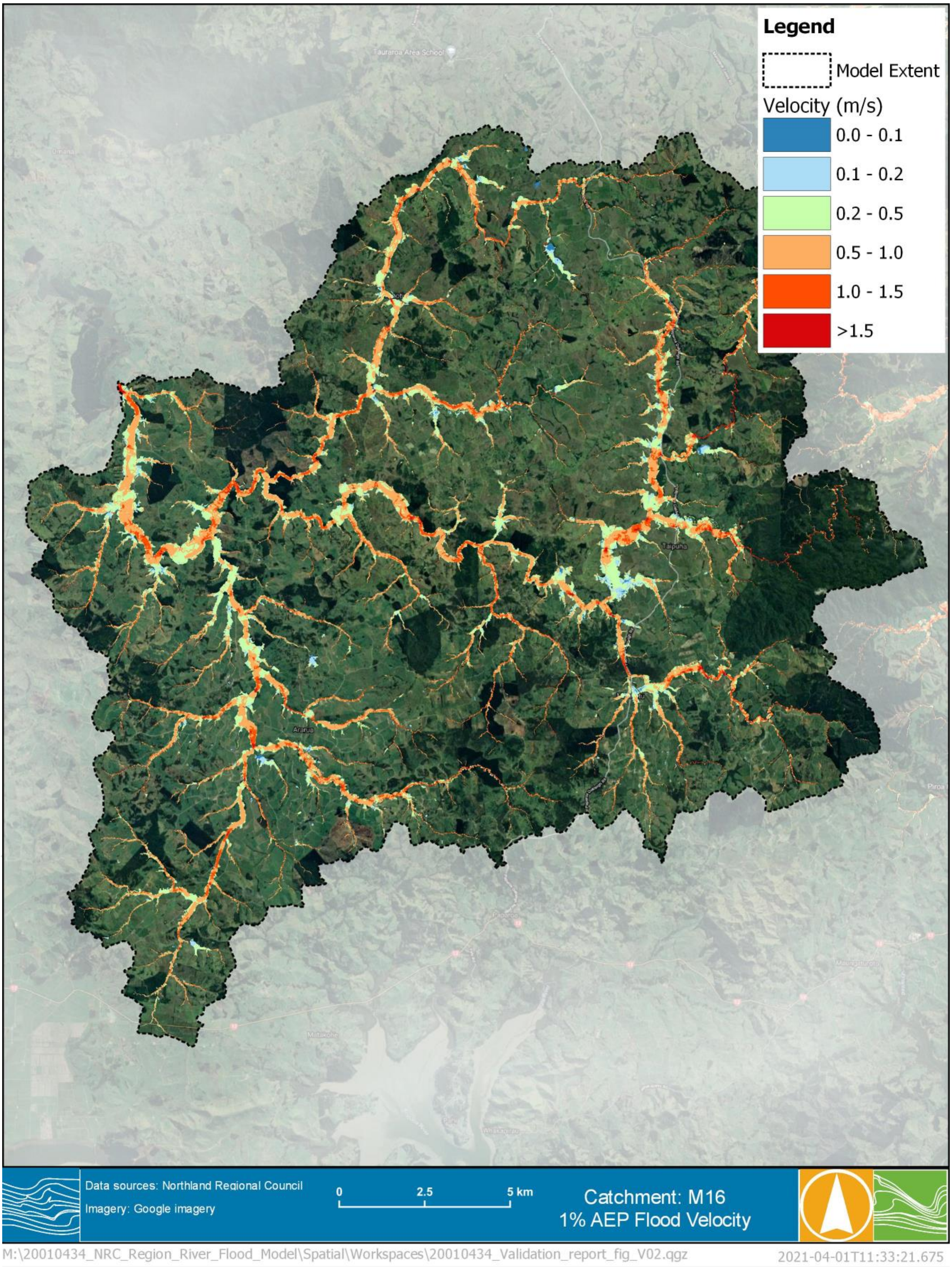
FIGURE 4-1 DESIGN MODELLING OF 1% FLOOD DEPTH


Legend
Model Extent
Velocity (m/s)
0.0 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 1.5
>1.5
Data sources: Northland Regional Council
Imagery: Google imagery
0
2.5
5 km
Catchment: M16
1% AEP Flood Velocity
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2021-04-01T11:33:21.675

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

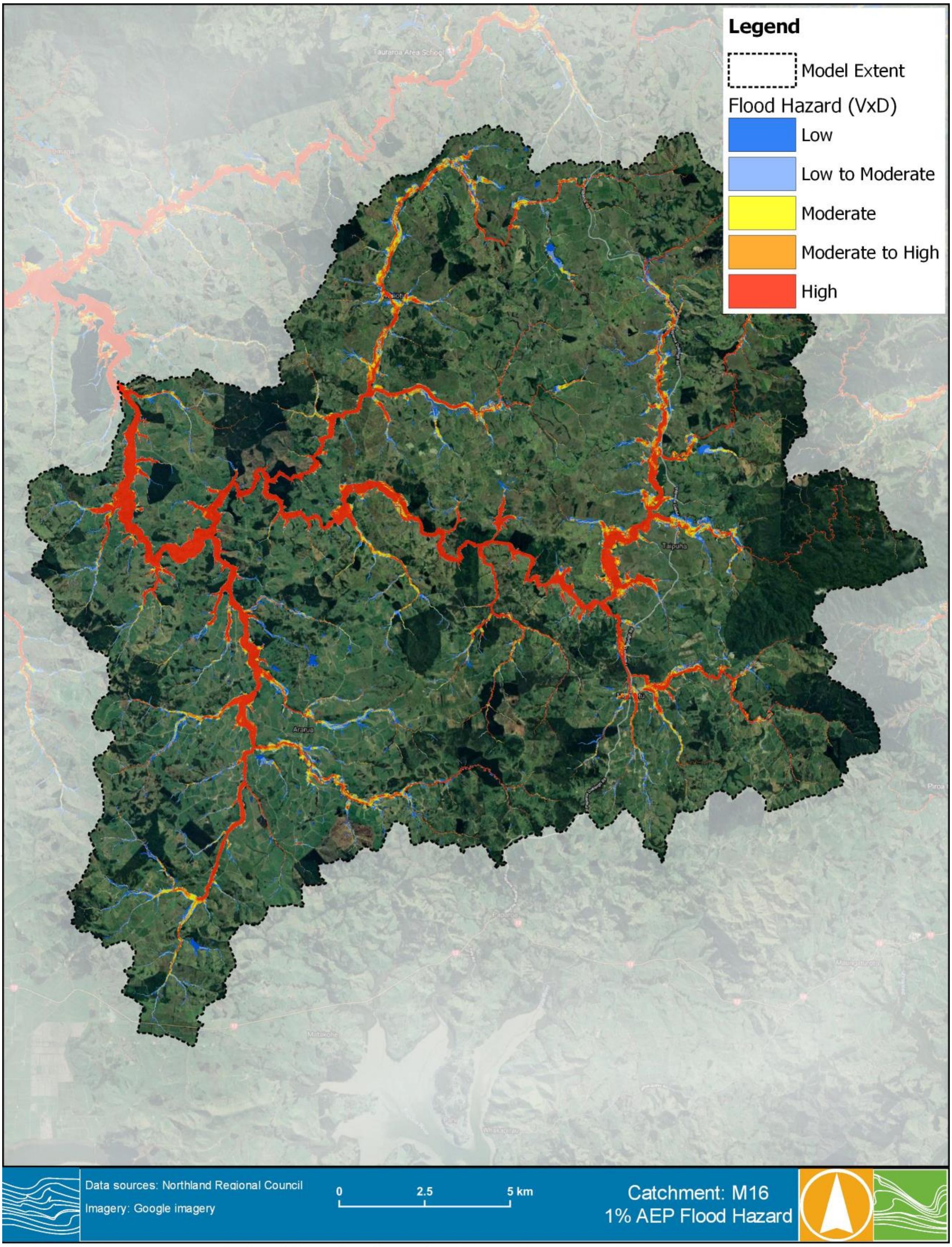

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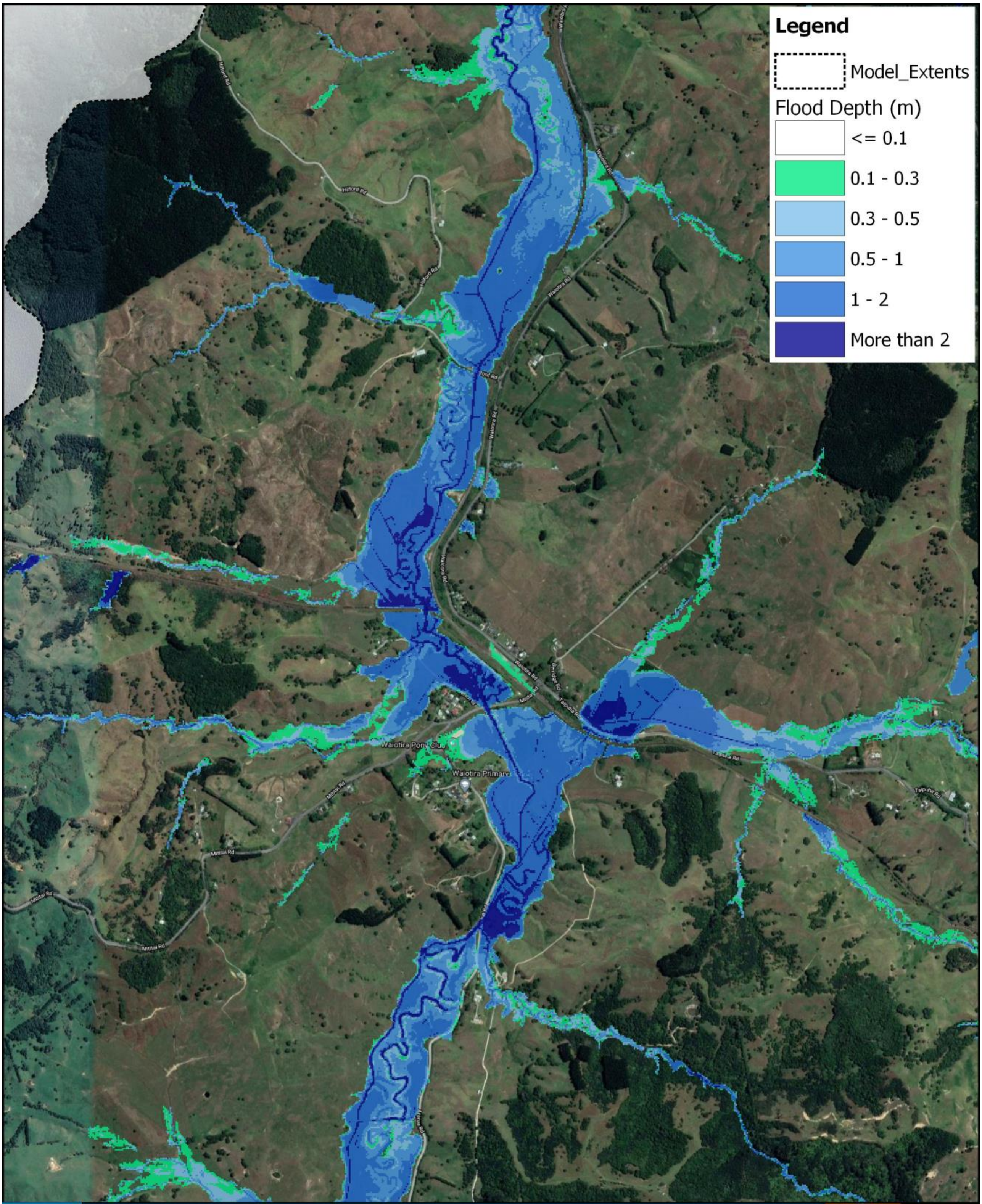
FIGURE 4-3 DESIGN MODELLING OF 1% AEP FLOOD HAZARD



Data sources: Northland Regional Council
Imagery: Google imagery

0 250 500 m

Catchment: M16
1% AEP Flood Depth

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

5 VERIFICATION OF DESIGN FLOWS

Figure 5-1 displays the streamflow gauge found within the Manganui catchment. A flow line was included at the Manganui permanent station in the hydraulic model as a 2D Plot Output (2D PO) for design events. This allows flow hydrographs and peak flows to be extracted at this location.

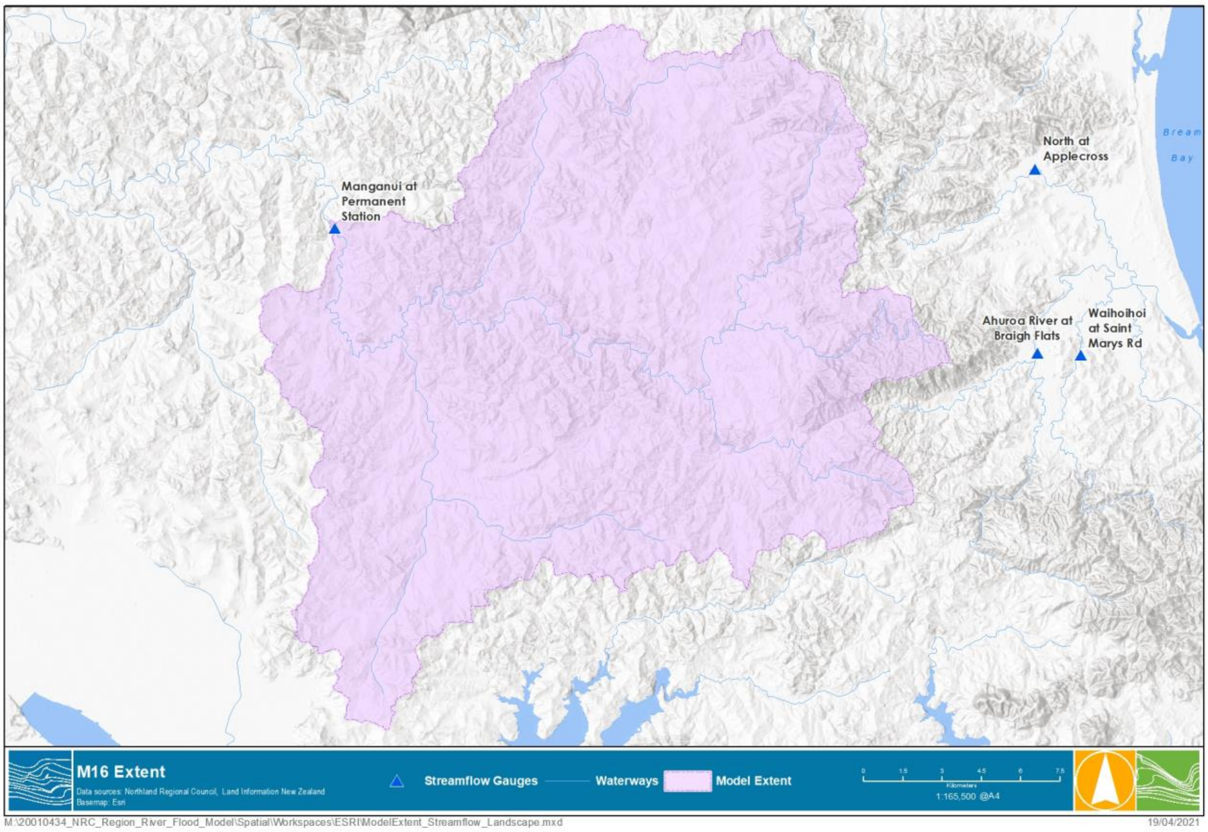

FIGURE 5-1 AVAILABLE STREAMFLOW GAUGES WITHIN MANGANUI CATCHMENT

The modelled peak flow for the 1% AEP design flood was compared with hydrological estimates, including FFA, rational method and SCS method, as well as observations from 2011 and historic maxima from streamflow gauge records.

5.1 Flood Frequency Analysis

A Flood Frequency Analysis (FFA) was undertaken for streamflow gauging stations with at least 25 years of record. The length of record for can affect the reliability of the FFA especially for the estimation of major flood events (e.g. 1% AEP). The design flow estimates provided additional verification against the design hydraulic modelling results. The streamflow gauging stations that were selected for FFA and the corresponding 1% AEP flow estimates can be found in the Calibration Report (R01).

The annual series (maximum streamflow values for each year of gauge record) were calculated and input into FLIKE. FLIKE is a software package used for FFA and provides five different probability distributions for fitting the historical records. Log Pearson III distribution is commonly used across New Zealand and south east Australia to fit streamflow records and was used for all gauges within the study area. The FFA results showed that the probability distribution had a relatively good fit at all stations.

An example flood frequency curve fitting the annual maximum streamflow values with the Log Pearson III distribution is shown in Figure 5-2. The design curve generated by the probability distribution shows a good fit with the historic records in more frequent events (i.e. 1 in 10 year or more frequent) but may slightly overestimate the design flows for rare events (e.g. 1% AEP flow). The flattening of the historic points may also suggest limitations with the current rating curves. Overall, the design curve shows a good fit with the tight confidence intervals indicating low uncertainty within these estimates.

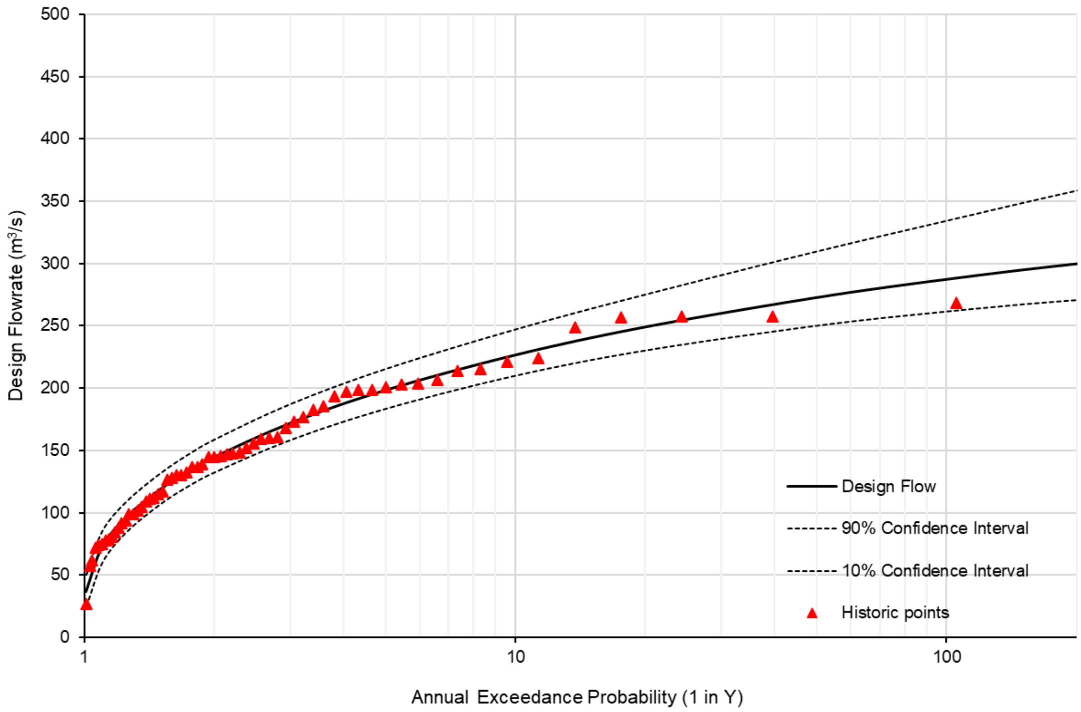

FIGURE 5-2 EXAMPLE OF FLOOD FREQUENCY CURVE OF LOG PEARSON III DISTRIBUTION FIT

5.2 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 verify design flows. These methods were checked for each streamflow gauge location within the study area and are described below.

NIWA New Zealand River Flood Statistics Portal

The New Zealand River Flood Statistics portal[3] 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 (at flow gauge).
- Flood Frequency estimates, noted as Henderson & Collins 2018 (at river reach).
- Rational Method HIRDS V3 (at river reach).

[3] NIWA Flood Frequency tool, accessed via: https://niwa.co.nz/natural-hazards/hazards/floods

The flood frequency estimates given by the portal are determined using the Mean Annual Flow method developed by Henderson & Collins (2018)[4].

SCS method

The Soil Conservation Service (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.

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 meters 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.

[4]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

5.3 Verification Results

Table 5-1 summarises the comparison of 1% AEP peak flow estimates with the modelled value at Manganui at Permanent Station gauge in the Manganui catchment and the differences between the estimation methods and modelled results can be visualised in Figure 5-3.

The Rational Method and the SCS are only applicable for relatively small catchment with SGS method limited to 12km^2. The catchment size of the streamflow is more than 400 km^2 so these two methods are subject to significant uncertainty in summarising catchment characteristics.

As shown in Figure 5-3, the modelled design flow at the Manganui at Permanent Station gauge tend to sit within a reasonable range of all the design flow estimates.

The use of empirical method estimations provides an additional degree of verification for streamflow gauges with less than 25 years of record. It is also noted that the calibration process on other Whangarei District catchments, (this catchment is not calibrated) identified uncertainty with the streamflow records for high flows. The uncertainty of high flow extrapolation at these gauges could result in further uncertainty of flow estimation methods that rely solely on streamflow gauge data.

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

PO line location	Hydraulic model (m^3/s)		Records at gauge (m^3/s)		Empirical estimates (m^3/s)			NIWA Flood Frequency Tool 2018 (m^3/s)		
	Critical duration	Modelled peak	Jan 2011 peak	Highest on record	FFA	SCS	Rational method	NIWA – FF at gauge		NIWA – H&C 2018
Manganui at Permanent Station	24 hr	593.1	248.4	320.4	328.6	555.6	324.5	369		659

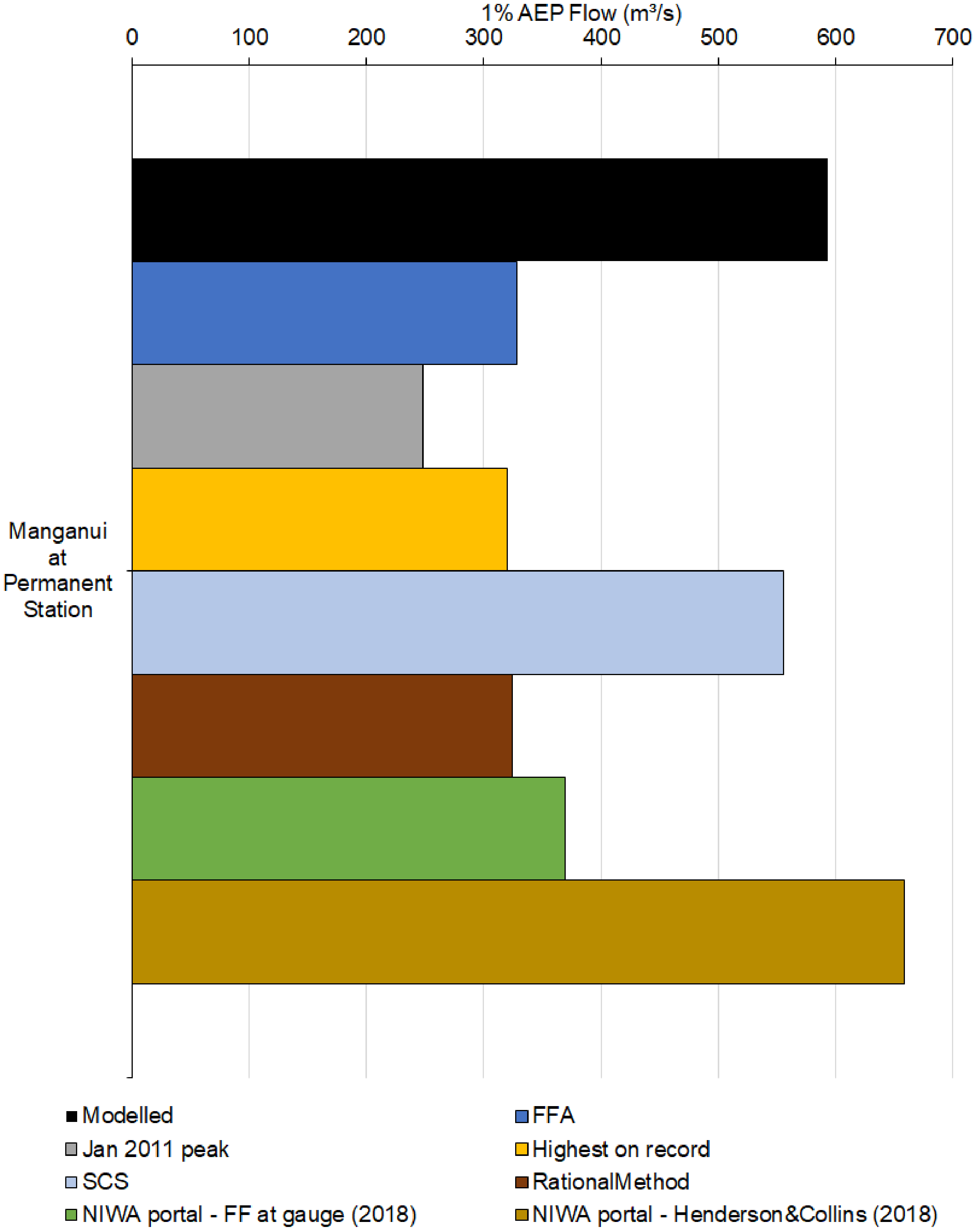

FIGURE 5-3 VERIFICATION OF DESIGN MODELLING RESULTS AGAINST HYDROLOGICAL ESTIMATES

6 SUMMARY

The Manganui catchment model (M16) was not calibrated and its model parameters were adopted based on calibrated catchments (i.e. M01, M13, M14 and M15) in the Whangarei District. 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 flow at the Manganui at Permanent Station gauge was verified against several design flood estimation methods. The modelled design flow has a reasonably good match to these estimates and sits within a reasonable range of peak flow estimates.

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.