Rotorua Lakes Council

Catchment 6 Stormwater Model Build and System Performance Report

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Catchment 6

Stormwater Model Build and System Performance Report

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Contents

List of Figures

List of Tables

1 Introduction

Rotorua Lakes Council (RLC) has commissioned Opus International Consultants (Opus) to produce an assessment of the performance of Stormwater Catchment 6 within the Rotorua Township. As part of the project, a hydraulic stormwater model for the area has been built that will provide inputs to understanding the issues across the catchment solely, and in conjunction with the previously modelled Catchment 5, with particular reference to identifying the potential for interaction of overland flows in the area of Neil Hunt Park.

The desired outcome of the model build is to develop a model that can be used to:

- Identify key flooding issues;
- Identify critical infrastructure and failure risks;
- Provide inputs for master planning; and,
- Assist operation and maintenance.

The scope of this project involves the following stages:

Stage 1 - Data Review and Acquisition

Stage 2 - Model Build and Sensibility Checks

Stage 3 – Stormwater System Capacity Review

Stage 4 – Development of high-level options

This report represents the deliverables for Stages 1-3. Stage 4 will be addressed in a separate memorandum detailing the proposed high-level options.

2 Catchment Description

2.1 Catchment Extent

Catchment 6 is one of Rotorua's stormwater catchments covering an upstream rural area draining through the urban area of Ngapuna, to the south east of the lake. The urban area is the smaller of the two at approximately 130 ha, and covers the development to the north of Tarawera and Te Ngae Roads. It is bounded to the west by the Puarenga Stream. The urban area is predominantly industrial, although there are residential areas along Tarawera Road and around Hurunga Avenue. The rural area is 240 ha in size and is located to the south of the urban catchment. It is predominantly forested. Figure 2-1 shows the location of the two areas comprising Catchment 6.

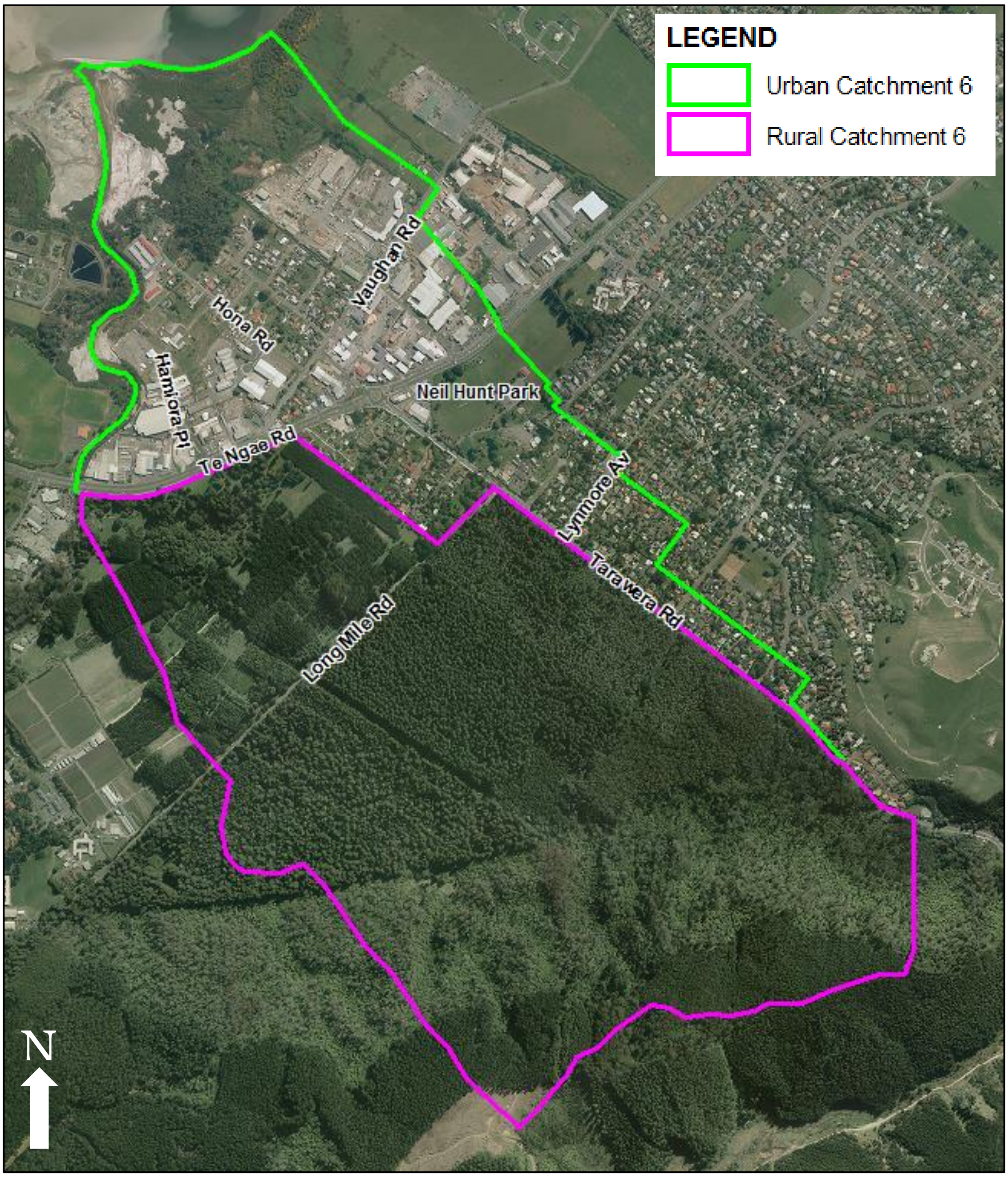

Figure 2-1: Catchment Extent

For simplicity, throughout the remainder of the report, "Catchment 6" will describe both the urban and rural catchments as one. The project is focussed on understanding the potential for the cross-connection of overland flows between catchments 5 and 6 at Neil Hunt Park, although RLC also reports historical flooding issues at Hamiora Place.

2.2 Topography

The rural area in the south features fairly steep topography from elevations between 500 m AD and 340 m AD, before levelling off to around 300 m AD. The developed area north of Te Ngae Road is much flatter, with elevations between 290 m and 280 m AD. Figure 2-2 shows the elevations across the catchment.

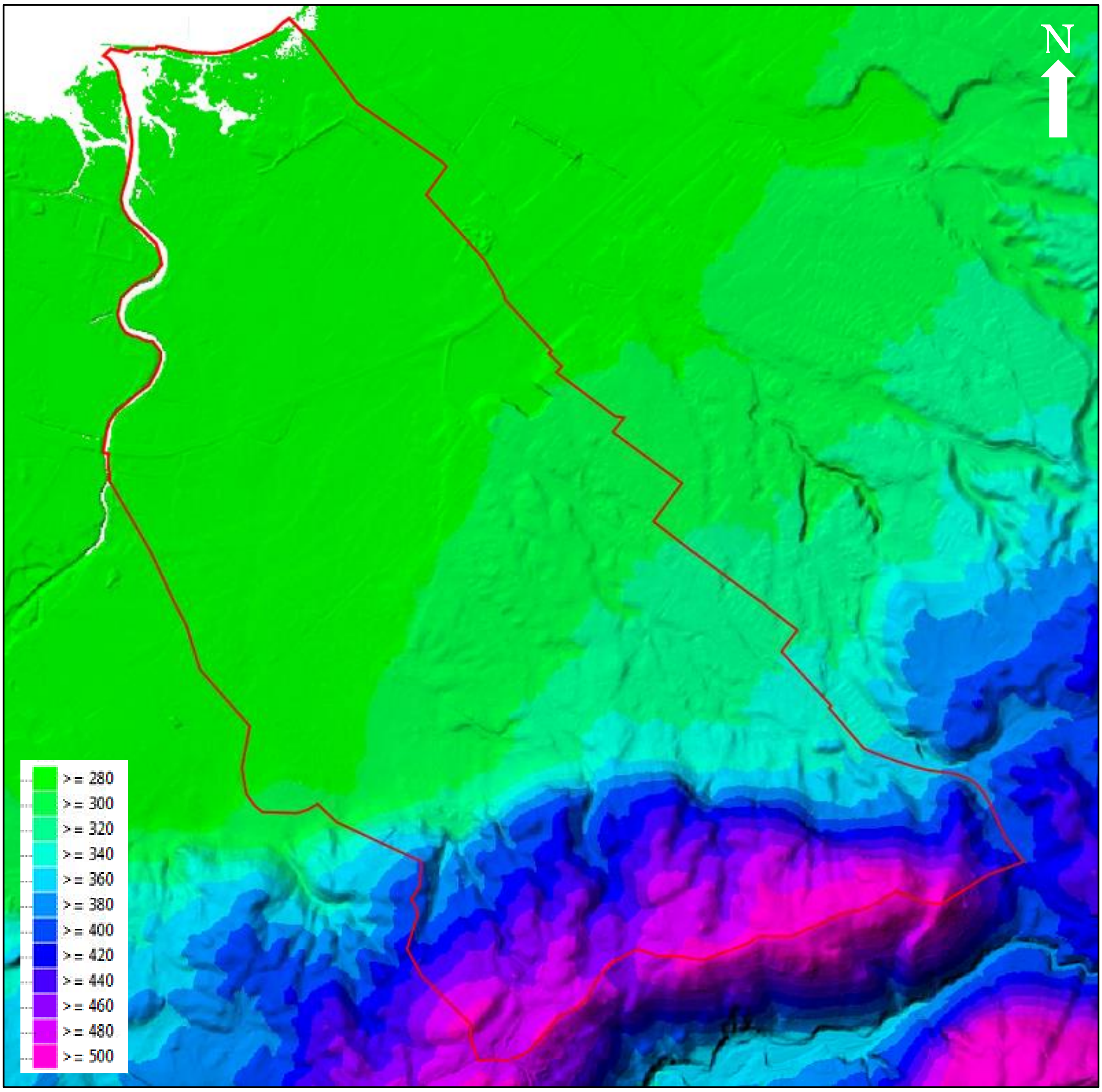

Figure 2-2: Catchment 6 Topography

2.3 Geology and Soils

The catchment is situated on the shores of Lake Rotorua where the geologic setting consists of late Quaternary alluvium, colluvium lake deposits more commonly known as Zealandia Megasequence Terrestrial, and Shallow Marine Sedimentary Rocks. Soils in the area are generally formed from Tarawera Lapilli and rhyolitic tephra. Figure 2-3 shows the distribution of soil types across the catchment. As can be seen, the predominant soil type is F6.1a (Well-drained, low fertility soils from mid-age rhyolitic tephra).

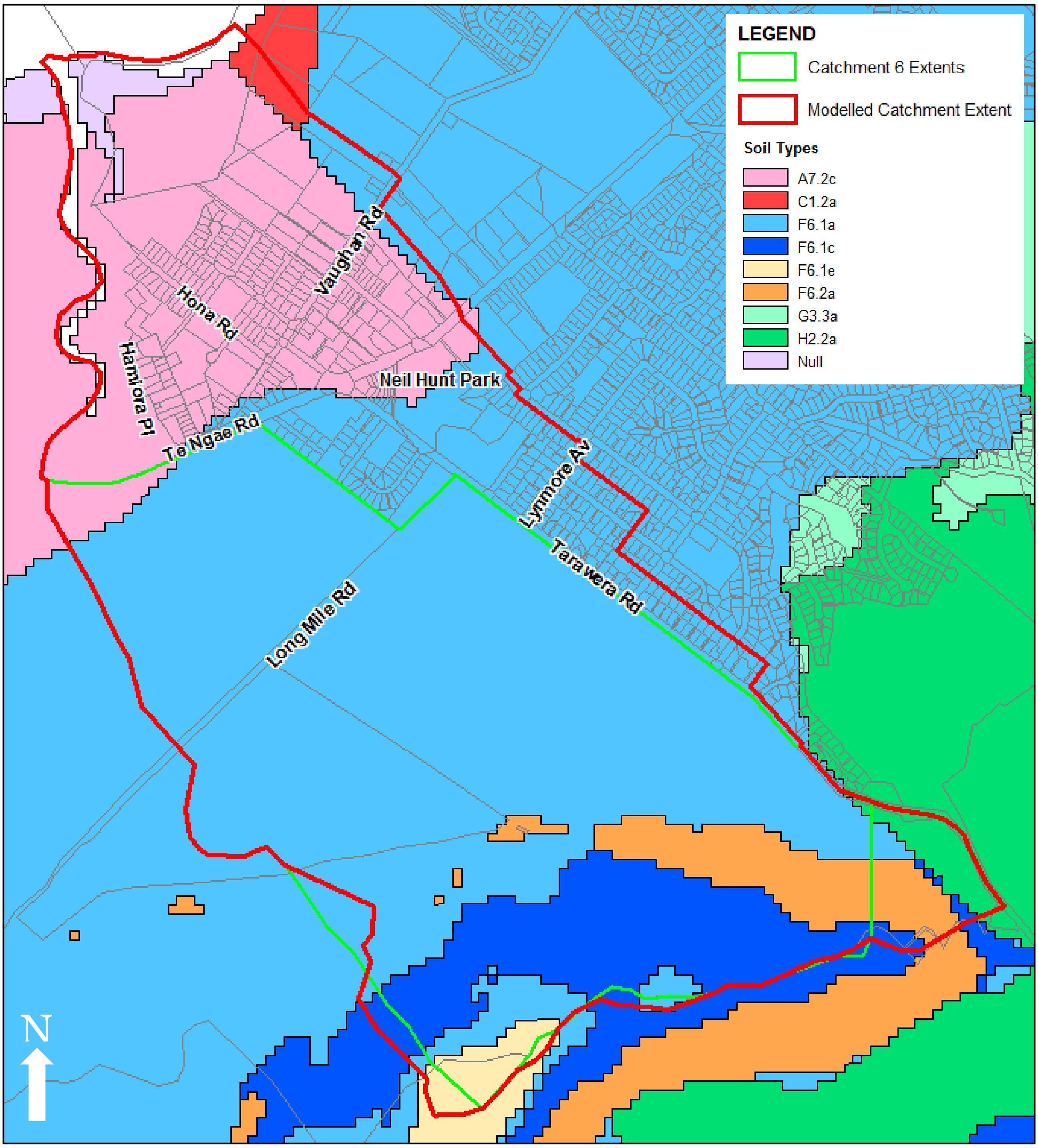

Figure 2-3: Soil Types ((Landcare Research New Zealand, 2002))

Table 2-1 details the soil types within the model boundary.

Table 2-1: LENZ Soil Types ((Landcare Research New Zealand, 2002))

Level III Classification	Landform	Soils	Level IV Characteristics
A7.2	Very gently undulating hills	Imperfectly drained soils of low fertility from rhyolitic tephra and alluvium, some peat and greywacke	c) lower winter temperatures, well-drained
C1.2	Gently undulating plains	Poorly-drained peat soils of low fertility with some alluvium	a) Warm temperatures, high solar radiation, slight annual water deficits
F6.1	Undulating hills	Well-drained, low fertility soils from mid-age rhyolitic tephra	a) Warmer temperatures c) Cooler temperatures
F6.2	Steep mountains	Well-drained, low fertility soils from mid age rhyolitic tephra	No subdivision at Level IV
G3.3	Very gently undulating flood plains	Recent, well-drained soils of low fertility from mixed alluvium	Warm temperatures, high solar radiation, moderate vapour pressure deficits, low annual water deficits
H2.2	Easy rolling hills	Recent, well-drained soils of moderate fertility from Tarawera lapilli and rhyolitic tephra	a) rolling hills, low fertility

2.4 Stormwater Network Overview

The stormwater system is shown in Figure 2-4 and consists of a combination of piped networks and natural and man-made waterways. The piped networks intercept and convey stormwater flows from the road corridor and property connections to the nearest stream channel or culvert. Stormwater collected from the road corridor consists of both road run-off and property discharges to the kerb and channel.

There are two primary drains in the catchment that converge into a single drain, but there are also other open channels in the network that connect into the drains or provide connections between different parts of the piped network.

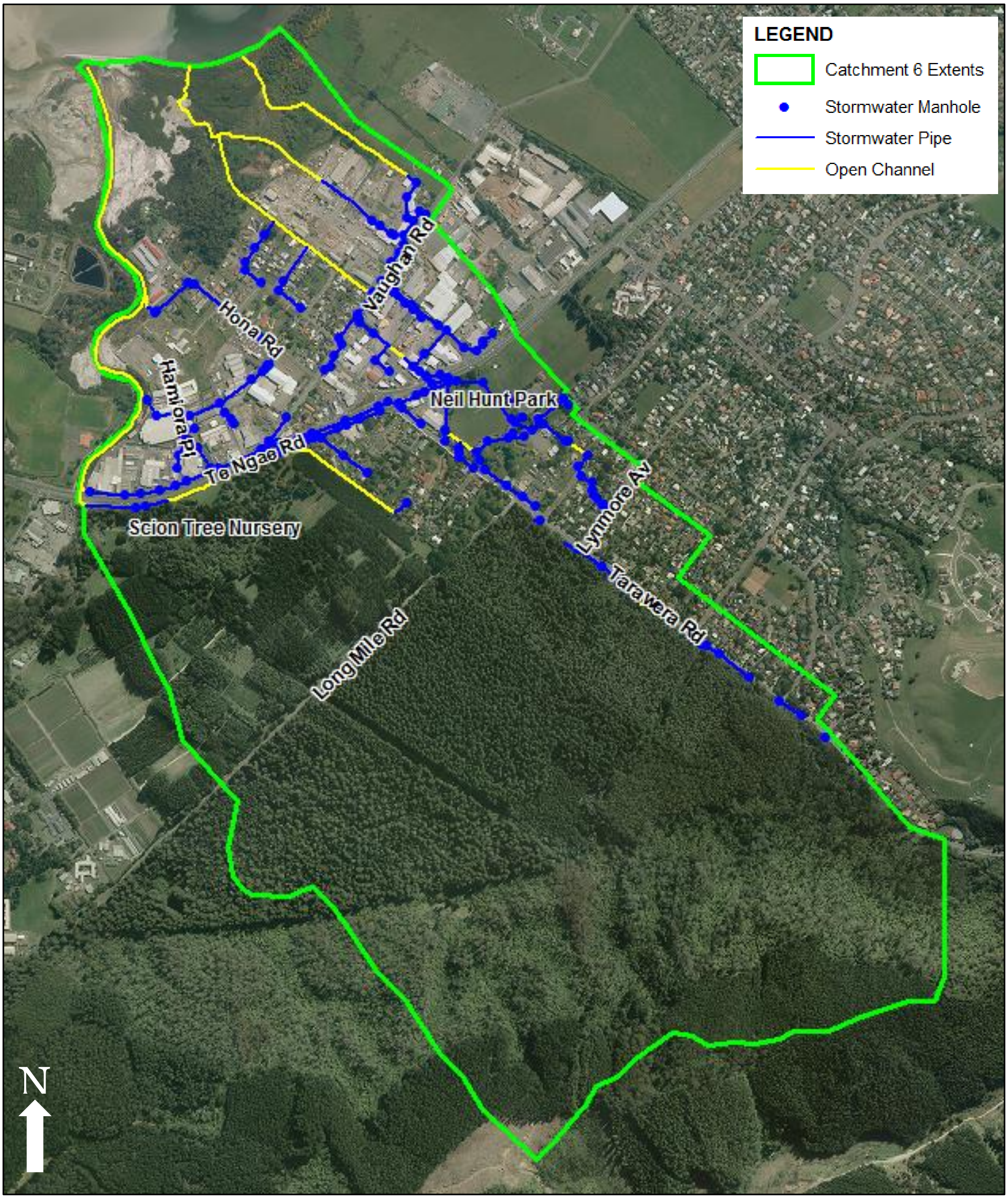

Figure 2-4: Catchment 6 Stormwater Network

The Scion Tree Nursery to the south of Te Ngae Road has had a number of swales and bunds constructed (see Figure 2-5) to protect Te Ngae Road (SH30). The park can also act as a designated floodable area when the levels within Puarenga Stream are high.

Neil Hunt Park also serves as a natural detention pond but shares volume with catchment 5 to the north.

Figure 2-5: Flood Protection by Te Ngae Road

2.5 Land Use

The catchment contains a significant area of rural land to the south encompassing approximately 60% of the catchment, the majority of which is densely forested. The east and north of the catchment are considerably more developed, with a mixture of residential and industrial land uses. Land uses within the catchment are presented in Figure 2-6 (Rotorua Lakes Council, 2016).

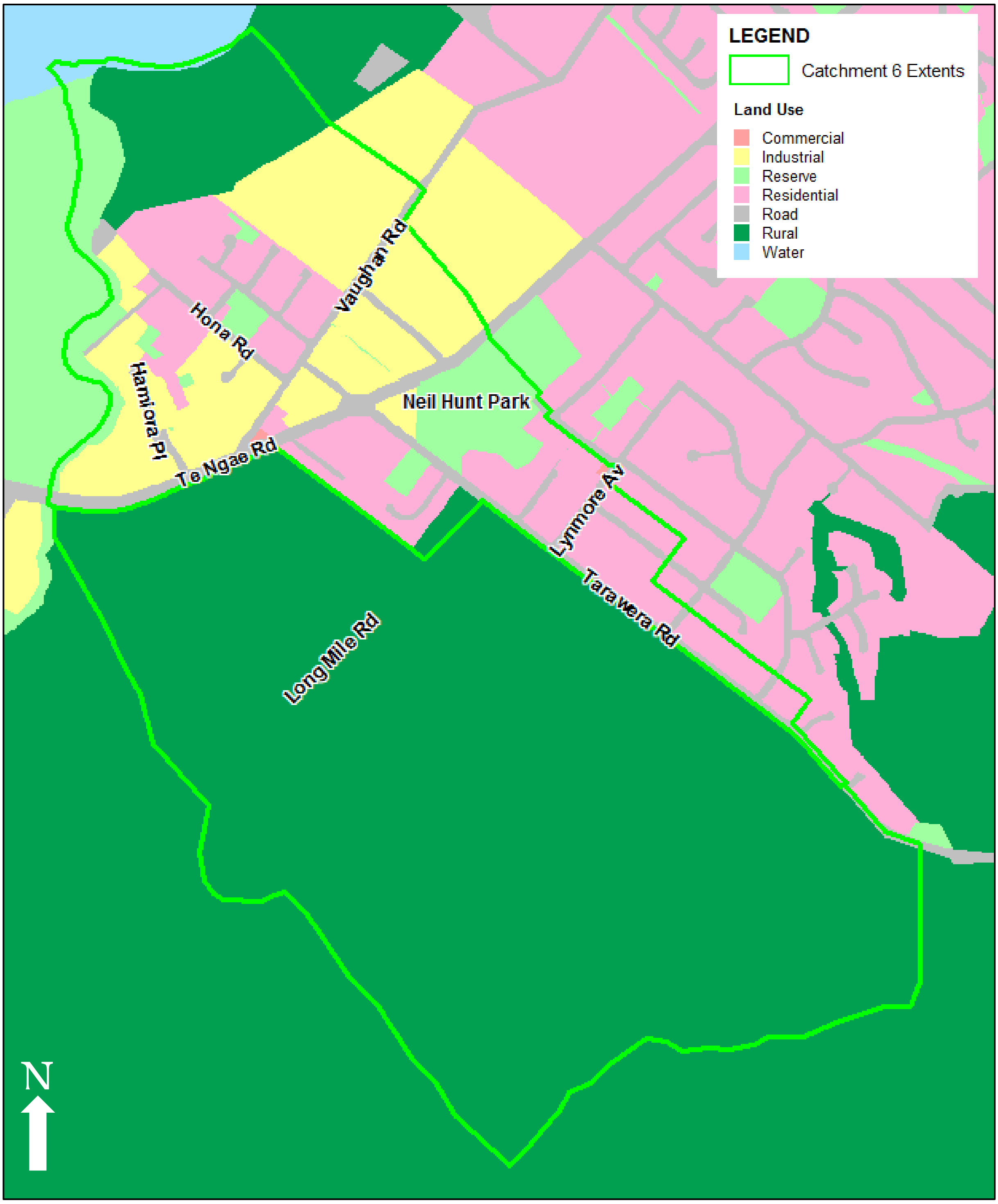

Figure 2-6: Land Use

2.6 Stormwater Issues

The predominant stormwater issue within the catchment, and the main driver for this investigation is the cross-connection of overland flows at Neil Hunt Park between catchments 5 and 6. Catchment 5 has experienced flooding during large storm events, and as a result, was prioritised by RLC and has already had flood alleviation concept options developed for it, independent of

Catchment 6. As RLC wish to better understand the overland flow relationship between the two catchments, the catchment 6 model now also incorporates the Catchment 5 model.

Flooding has also been experienced on Hamiora Place, although it is believed that this is constrained within the roadway, and does not affect properties. Hamiora Place is located within a depression in the topography, on the north of Te Ngae Road. The capacity within the stormwater system in this area may be also be influenced by the levels in the Puarenga Stream.

3 Model Build

3.1 Hydraulic Model

RLC provided Opus with the stormwater layout in MapInfo TAB file format. This was imported into InfoWorks ICM v7.0 as a 1D hydraulic model, where the data cleansing and 1D model build was undertaken. Once the 1D model was built, it was converted to a linked 1D-2D hydraulic model incorporating a 2D surface based on LiDAR.

The coordinate system used was the New Zealand Geodetic Datum 2000 (NZGD2000) using the New Zealand Transverse Mercator (NZTM) projection. Levels are in terms of the Moturiki Mean Sea Level Datum 1953.

3.2 Asset Data

Asset and survey data required for development of the hydraulic model was collated from the following sources:

- RLC
  - GIS data;
  - DTM ground level information;
  - Aerial imagery;
- Opus International Consultants
  - Site inspections;
  - Level surveys for selected inlets/outlets and cross sectional surveys of open channels.

Table 3-1 lists the flags that have been used to identify the various data sources in the model.

Table 3-1: Data Flags Used

Flag	Description
#A	Asset Data
#D	System Default
AS	Data assumed based on engineering judgement
DU	Dummy parameter
EJ	Engineering Judgement
FIX	Modelling Fix
GIS	From RLC GIS Datasets
HY	Hydraulic calculation
IF	Data inferred by InfoWorks automated process
LD	Inferred from LiDAR
PHO	Data from photos, aerials, Google Street view
RPTD	Report – Technical Document e.g. Culvert Design Guide, TP108
SD	Survey data – RLC Survey
ST	RLC Standards

3.2.1 Survey

Key infrastructure was surveyed by Opus in April 2017. The following data was collected:

- Incoming and outgoing pipe diameters and levels at important locations along the primary drains;
- Inlet and outlet levels on open channels; and
- Multiple cross sections along culverts and open channels.

This information was incorporated into the model.

3.2.2 Nodes

The nodes are named as per the original GIS dataset provided by RLC. A few additional nodes were added to the model for connectivity purposes and where required to model complex structures such as culverts beneath Vaughan Road. Flood types used in the model are summarised in Table 3-2.

Table 3-2: Flood types used to represent point assets

ICM Flood Type	Objects	Description
Sealed	Junctions	Water levels can rise indefinitely, pressurising the system.
2D	Manholes	Stormwater can flow to and from the 2D surface. The weir equation is used to control flow.
2D Outfall	Outfall	Used at the downstream ends of small networks that discharge into a stream and for inlets and outlets to sections of culvert outside the river reaches. Flow exiting these outfalls flows onto the 2D mesh.
2D Gully	Gully / inlet	Used to model sumps as identified by RLC's GIS "inlet" table. A head discharge curve is used to control flow. Assumed to be single sumps unless identified as other.
Outfall	Outfall	Stormwater is lost from the system - used at the end of the stormwater system.
Break	Nodes	Used to connect the piped network to modelled river reaches.

All manhole data was calculated using the InfoWorks ICM defaults, including the node chamber area.

Figure 3-1 shows how this is calculated.

$$A = \frac{\pi}{4} \times (W + 0.762)^2$$

where:

A = default area

W = width of widest link incoming or outgoing

Figure 3-1: Calculation of chamber area in ICM (Innovyze, 2014)

3.2.2.1 Sumps

Gullies / catch pits / sumps have been modelled using a head discharge profile that is based on empirical flow curves developed through laboratory testing. Unless specific details are provided, they have been assumed to be single catch-pits with back entry, referred to as a "combination 13 inlet" (James C Y Guo, 2009).

3.2.2.2 Soak Holes

There are no known soak holes in the network. There may be some private on-site soakage, however no initial losses to account for these storage devices has been included in the model.

3.2.3 Pipes

The RLDC GIS was relatively complete with only approximately 18% (or 34 pipes) in the RLC GIS "SWMainLine" dataset missing an upstream, downstream or both invert levels.

No level or diameter information was provided for the sump leads, identified from the "SWLead" dataset. This is common for Stormwater GIS datasets. In general, the missing diameters have been assumed to be DN225, and levels have been assumed using RLC's standard drainage drawings (Rotorua Lakes Council, 2004). If a sump was identified as a double sump, the sump lead has been modelled as DN300.

The manhole survey provided invert levels for less than 5% of the missing data points; the remaining levels were inferred either directly from their connecting manhole or by straight line interpolation. The interpolated results were then checked to ensure that the long section looked sensible when compared to LiDAR. Outlet pipes were assumed to have their invert level at ground level at the point of outfall based on LiDAR or survey where available.

In some instances it was necessary to use engineering judgement to set invert levels for terminal manholes on a pipeline or for pipes where the straight line interpolation put the pipeline above ground. In general, a minimum pipe cover based on the levels of surrounding manholes and DTM data was assumed, unless this was deemed inappropriate.

Surface friction is applied to the piped network using typical Colebrook-White roughness coefficients depending on pipe material (range: 0.6-1.5).

Transitional head losses at the manholes have been inferred in ICM and applied to the pipes. The transitional head losses are based on the manhole approach and exit angles, pipe grade and approach velocity. The "Normal" head loss curve was used which is appropriate for well-constructed manholes.

Pipe gradients were calculated using InfoWorks ICM. Where gradients greater than 0.1m/m were calculated, the associated structure energy loss was set to "None", to reduce model instabilities, as is recommended by Innovyze.

Service connections / private laterals have been excluded from the modelling.

3.2.4 Culverts

Turbulence losses associated with the entry and exit of culverts between river reaches have been modelled using culvert inlet and outlet links. Detailed entry losses have been modelled using values recommended in Table A1.3 of the Culvert Design Manual (CIRIA, 2010).

3.2.5 Open Channels

As shown in Figure 3-2, there are several open channels/drains in Catchment 6, the largest and longest of which is the Puarenga Stream, tracing the western boundary of the catchment. It collects runoff from Te Ngae Road as well as those coming from the forested area south of Te Ngae Road. However, the conveyance of Puarenga Stream was not specifically modelled, but rather, it was lumped to inflow points in the stormwater network.

The open channels modelled include two north-westerly drains bordering the large industrial lot north of the Vaughan Road and Allen Mills Road intersection. These are well defined drains with some degree of ponded flow and overgrowth. They were surveyed at multiple locations to capture their geometry via cross sections.

Additionally, there is one short drain in the industrial area between Marino Road and Allen Mills Road, and another short drain at the southwest corner of Neil Hunt Park.

Photos of the various channel profiles, key structures and potential flow restrictions are provided in Appendix A. The cross-section data was used to create river reaches that were then linked to the 2D surface via bank lines to permit lateral flow, and the 1D Stormwater pipe network where applicable. The bank lines for grassed channels have been modelled using a discharge coefficient of 1 with a modular ratio of 0.7. Manning's roughness values have been applied based on the channel profiles shown in aerial photos.

Figure 3-2: Open Channel Route

Finally, to the south of Te Ngae Road and bounded to the west by the Puarenga Stream, the Scion Tree Nursery contains a combination of open channels, swales and bunds to provide protection for Te Ngae Road, and to act as a storage facility when levels in the stream are high (see Figure 3-3).


Figure 3-3: Scion Tree Nursery – Open Channels, Swales and Bunds – Providing Stormwater Storage

3.2.6 Detention Ponds/Storage Areas

Neil Hunt Park has been identified as an area where water ponds during heavy rainfall. During the Catchment 5 analysis, it was also highlighted that flows from Catchment 5 could flow into Catchment 6. The park has been modelled using the 2D surface, which has been deemed to have adequate resolution to enable the correct volume of storage to be represented in this area. There is an inlet structure in the western corner of Neil Hunt Park, by Te Ngae Road (see Figure 3-4).


Figure 3-4: Neil Hunt Park – Inlet Structure

3.3 Hydrological Model

Initially, Horton's runoff parameters were proposed for use. However, due to this runoff method's incompatibility with the nested storms used for flood map generation, the SCS runoff model has been used instead. This is because the SCS method has an infiltration loss proportional to intensity, whereas Horton uses a fixed infiltration rate. This can lead to higher runoff values versus the SCS approach.

The SCS runoff model is a well-established approach suited to both rural and urban catchments but uses a combined runoff model for pervious and impervious surfaces referred to as a 'CN' curve. The CN curve number is based on soil characteristics, plant cover, level of impervious area and surface storage. Values presented in this report are derived from the Urban Hydrology for Small Watersheds TR-55 Document (United States Department of Agriculture, 1986).

3.3.1 Sub-catchments

Model sub-catchments were constructed in InfoWorks ICM. The sub-catchment boundaries align with either parcel boundaries or ground contours and were attributed to a node based on the ground contours and the road and reticulation layout. A GIS layer showing stormwater service connections was available for the catchment and this information was used to allocate sub-catchments in this area. Sub-catchments have also been digitised to include only one land use type, which are based on the zoning information supplied by RLC and an inspection of aerial imagery.

3.3.2 Hydrologic soil group

The SCS approach uses four soil group categories; A, B, C and D, which range from low to high runoff potential (USDA, 2007). Catchment 6 has dominant soil types of F6.1a and A7.2c (Figure 2-3), both of which are characterised to have good drainage potential. All curve numbers were therefore chosen using hydrologic soil group A.

3.3.3 Cover type

Cover type was determined by undertaking a desktop assessment of aerial photography. Three cover types were identified:

- Industrial districts;
- Residential: lot size 1000 m² (average for catchment 6 is approximately 930 m²);
- Streets/roads: sealed.

The assigned sub-catchment cover types and their corresponding curve numbers are detailed in Table 3-3.

Table 3-3: Curve numbers for sub-catchments

Cover description	Average Impervious Area (%)	Curve Number
Open Spaces	0	39
Residential: lot size 1000 m²	38	61
Commercial and business	85	89
Streets/roads: sealed	98	98

3.3.4 Hydrologic Condition

Hydrologic condition is accounted for during determination of cover type. Pervious urban areas are assumed to have good hydrologic condition, while impervious areas are assumed to have an imperviousness of 98% and be directly connected to the drainage system.

3.3.5 Antecedent rainfall condition

All CN's are calculated for average antecedent rainfall conditions. The nested storm profile (also known as the Chicago profile) is shaped to ensure the catchment is saturated prior to the peak of the storm is occurring and typically has little sensitivity to initial condition at peak flow.

3.3.6 2D Surface

A 2D mesh surface has been included in the model. It is based on the supplied DTM. The mesh has the following attributes:

- Min triangle - 5 m^2
- Max triangle - 25 m^2
- Default Surface roughness - 0.1
- Boundary condition – Normal hydraulic condition (where no boundary condition has been applied)

3.3.7 Surface Roughness

Table 3-4 shows the range of Manning's 'n' surface values for differing cover type based on industry guidance.

Table 3-4: Typical 2D Manning's 'n' Roughness Values

Land Use	Manning's 'n' values
Urban Residential	0.08 – 0.12
Industrial / Commercial	0.1 – 0.5
Roads	0.013 – 0.02
Grass	0.03 – 0.06
Gardens / Dense Vegetation	0.06 – 0.15

For catchment 6, a standard Manning's 'n' surface roughness of 0.1 has been used. This value represents roughness values appropriate for industrial buildings and urban residential parcels. Road parcels have been imported into the network as roughness zones and assigned a roughness of 0.013. It would also be suitable for the densely forested area that makes up the majority of the catchment.

3.4 Boundary Conditions

The channel has been modelled with a boundary level of 281.18 m AD at the downstream extent of the model. This level was provided by the RLC GIS team. It is taken from drawing number 10383-05 and is contained within the District Plan GIS layers as the peak flood level for the lake during a 1 in 50 year ARI (2% AEP) flood. The red area in Figure 3-5 shows the area below this level, based on the provided LiDAR.

Figure 3-5: Extent of Catchment 6 lower than the 1 in 50 Year ARI Level

3.5 Summary of Modelled Objects

Table 3-5 summarises all the modelled objects.

Table 3-5: Modelled Objects (includes both Catchment 5 & 6)

Modelled Object	Number
Number of Nodes	741
Number of Manholes Modelled	653
Number of Sumps Modelled	-
Number of River Reach (Break) Nodes	46

Modelled Object	Number
Number of Outfall Nodes	4
Number of 2D Outfall Nodes	38
Number of Modelled Pipes	636
Total Modelled Pipe Length (m)	19,657
Pipe / Culvert Size (mm)	200 – 1,350
Number of River Reaches	38
Number of Sub-Catchments	322
Total Sub-Catchment Area (ha)	245
Average Sub-Catchment Size (ha)	0.76

3.6 Data Issues

The following data issues were identified and resolved during the model build process:

- Approximately 18 % of the pipe invert levels were missing from the GIS dataset. Roughly 3% of the missing invert levels were collected in the survey and the remainder were interpolated, inferred, or assumed.
- The inlets and connecting sump leads had no information held within the GIS datasets. Ground levels have been calculated using LiDAR data, pipe diameters have been assumed to be DN225, and invert levels have been assumed based on adjacent invert levels.

3.7 Assumptions

A number of assumptions were agreed with RLC in order to simplify the model build process. The impact of these assumptions on the model outputs are discussed below

3.7.1 Culvert Inlet Losses

Where possible, inlet losses have been based on survey photos. However, there are a number of inlets that were not surveyed and so engineering judgement and aerial imagery has been used to determine the appropriate inlet headloss.

3.7.2 Pervious Runoff

All sub-catchment CN values have been set based on SCS CN curve guidance.

3.7.3 Baseflow

Baseflow has not been added to any sub-catchments, but would be likely to be insignificant when compared to stormwater runoff during significant rainfall events.

3.7.4 Soak holes

Soak holes / soak pits have not been modelled. However, they can be either explicitly modelled or implicitly modelled.

ICM includes a SUD's tab so that nodes can include soakage to represent soakage pits – this allows for explicit representation of them, but this involves a lot of detailed modelling using as-built information, or creation of representative systems using GIS on a parcel basis. This option would only be used if the performance of soakage systems needs to be understand at the property / macro level.

To implicitly represent soakage systems, the hydrology can also be modified to represent their influence on run-off from impervious areas. This is a more commonly used approach to simplify the model build process. For this approach you would design a typical soakage pit for a typical roof area. The assumed or known infiltration rate (mm/hr) is then applied to the contributing impervious area (using Horton or constant infiltration volume models) with the infiltration value factored by the soakage area to impervious roof area. The same is done for the chamber storage volume i.e. the chamber / void space volume is divided by the impervious area and applied as an equivalent depression storage depth. This allows for full soakage during small and long duration events, as well as exceedance during shorter duration events which exceed the 1 hour building code requirement for soakage. This is the approach typically used where the private property level drainage does not need to be assessed in detail.

4 Model Sensibility Checks

4.1 Sensibility Checks

The model was not calibrated against observed river levels, flow or rainfall data under the current scope of works, as no available gauge information exists within this catchment.

However, sensibility checks have been undertaken to ensure that the model data appears appropriate and is suitable for the intended purpose. The model outputs were checked against the following:

- Audit / visual review of model asset data
- Observed and anecdotal evidence for the August 2014 storm event
- Mass balance checks
- Rational Method runoff checks

4.2 Storm Event Validation

The model reliability has been tested by comparing the predicted flooding against observed flooding for a recent storm event with known rainfall – the August 2014 storm event. The flood map shown in Appendix B shows the extent of the modelled flooding for the August 2014 event.

4.2.1 Rainfall

Rainfall for the event, as shown in Figure 4-1, has been taken from records for the Kaituna at Whakarewarewa rain gauge. This rain gauge is located approximately 2 km from Catchment 6, and due to potential spatial variation in rainfall intensity, can only provide an approximate rainfall profile to input into the model. The event occurred on the 20th August 2014, peaking at 09:10am with a recorded peak intensity of 84 mm/hr and a total depth of 23 mm.

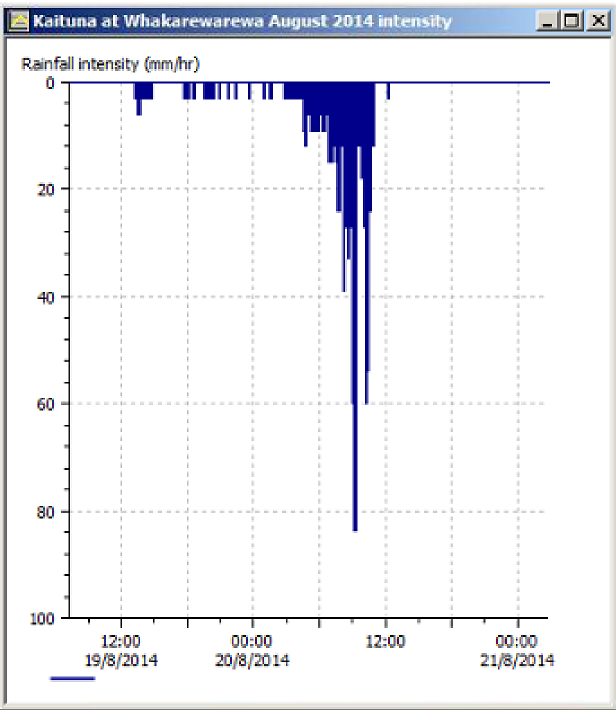

Figure 4-1: Observed rainfall between 19/08/14 and 21/08/14 used for model runs.

4.2.2 Te Ngae Road and Neil Hunt Park

Neil Hunt Park receives flows from both Catchments 5 and 6. Previously, when only Catchment 5's network was modelled, significant surface ponding was predicted along the south side of Te Ngae Road. With the incorporation of Catchment 6 network, this surface ponding has now "moved" and is concentrated at the southwest corner of the park, as shown in Figure 4-2, where an inlet to the stormwater pipe system is located. This is consistent with field observations.

Figure 4-2: Te Ngae Road and Neil Hunt Park

4.2.3 Hamiora Place

Historically, Hamiora Place has experienced flooding/ponding as it is located within a depression in the topography on the north of Te Ngae Road. Overland flow from Te Ngae Road ponds at the low spot at the Hamiora Place and Te Ngae Road intersection before proceeding north on Hamiora Place. However, it is believed that the flooding is constrained within the roadway, and does not affect properties.

The extent of the predicted flooding in Hamiora Place is shown in Figure 4-3. Since curbs and roadway depressions were not explicitly modelled, flooding of properties along Hamiora Place is predicted. However, inclusion of the kerbs are unlikely to change the results significantly due to the depth of ponding predicted.

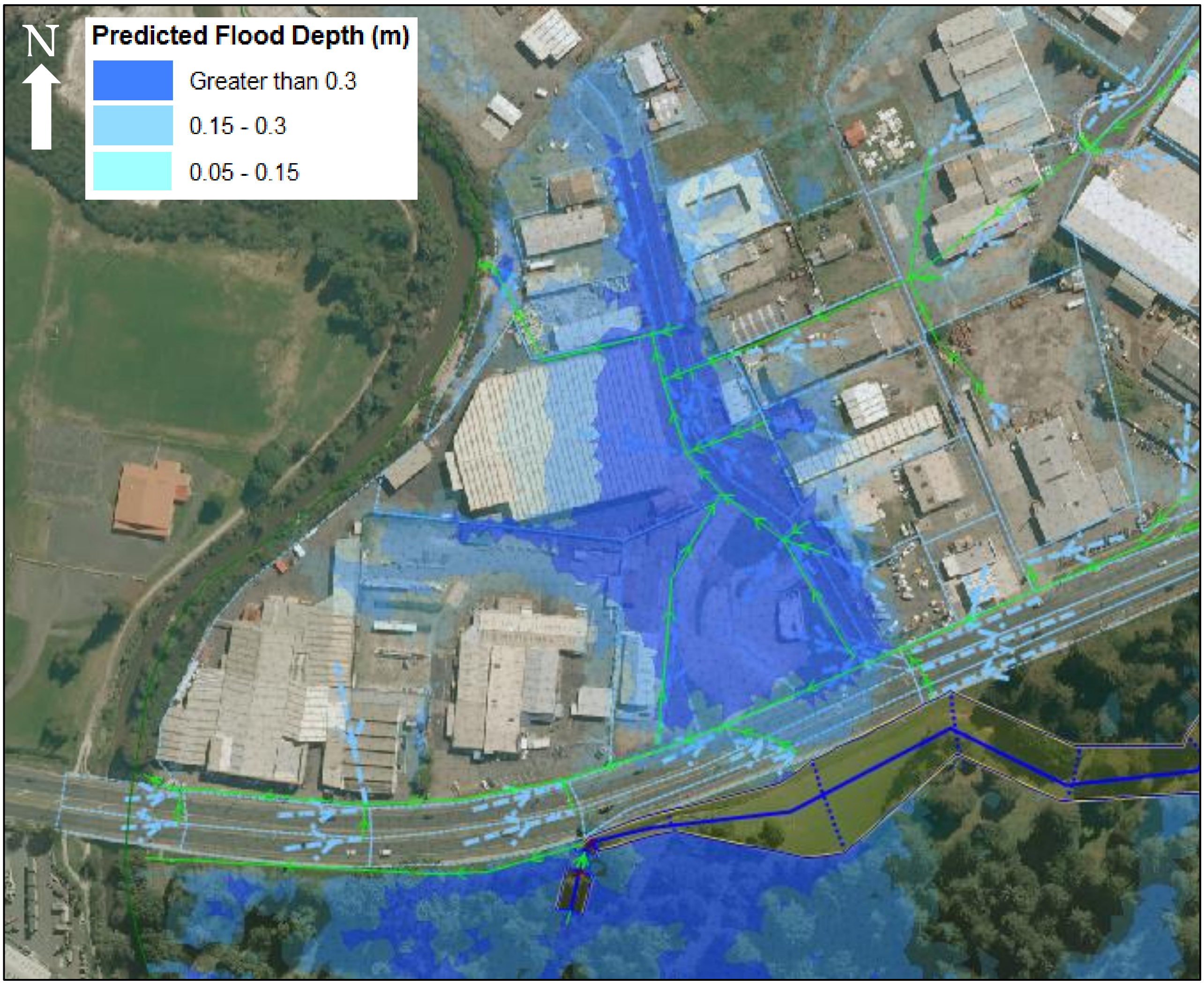

Figure 4-3: Hamiora Place Flooding Extent

4.2.4 Tarawera Road & Te Ngae Road

It has been field observed that stormwater would run down Tarawera Road to the Te Ngae Road intersection before turning southwest on Te Ngae Road. The model predicts this to a certain degree. However, to a larger degree, it predicts a significant portion of the runoff on Tarawera Road being diverted into the forested area west of the Long Mile Road intersection. This stormwater travels further west before being collected on Awatea Terrace. Furthermore, stormwater on Tarawera Road also travels north into Neil Hunt Park. These model predictions are illustrated in Figure 4-4, velocities are shown as red arrows.

A reasonable explanation for discrepancies observed between model predictions and field observations is, similar to that for the flooding in Hamiora Place, curbs and roadway depressions are not explicitly modelled.

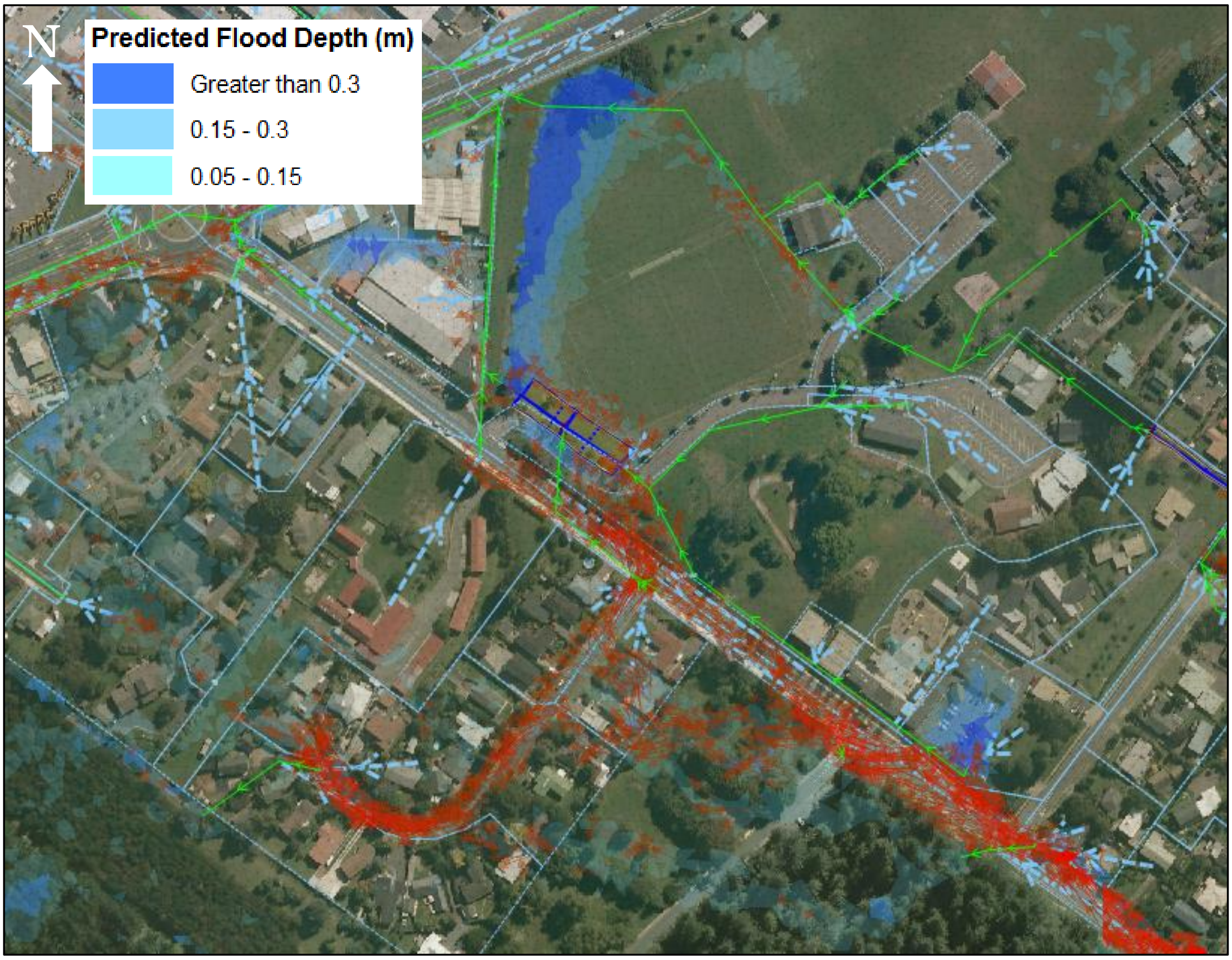

Figure 4-4: Runoff on Tarawera Road

4.3 Mass Balance Checks

Cumulative mass balance checks are automatically undertaken by ICM's software engine by default at each simulation time step. If the cumulative mass balance error exceeds 0.01 m³ at any time step, the simulation is automatically terminated. Thereby, any completed simulation can be considered to have passed this check.

Following the successful completion of the simulation, the simulation log file identifies the volume balance for each node within the network, and as a total for the whole simulation. The volume balances for the 24-hour duration nested storm simulations are shown in Table 4-1.

Table 4-1: Summary of % Volume Balance

Design Storm Event (AEP)	1D Volume Balance		2D Volume Balance	
	m³	%	Mass Error Balance (%)	Total Mass Error (m3)
10%	-63.3	1.0	0	0
2%	-82.2	1.4	0	0

4.4 Rational Method Runoff Checks

The runoff predicted during the 10% and 2% AEP nested storms were compared against the runoff generated using the Rational Method as a manual check of the model hydrology. A sample of six sub-catchments were chosen, covering residential, open spaces and road areas.

The results showed a reasonable correlation between the predicted and calculated runoff. The results are shown in Table 4-2.

Table 4-2: Summary of Rational Method Check

Sub-catchment ID	10% AEP Difference	2% AEP Difference
DH001134	-5%	0%
DH001040	-3%	2%
DH001138	-5%	13%
DH001086	-8%	10%
DI006186	-6%	12%
DN127030	-15%	16%
DI014117	-5%	-2%
Area-Weighted Average – Difference	**-10%**	**12%**

5 System Performance

System performance was assessed for both the 10% and 2% AEP 24 hour nested storms with climate change, see Figure 5-1. The nested storms have been generated using HIRDS v3 rainfall data (NIWA, n.d.). Climate change has been accounted for using a temperature increase of 2.1°C.

All system performance maps can be found in Appendix C; these include flood depth, parcels with flood depths greater than 300 mm, and flood hazard maps.

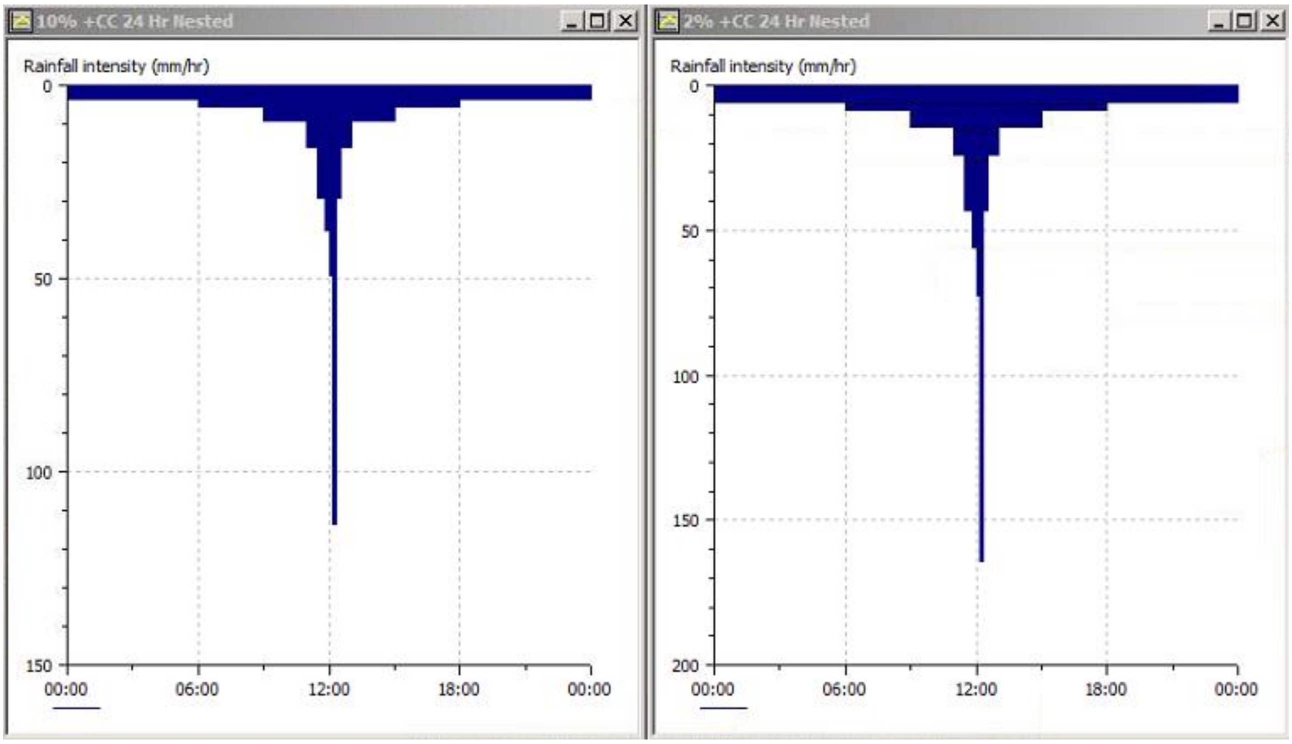

Figure 5-1: 24 hour nested storm with climate change (left 10% AEP, right 2% AEP)

5.1 Predicted Flood Depths

Table 5-1 summarises the total ponding areas by depth of ponding excluding those areas that have been modelled as river reaches. Flood maps in Appendix C show these ponding locations spatially. In these maps, flows within the open channels modelled as river reaches were assumed to be greater than 300 mm deep. For reference, the total modelled catchment size is 387 ha.

Table 5-1: 2D ponding depths

Event	Ponding depth areas (ha)			
	≥ 50 mm	≥ 150 mm	≥ 300 mm	Total
10% AEP	33.9	39.3	28.1	73.2 (18%)
2% AEP	45.3	51.7	33.8	97.0 (25%)

5.2 Parcels with Ponding

Parcels that intersected with any ponding that was greater than 300 mm were identified. This excluded open channels modelled as river reaches unless there was out of bank flow causing significant ponding. The number of parcels with ponding greater than 300 mm are shown in Table 5-2. For reference, the total number of parcels within or intersecting the Catchment 6 boundary is 621. The locations of these parcels are shown in Appendix C together with the extent of ponding.

The plans show that most of the flooded parcels at greater depths are undeveloped. With the exception of Hamiora Place, the majority of the developed parcels with a predicted flood depth over 300 mm are isolated locations rather than within significant ponding areas.

Table 5-2: Parcels with ponding greater than 300 mm

Event	Parcels with Ponding greater than 300 mm	Percentage of Total Parcels (%)	Developed Parcels with Ponding greater than 300 mm
10% AEP	68	11	37
2% AEP	111	18	60

5.3 10% AEP Predicted Flooding

While RLC note that there are no reported flooding or ponding complaints within Catchment 6, the model does predict flooding within developed parcels. The following section provides detail on the mechanisms of the predicted flooding within the developed parcels. It should be noted that only flooded parcels are identified, not flooded properties, as floor levels are not known at this point in time. In addition, any potential impediments to overland flow, such as property boundary walls or fences have not been included in the model at this stage.

5.3.1 Hamiora Place

During the 10% AEP storm event, the industrial parcels in Hamiora Place have predicted ponding depths greater than 300 mm. The ponding at this location is originated, for the most part, from runoff on Te Ngae Road (see Figure 5-2).

A significant portion of the Te Ngae Road runoff comes from stormwater overtopping of Te Ngae Road, despite the swales and bunds which are intended to protect the Te Ngae Road from flooding.

In addition, the sumps, as well as the 675 mm stormwater pipes along Te Ngae Road leading to the Puarenga Stream, are predicted to have insufficient capacity and thus cause flooding onto Te Ngae Road. The stormwater then enters a natural depression that is the Hamiora Place and Te Ngae Road intersection, before flowing north onto Hamiora Place, causing predicted flooding to properties.

In order to better predict the ponding extent, it is recommended that the roadways, Te Ngae Road and Hamiora Place, be modelled with curbs to better mimic the surface drainage path.

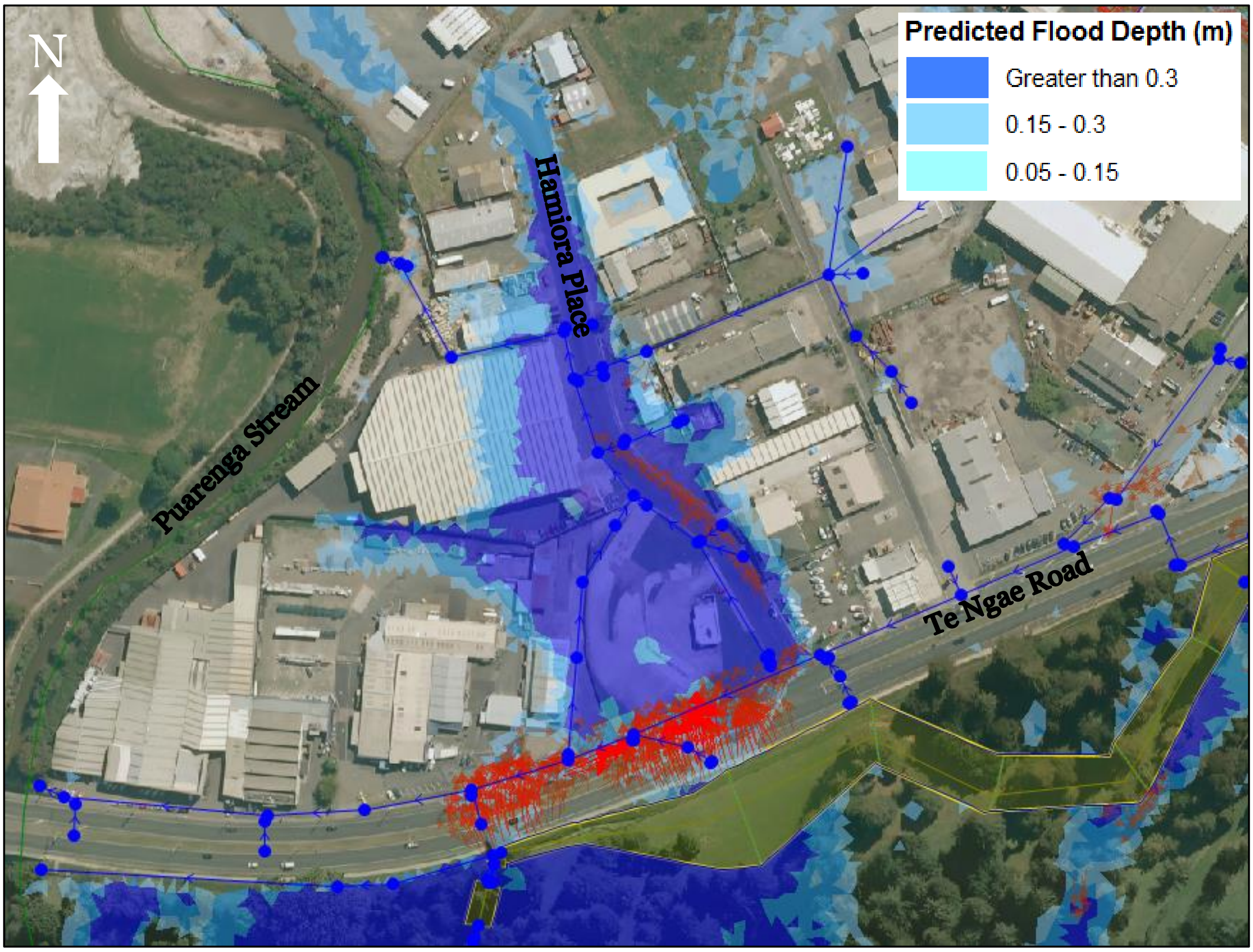

Figure 5-2: Predicted Flooding at Hamiora Place (10% AEP)

5.3.2 Vaughan Road

During the 10% AEP storm event, the industrial parcels north west of Vaughan Road in Catchment 6 have predicted ponding depths greater than 300 mm. The ponding at this location is partially due to the lack of capacity within the 375 mm stormwater pipes, which cause stormwater to flow north onto Vaughan Road and into the industrial developments (see Figure 5-3).

A larger contribution comes from the drain in Catchment 5 to the north of this location breaking out of bank (see red arrows indicating surface runoff direction in Figure 5-3). This is caused by the limited capacity of the culvert crossing Vaughan Road. Note that it was previously thought that the only interaction between Catchments 5 and 6 is at Neil Hunt Park – this modelling suggests this is not the case.

The drain downstream (northwest) of the industrial developments does not have capacity to collect and convey all the stormwater away.

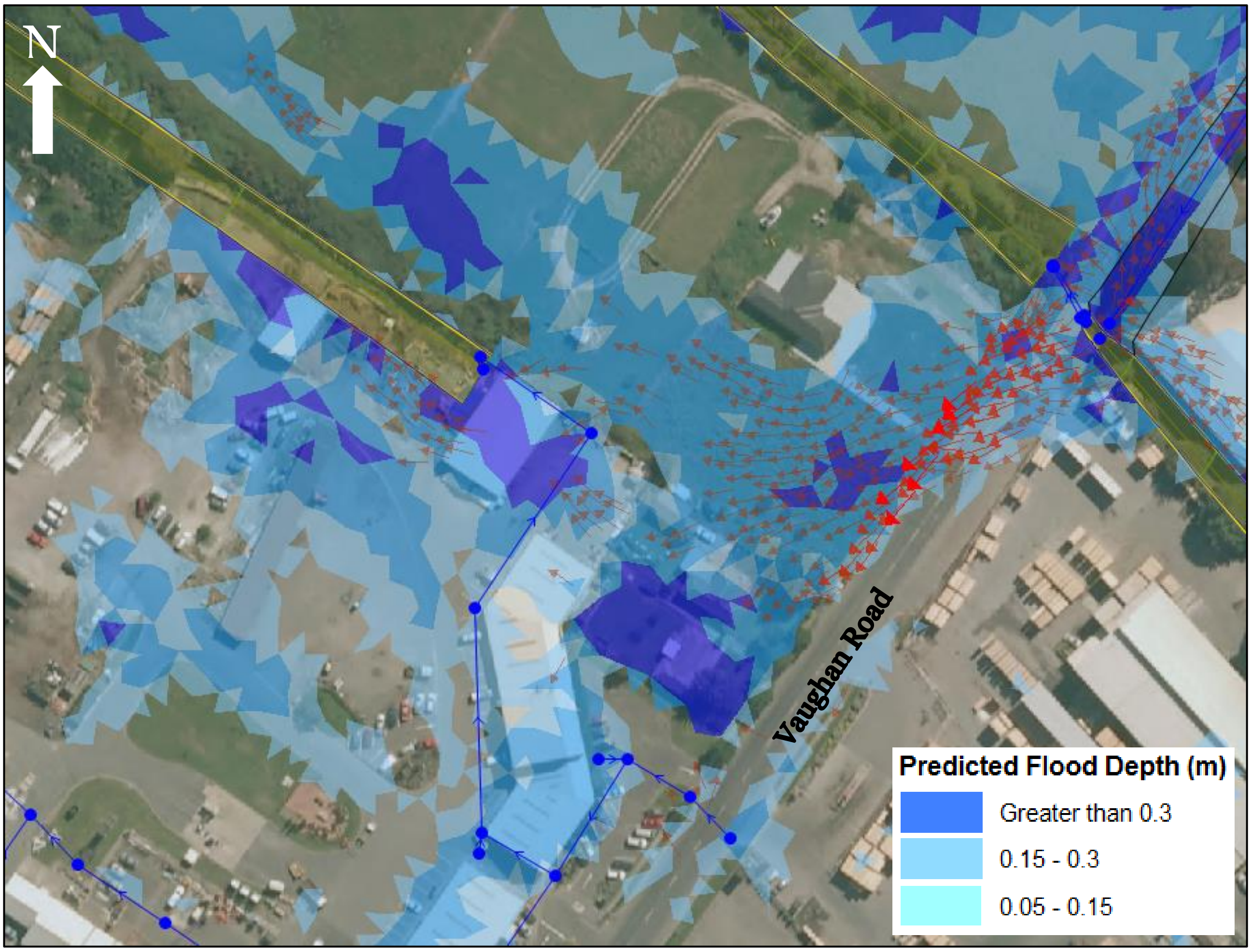

Figure 5-3: Predicted Ponding at Vaughan Road (10% AEP)

5.3.3 Te Ngae Road & Tarawera Road Intersection

During the 10% AEP storm event, the parcels east of the Te Ngae Road and Tarawera Road intersection have predicted ponding depths greater than 300 mm. The ponding is caused by the natural depression in topography and does not affect the buildings. Ponding is only predicted at the parking lots as shown in Figure 5-4.

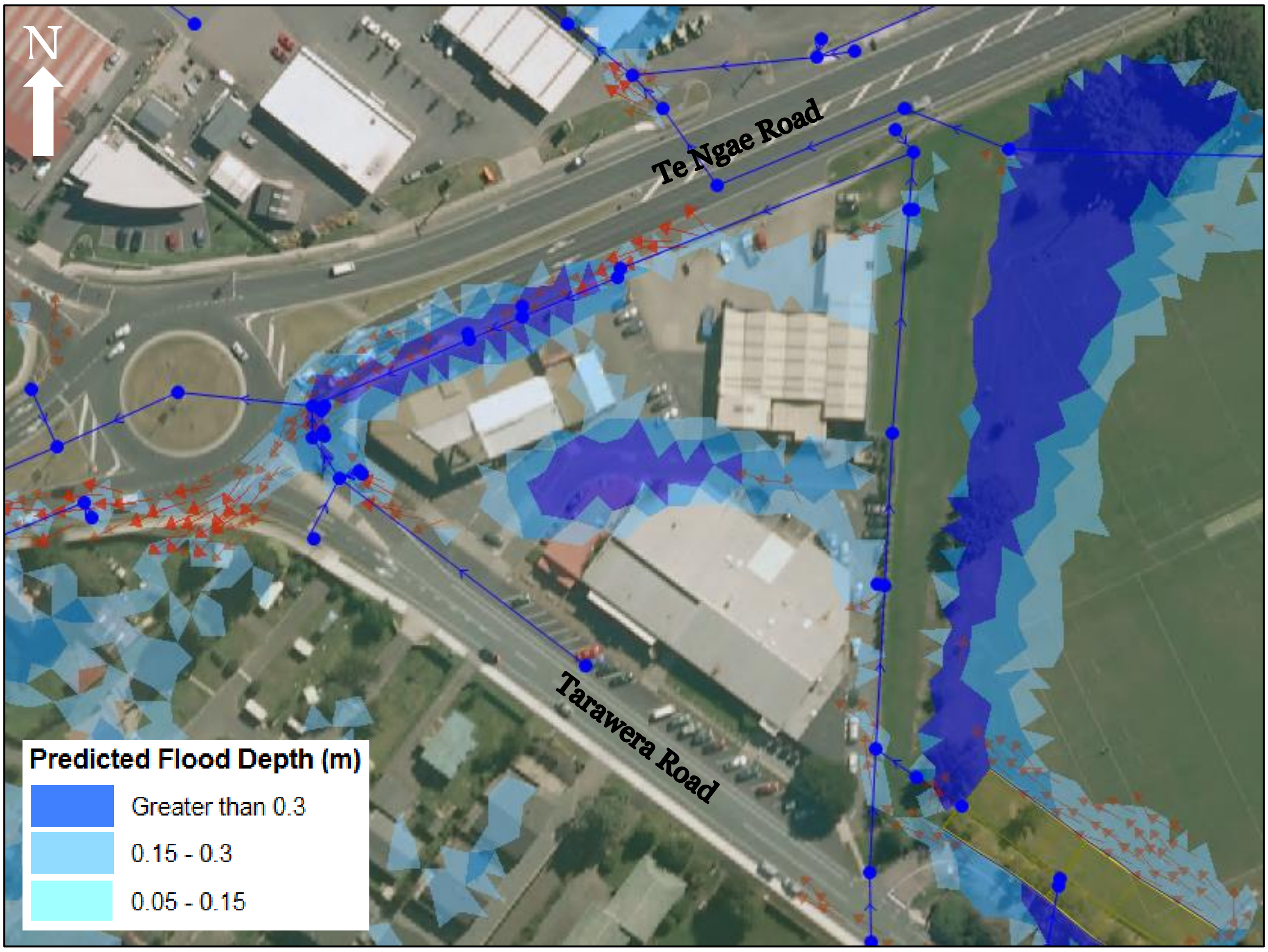

Figure 5-4: Predicted Ponding at Te Ngae Road & Tarawera Road (10% AEP)

5.3.4 Allen Mills Road

During the 10% AEP storm event, a small localized area south of Allen Mills Road has predicted ponding depths greater than 300 mm (see Figure 5-5). The ponding is mainly caused by the natural depression in topography and does not affect the buildings, with the exception of the building immediately north of the drain. Limited drain capacity causes stormwater to overtop the right bank and flood the building to the north.

There is also a pipe size reduction from DN1050 to DN675 in the system downstream of the short section of open channel. The DN1050 inlet from the open channel was confirmed during survey. It is recommended that the pipe diameters further downstream on this line are confirmed.

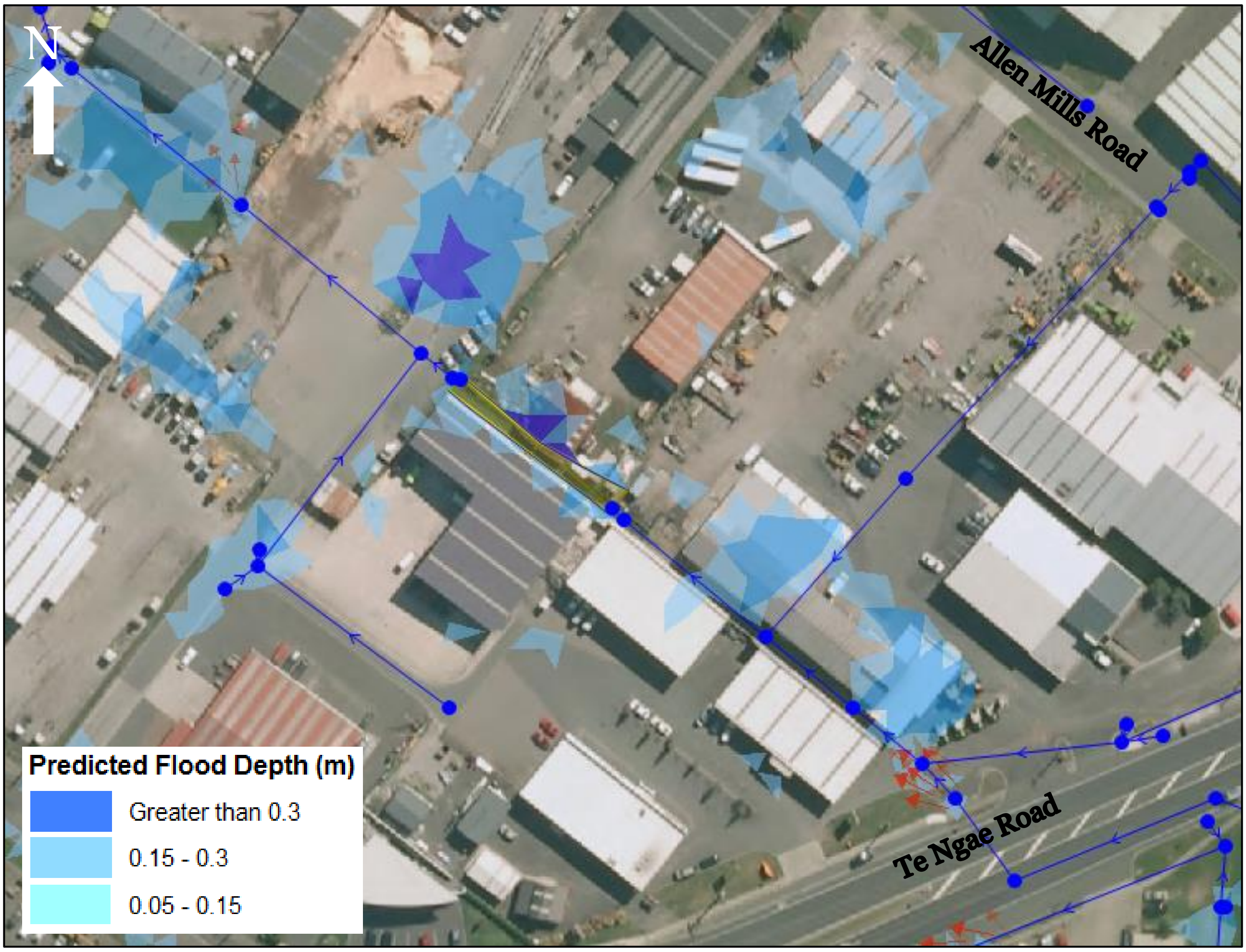

Figure 5-5: Predicted Ponding at Allen Mills Road (10% AEP)

5.3.5 Moana / Awatea Terrace

During the 10% AEP storm event, the parcel north of the Tarawera Road and Moana Terrace intersection has predicted ponding depths greater than 300 mm. The ponding is mainly predicted within the parking lot, which is located in a natural depression. The stormwater runoff from Tarawera Road ponds here before continuing down towards Te Ngae Road (see Figure 5-6), and crossing Tarawera Road to flow through properties on Awatea Terrace.

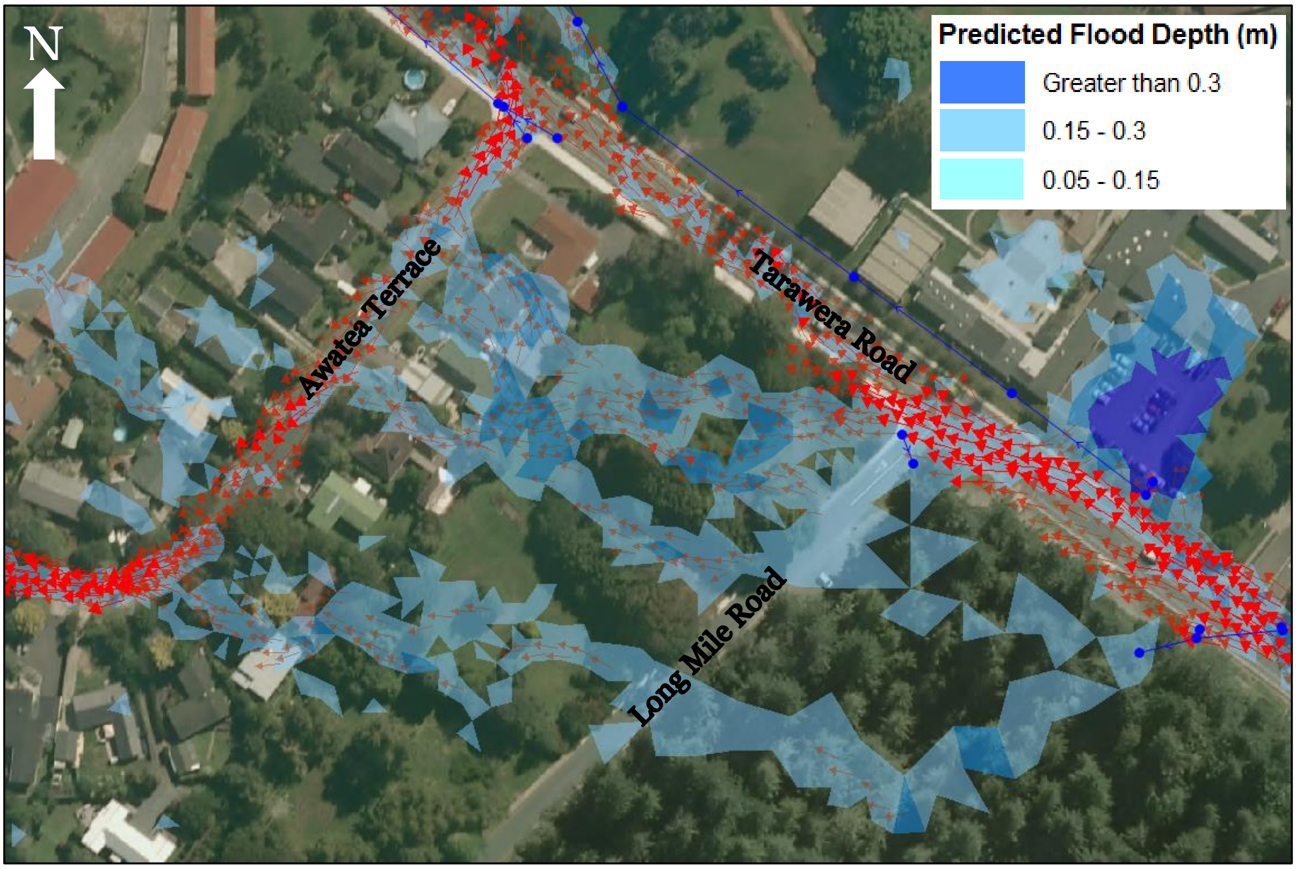

Figure 5-6: Predicted Ponding at Moana and Awatea Terraces (10% AEP)

5.3.6 Lynmore Avenue

During the 10% AEP storm event, the parcels north and south of Lynmore Avenue have predicted ponding depths greater than 300 mm (see Figure 5-7).

The ponding is predominately caused by the lack of capacity in the DN225/DN300 pipes on Lewis Road, which causes stormwater to run down Lewis Road to pond on the property (low spot) south of the Lynmore Avenue and Lewis Road intersection.

Figure 5-7: Predicted Ponding at Lynmore Avenue (10% AEP)

5.3.7 Catchment 5 & 6 Interaction

It was previously believed that the only interaction between Catchments 5 and 6 is through Neil Hunt Park. The model, however, has predicted two other locations where cross-flows occur between the two catchments.

The first location is on Vaughan Road and has been identified in Figure 5-3. The second location is located on Tarawera Road between Selwyn Road and Hilton Road as shown in Figure 5-8. However, explicit inclusion of kerb and channel could modify this predicted flow path.

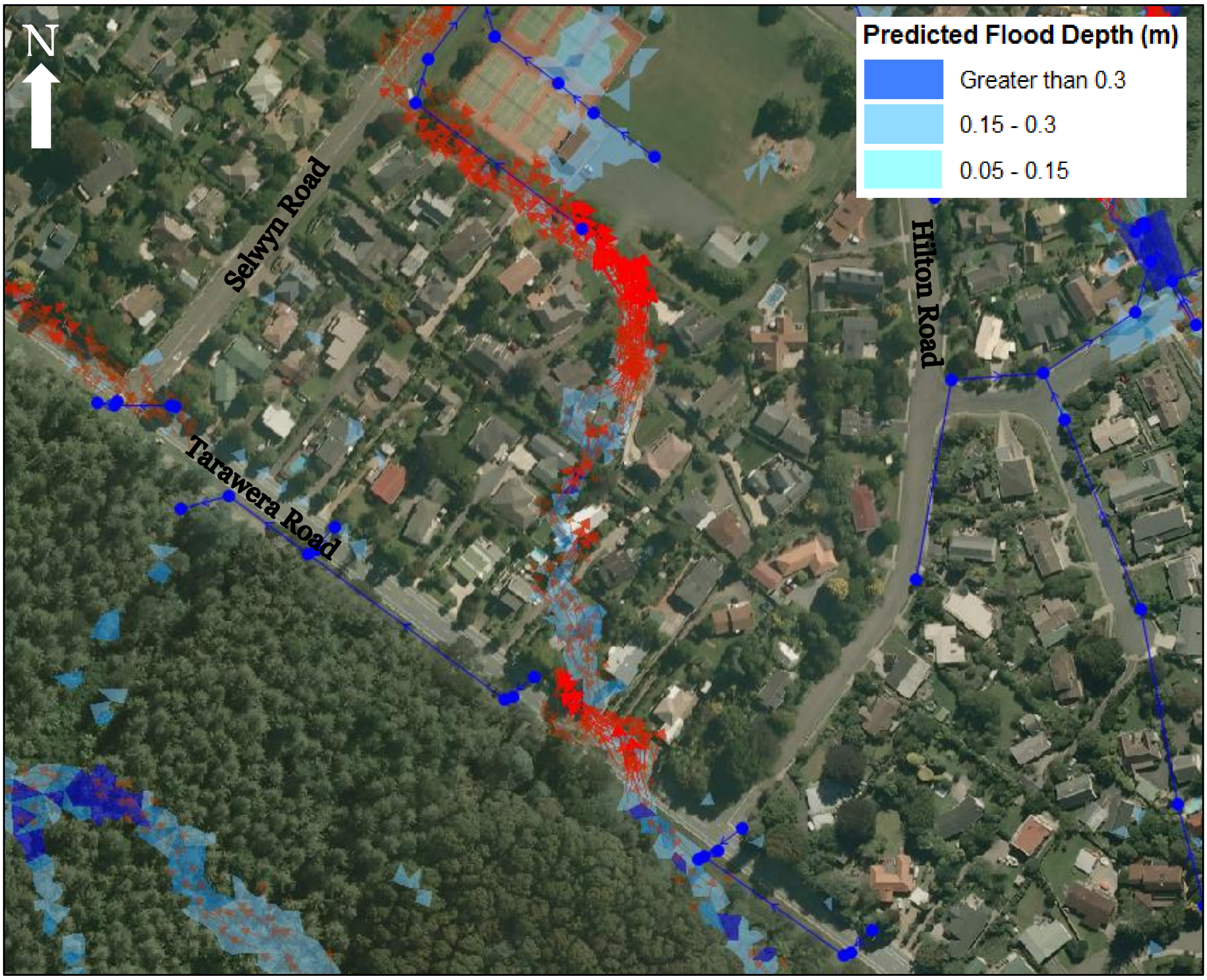

Figure 5-8: Catchment 5 & 6 Cross Flow (10% AEP)

5.4 Flood Hazard

Flood hazard maps have been produced for emergency planning purposes (see Appendix B), and are intended to provide an indication of the severity of flooding during both the 10% and 2% AEP event. These maps utilise a Hazard Rating (HR) to quantify the flood risk to the public during such an event. The Hazard Rating calculated in ICM is based on the flood flow velocity, depth of flow, and a debris factor, according to the following formula:

$$HR = d \times (v + 0.5) + DF$$

Where:

d = depth of flooding (m)

v = velocity of flood waters (m/s)

DF = debris factor

The full methodology applied is described in "Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose" (Surendran et. al. 2008).

Table 5-3 defines the flood hazard ratings used in the emergency planning maps. The relationship between flood hazard rating, flow depth and velocity is illustrated in Figure 5-9.

River reaches were set to extreme hazard which is appropriate for an open channel in flood.

Table 5-3: Flood Hazard Rating Criteria

Thresholds for Flood Hazard Rating	Degree of Flood Hazard	Flood Hazard Description
< 0.75	Low	Caution - flood zone with shallow flowing water or deep standing water
0.75 - 1.25	Moderate	Dangerous for some (i.e. children) - flood zone with deep (< 250 mm) or fast flowing water
1.25 - 2.0	Significant	Dangerous for most people - flood zone with deep (250 mm – 500 mm), fast flowing water
> 2.0	Extreme	Dangerous for all - flood zone with deep (500 mm or greater), fast flowing water

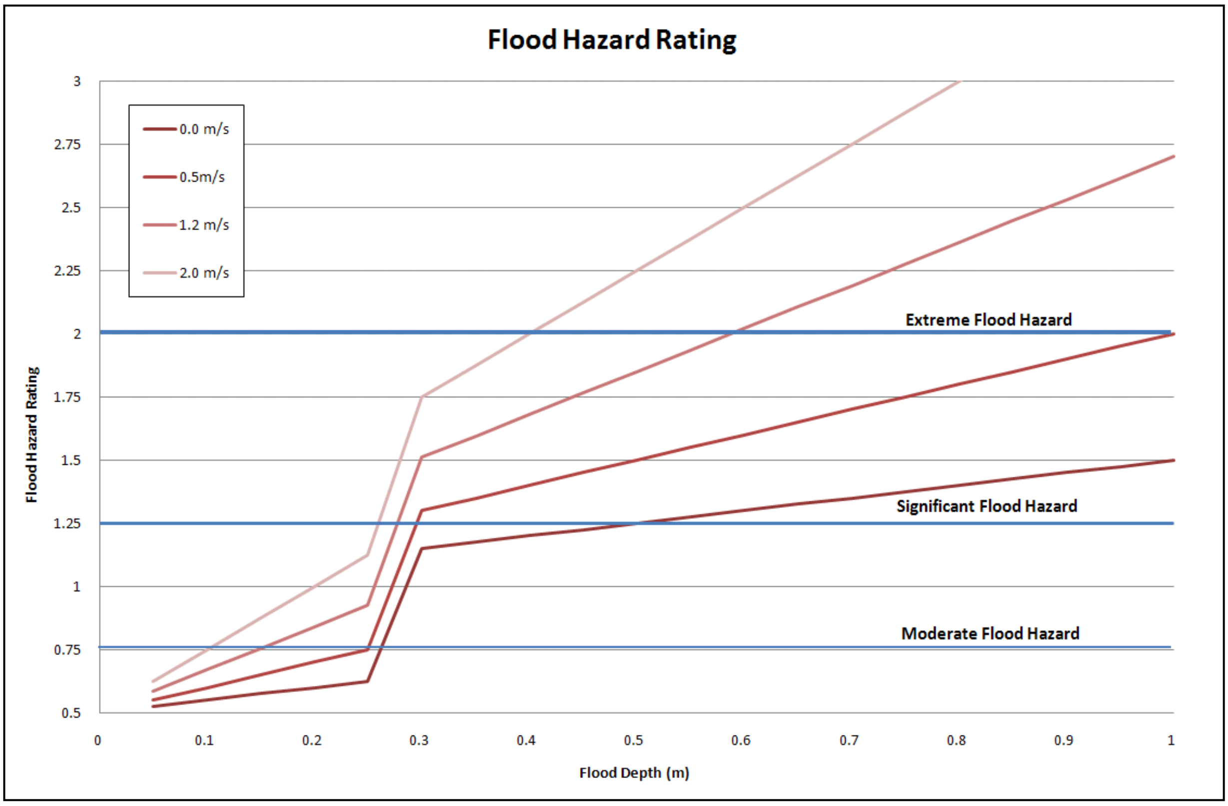

Figure 5-9: Flood Hazard Rating details

6 Model Confidence and Recommendations

6.1 Model Confidence

Based on the quality of the survey data available to build the model and a reasonable correlation between predicted and observed levels within the stream, the model is thought to be the best tool currently available to RLC to provide inputs to the options assessment against the overarching Levels of Service identified within the Infrastructure Strategy 2015-2045.

However, the model results are likely to be highly dependent on factors such as antecedent rainfall (catchment wetness). Further sensitivity analysis could be used to confirm areas within the model where the results are largely independent of parameter changes. The model can then be used in these areas with higher certainty for planning purposes and decision making.

Improving model confidence in areas with lower certainty could be targeted and improved at a later date by calibrating the model against recorded flow and rainfall data. This would provide greater confidence in the pervious, baseflow, soakage and hydraulic assumptions.

6.2 Recommendations

The following model enhancement or investigation is recommended:

- **Incorporate Depression of Roadways (i.e. curbs) into the Model** – there are discrepancies between observed and model predicted stormwater runoff path on roadways, especially along Tarawera Road and also in Hamiora Place. Modelling of curbs would allow the model to better mimic observed surface drainage path and should be completed prior to any flood alleviation works in these areas.
- **RLC Stormwater Catchments to be Redefined –** it is critical to accurately define catchment boundaries for independent modelling and analysis of stormwater catchments. Catchments 5 and 6, and potentially Catchment 4, should be assessed together to identify flood alleviation works.
- **Confirmation of Pipe Diameters in Industrial Estate on Vaughan Road –** surcharge is predicted in the line through the estate bounded by Marino and Allen Mills Roads due to a pipe size reduction from DN1050 to DN675.
- **Sensitivity testing on Sump Lead size** – It has been assumed that sump leads are of DN225 diameter, unless identified as a double sump, in which case they have been modelled as DN300. Sensitivity testing could be undertaken by upsizing all sump leads to DN300 as this would produce more conservative trunk main flows.

In addition, the following sensitivity analyses could be undertaken:

- **Hydrology** – The SCS curve applied to pervious areas could be set higher or lower and initial loss / antecedent condition sensitivity tested;
- **Manhole Headloss** – Set the headloss curve to High instead of Normal;
- **Roughness** – Surface roughness can be increased or decreased;
- **Boundary Conditions** – Check impact of varying lake levels on the catchment; this could affect predicted channel velocity in the lower reaches.

These analyses will indicate how sensitive the model results are to changes in the model parameters.

7 High-level Options for Consideration

As part of the next stage of the project scope for Catchment 6, three key issue areas (Figure 7-1) have been identified where remediation options can be assessed. Following a workshop with RLC to discuss the viability and suitability of these options, a maximum of two high-level options will be implemented in the model to assess their performance on the identified issues. A brief memorandum will be produced to present the options and their predicted performance.

It can be concluded that apart from the ponding in Hamiora Place and Vaughan Road, the ponding issues elsewhere are attributed to localized low spots. Hence, flood alleviation works/options could be considered for Hamiora Place and Vaughan Road. It is suggested that they are considered following any model updates as a result of the recommendations outlined in Section 6.2.

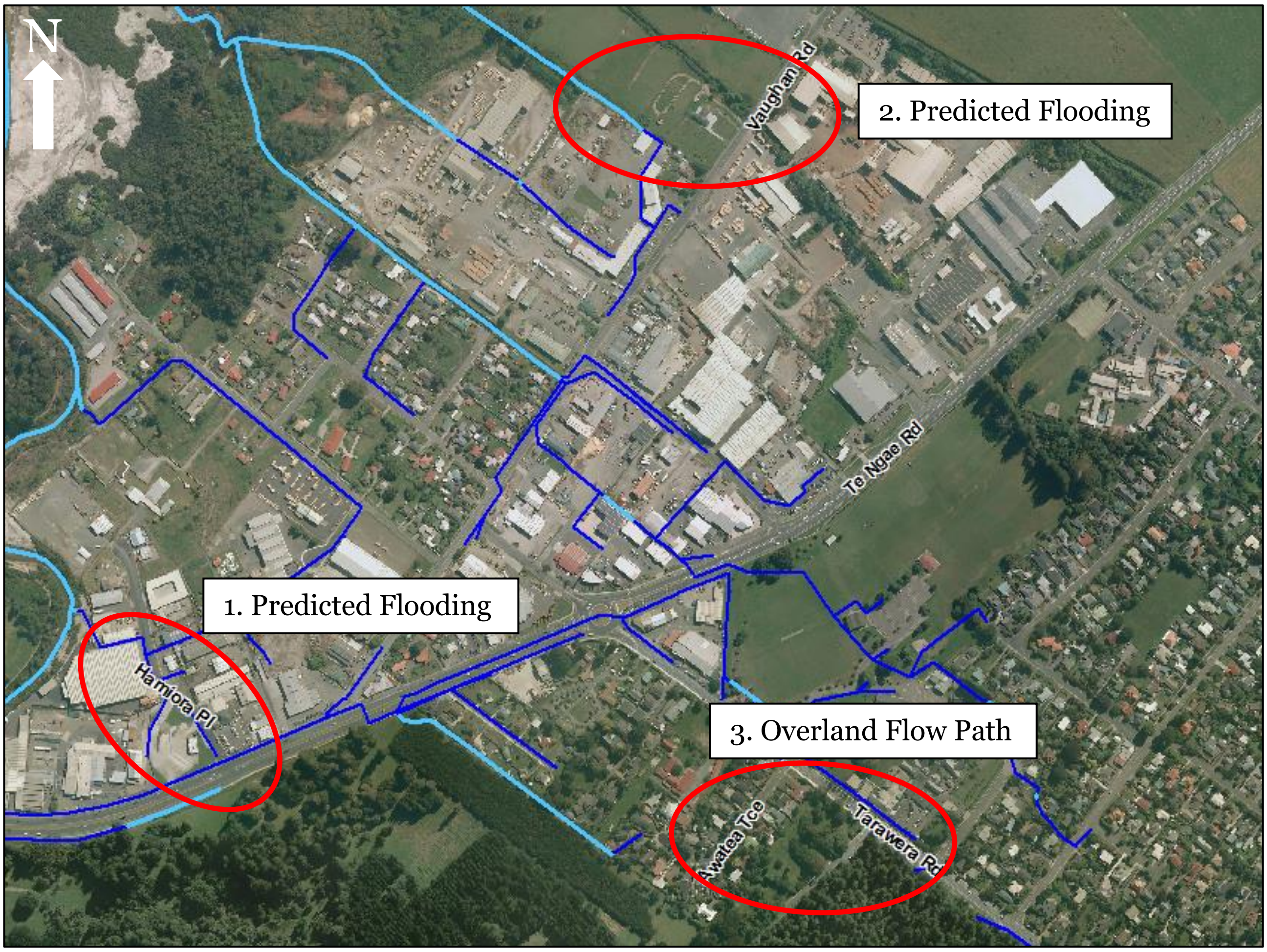

Figure 7-1: Locations of Potential Options

7.1 Hamiora Place

NZTA is currently working on expanding the section of Te Ngae Road (State Highway 30) that is predicted to flood. There is scope for collaboration to improve the drainage in this area, for instance, we can consider raising the roadway to remove the depression and subsequently minimizes stormwater from overtopping onto Te Ngae Road from the south.

7.2 Vaughan Road

The main cause of ponding in this area is attributed to runoff from Catchment 5, via the overtopping of a drain in Catchment 5 as a result of insufficient culvert capacity. Any flood alleviation options for this area should be developed by looking at Catchments 5 and 6 as one single interconnected catchment.

7.3 Tarawera Road

Although not to great depths, there is a significant predicted flow path through properties to the west of Tarawera Road, through Awatea Terrace. There is scope to upsize and renew the existing drainage ditches on Long Mile Road to divert this flow away from residential properties and down towards the Te Ngae Road swale.

8 Optioneering Workshop

During the joint Catchment 4 and 6 system performance and optioneering workshop held on 29/08/17 with several staff from RLC, it was identified that:

- The use of CN 30 was possibly overestimating the runoff for the conditions on the forested area. It was identified that Catchment 4 would trial the use of CN 17 and report on the differences. No further works were required for Catchment 6.
- The overland flow paths located through the forested areas to the south of Tarawera Road were not replicating the anecdotal knowledge of certain experienced staff members. It was agreed that the LiDAR accuracy in this area is likely to be the major cause of discrepancies. To rectify this, a significant topographical survey effort would be required and this was deemed to be of low importance given the availability of local knowledge and input from RLC staff.
- The interaction with the adjacent Puarenga Stream was identified to be a significant element for this area. As limited modelling information was available from Bay of Plenty Regional Council (BOPRC) at this stage, it was agreed that the model identifies the key performance elements of the local stormwater reticulation network. It is likely that the river interaction would further exacerbate this along the networks that discharge to the watercourse.
- The pipe discharging to the stream to the north of State Highway 30 was identified to flow eastward due to localised ground settlement at the entrance to Hamiora Place.

The workshop meeting identified that the model provides RLC with a valuable tool on which to build further layers of data, knowledge and information. This will enable RLC to support future requirements such as natural hazard understanding, infrastructure planning around existing and future Levels of Service. It was identified at the workshop that the options identified for Catchment 6 were not required to be investigated further at this stage.

Further steps for Catchment 6 involve RLC taking on the catchment model and keeping it 'live' using in-house staff as well as including additional information as it becomes available.

In conclusion, it is advised that:

- Work with BOPRC to refine the model in and around Puarenga Stream and undertake further system performance assessments across a range of scenarios.
- Test the performance of the storage areas and stream interactions within the forested areas to refine and optimise the protection afforded by this arrangement.
- Work with NZTA to arrive at a mutually beneficial outcome from the proposed State Highway 30 upgrade works (roughly between Sala Street and Iles Road).

9 References

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United States Department of Agriculture. (1986). *Urban Hydology for Small Watersheds (TR-55).*

10 Appendices

Appendix A – March 2017 Survey Photos

Appendix B – Model Validation Map

Appendix C – System Performance Maps

Appendix A – Channel Survey Photos

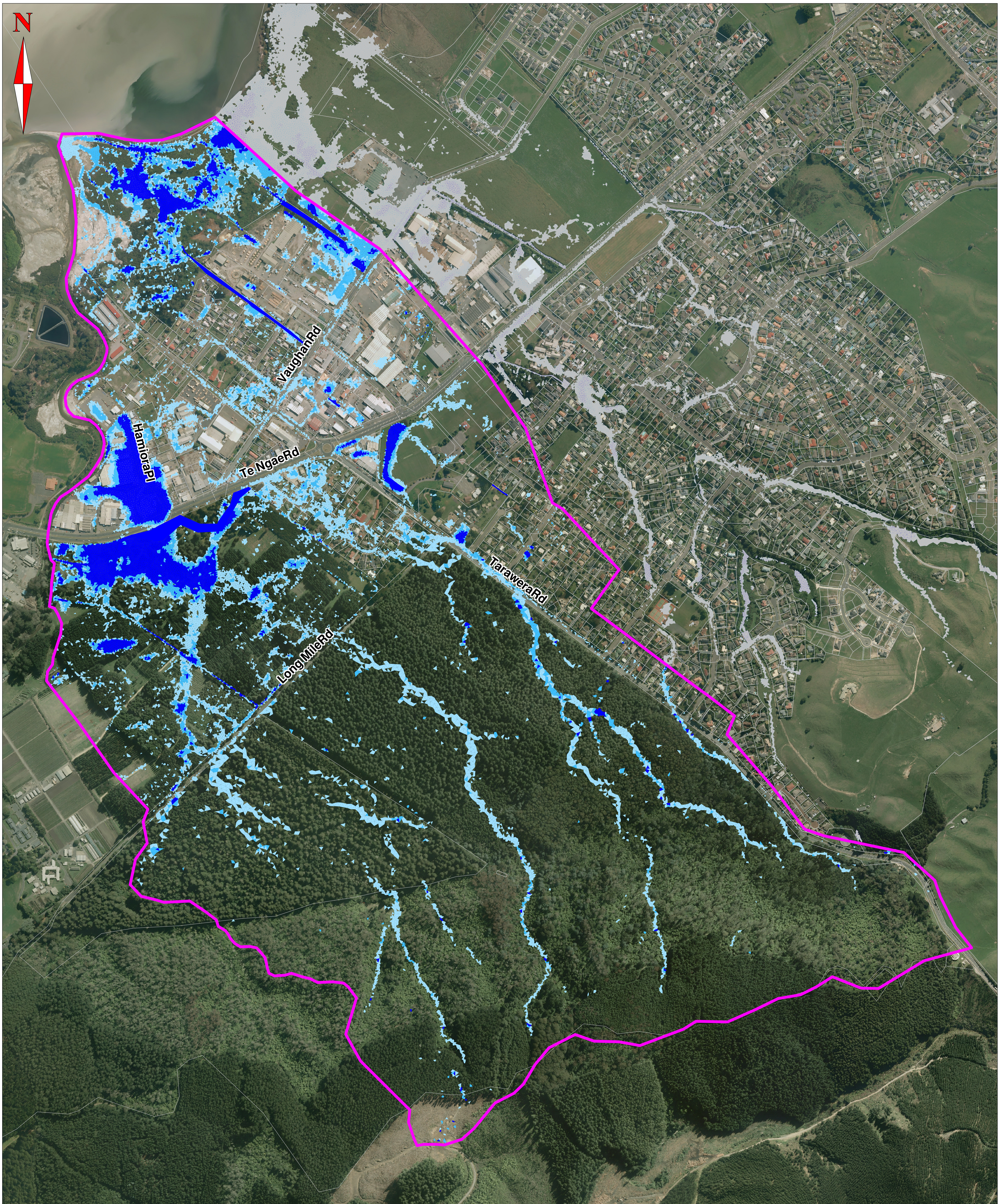
Figure A-10-1: Vaughan Road (North Drain)

Figure A-10-2: Vaughan Road (South Drain)

Figure A-10-3: Marino Road/Allen Mills Road Drain

Figure A-10-4: Neil Hunt Park Drain

Appendix B – Model Validation Map



LEGEND

Modelled Boundary

Parcel Boundary

Flood Depth (m)

Greater than 0.3

0.15 to 0.3

0.05 to 0.15

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DRAWN LAF	APPROVED LF	REV 1	REV DATE AUGUST 2017	PROJECT **Rotorua Lakes Council Catchment 6 Stormwater Modelling**
				PLAN **August 2014 Validation Event**
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Original Sheet Size: A3 (V)

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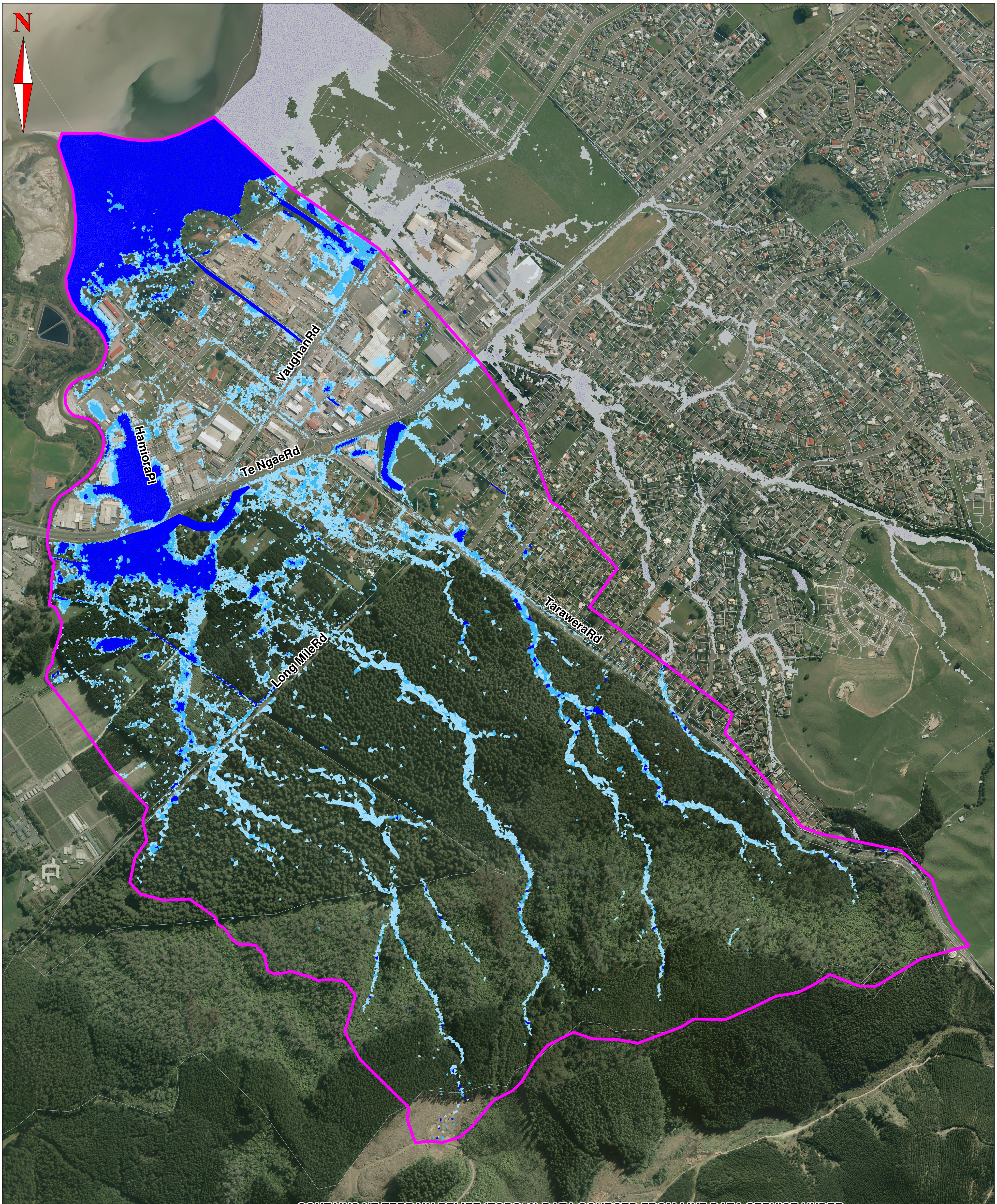
Appendix C – System Performance Maps



CONTAINS NZ TERRAIN RELIEF (TOPO50) DATA SOURCED FROM LINZ DATA SERVICE UNDER CREATIVE COMMONS ATTRIBUTION 3.0 NEW ZEALAND (CC BY 3.0 NZ)

Whilst we have attempted to produce mapping that is as reliable as possible, Rotorua Lakes Council and Opus International Consultants accept no responsbility for the accuracy of the mapping, nor any decisions based on it.

LEGEND

- Modelled Boundary
- Parcel Boundary

Flood Depth (m)

- Greater than 0.3
- 0.15 to 0.3
- 0.05 to 0.15

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DRAWN	APPROVED	REV	REV DATE	PLAN
LAF	LF	1	AUGUST 2017	**10% AEP Flood Depth Map**

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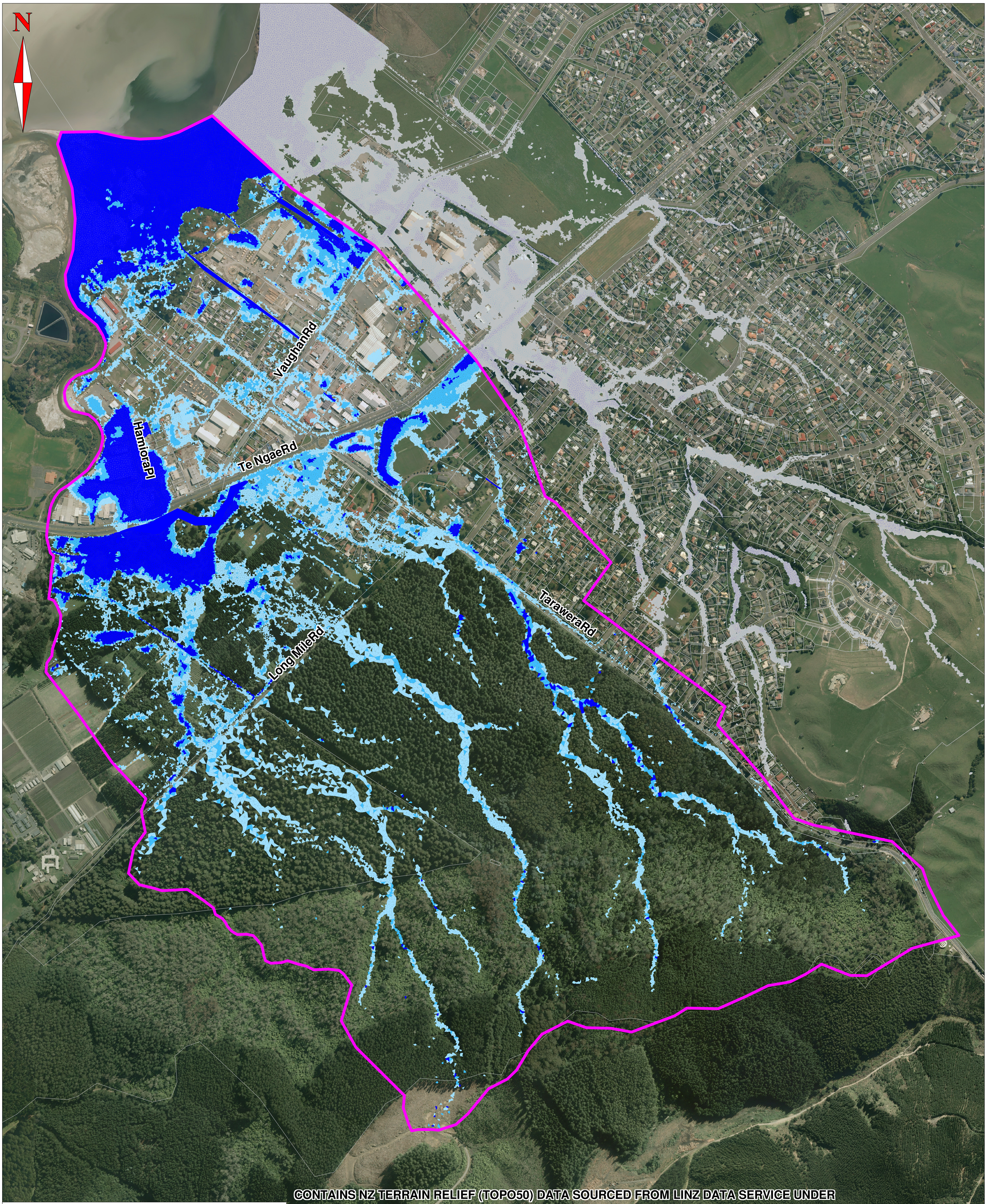

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Whilst we have attempted to produce mapping that is as reliable as possible, Rotorua Lakes Council and Opus International Consultants accept no responsbility for the accuracy of the mapping, nor any decisions based on it.

LEGEND

Modelled Boundary

Parcel Boundary

Flood Depth (m)

- Greater than 0.3
- 0.15 to 0.3
- 0.05 to 0.15

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PROJECT	Rotorua Lakes Council Catchment 6 Stormwater Modelling			
DRAWN: LAF	APPROVED: LF	REV: 1	REV DATE: AUGUST 2017	PLAN: 2% AEP Flood Depth Map
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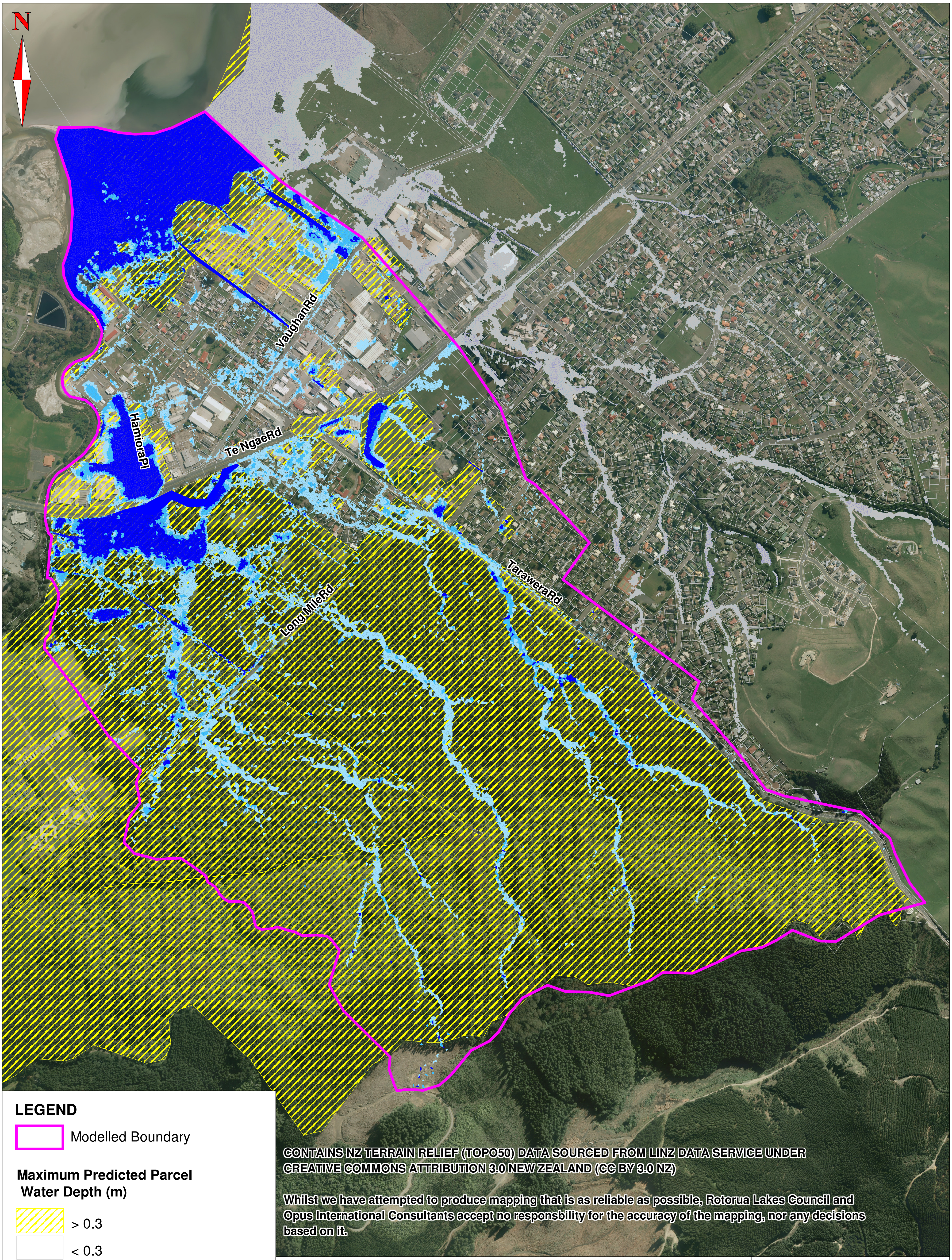

LEGEND

Modelled Boundary

Maximum Predicted Parcel Water Depth (m)

- > 0.3
- < 0.3

Predicted Flood Depth (m)

- Greater than 0.3
- 0.15 to 0.3
- 0.05 to 0.15

CONTAINS NZ TERRAIN RELIEF (TOPO50) DATA SOURCED FROM LINZ DATA SERVICE UNDER CREATIVE COMMONS ATTRIBUTION 3.0 NEW ZEALAND (CC BY 3.0 NZ)

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PROJECT: **Rotorua Lakes Council Catchment 6 Stormwater Modelling**

DRAWN	APPROVED	REV	REV DATE	PLAN
LAF	LF	1	AUGUST 2017	**10% AEP Parcels > 300mm Depth**

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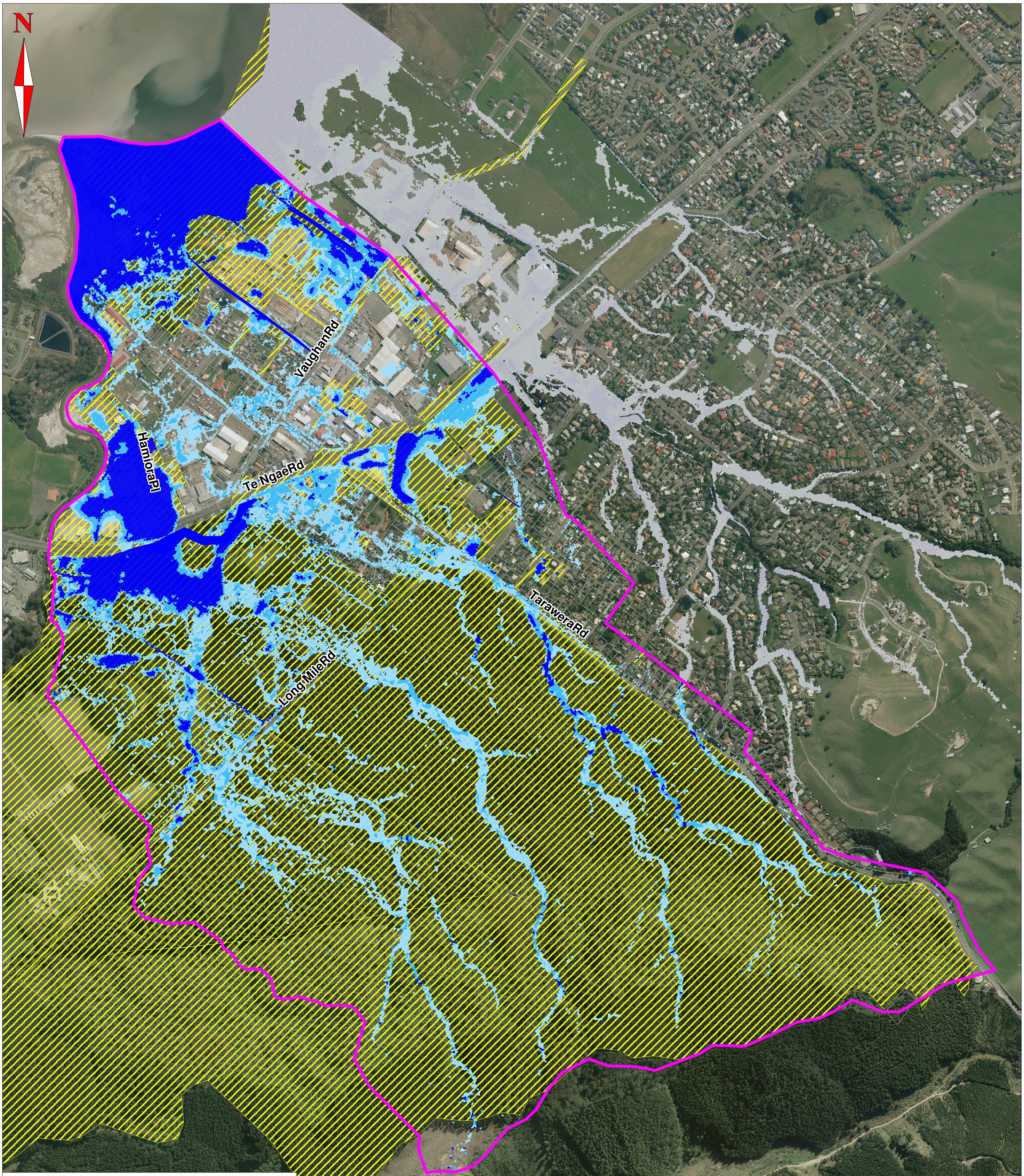

LEGEND

Modelled Boundary

Maximum Predicted Parcel Water Depth (m)

> 0.3

< 0.3

Predicted Flood Depth (m)

Greater than 0.3

0.15 to 0.3

0.05 to 0.15

Original Sheet Size: A3 (V)   Projection: NZTM

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PROJECT	**Rotorua Lakes Council Catchment 6 Stormwater Modelling**			
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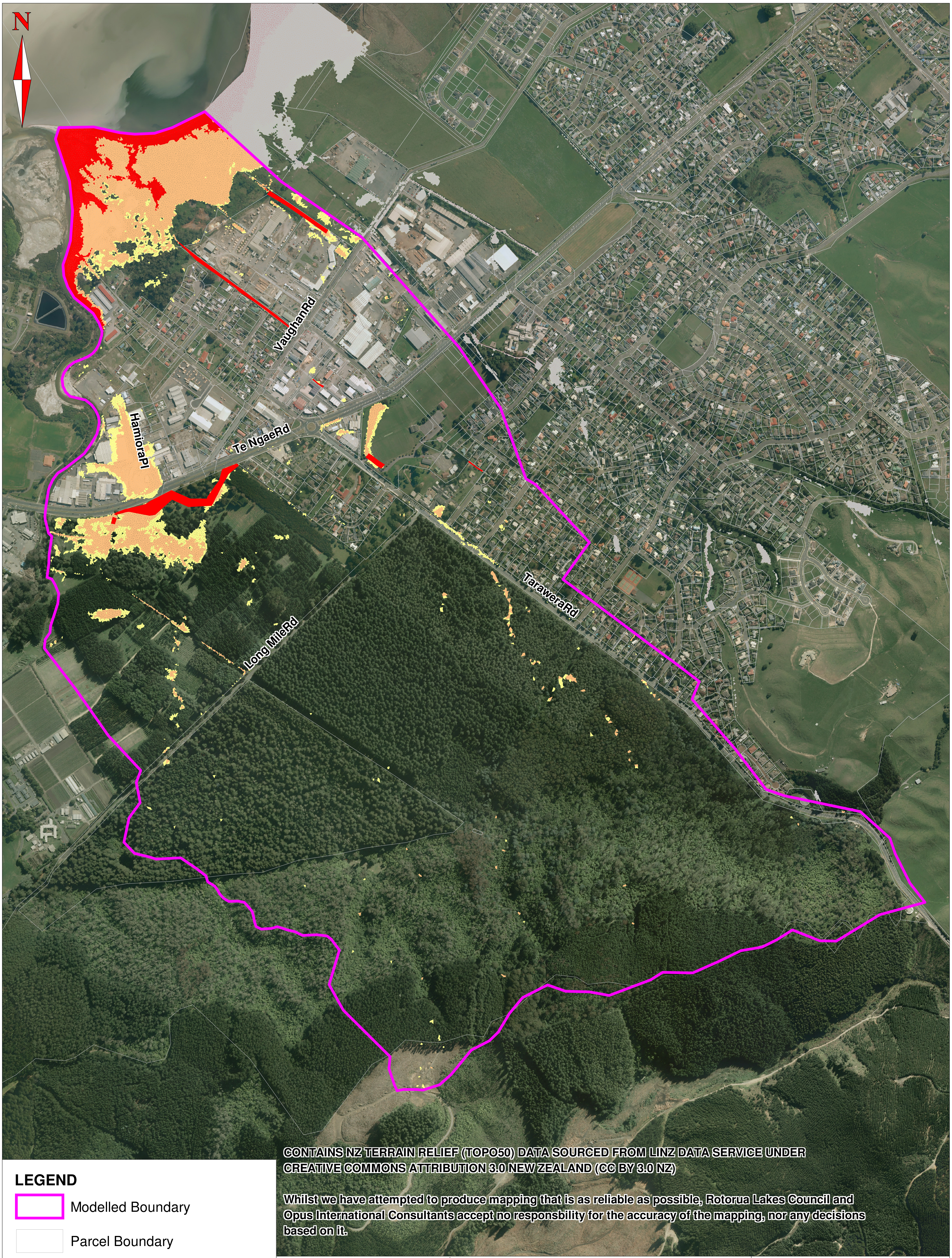

Whilst we have attempted to produce mapping that is as reliable as possible, Rotorua Lakes Council and Opus International Consultants accept no responsbility for the accuracy of the mapping, nor any decisions based on it.

LEGEND

- Modelled Boundary
- Parcel Boundary

Hazard Classification

- > 2 (Extreme)
- 1.25 to 2 (Significant)
- 0.75 to 1.25 (Moderate)

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DRAWN LAF	APPROVED LF	REV 1	REV DATE AUGUST 2017	PLAN **10% AEP Flood Hazard Map**
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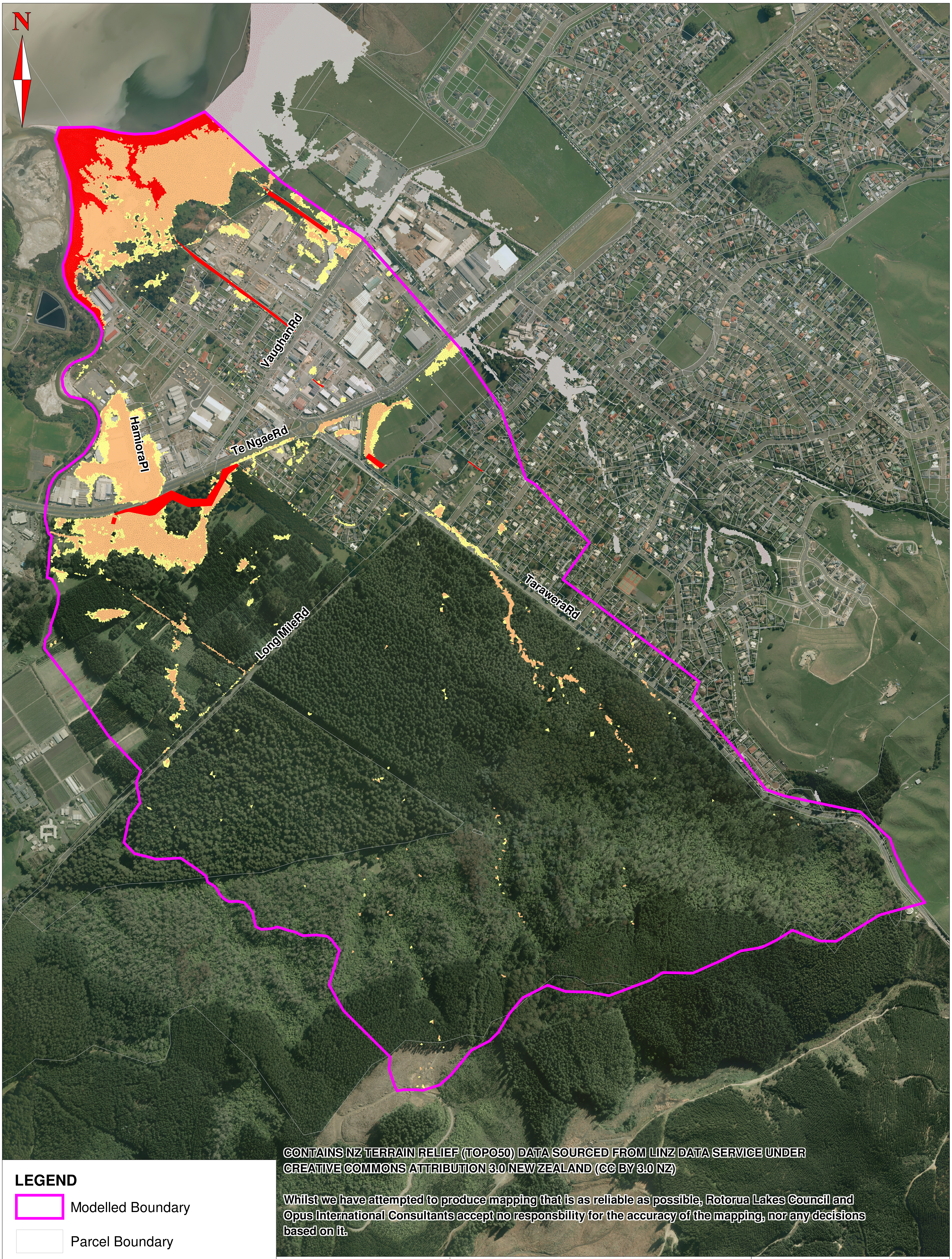
Original Sheet Size: A3 (V)   Projection: NZTM



CONTAINS NZ TERRAIN RELIEF (TOPO50) DATA SOURCED FROM LINZ DATA SERVICE UNDER CREATIVE COMMONS ATTRIBUTION 3.0 NEW ZEALAND (CC BY 3.0 NZ)

Whilst we have attempted to produce mapping that is as reliable as possible, Rotorua Lakes Council and Opus International Consultants accept no responsbility for the accuracy of the mapping, nor any decisions based on it.

LEGEND

Modelled Boundary

Parcel Boundary

Hazard Classification

> 2 (Extreme)

1.25 to 2 (Significant)

0.75 to 1.25 (Moderate)

ROTORUA LAKES COUNCIL
Te kaunihera o ngā roto o Rotorua

OPUS

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PROJECT	**Rotorua Lakes Council Catchment 6 Stormwater Modelling**			
DRAWN LAF	APPROVED LF	REV 1	REV DATE AUGUST 2017	PLAN **2% AEP Flood Hazard Map**
PROJECT NO. 3-C1423.06	SCALE 1:11,000 @ A3	PLAN NO Plan C6	SHEET NO 1 of 1	FILE REF O:\env\tla_north\rotorua\proj\3-c1423.06 - stormwater modelling services - catchment 6\01 Data\GIS\Workspaces\Plan C6 2% AEP Hazard.wor

Original Sheet Size: A3 (V)   Projection: NZTM

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