Rotorua Lakes Council

Catchment 14

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 WSP Opus to produce an assessment of the performance of Stormwater Catchment 14 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.

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 final report represents the deliverables for Stages 1-3. Stage 4 has been partially completed with potential high-level options identified. However, RLC instructed WSP Opus not to proceed with the testing of these options.

2 Catchment Description

2.1 Catchment Extent

Catchment 14 is a stormwater catchment to the east of Rotorua's town centre. The catchment covers an upstream rural area draining through the urban area of Fordlands via the Otamatea Stream and multiple tributaries. The urban area is predominantly residential and covers approximately 290 ha to the north-east of Pukehangi Road. The rural area, which is predominantly grassland, is approximately 90 ha and is located to the south-west of the urban area. A large proportion of the rural area is due to be developed for residential housing as part of several separate developments. Figure 2-1 shows the location of the two areas comprising Catchment 14.

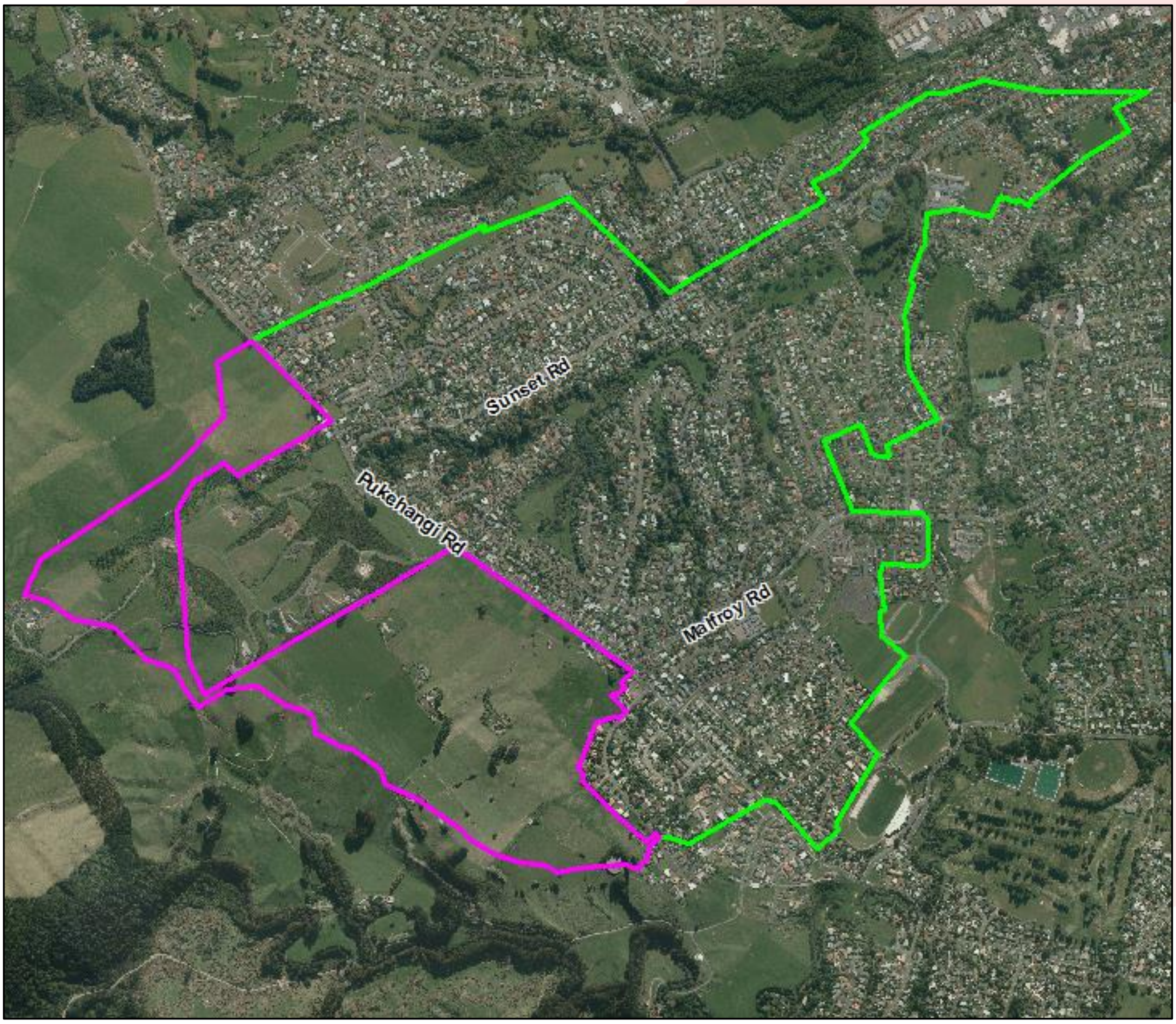


Figure 2-1 : Catchment Extent

For simplicity, throughout the remainder of the report, "Catchment 14" will describe both the urban and rural catchments as one. The project is focussed on quantifying and understanding the flows and velocities through the culverts on the Otamatea Stream, and the current network performance prior to the development in the rural area. RLC has provided details of known flooding issues, which mainly occur around the Otamatea Stream near Ford Road and Sunset Road.

2.2 Topography

The rural area to the south of Pukehangi is fairly steep, with elevations between 400 m AD and 310 m AD. By contrast, the remaining developed area is much flatter, with elevations between only 310 m AD and 280 m AD. Figure 2-2 shows the elevations across the catchment.

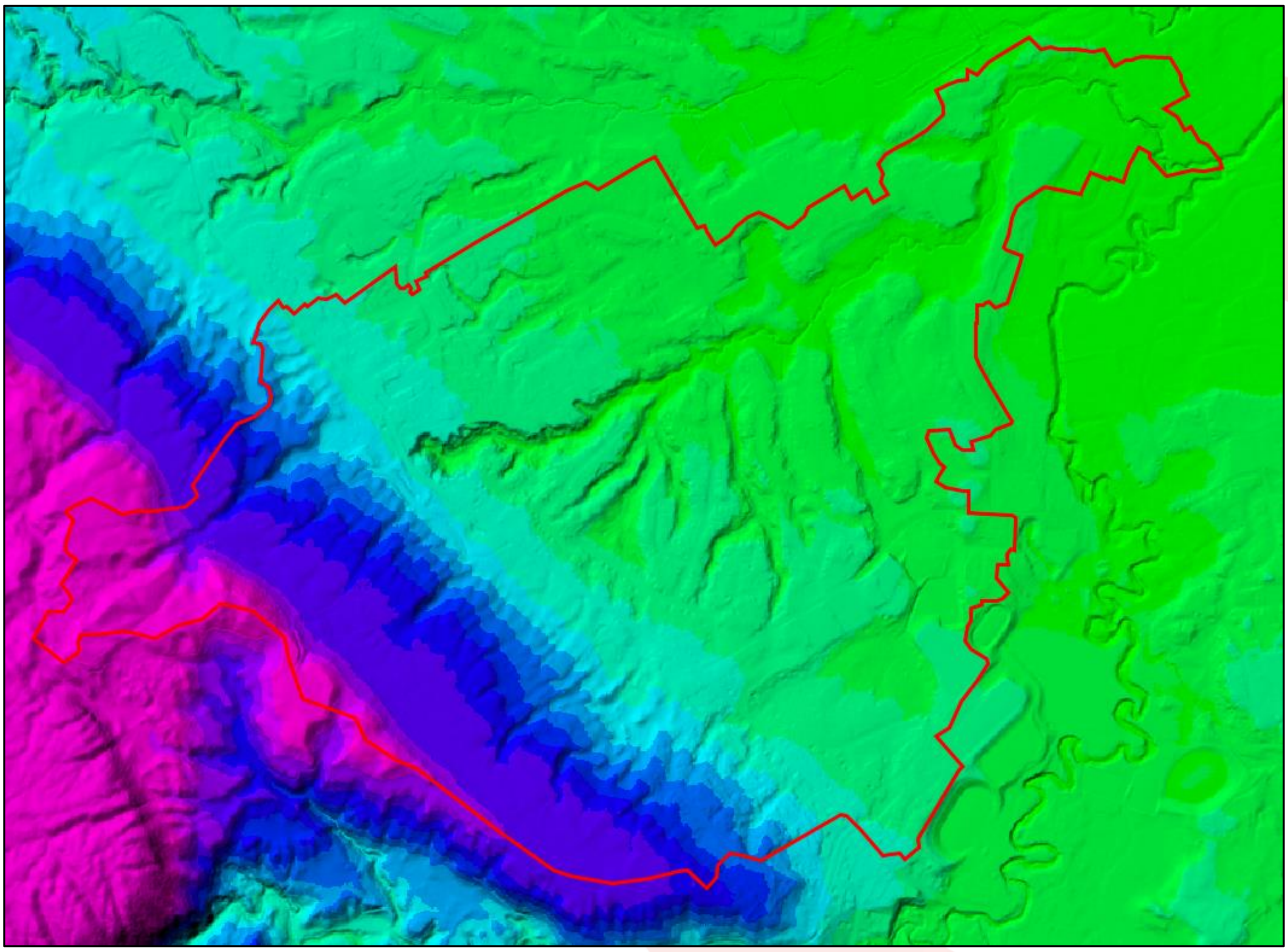


Figure 2-2: Catchment 14 Topography

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).

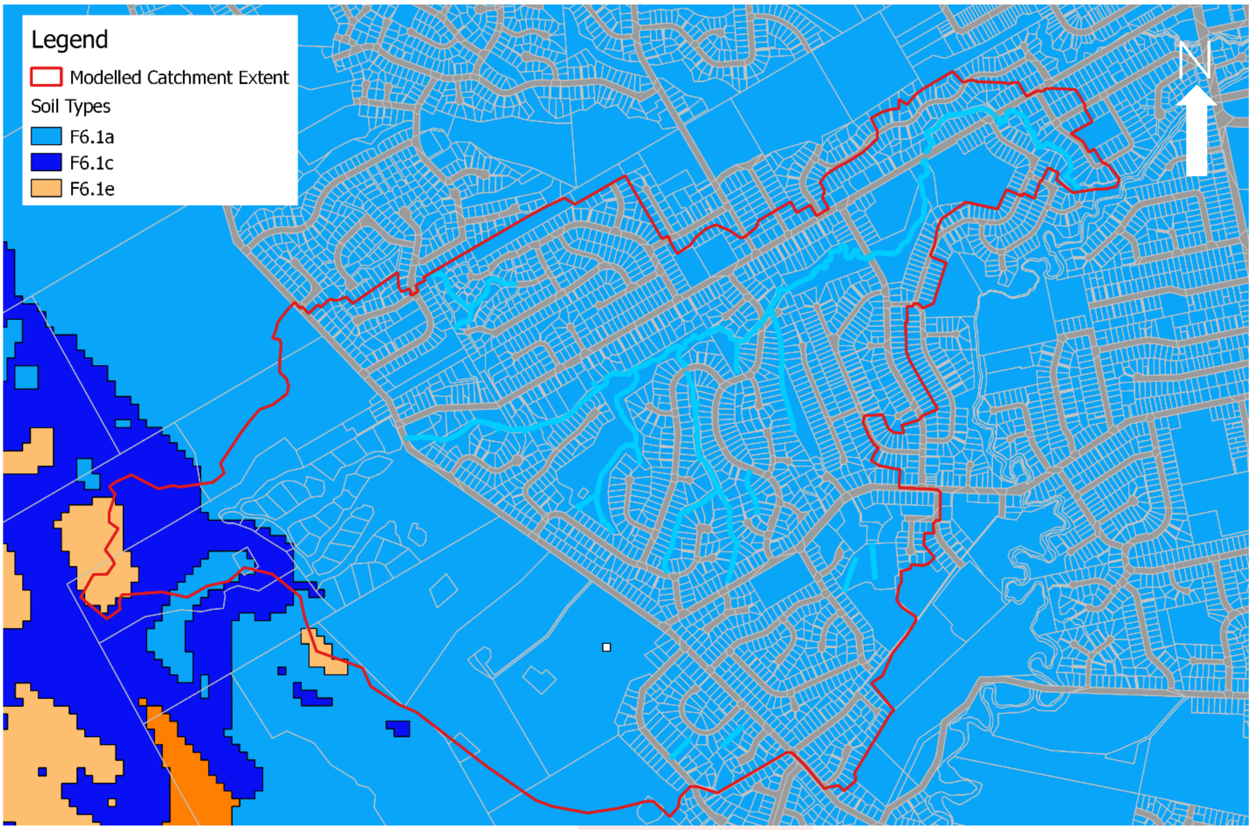


Figure 2-3: Soil Types (Landcare Research New Zealand, 2002)

Table 2-1 details the soil types within the catchment.

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

LEVEL III CLASSIFICATION	LANDFORM	SOILS	LEVEL IV CHARACTERISTICS
F6.1	Undulating hills	Well-drained, low fertility soils from mid-age rhyolitic tephra a) Warmer temperatures	a) Warmer temperatures c) Cooler temperatures e) Cooler temperatures, lower vapour pressure deficits

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 (open channels). The piped network intercepts and conveys stormwater flows from the road corridor and property connections to the open channel. Stormwater collected from the road corridor consists of both road run-off and property discharges to the kerb and channel.

The Otamatea Stream is the predominant open channel in the catchment. It starts at Pukehangi Road in the west and runs in a north-easterly direction, adjacent to Sunset Road. The stream discharges into the Utuhina Stream in the far east of the catchment.

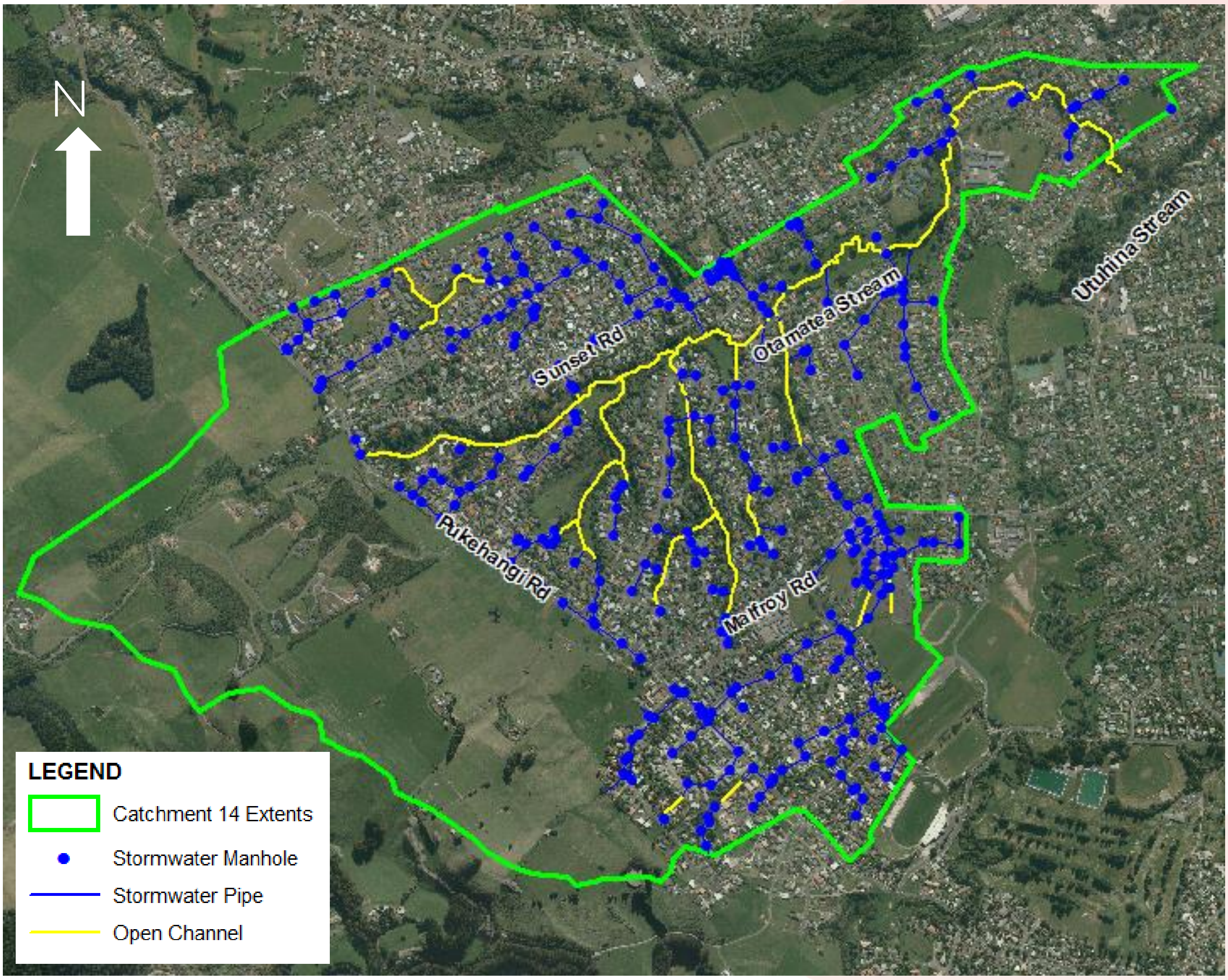


Figure 2-4: Catchment 14 Stormwater Network

2.5 Land Use

The upstream end of the catchment contains a significant area of rural land encompassing approximately 60% of the catchment, while the remainder of the catchment is urban residential. Land uses within the catchment are presented in Figure 2-5 (Rotorua Lakes Council, 2016).

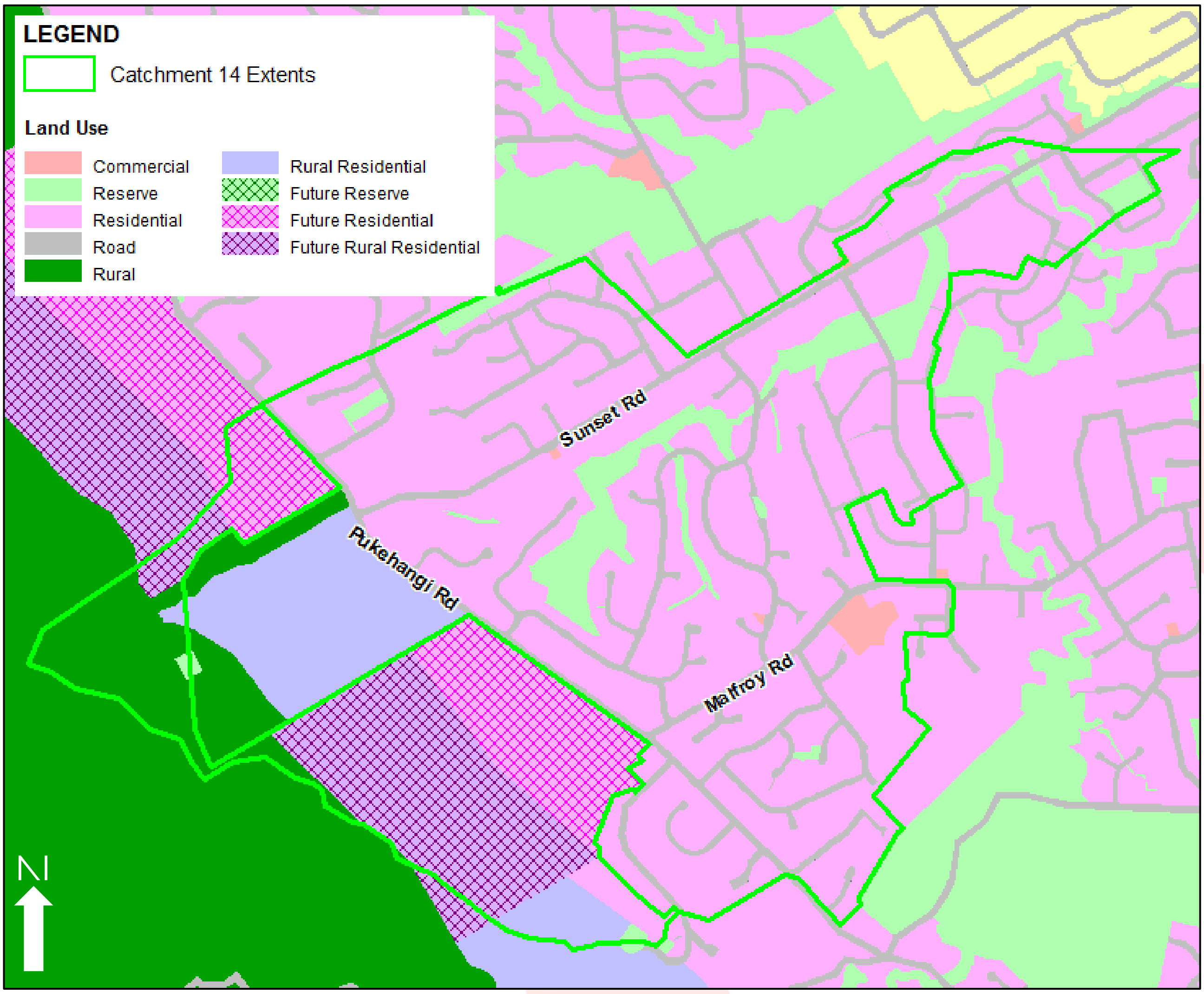


Figure 2-5: Land Use

2.6 Stormwater Issues

The predominant stormwater issue within the catchment, and the main drivers for this investigation, are the capacities of the culverts on the Otamatea Stream, and the interaction at the confluence of the Otamatea and Utuhina Streams.

A secondary issue is the potential impact of the development on the existing stormwater flows in the catchment.

3 Model Build

3.1 Hydraulic Model

RLC provided Opus with the stormwater layout in GIS format in August 2017. This was imported into InfoWorks ICM v7.5 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 from April 2012.

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 acquired for development of the hydraulic model included:

- GIS data;
- DTM ground level information;
- Aerial imagery;
- Site inspections; and
- Level surveys for selected inlets/outlets and cross-sectional surveys of the open channel.

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
OBS	Observation from site visit or inspection
PHO	Data from photos, aerials, Google Street view
RPTD	Report – Technical Document e.g. Culvert Design Guide, TP108
SD/SD17	Survey Data/Survey Data from 2017
ST	RLC Standards

3.2.1 Survey

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

- Inlet and outlet levels on open channels; and
- Multiple cross sections along culverts and open channels.

3.2.2 Nodes

The nodes were 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 the culverts on the Otamatea Stream. Flood types used in the model are summarised in Table 3-2.

The model has been simplified to improve model performance. This has involved the removal of sump/inlet nodes and the associated pipes connecting them to the main storm pipes. This has mainly been performed in the less critical areas of the model. Therefore, this is unlikely to have an impact on model results.

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 (in conjunction with a boundary level condition) - 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 were modelled using a head discharge profile 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 have been included in the model.

3.2.3 Pipes

Approximately 63% (532 pipes) of the RLC GIS "SWMainLine" dataset was 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, these 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 a DN300.

The manhole survey provided invert levels for key outlets and culverts and 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 the 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.

Surface friction is applied to the piped network using typical Colebrook-White roughness coefficients depending on pipe material, see Table 3-3. Where the material is unknown, a Ks value of 1.5 has been assumed. The Ks value has been applied to both the top and bottom of the pipe.

Table 3-3: Typical 1D Colebrook-White Ks Roughness Values

Classification	Colebrook White Ks Values
Pipe Material	
Vitreous Clay	1.5
Precast Concrete Pipe	1.5
Cast In-situ Concrete	3.0
PVC / PE	0.6
Corrugated Aluminium, PE or PP	30

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. Head losses have been removed from the inlet pipes along Pukehangi Road to improve model stability.

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. The model has been simplified to improve model performance. This has involved the removal of sump/inlet nodes and the associated pipes connecting them to the main storm pipes. This has mainly been performed in the less critical areas of the model. Therefore, this is unlikely to have an impact on model results.

3.2.4 Culverts

Turbulence losses associated with the entry and exit of culverts between river reaches have been represented using culvert inlet and outlet links. Culvert inlets have also been used to represent the inlets from the fields west of along Pukehangi Road. Entry losses have been modelled using values recommended in Table A1.3 of the Culvert Design Manual (CIRIA, 2010).

3.2.5 Open Channel

The Otamatea Stream is the predominant open channel in the catchment. It starts at Pukehangi Road in the west and runs in a north-easterly direction, adjacent to Sunset Road. The stream discharges into the Utuhina Stream in the far east of the catchment.

The head of the Otamatea Stream is between residential properties in an area of heavily vegetated land and is fairly undefined. Further downstream the channel becomes more defined and less vegetated. It continues to run between residential properties and contains multiple culverted road crossings. There is a low spot at Ford Road, where flooding has been reported. Upgrades to the Ford Road culvert were constructed in 2008/2009.

Four tributaries discharge into the Otamatea Stream from the south. Otamatea Stream discharges into the Utuhina Stream in the far east of the catchment.

The Otamatea Stream and its tributaries were surveyed at multiple locations to capture there geometry via cross sections. 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 linked to the 2D surface via bank lines to permit lateral flow. The bank lines have been modelled using a discharge coefficient of 0.7-1.0 (the majority being grass lined and therefore set to 1.0) with a modular ratio of 0.9. Manning's roughness values have been applied based on the channel profiles shown in aerial photos.

3.2.6 Detention Ponds

There are three detention pond within the catchment. These are located in the rural area west of Pukehangi Road and receives flows from the recently developed land off Pukehangi Road. These ponds limit the storm flow from this development to an agreed rate. The pond is designed to retain storm volume up to a 50 year design event. It includes an emergency weir designed to discharge flow greater than this onto Pukehangi Road. The developments have been modelled using a two sub-catchments. The contributing area for these have been calibrated using a 2% AEP storm event. These sub-catchments are applied to the ponds, which have been represented by the 2D zone. The discharge flow rate from these ponds is controlled by the outgoing pipe.

3.3 Hydrological Model

As with previous Rotorua catchments, the SCS runoff model has been used.

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 digitised 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.

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. Catchment 14 has dominant soil type of F6.1a (Figure 2-3), which is characterised to have good drainage potential. All curve numbers were therefore based on the hydrological soil group A.

3.3.3 Cover type

Cover type was determined by undertaking a desktop assessment of aerial photography. Four cover types were identified in line with TR-55 classifications:

- Open Spaces;
- Residential: lot size 1000 m^2 (average for catchment 14 is approximately 800 m^2);
- Commercial; and

- Streets/roads: sealed.

The assigned sub-catchment cover types and their corresponding curve numbers are detailed in Table 3-4.

Table 3-4: Curve numbers for sub-catchments.

Cover description	Average Impervious Area (%)	Curve Number
Open Spaces	0	39
Residential: lot size 8000 m^2	12	46
Residential: lot size 1000 m^2	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 (surface infiltration capacity), 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 CNs 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 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 Digital Terrain Model (DTM). The mesh has the following attributes:

- Min triangle - 25 m^2
- Max triangle - 100 m^2
- Default surface roughness - 0.1
- Boundary condition – Normal hydraulic condition (where no boundary condition has been applied).

A minimum triangle size of 5m^2 and maximum of 25m^2 was originally tested. However, the model failed to run at this resolution.

3.3.7 Surface Roughness

Table 3-5 shows the range of Manning's 'n' surface values for differing cover type based on industry guidance.

Table 3-5: 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 14, a standard Manning's 'n' surface roughness of 0.1 has been used. This value represents roughness values appropriate for urban residential parcels. Road parcels have been imported into the network as roughness zones and assigned a roughness of 0.013. Further roughness zones have been digitised manually; open spaces, reserves and the upstream rural area have been assigned a roughness of 0.07, the upper part of the Otamatea stream has been assigned a roughness of 0.15 due the dense vegetation observed on the site visit.

3.4 Boundary Conditions

The Otamatea Stream has been modelled with a downstream boundary level based on the report "Hydraulic Modelling of the Otamatea Stream" (Environment Bay of Plenty, Feb 2007). This report indicates a level in the Utuhina Stream at the confluence with the Otamatea of 284.5 m (5% AEP event) and 285.1 m (1% AEP event).

3.5 Summary of Modelled Objects

Table 3-6 summarises all the modelled objects in the model after simplification.

Table 3-6: Modelled Objects

Modelled Object	Number
Number of Nodes	794
Number of Manholes Modelled	329
Number of Sumps Modelled	224
Number of River Reach (Break) Nodes	74
Number of Outfall Nodes	1
Number of 2D Outfall Nodes	19
Number of Modelled Pipes	634
Total Modelled Pipe Length (m)	18,918
Pipe / Culvert Size (mm)	225 – 1900
Number of River Reaches	59
Number of Sub-Catchments	518
Total Sub-Catchment Area (ha)	251
Average Sub-Catchment Size (ha)	0.485

3.6 Data Issues

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

- Approximately 63 % of the pipe invert levels were missing from the GIS dataset. The missing invert levels 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.

3.7.1 Culvert Inlet Losses

Where possible, inlet losses have been based on survey photos.

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 as it is 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.

4 Model Sensibility Checks

4.1 Sensibility Checks

The model will not be 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 of flooding;
- Mass balance checks; and
- Rational Method runoff checks.

4.2 Storm Event Validation

The model reliability has been tested by comparing the predicted flooding locations against reported flooding locations for a significant storm event with known rainfall. From Tuesday 19th through to Wednesday 20th August 2014, Rotorua experienced heavy rainfall causing flooding within the catchment, mainly in relation to the capacity of the Otamatea Steam.

Details of observed flooding were provided by RLC. The model predicted flooding in these locations, as well as others not observed to flood during the validation event. However, RLC confirmed that these locations have flooded at other times, and flooding during the validation event may have occurred and gone un-reported. The flood map shown in Appendix B shows the extent of the predicted flooding for this event.

As a result of this exercise, the percentage rainfall (39%) applied to the 2D zone was confirmed as acceptable.

4.2.1 Rainfall

Rainfall for the event was taken from records for the Kaituna at Whakarewarewa rain gauge. This rain gauge is located approximately 3 km from Catchment 14, 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 139 mm. Figure 4-1 shows the recorded rainfall for the event.

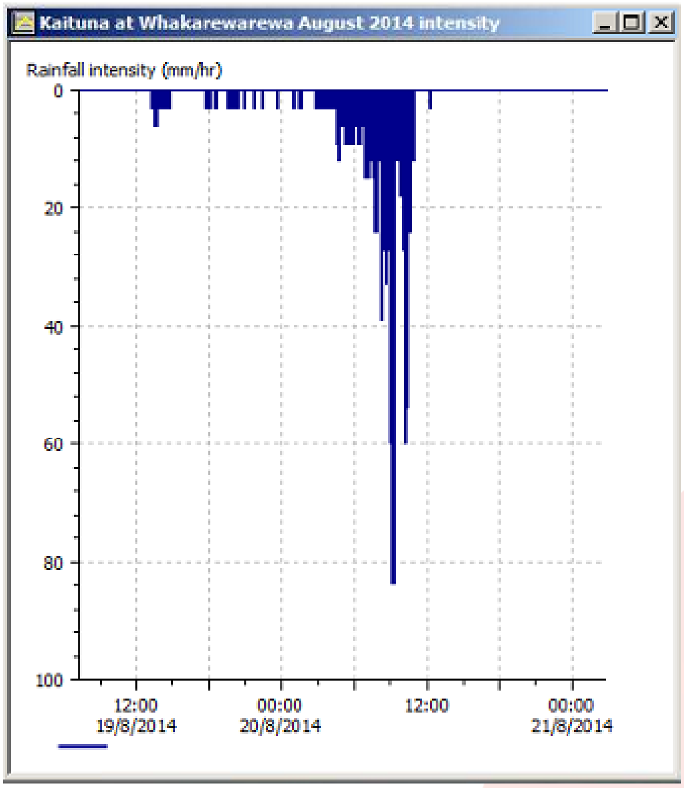


Figure 4-1: Observed rainfall between 19/08/14 and 21/08/14 used for model runs.

4.2.2 Flood Extent Review

The flood extent and locations predicted by the model for the validation were compared with reports of known flooding. RLC identified that during the validation event, the following flooding was observed or believed to have occurred;

- At the Ford Road/Otamatea stream culvert during the August 2014 storm event,
- On the Otamatea stream, downstream of the Ford Road culvert and around Sunset Road during the August 2014 storm event,
- On the Otamatea stream, upstream of the Ford Road culvert around Pullar park and the Eastern end of Wright Park. No direct reports, but RLC confirmed that flooding was likely in this area during the August 2014 storm event,
- At properties around the area of 240 – 248 Sunset Road historically and may have flooded during the August 2014 storm event,
- Near the junction of Petrie Street and Hathor Street historically, resulting in RLC buying 22 Petrie Street and using it as a flow path for storm water. No direct reports of flooding during the August 2014 storm event, however RLC has indicated that most likely will have flooded.

A review of the predicted flooding identify that the model replicates flooding at the above locations. See 4.2.2.1 to 4.2.2.3 for more details of the model predicted flood extents for these areas. The model also predicts some minor flooding in the roads in some parts of the catchment, see 4.2.2.4 for more details.

Please see Appendix B for the flood extent map of the catchment for the validation event.

4.2.2.1 Ford Road and Sunset Road Culverts

The Ford Road and Sunset Road culverts on the Otamatea stream have a history of flooding, as it is a low spot in this area. Figure 4-2 shows the model predicted results for this area during the validation event. Figure 4-3 and Figure 4-4 are photos of flooding in this area.

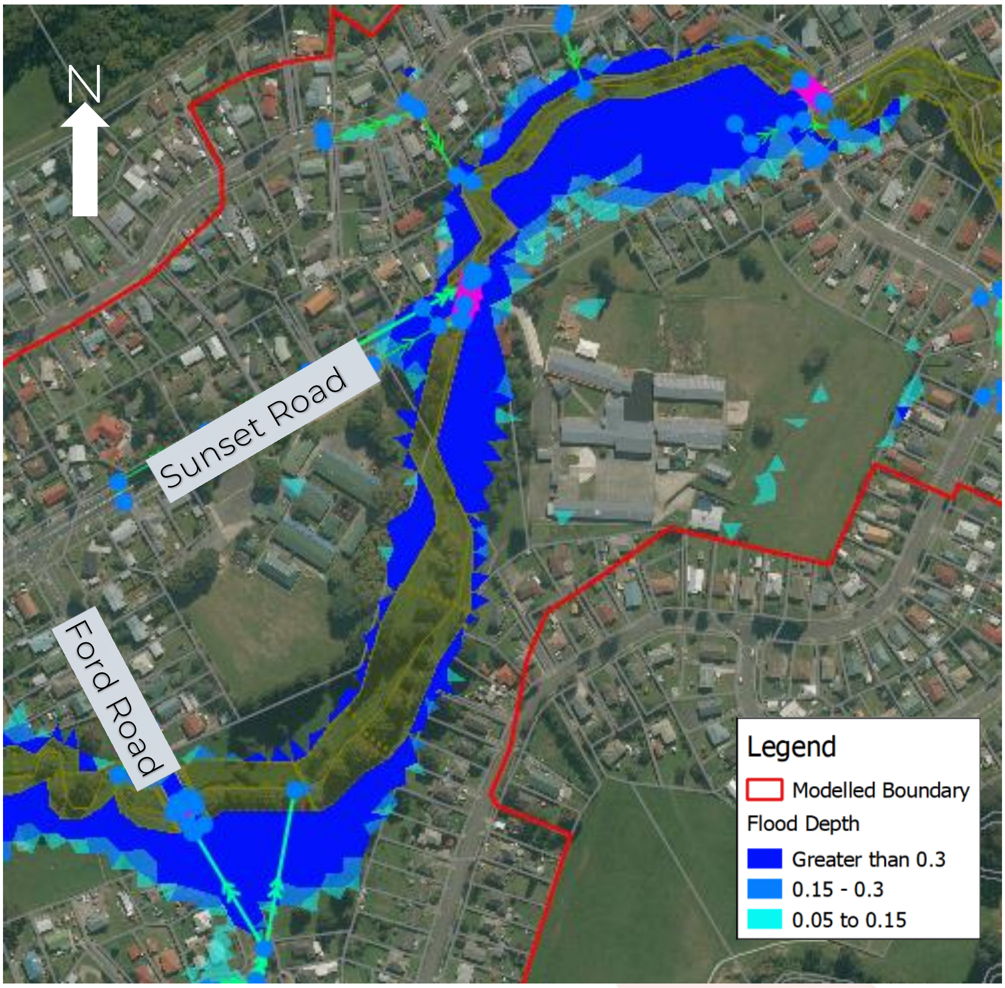


Figure 4-2: Ford Road Culvert

Figure 4-3: Flooding at Sunset Road (taken from 114 Sunset Road)

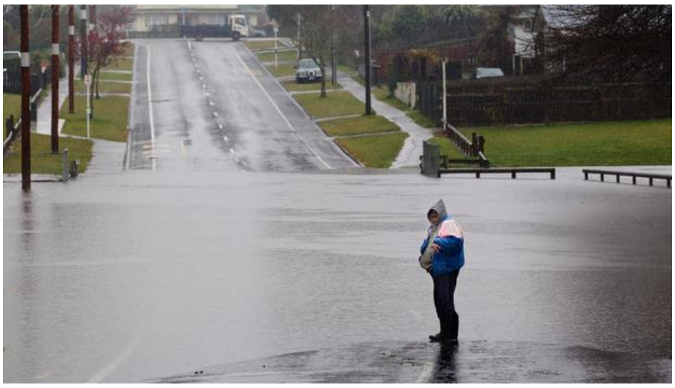


Figure 4-4: Flooding at Ford Road (taken looking north towards the Ford Road culvert)

4.2.2.2 Pullar Park/Wright Park and 240-248 Sunset Road

This area is just upstream of the Ford Road culvert, and RLC have identified that flooding here during the validation event was very likely due to the backing up of the Otamatea stream. 240-248 Sunset Road is predicted to flood during the validation event, and RLC have identified that this may have occurred as it has flooded historically.

Figure 4-5 shows the model predicted results for this area during the validation event.

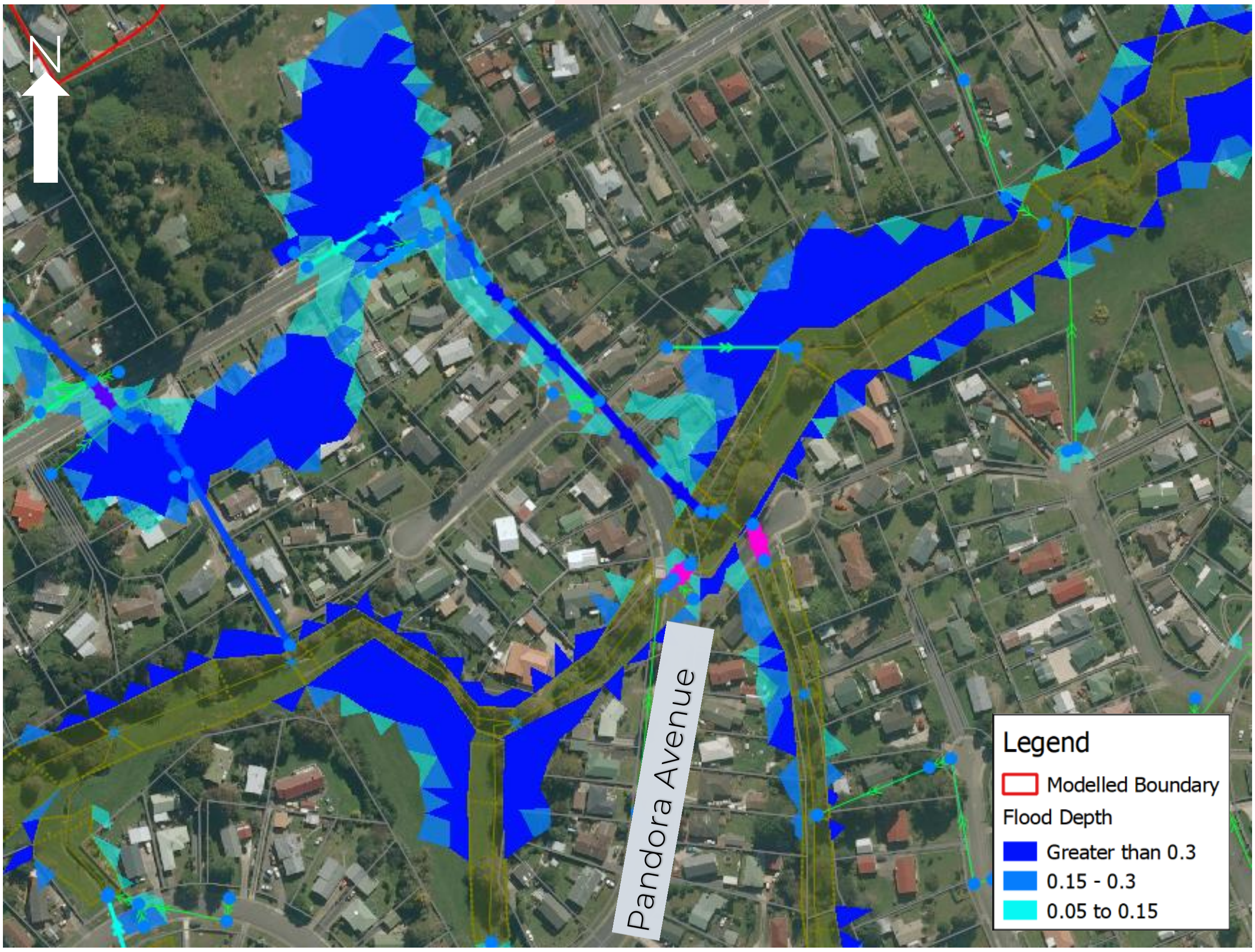


Figure 4-5: Pullar Park/Wright Park

4.2.2.3 Petrie Street and Hathor Street

RLC have identified that there is a history of flooding at this location and that although flooding was not reported during the validation event, it was likely to have occurred. Figure 4-5 shows the model predicted results for this area during the validation event.

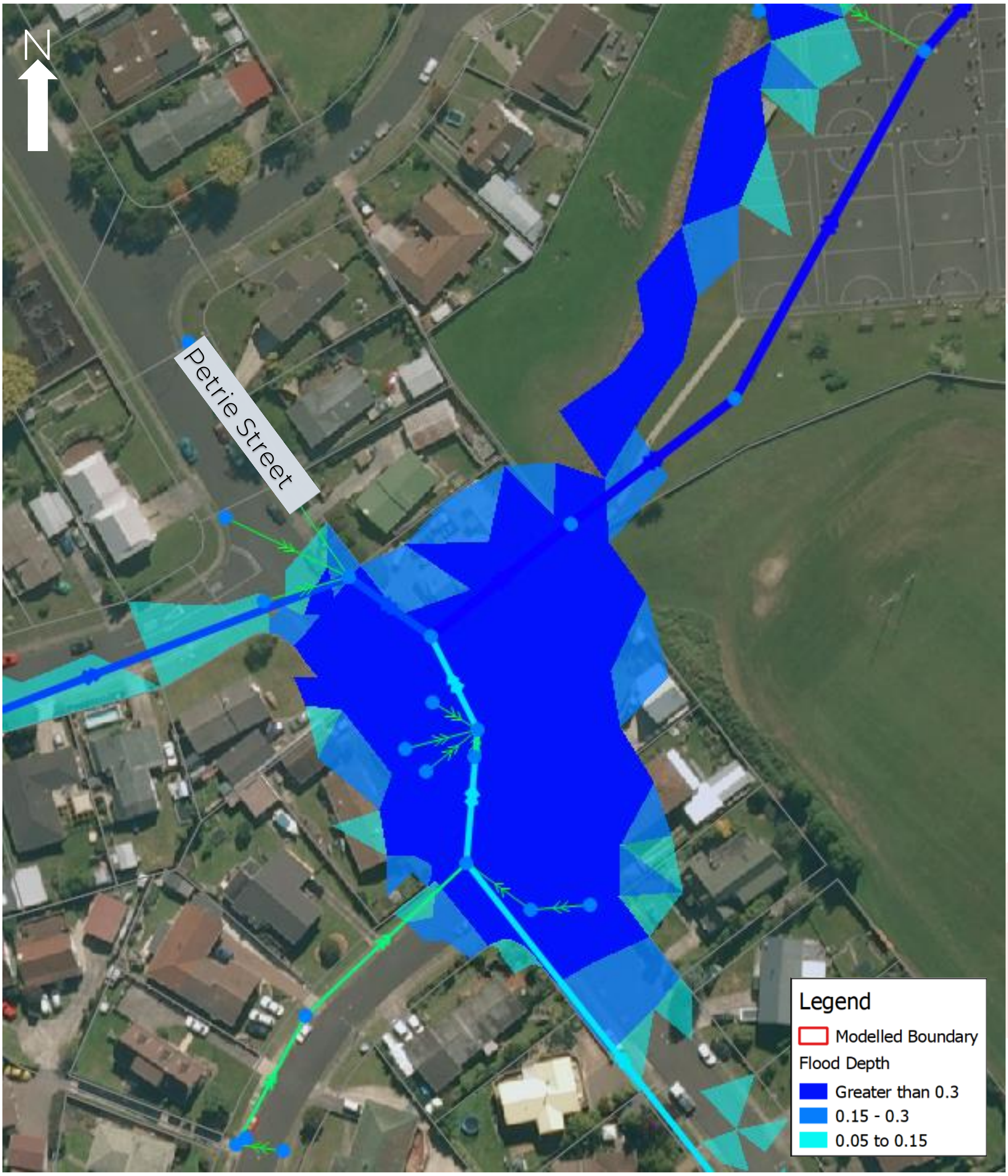


Figure 4-6: Petrie Street and Hathor Street

4.2.2.4 Unreported Flooding

The model predicts flooding in locations where there are no confirmed reports of flooding. Although there are no reports of flooding in these locations, as it is low depth and in the road it is unlikely to have been reported. See Figure 4-7 for an example of road flooding within the catchment, and Appendix B for further locations.

There are also some predicted flow paths through properties. This may be a result of the model over predicting run off in this area, or the inlet capacity being under estimated due to model simplifications or the 2D zone resolution being not fine enough. It is recommended that this is investigated further, if further confidence is required in these areas.

Figure 4-7: Example of road flooding

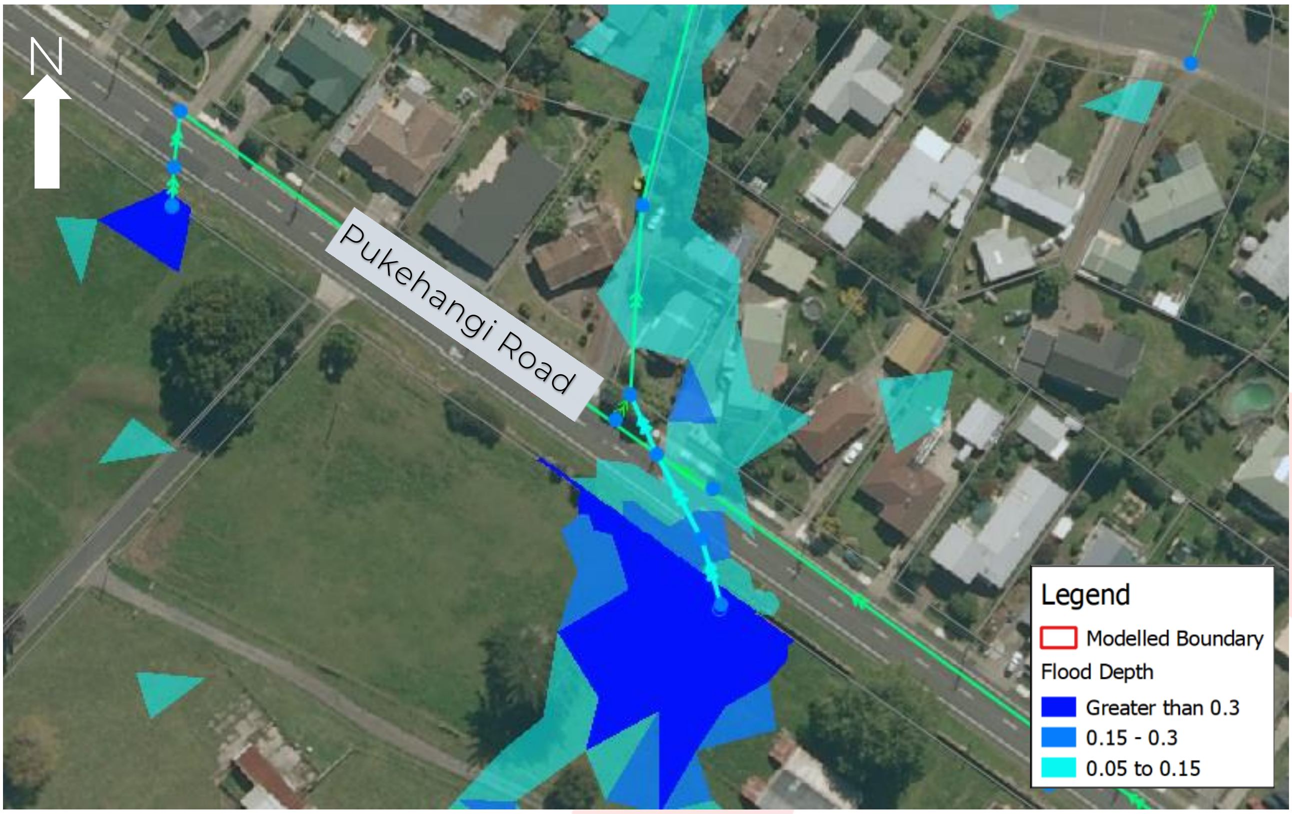


Figure 4-8: Flow path through 364 Pukehangi Road

4.3 Mass Balance Checks

Cumulative mass balance checks are automatically undertaken by ICM's software engine at each simulation time step. If the cumulative mass balance error exceeds 0.01 m^3 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	
	m^3	%	Mass Error Balance (%)	Total Mass Error (m3)
2%	0	0	0	0.0001
10%	0	0	0	0.0001

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
DI26457	-12%	6%
DI125207	-3%	13%
DH000751	-5%	12%
DH000775	-1%	-1%
DI125529	-3%	13%
DI000600!	-5%	12%
Area-Weighted Average – Difference	-5%	9%

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.

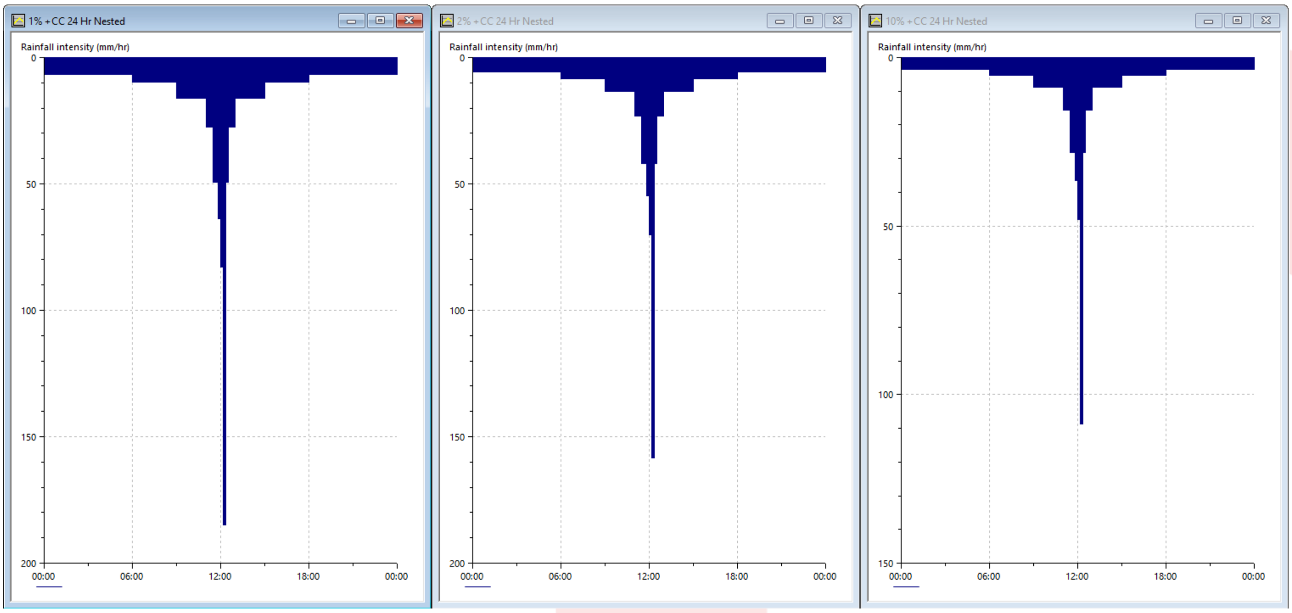


Figure 5-1: 24 hour nested storms with climate change (left 1% AEP, middle 2% AEP, right 10% AEP)

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	12.0	4.1	7.2	23.3
2% AEP	19.3	5.7	12.2	37.2
1% AEP	23.0	6.2	14.6	43.8

5.2 Parcels with Predicted 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 14 boundary is 2,464. The locations of these parcels are shown in Appendix C together with the extent of ponding.

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

EVENT	PARCELS WITH PONDING GREATER THAN 300 MM	PERCENTAGE OF TOTAL PARCELS (%)	DEVELOPED PARCELS WITH PONDING GREATER THAN 300 MM
10% AEP	261	11	252
2% AEP	402	16	393
1% AEP	465	19	456

5.3 10% Rainfall AEP Predicted Flooding

The model predicts flooding at a number of locations during the validation event. The majority of this flooding has been confirmed by RLC as either reported or likely to have occurred. During the 10% AEP storm event, the flood depths and extents are predicted to be slightly greater. However, the model does not predict any significant flooding at locations not identified in the validation event.

The majority of the flooding appears to be the result of the capacity of the Otamatea Stream and the downstream Utuhina Stream. This lack of capacity results in flow either over-spilling the banks of Otamatea Stream or backing up of flows in the piped network. This results in land parcels having ponding greater than 300mm.

The following section provides detail on the mechanisms of the predicted flooding within the land parcels. It should be noted that only flooded parcels are identified, not flooded houses, 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.

5.3.1 Ford Road and Sunset Road Culverts

During the 10% AEP storm event, the areas adjacent to the banks of the Otamatea stream near the Ford Road and Sunset Road culverts have predicted ponding depths greater than 300mm. The ponding at these location is due to the area being low lying and the downstream river and culverts having insufficient capacity. The river level in the Utuhina Stream will also impact flood depths in this area.

The majority of the catchment (approx. 230 ha) contributes to the flow at this area.

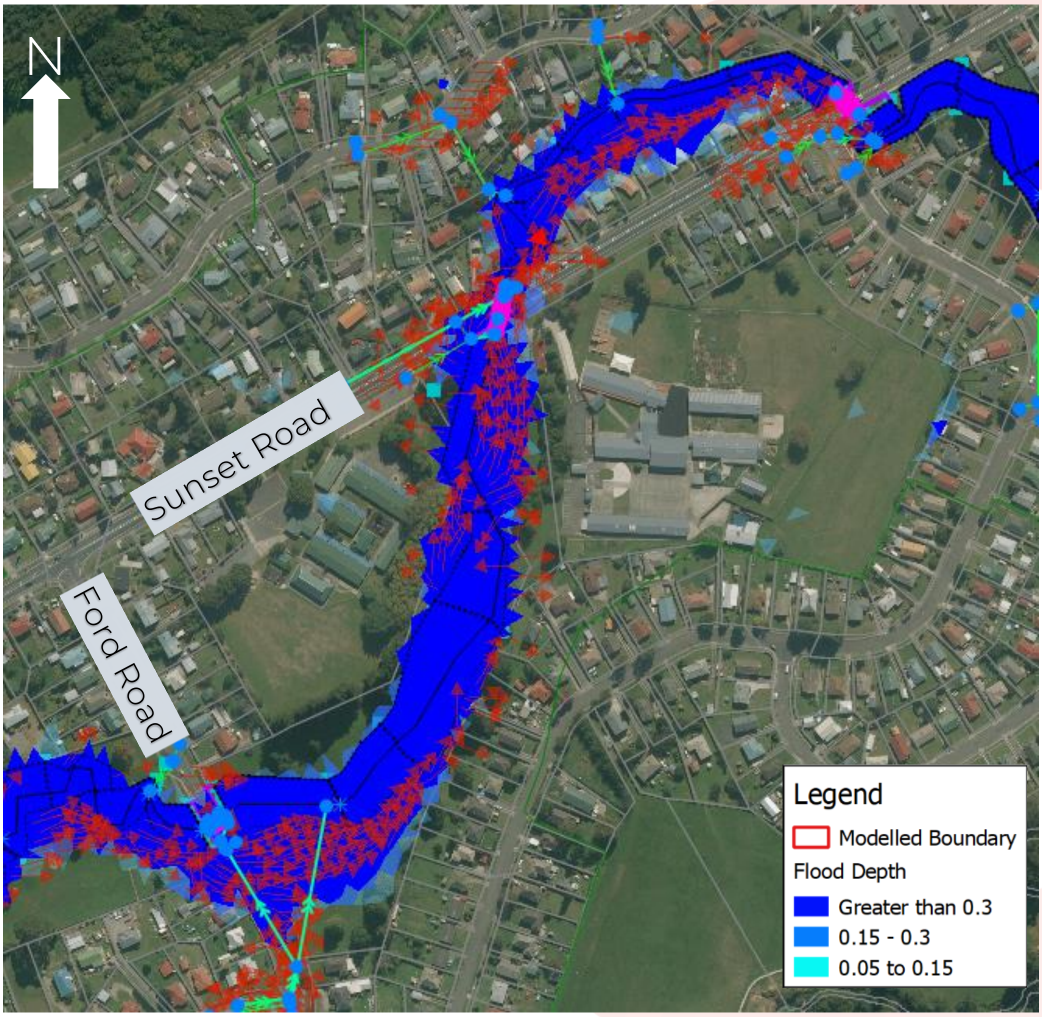


Figure 5-2: Ford Road and Sunset Road Flooding

5.3.2 Pullar Park/Wright Park

During the 10% AEP storm event, the Pullar Park/Wright Park area has predicted ponding depths greater than 300mm. The model indicates this ponding has the potential to impact properties adjacent to the parks. This area is just upstream of the area described above, and ponding is a result of the same capacity issue described above.

The majority of the catchment (approx. 210 ha) contributes to the flow at this area.

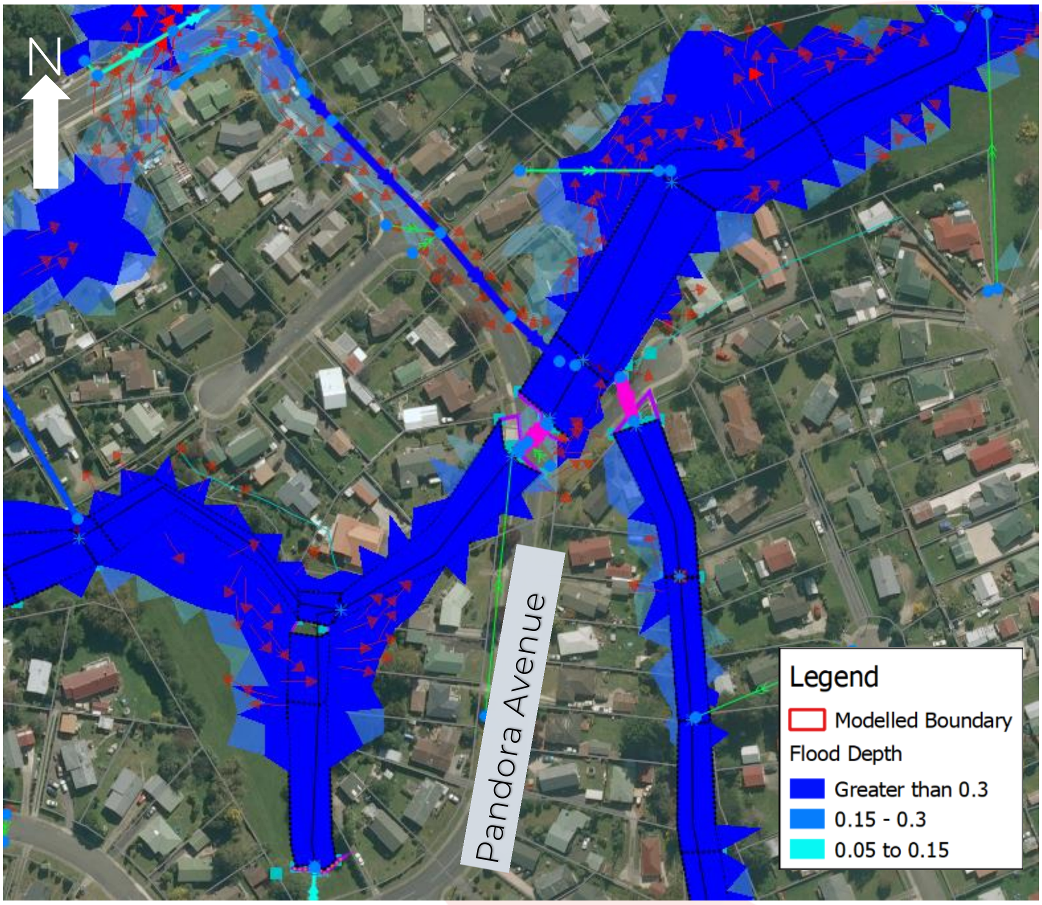


Figure 5-3: Pullar park and Wright Park Flooding

5.3.3 231 and 240-248 Sunset Road

During the 10% AEP storm event, 231 and 240-248 Sunset Road has predicted ponding depths greater than 300mm. This area had upgrades to the storm network between 231 Sunset Road and 99 Pandora Avenue delivered in 2014. The model indicates that the cause of the flooding at this location is due to the level in the Otamatea stream and local incapacity in the network. The model predicts that storm flow spills from the piped network and upstream of this area. This flow goes overland along the roads and through properties, finally ponding in 231 and 240-248 Sunset Road.

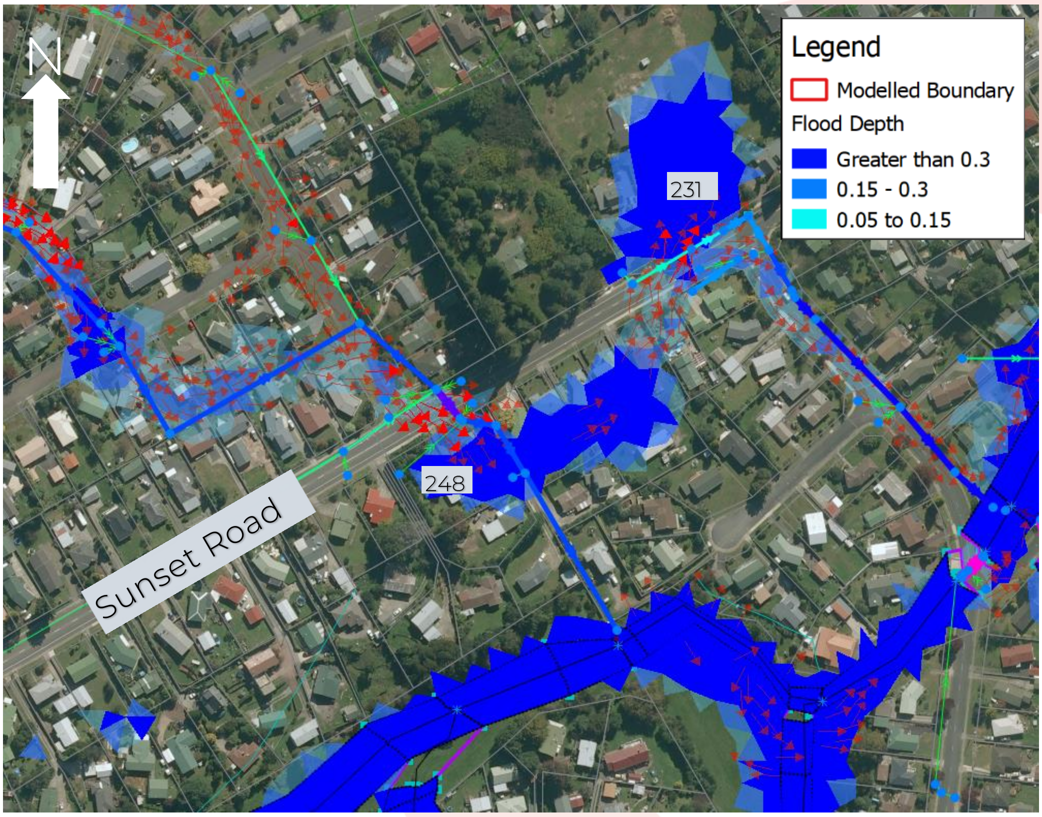


Figure 5-4: 231 and 240-248 Sunset Road Flooding

5.3.4 *Petrie Street and Hathor Street*

During the 10% AEP storm event, Petrie Street and Hathor Street have predicted ponding depths greater than 300mm. The model indicates that piped network in this area is under capacity causing high surcharge levels. This results in ponding here due to this being a low spot in the area.

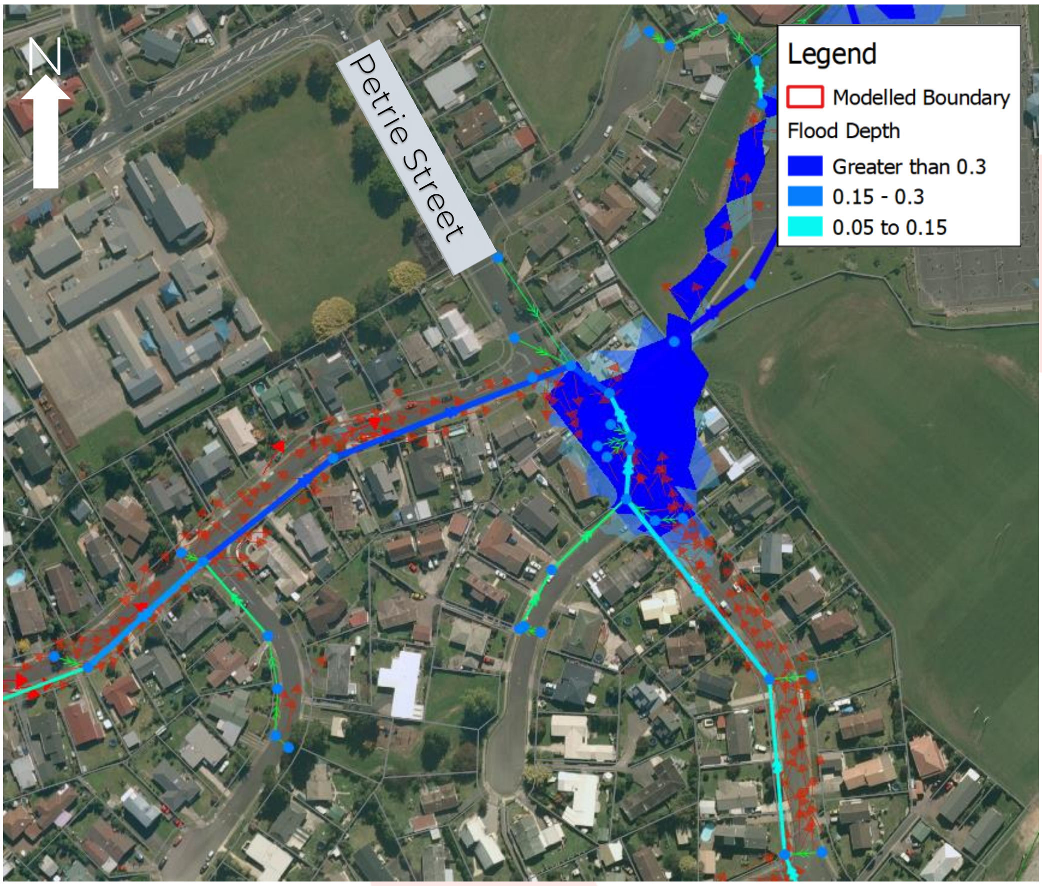


Figure 5-5: Petrie Street and Hathor Street Flooding

5.4 Flood Hazard

Flood hazard maps have been produced for emergency planning purposes (see Appendix C), and are intended to provide an indication of the severity of flooding during the 10%, 2% and 1% AEP events. 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 5-6.

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

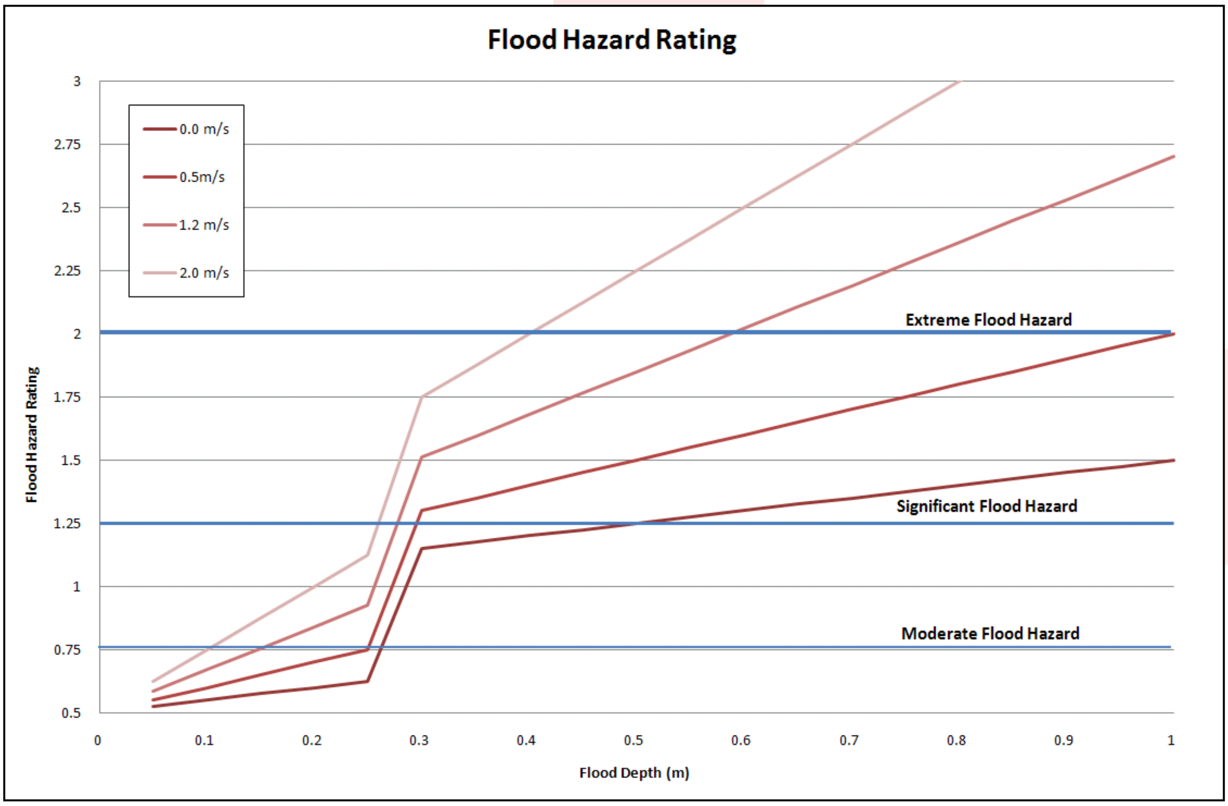


Figure 5-6: Flood Hazard Rating details

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 Limitations

The model has been developed as a catchment planning tool and is not suitable for detailed design.

Model predictions have been validated against historic performance and anecdotal evidence. However, the model has not been calibrated against measured flow data. Therefore, predicted flow rates and volumes should be treated with caution.

6.3 Recommendations

The following additional model enhancements or investigations are recommended:

- Model Calibration – calibrate the model against measured flow data across the catchment.
- Sensitivity Testing of Utuhina Stream – the level of the Utuhina Stream has an impact on the flooding from the Otamatea Stream. A sensitivity test to see the impact on flooding with varying Utuhina Stream levels could identify the potential benefit in catchment 14 due to improvements in the downstream catchment.
- Sensitivity Testing on Obstructions – RLC has identified that debris and sediment can build up within Otamatea stream. There is the potential for this to create localised headloss / flow restriction. A sensitivity test to see the effect on the predicted flood extents as a result of a blockage is recommended to inform RLC operational activity pre-event.
- Sensitivity Testing of Bank Line Discharge Co-efficient – the bank line discharge coefficient has used the standard value of 1. It is recommended that sensitivity testing is undertaken to determine the effect of varying this value.

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 Utuhina stream 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

Based on the performance assessment, ponding is predicted at a number of locations. These model predictions confirm reported catchment issues. The model has identified that the cause of this ponding is a lack of capacity to cope with the high flows predicted. The main capacity issues are within the Otamatea stream and some parts of the parts of the piped network. The following high level options focus on either reducing the peak flow reaching these low capacity areas, or increasing the capacity in these areas.

It was intended that following a workshop with RLC to discuss the viability and suitability of these options, a maximum of two high-level options would be implemented in the model to assess their impact on catchment performance. This report would then have been updated with the results of this assessment.

However, RLC instructed WSP Opus not to proceed with the testing of these options. Therefore, the following high-level option have not been tested in the model to determine their effectiveness.

7.1 Storage along Pukehangi Road

The rural hills above Pukehangi Road generate a significant amount of run-off in the catchment. Figure 7-1 shows the proportion of run-off being discharged towards the Otamatea stream from various locations along Pukehangi Road. It is proposed to intercept this run-off before Pukehangi Road, provide attenuation storage and limit the peak discharge rate into the downstream catchment. The peak discharge flow rate will be reduced by 20%, and the required storage volume then estimated.

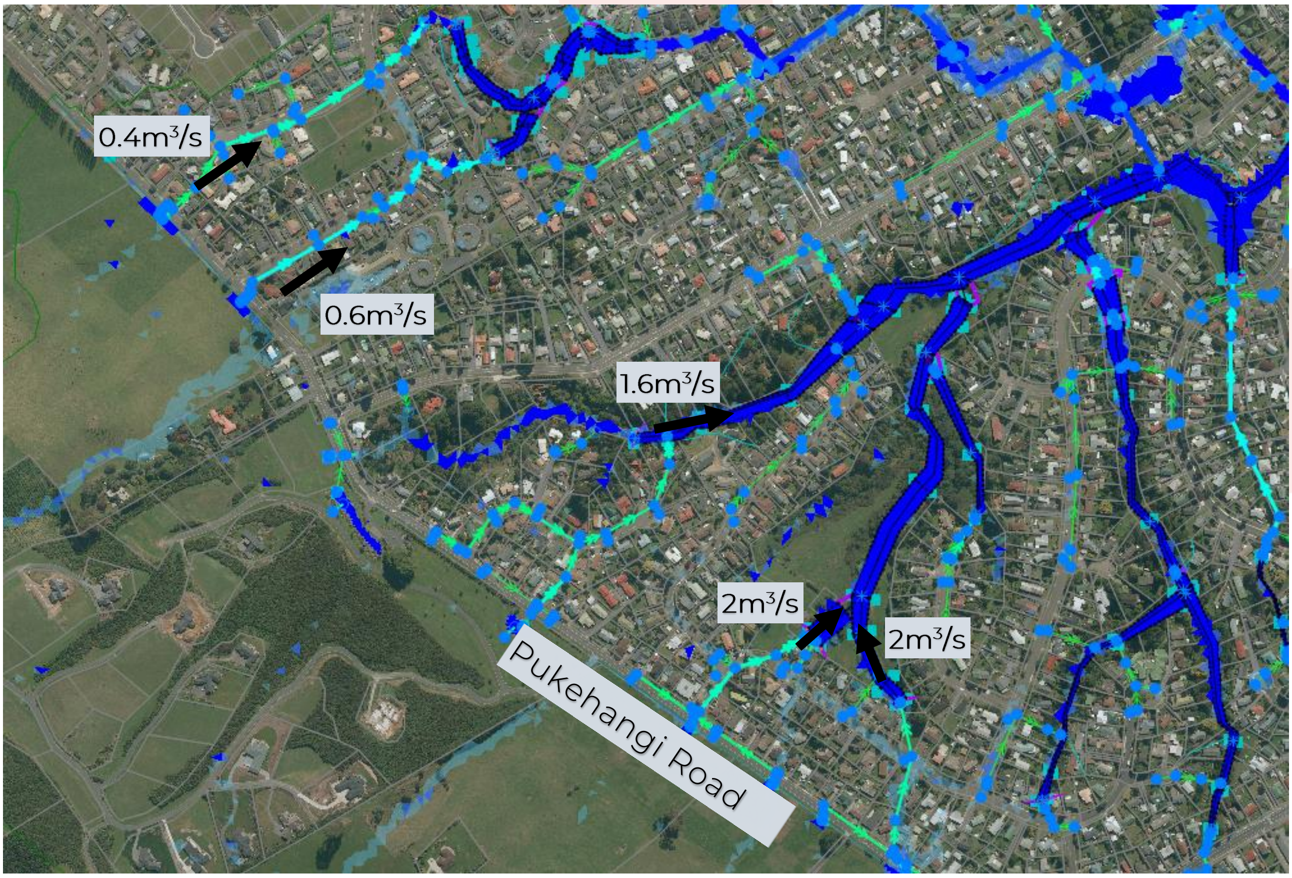


Figure 7-1: Distribution of flow from Pukehangi Road in 10% AEP storm event

Potential Benefits

- Reduction in peak run-off entering Otamatea Stream and therefore reducing the flood risk associated with Otamatea Stream performance.
- Potential to incorporate storage construction into any development of the area above Pukehangi Road.

Potential Residual Risks

- New asset requiring ongoing maintenance.

7.2 Storage at Hodgkins Street Reserve

As above, the purpose of this option is to limit the peak discharge from the rural hills above Pukehangi Road. However, this is a smaller scale solution that focusses on the flows causing ponding around 231 and 240 to 248 Sunset Road.

It is proposed to intercept flow just adjacent to Hodgkins Street Reserve, provide attenuation storage and limit the peak discharge rate into the downstream catchment. The peak discharge flow rate will be reduced by 20%, and the required storage volume then estimated.

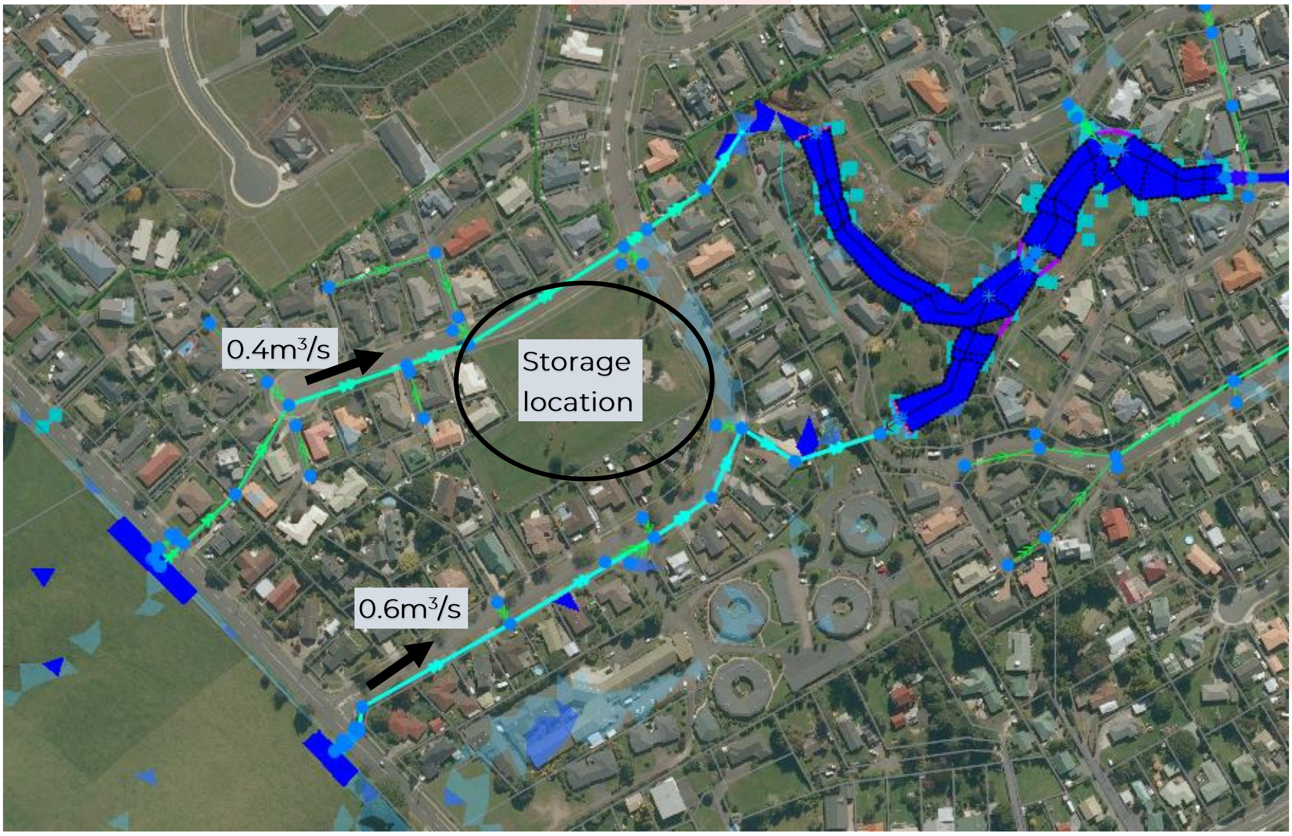


Figure 7-2: Hodgkins Street Reserve Storage Location

Potential Benefits

- Reduction in peak run-off entering Otamatea Stream and therefore reducing the flood risk associated with Otamatea Stream performance.

- Potential to incorporate storage construction into any development of the area above Pukehangi Road.

Potential Residual Risks

- New asset requiring ongoing maintenance.

7.3 Storage at Wright Park

As above, the purpose of this option is to limit the peak discharge from the rural hills above Pukehangi Road. However, this is a smaller scale solution that focusses on the flow arriving in the Otamatea Stream through Wright Park.

It is proposed to intercept the flow and provide attenuation storage and limit the peak discharge rate into the downstream catchment. The peak discharge flow rate will be reduced by 20%, and the required storage volume then estimated.

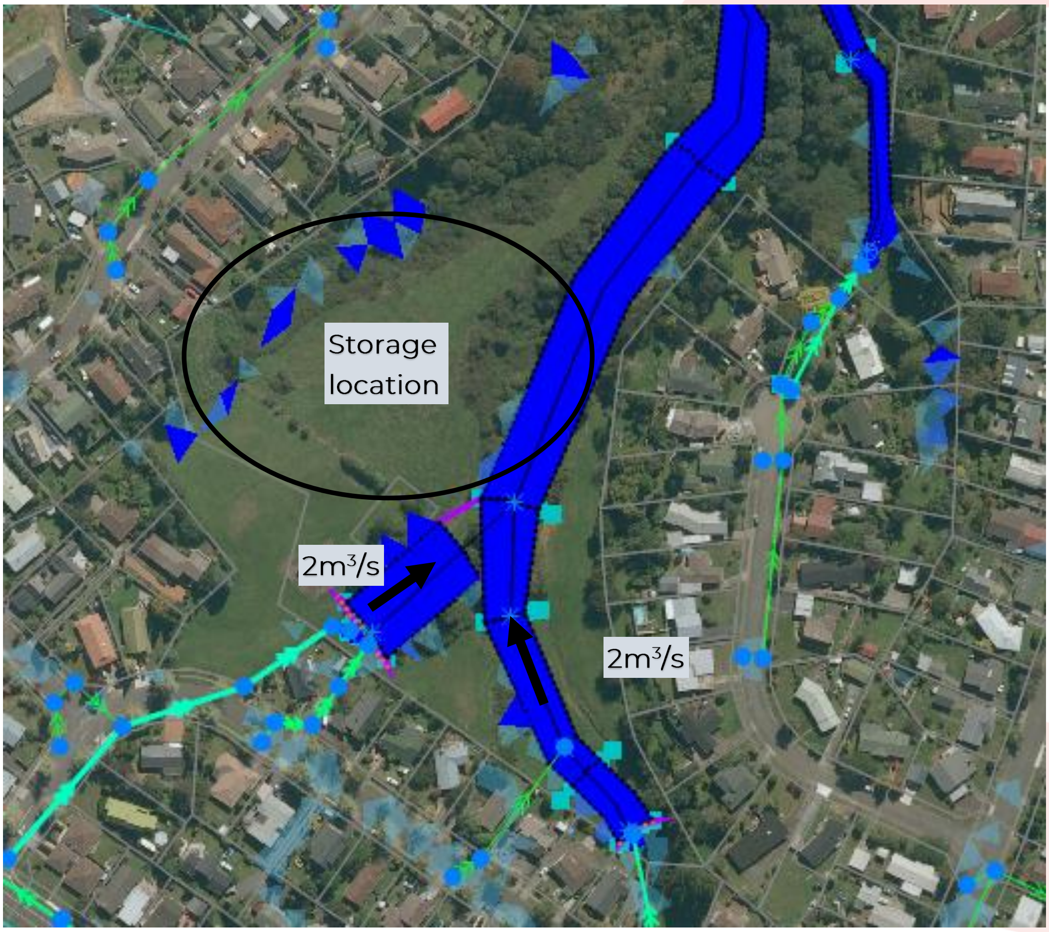


Figure 7-3: Wright Park Storage Location

Potential Benefits

- Reduction in peak run-off entering Otamatea Stream and therefore reducing the flood risk associated with Otamatea Stream performance.
- Potential to incorporate storage construction into area to further mitigate for any development of the area above Pukehangi Road.

Potential Residual Risks

- New asset requiring ongoing maintenance.

7.4 Storage at Petrie Street

Ponding is predicted on Petrie Street as a result of high flows and a lack of pipe capacity in this area. It is proposed to increase the pipe capacity and provide storage to reduce the risk of ponding in this area.

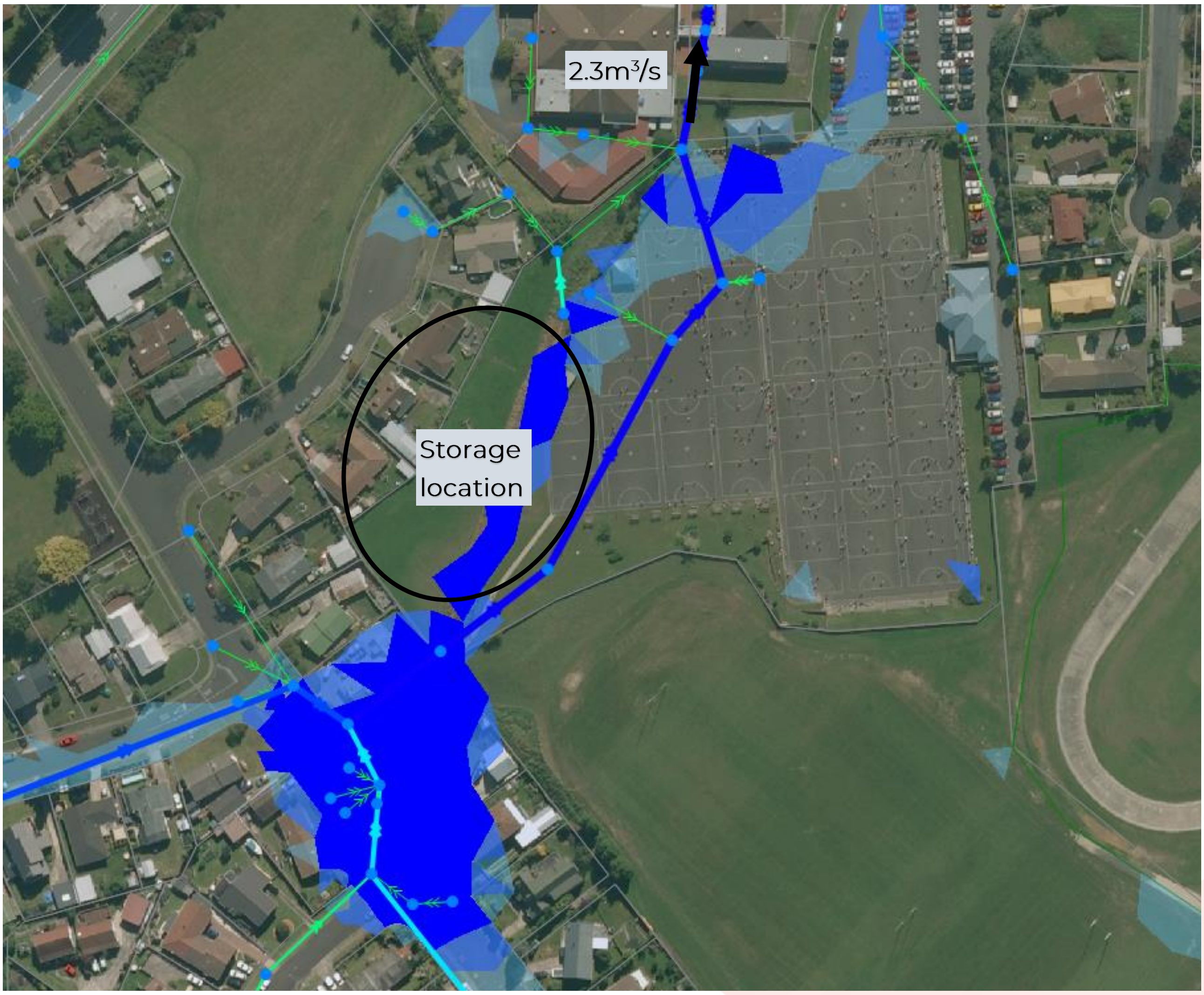


Figure 7-4: Petrie Street Storage Location

Potential Benefits

- Reduction in flood risk at Petrie Street.
- Potential to also reduce the peak run-off entering Otamatea Stream and therefore reducing the flood risk associated with Otamatea Stream performance.

Potential Residual Risks

- New asset requiring ongoing maintenance.

7.5 Flow diversion on Malfroy Road

Ponding is predicted on Petrie Street as a result of high flows and a lack of pipe capacity in this area. High flows in this area also contribute to the high flow in the Otamatea stream, further downstream. Therefore, it is proposed to increase the pipe capacity between Petrie Street and Malfroy Road. From Malfroy Road the flow will be redirected to the Utuhina Stream to the east. This will require construction of a deep pipe along Malfroy Road.

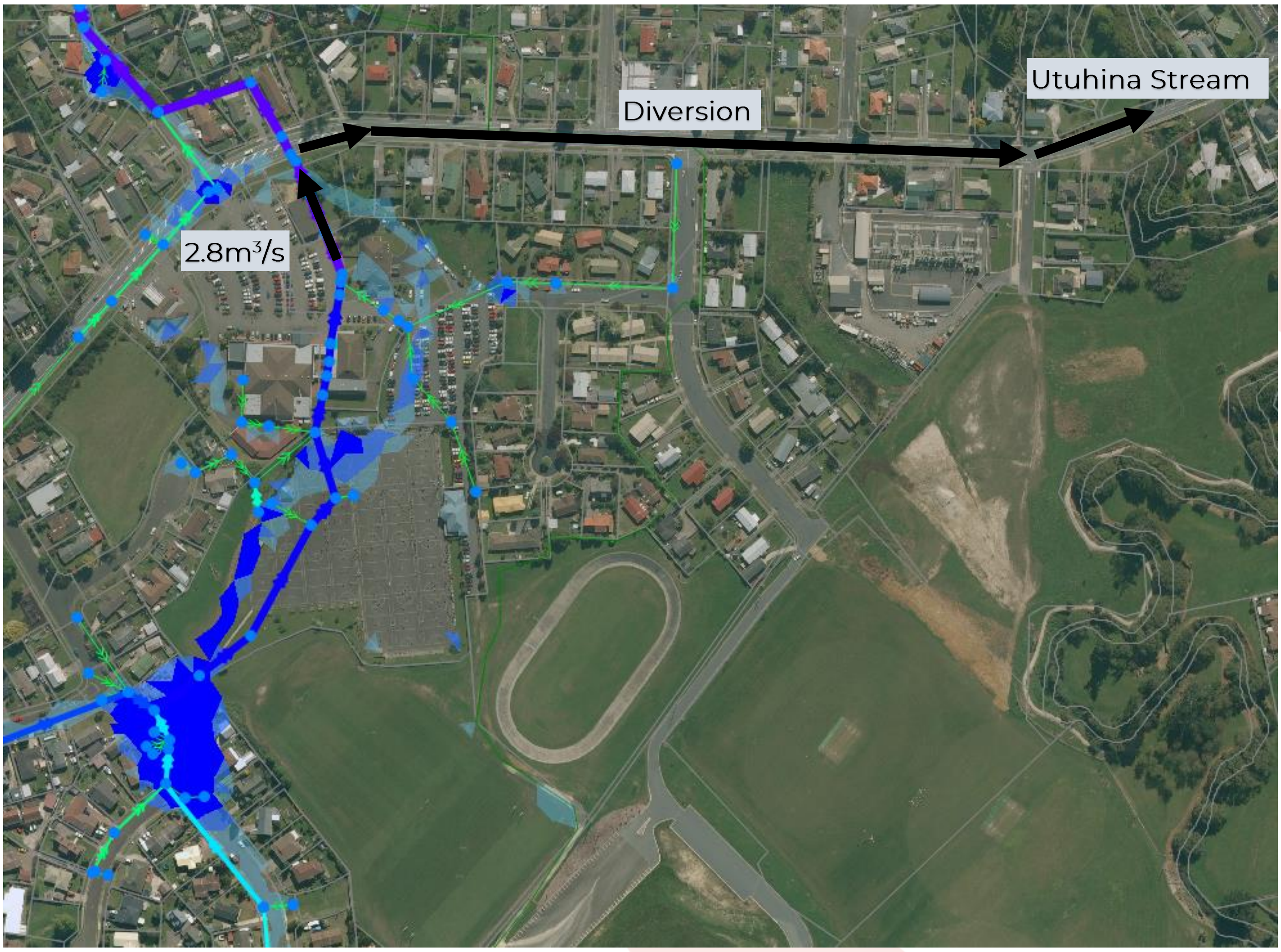


Figure 7-5: Flow Diversion on Malfroy Road

Potential Benefits

- Increase local capacity and so reduce flood risk at Petrie Street.
- Reduce the flow being discharged to the Otamatea Stream and therefore reducing the flood risk associated with Otamatea Stream performance.

Potential Residual Risks

- Potential to increase the flood risk on the Utuhina Stream.
- Deep pipe (max depth approx. 12m) potentially hard to construct and maintain.

7.6 Otamatea Stream Improvements

The majority of the catchment issues relate to the capacity of the Otamatea Stream from Ford Road culvert onwards. Therefore, it is proposed to increase the capacity of the stream and culverts under Sunset Road.

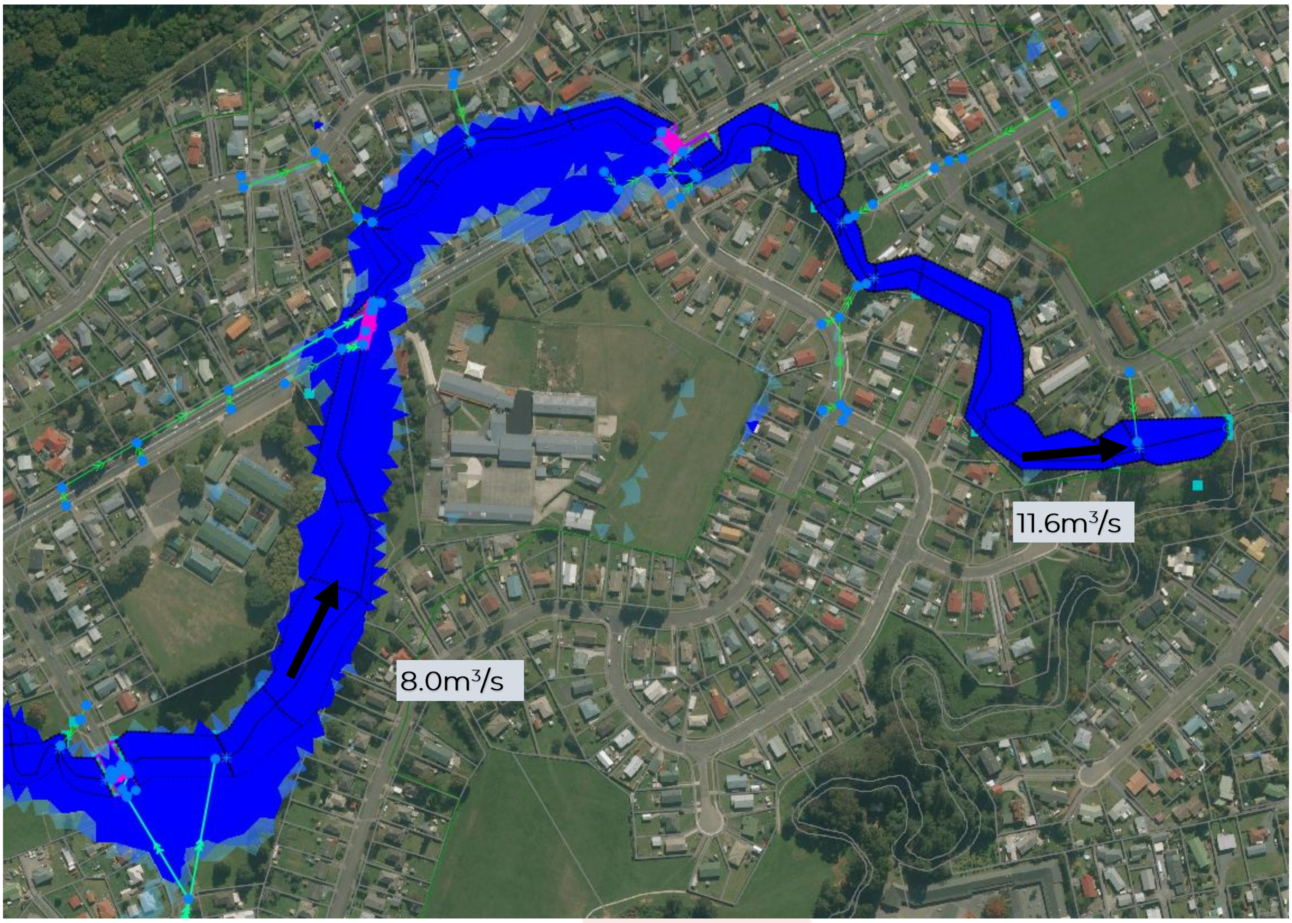


Figure 7-6: Otamatea Stream Improvements

Potential Benefits

- Reduce risk of flooding along Otamatea Stream and areas nearby affected by high levels in this stream.

Potential Residual Risks

- By increasing the flow downstream this will increase the flood risk on the Utuhina Stream.

8 References

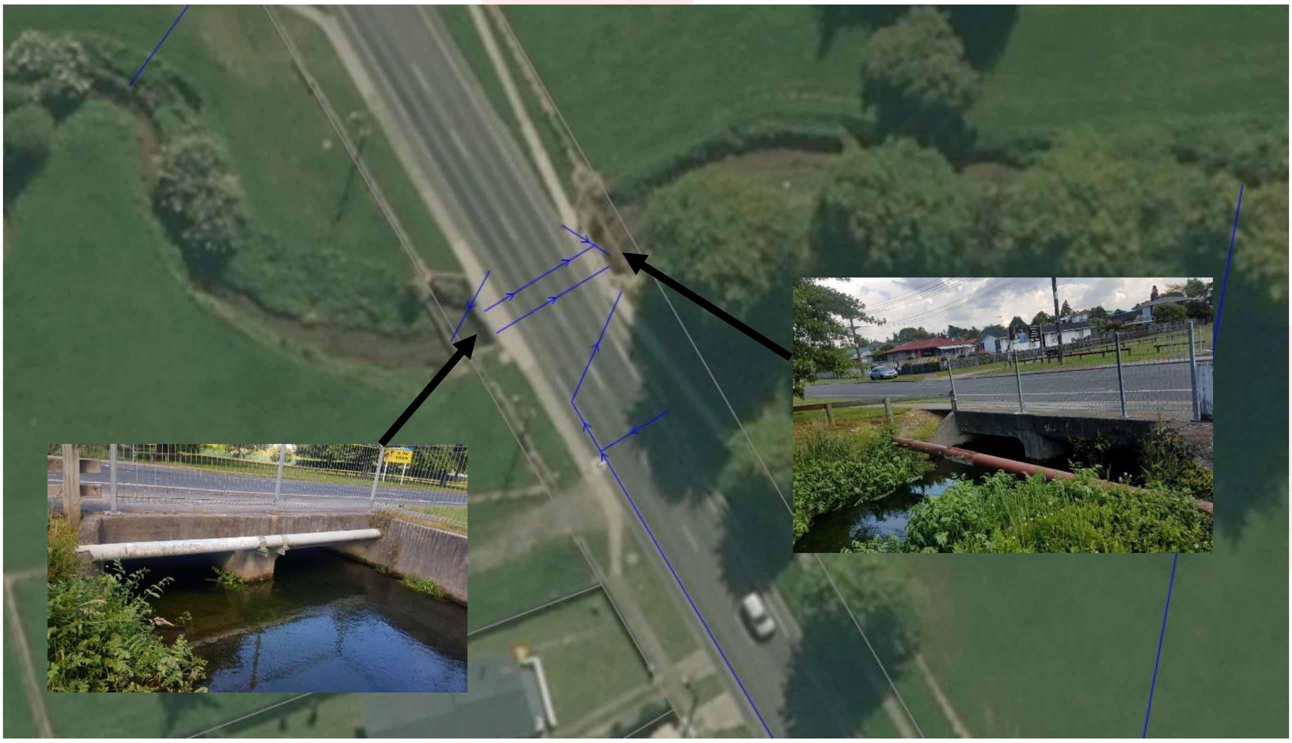
CIRIA. (2010). *Culvert Design Manual.*
Innovyze. (2014). *InfoWorks Help.*
James C Y Guo, K. A. (2009). Design of Street Sump Inlet. *Journal of Hydraulic Engineering, Vol 135, No. 11 ASCE.*
Landcare Research New Zealand. (2002). *Land Environments of New Zealand: A Technical Guide.*
NIWA. (n.d.). *High Intensity Rainfall System v3.* Retrieved from www.hirds.niwa.co.nz
Rotorua Lakes Council. (2004). *Rotorua Civil Engineering Industry Standard - Stormwater and Land Drainage.*
Rotorua Lakes Council. (2016). *Rotorua District Plan.*
United States Department of Agriculture. (1986). *Urban Hydology for Small Watersheds (TR-55).*

Appendix A

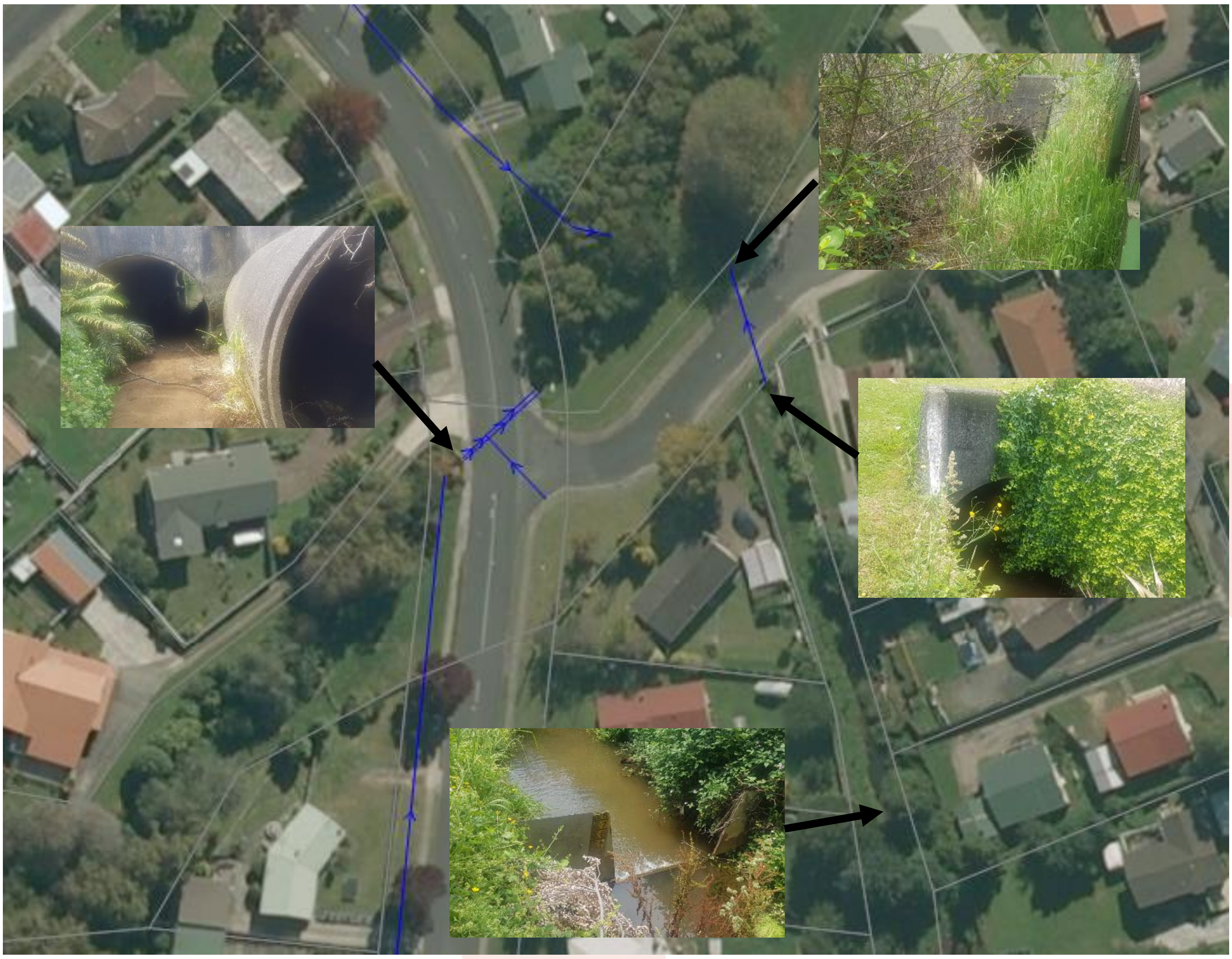
Key Culvert and Channel 2017 Survey Photos

Sunset Road Culvert

Sunset Road Culvert



Ford Road Culvert



Pandora Avenue Culvert

Appendix B
Validation Event Flood Extent Map

Appendix C

Flood Depth Maps

Parcel Flooding Maps

Flood Hazard Maps

www.wsp-opus.co.nz