TAUPO URBAN STORMWATER

Hydraulic Modelling Report

Taupo District Council

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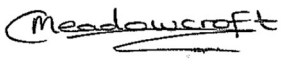
REVIEWED	 Colin Meadowcroft - Project Manager CDM Consultants Ltd
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1.0 EXECUTIVE SUMMARY

Taupo District Council (TDC) commissioned CDM Consultants Ltd (CDM) during late 2017 to develop two-dimensional (2D) Rain-on-Grid (ROG) stormwater models for Taupo Region urban areas in order to better understand overland flow-paths affecting properties. The models included the best information made available by TDC at the time, with improvements and field validation subsequently undertaken by various summer students with CDM guidance.

InfoWorks ICM (Integrated Catchment Management) software Version 8.03 was used to undertake this hydraulic modelling for TDC. This is a reputable software, known to be one of the best available for this purpose. TDC has historically preferred InfoWorks software and has used it for wastewater and water supply modelling. TDC has also developed water supply models in recent years using InfoWorks WS Pro software.

The ROG modelling was initially developed for understanding property flooding, which is a different scope and purpose from the more recent proposal for inclusion within the Natural Hazards section of TDC's District Plan. Further model development is therefore recommended to ensure that the final models are sufficiently robust for release to the public.

As intended, it is believed that the existing models have defined the general flood hazard areas well within overland flow paths. Taupo's flow paths are often well defined by gulley systems formed by water flow through the highly erodable pumice soils. The resulting overland flow paths compare reasonably well by comparison to previous ROG modelling as completed by AWT (Mott MacDonald).

Due to lack of available asset data, the models could not have stormwater pipes well represented. However, where property flooding was considered to be influenced by stormwater pipes, some pipes were subsequently included with interpolated invert data. Stormwater pipe invert levels generally had to be assumed due to limited asset data and survey budget. It is however arguable that for the extreme 100-year rainfall (1% AEP) events under consideration, stormwater pipes likely have minimal influence as they typically only convey a 5-year rainfall flow-rate.

Taupo has been affected by relatively few significant urban stormwater floods in recent years however the most significant recently being experienced on 7 February 2025 which resulted in several properties and roads being flooded. This event was estimated to be excess of a 50-year return period event over a 30-minute duration, based on the high peak intensity rainfall measured. Prior to this event, the models have not been calibrated or validated against known rainfall events as TDC has not historically collected measurable data for this purpose.

The resulting overland flow path modelling outputs are considered to be the most reliable flood risk information available but must be used with the understanding that a hydraulic model is never absolutely correct. The overland flow path models are currently the best available tool to understand the location and severity of overland flow paths during extreme rainfall events. The modelling is certainly useful for the purpose of understanding hazards and can easily define flow velocities, depths and therefore hazards. The challenge is now understanding the absolute accuracy of the predicted flooding extent, where further site-specific detailed modelling is required.

It is expected that the existing flow-path locations are accurate but conservative with slightly wider extents and greater depths than reality. This can be modified and improved over time with better asset and validation data to allow for the reduction of rainfall-runoff and improved understanding of groundwater infiltration in particular.

2.0 INTRODUCTION

2.1 MODEL HISTORY AND PURPOSE

The urban stormwater models were initially developed using limited operational budgets to better understand properties at risk of stormwater flooding. The models are a valuable tool to develop solutions to mitigate stormwater flooding and have been used to identify various flood mitigation projects included within TDC's Long Term Plan (LTP).

TDC has since considered inclusion of the identified stormwater hazard zones within the District Plan Natural Hazards section. The modelling was thus peer reviewed by Tonkin & Taylor based on this assumed purpose for which the models were not initially developed. Improvements have been suggested within Section 6 (Recommendations) in order to ensure that the modelling is fit-for-purpose in this respect. Section 3 describes the current model build in more technical detail.

The model inputs include design rainfall, ground models, point source inflows, and limited pipe asset data. The model outputs can be provided in various forms however it is expected that flood hazard maps will be the most useful output to convey extreme event flood hazard information.

3.0 CATCHMENT DESCRIPTION

3.1 CATCHMENT EXTENT

The Taupo urban stormwater models include the full urban catchment extents where LIDAR was available at the time, in the following urban areas (Appendix B):

Taupo	Omori	Broadlands
Nukuhau	Whakamaru	Whareroa
Acacia Bay	Mangakino	Waihi
Turangi	Hatepe	Tauranga Taupo
Tukaanu	Waitahanui	Motuapa
Kuratau	Kinloch	

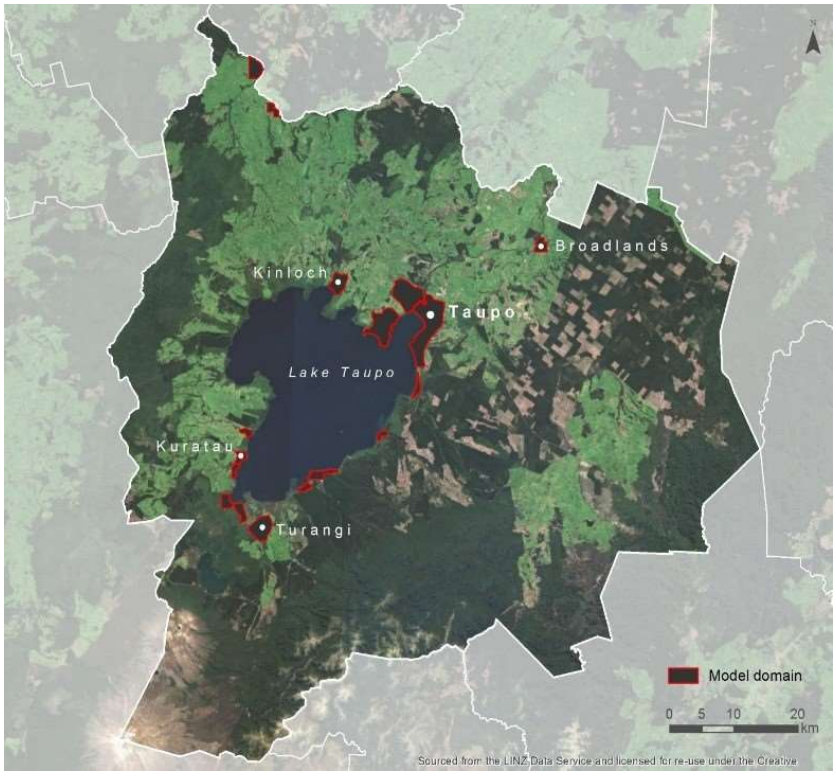


FIGURE 1: TAUPO REGION URBAN MODEL CATCHMENT PLAN

The preliminary models were limited by LIDAR availability and generally excluded rural catchments which have since been accounted for by means of point source inflows based on hydrological inputs provided by Te Miro Consultants Ltd (Appendix A).

With the availability of new LiDAR data and the rural inflows being applied to each catchment model, a higher degree of model accuracy can be expected for the latest modelling, once fully updated.

3.2 TOPOGRAPHY

The LIDAR used for modelling to-date was provided from various sources and was converted into ASCII files specifically for the model import using a 1m grid for the 2D ground model. It has been recommended that LIDAR inputs are updated to be sure the latest data (with audit trail) is utilised.

The latest LiDAR data has since been updated by Waikato Regional Council and was only available for Taupo, Nukuhau, Acacia Bay and Kinloch at the time of writing. The remaining models are expected to be updated with the latest LiDAR data now available.

3.3 HYDROLOGY (RURAL INFLOWS)

The models were initially developed with a conservative approach with no groundwater infiltration and 100% rainfall runoff (not considered to be unreasonable for a highly urbanised area with a known fast runoff 'Hydrophobic Conditions' after dry conditions when thunderstorms often occur in summer).

Ter Miro Water was subsequently commissioned by TDC to provide hydrological inputs for the rural catchments flowing into the urban catchments of most significance. Te Miro supplied hydrographs that were applied to the 2D ground model as 'Point Source Inflows' at the urban edge of the 2D zone (see Appendix B, large dots). Te Miro hydrological report is included within Appendix A.

Several of the rural inflow hydrographs were applied immediately upstream of the large culverts crossing the new Eastern Taupo Arterial State Highway 1.

3.4 GEOLOGY AND SOILS

Taupo region generally has volcanic pumice sandy soils with good drainage characteristics. The soil type and geology are not explicitly modelled. The modelling generally assumes that the ground is saturated with no infiltration for the urban areas, which is the worst-case scenario considered appropriate for high level planning purposes. Given the importance of the District Plan Review, infiltration was applied for larger reserves and Te Miro provided appropriate rainfall-runoff, hydrological inputs, and infiltration rates for rural areas to improve confidence in the modelling.

3.5 INFILTRATION MODEL

As initial "Rain on Grid" models assumed 100% runoff, the model runs resulted in conservative flooding estimates. This assumption was made based on the worst-case scenario, assuming flash flooding with no ability for ground infiltration. This also allows for the maximum flood extent to be identified during stormwater modelling.

Highly infiltrative pumice-rich soils are dominant in Taupō (Table1). These soils are known to be '***hydrophobic***' in antecedent dry conditions, as a result of the soil's unique macro-porosity. Hence, the worst-case scenario was considered reasonable in simulating 100% runoff scenario for urban areas for design runs.

Soil	Classification	Texture Class	General Location
Tirau	Typic Orthic Allophanic Soil	Silt Loam	South of Tirau
Tihoi	Humose Orthic Podzol	Sand	East of Benneydale
Taupo	Immature Orthic Pumice Soil	Sandy Loam	East of Tokoroa
Ngakuru	Typic Orthic Allophanic Soil	Sandy Loam	North of Mokai
Waipahihi	Immature Orthic Pumice Soil	Sand	Tahora

Table 1: Infiltration Measurement Sites

In order to reduce the model conservatism, a certain level of infiltration was assumed in the non-urban areas (with 100% runoff being sustained in the urban areas). Scarce amount of research has been conducted on the infiltration characteristics of pumice soils. Table 1 above demonstrates the *"Infiltration Characteristics of Soils Under Forestry and Agriculture in the Upper Waikato Catchment"* by NIWA. Taupō soils are identified as an Immature Orthic Pumice Soil type. Based on this perception, Taupō soils can arguably be assumed to have similar infiltration characteristics to Sandy Loam (Table 2 below).

Texture class	Effective water capacity (Cw) (mm)	Infiltration rate (f) (mm/hour)	Hydrologic soil grouping
Sand	8.89	210.1	A
Loamy sand	7.874	61.2	A
Sandy loam	6.35	25.9	A
Loam	4.826	13.2	B
Silt loam	4.318	6.9	B
Sandy clay loam	3.556	4.3	C
Clay loam	3.556	2.3	D
Silty clay loam	2.794	1.5	D
Sandy clay	2.286	1.3	D
Silty clay	2.286	1.0	D
Clay	2.032	0.5	D

Table 2: Soil Type Typical Infiltration Rates

Table 2 above has identified that Sandy Loam has an infiltration rate of 25.9mm/hr. Taupo's pumice soils may have a greater infiltration rate than this, however come into steady infiltration to avoid any hydrophobic effects. The arguable lower infiltration rates applied for the pumice soils (as modelled) have also been justified in multiple studies (reference Vogeler 2008, Simcock 2006) and may be due the low macro-porosity of pumice soils, and also the effects of soil compaction.

Initial abstraction losses in the catchment through surface storage are inherently applied as the "rain on grid" model surface has depressions that will create storage for stormwater as it passes over the catchment.

Model sensitivity testing is recommended to better understand the effects of infiltration assumptions.

3.6 SURFACE ROUGHNESS

Initially, the models' surface roughness was applied globally with Manning's roughness set at 0.035. However, varying surface roughness has since been applied within the models as per Table 3 below. Sensitivity modelling can demonstrate that this assumption likely has minimal effect on the model outputs if considered necessary.

Land Use	**Manning's Roughness**
Grassed Land	0.035
Urban/Built up Area	0.015

Table 3: Modelled Mannings Surface Roughness

The roughness around the urbanized areas was changed to Mannings 0.015 whilst the roughness in the rural, grass land remained at Mannings 0.035. Figure 2 below shows an example of the defined urban area (highlighted in purple) and the non-urban/grass land area (yellow 2D zone boundary).

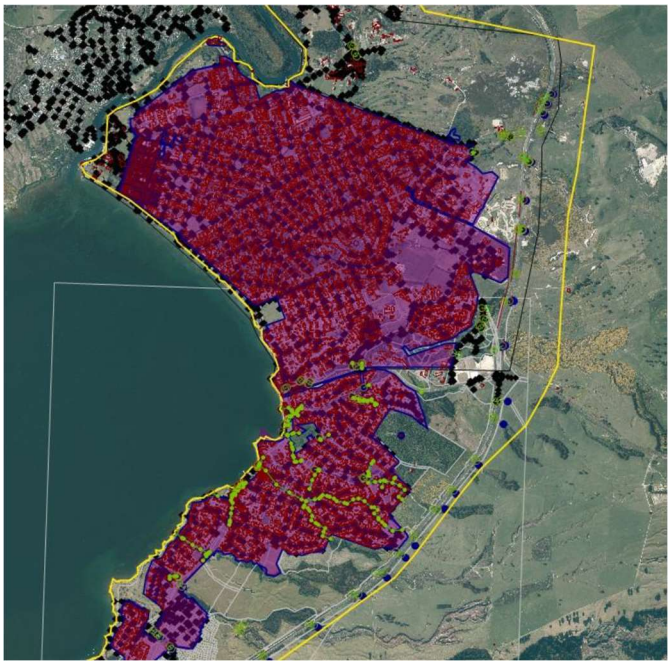


FIGURE 2: TAUPO URBAN AREA (PURPLE) AND RURAL 2D CATCHMENT (WITHIN YELLOW BOUNDARY)

Varying roughness has not been applied for every land use category as we consider it would over complicate the models without calibration available to justify this detail. Model sensitivity testing is recommended to better understand the effects of roughness assumptions.

3.7 TERRAIN AND RESOLUTION

For faster preliminary runs, the model used a triangular mesh resolution of 25m^2 to 100m^2 to define the 2D topography of the model. The model was later refined with a resolution used in the non-urbanized areas of 5 to 25m^2 triangulated mesh area, whilst the urbanized areas (urban dwellings, streams, watercourses etc) is 4 to 16m^2. We believe that this resolution is fit-for-purpose for region-wide models, and the model audit is believed to support this view.

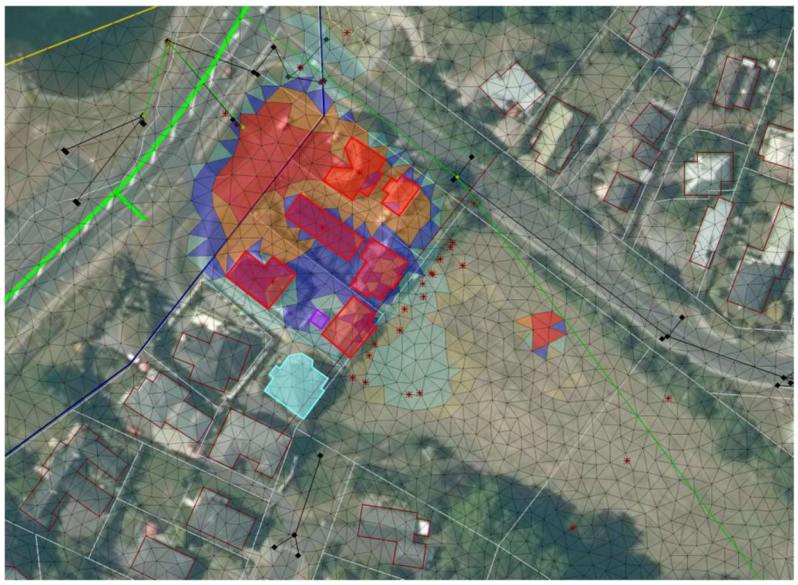


FIGURE 3: TRIANGULATED MESH RESOLUTION EXAMPLE AT HAWAI RESERVE KNOWN FLOOD LOCATION

3.8 STORMWATER NETWORK OVERVIEW

Models were developed with limited pipe network due to lack of available invert data. Pipes were subsequently included using interpolated data where they were considered to affect property flooding. This is described further within Section 4.

In many cases, pipe inverts have been estimated due to the lack of asset information. This is not considered critical for the more significant 100-year return period storm events. All significant stormwater networks were included in the model where data was available.

3.9 LAND USE

The catchments of interest are mainly urban residential, commercial and industrial areas where human occupation and livelihood is at risk.

4.0 MODEL BUILD

4.1 HYDRAULIC MODEL

InfoWorks ICM software v8.03 was used to combine one-dimensional (1D) pipe models with two-dimensional (2D) ground models.

Inflows to the stormwater network were modelled with "2D" manholes which allow stormwater to enter and exit the network. Taupo has no known higher inlet capacity 'Hushpits' or 'Megapits' which can allow up to 800-litres per second inlet flows.

LIDAR data was imported directly into InfoWorks ICM, which uses a 1m grid to form the ground model as a flexible triangular mesh. Surface roughness is represented in the model with Manning's roughness, n of 0.015 and 0.035 for less urbanised areas.

4.2 ASSET DATA

Asset data was supplied by TDC and stormwater network was modelled where it was deemed to have an effect on property flooding. Pipe invert levels were estimated where necessary.

There are no pump stations modelled as TDC has just three pump stations catchment-wide which only empty retention ponds. Where considered necessary, pumps could be modelled with their corresponding head-discharge curves to be provided by TDC.

4.3 HYDROLOGICAL MODEL / APPROACH

Te Miro Water completed the rural hydrology as described in their report included within Appendix A. The hydrographs supplied by Te Miro were applied as "Point Source Inflows" on the outskirts of the urban areas modelled.

The hydraulic models were run with 'Rain-on-Grid' for urban catchments where the simulation represents 100% rainfall falling directly onto the 2D ground model. The ground model elevations dictate the direction of overland flow path towards the pipe network and/or Lake Taupo.

4.4 RAINFALL / CLIMATE CHANGE

NIWA's High Intensity Rainfall Design System (HIRDS) Version 4 design rainfall was applied for each specific urban location accordingly (HIRDSv4 - RCP 6.0 2081-2100) with 24-hour nested design rainfall patterns adapted for the Existing and Future RCP 6.0 (to 2100) for 10, 50, and 100-year rainfall events.

The use of future rainfall event data allows for the latest advice on future flooding arising from rainfall.

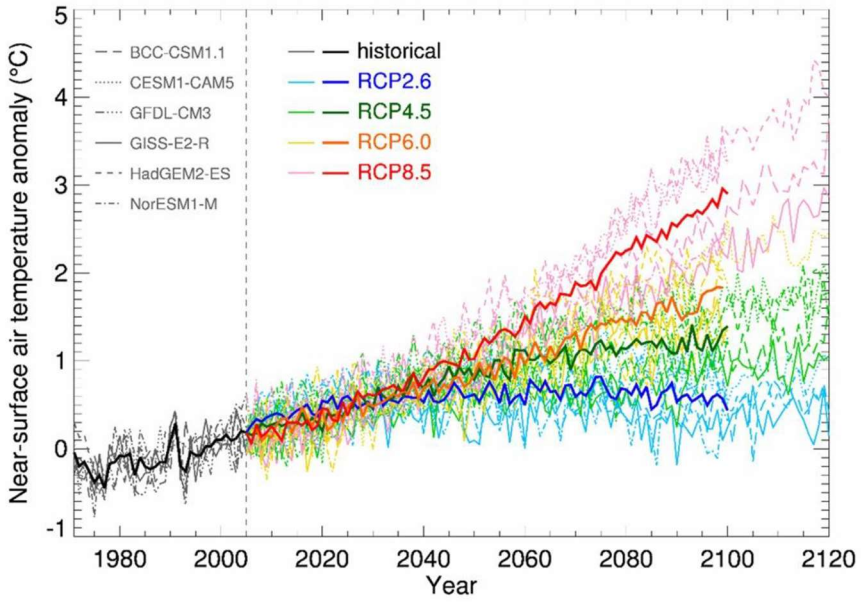


FIGURE 4: NIWA'S FUTURE CLIMATE CHANGE SCENARIOS WITH RCP6.0 BEING APPLIED

4.5 BOUNDARY CONDITIONS

Due to the generally steep nature of Taupo's catchments and elevation above lake level, no lake level or river boundary conditions have been applied for the purposes of modelling to-date. Appropriate boundary conditions should be agreed for all scenarios if the modelling is to be used for TDC's proposed District Plan flood hazard mapping.

4.6 STORMWATER PIPE NETWORK / DATA ISSUES

The supplied stormwater network asset data had limited invert information with no budget available for the significant survey required. Appendix B includes maps of stormwater network modelled (bolder lines) against full pipe network (lighter lines). It was mutually agreed with TDC that assuming/interpolating missing invert levels is expected to have limited effect on the overall hydraulics for larger rainfall events given that the stormwater flows are mainly head driven and limited by pipe capacity. Where necessary, data may be captured later if it is agreed to adversely impacts on modelling outcomes.

4.7 ASSUMPTIONS / SIMPLIFICATIONS / LEVEL OF CERTAINTY

The existing model assumes 100% runoff in the urban areas whilst a constant 25.9 mm/hr infiltration rate is applied to the non-urban areas (as detailed on section 3.5). A constant infiltration rate was used due to the lack of data to calibrate/validate an infiltration model.

The 2D model has not been calibrated/validated as it requires records of actual flooding to do so. The recent flood data has been collected and can be used for model validation on Council's instruction.

The outlet conditions for the culverts reaching the lake have not been modelled explicitly as appropriate scenarios must be agreed in advance.

5.0 MODEL SENSIBILITY CHECKS

5.1 SENSIBILITY CHECKS / GROUND TRUTHING

Model sensibility checks were completed with site checks on flood affected properties. This has not identified any concerns with the modelled flood affected areas. Council has provided some limited flood records which have been validated well against the modelled flood areas.

5.2 STORM EVENT VALIDATION/CALIBRATION

Model calibration / validation would ideally improve confidence in the model by checking the modelled flood levels/depths and ideally flow-rates against measured values for a measured intensity of storm event.

Unfortunately due to lack of available measured validation data, the model has not been well calibrated / validated. TDC has advised that there are limited historical flows or flood levels available for this purpose.

5.3 MASS BALANCE CHECKS

InfoWorks ICM undertakes mass balance checks automatically and they were within expected tolerances for the completed model runs.

6.0 MODEL CONFIDENCE AND RECOMMENDATIONS

6.1 MODEL CONFIDENCE

A high level of confidence is believed to have been achieved with respect to the location of overland flow-paths, and therefore with respect to the significant flood hazard areas.

Until further recommended model development is completed, there is a reduced level of confidence in the exact flood width, depths and velocities. It must be understood that a hydraulic model is often the best available information at the time. Appropriate model improvement and development to be considered fit-for purpose for a specific project requirement (i.e. District Plan Review) is only achieved with an appropriate level of expertise, time and budget.

Model validation has mainly been achieved by means of reviewing previous overland flow-path flood mapping, which has provided reasonable confidence in model outputs.

There is low confidence in a significant amount of stormwater pipe network asset data, however this is not generally believed to have a significant impact for 100-year return period rainfall events.

6.2 RECOMMENDATIONS

Prior to public release, it is considered to be in the best interests of TDC to continue investing in this important project.

The models (although populated with the most recent data) are not finalized. The latest data must be used to update the models, and subsequently, the flood affected properties.

Outstanding data confidence improvements include the following:

- The most recent LiDAR data (now available) must be used for final model runs.
- Actual flood validation data should be utilised for improved model calibration/validation as recommended by mode audit.
- Model sensitivity testing of unresolved auditing comments (such as roughness, infiltration, pipe modelling, etc).
- Culvert/Pipe data (to be updated as improved data is made available)
- Ongoing research to identify more optimized infiltration/roughness data for all models.

Additionally, the outlet conditions for the culverts reaching the lake could be modelled to improve model accuracy where considered necessary by Council and its advisors.

7.0 REFERENCES

Te Miro Water Hydrological Report (see Appendix A)

Vogeler I 2008. *Effect of long-term wastewater application on physical soil properties*. Water, Air & Soil Pollution 196: 385-392

Simcock R 2006. *Stormwater and erosion in the urbanising Acacia Heights Catchment, Taupo*. Landcare Research Contract Report: LC0607/034. Taupo District Council, Taupo

8.0 LIMITATIONS

This report is for the use by Taupo District Council only and should not be used or relied upon by any other person or entity or for any other project.

This report has been prepared for the particular project described to us and its extent is limited to the scope of work agreed between Taupo District Council and CDM Consultants Limited. No responsibility is accepted by CDM Consultants Limited or its directors, servants, agents, staff or employees for the accuracy of information provided by third parties and/or the use of any part of this report in any other context or for any other purposes.

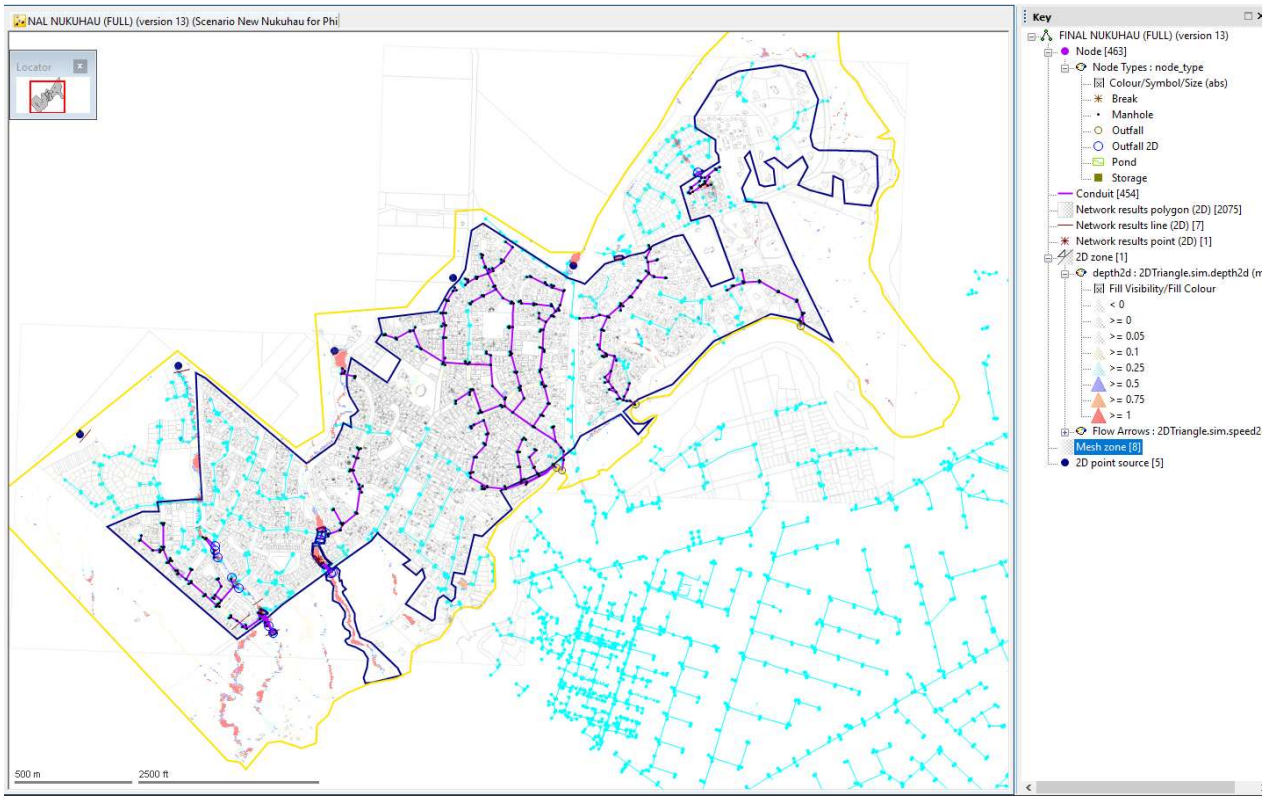
APPENDIX A

TAUPO HYDROLOGICAL REPORT BY TE MIRO WATER

APPENDIX B

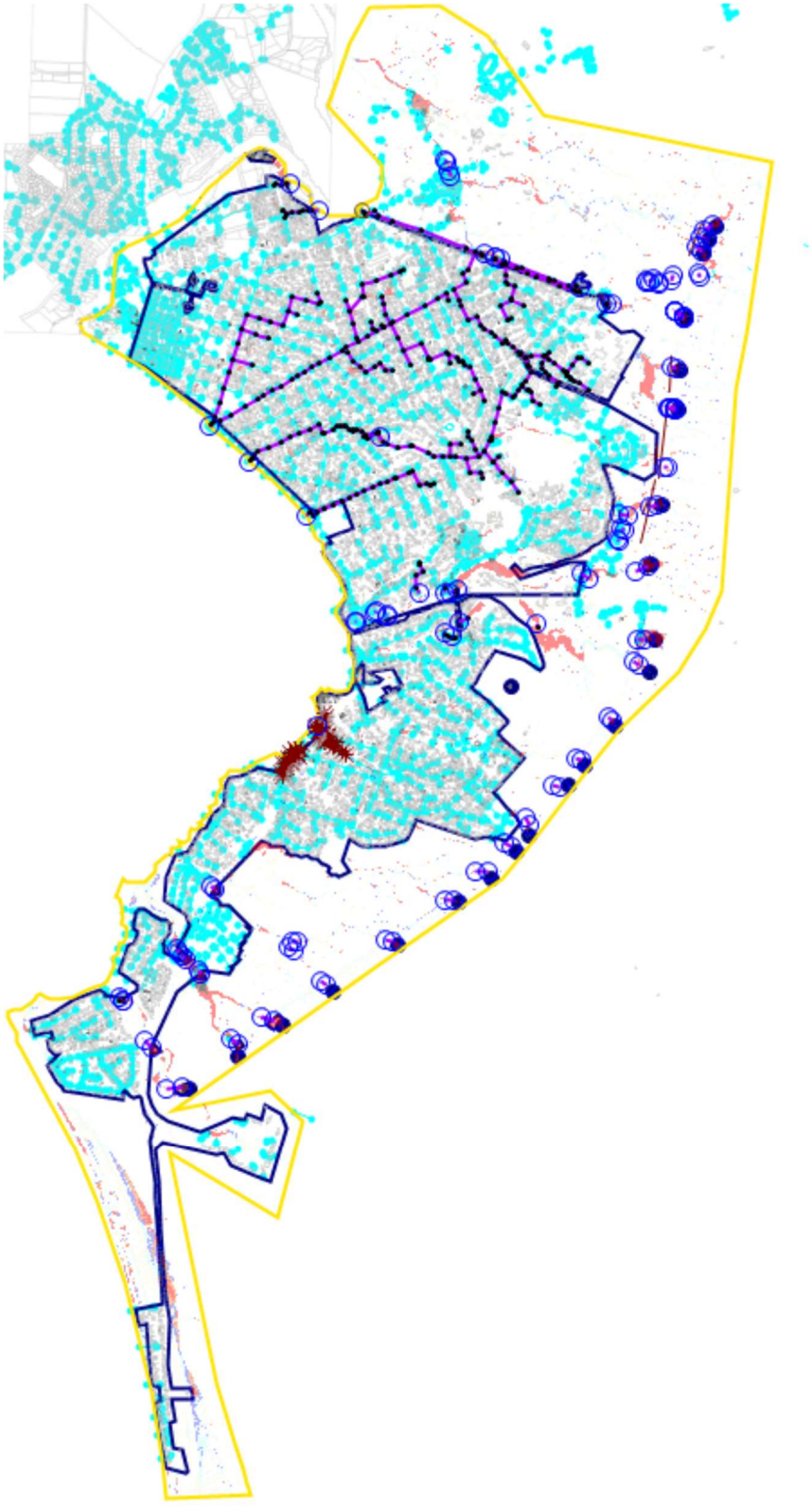
SW PIPES / CATCHMENT MODELLING EXTENT

Nukuhau SW 100-Year Flood Model Extent

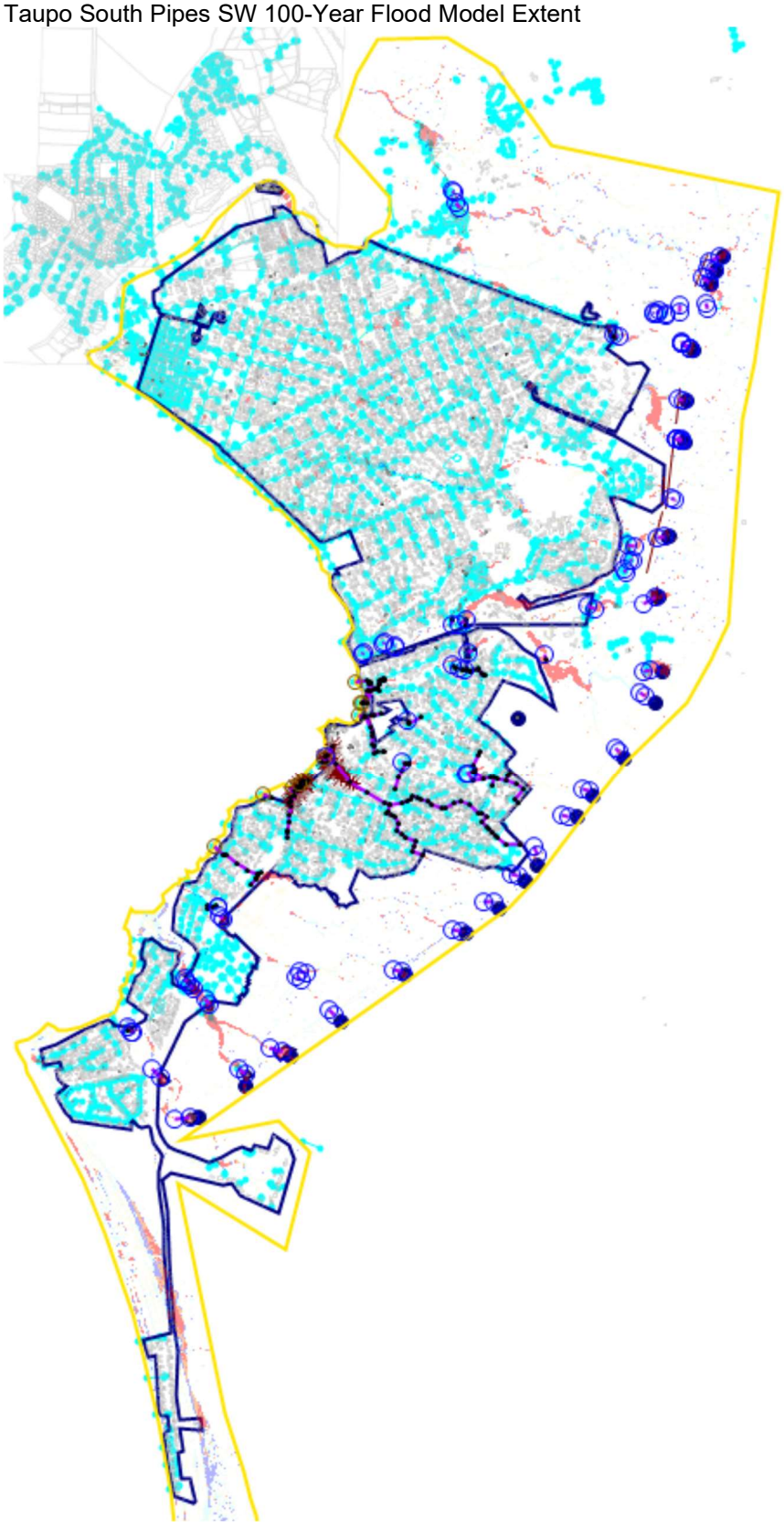


Note Cyan is Taupo SW Pipes (not modelled as not affecting property flooding)

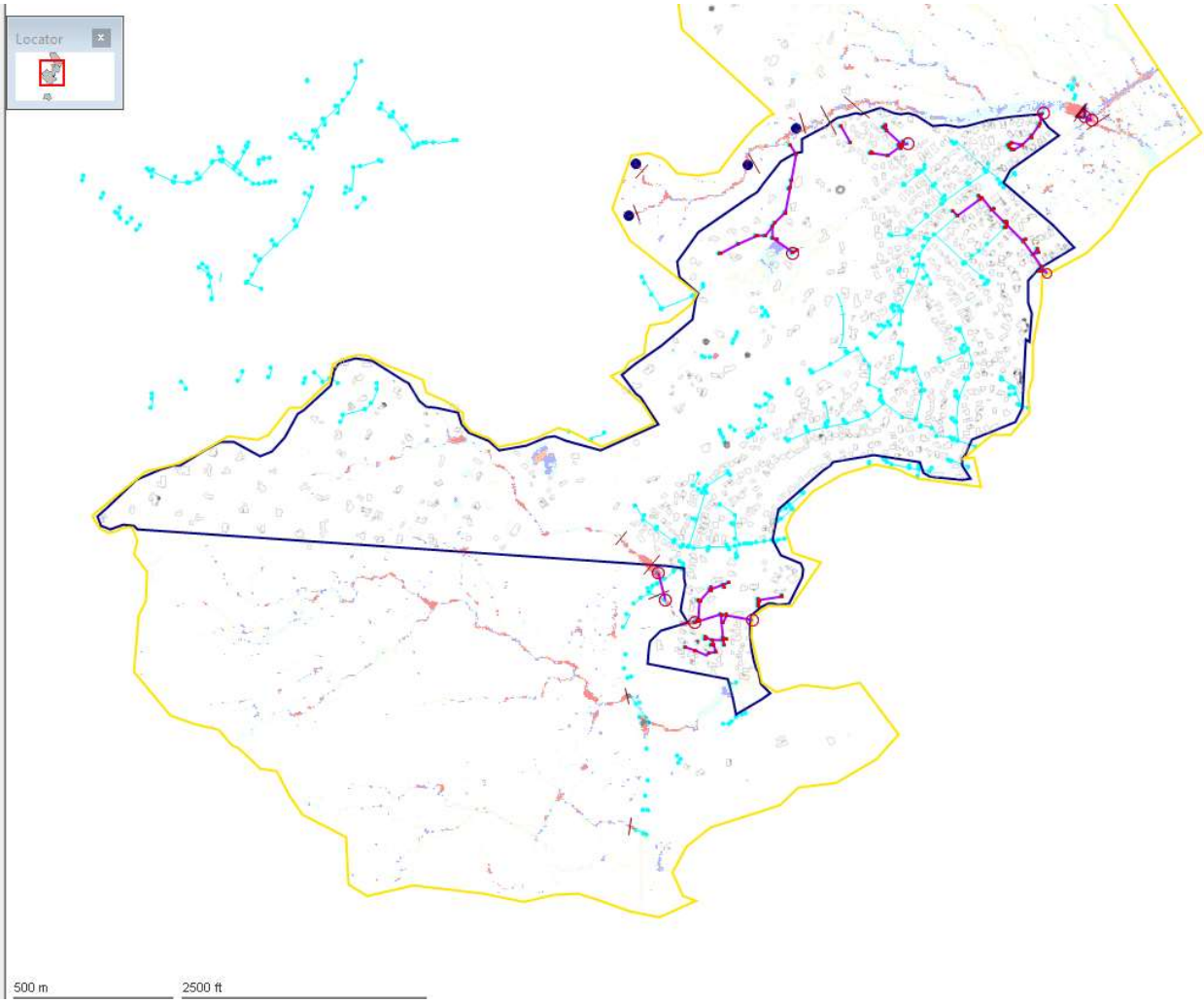
Taupo North Pipes SW 100-Year Flood Model Extent



Taupo South Pipes SW 100-Year Flood Model Extent



Acacia Bay Pipes SW 100-Year Flood Model Extent



Kinloch Pipes SW 100-Year Flood Model Extent (LiDAR extent in tan)

