Appendix B. Records of Title

Consenting for Te Ruaotehauhau Stream Water Storage Reservoir

Hydrology Assessment

TE TAI TOKERAU WATER TRUST

WWLA0239 | Rev. 1

01 September 2020

Te Ruaotehauhau Stream Water Storage Reservoir Hydrology Study

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Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) supported by a wider consortium of experts was commissioned by the Te Tai Tokerau Water Trust in July 2020 to prepare technical reports and documentation required for resource consent for a proposed 1.4 Mm^3 water storage reservoir in the catchment of the Te Ruaotehauhau Stream. The reservoir is known as the Te Ruaotehauhau Stream Water Storage Reservoir (TRSWSR).

1.1 Background

The TRSWSR (previously referred to as MN-06) was identified as a potential water storage reservoir site through the Northland Water Storage and Use Project (NWSUP) Pre-Feasibility Demand Assessment and Design Study, undertaken by WWLA and other technical experts for Northland Regional Council (NRC) in August 2019 (WWLA, 2020 a, b, c). In June 2020, the project was transferred to the Te Tai Tokerau Water Trust, who commissioned advancement of the TRSWSR scheme with detailed design and consenting programmes instigated.

The wider scope of works, undertaken to support consenting of the reservoir, includes the following by the indicated specialists:

- Consent documentation (WWLA);
- Ecological Assessment (Puhoi Stour);
- Archaeological Assessment (Geometria);
- Landscape Assessment (Simon Cocker Landscape Architecture);
- Geotechnical Assessment and Reservoir Conceptual Design (Riley Consultants); and
- Hydrological Assessment (WWLA).

This technical report presents the hydrological analysis and details the assessment of environmental impacts and effects on downstream water users.

1.2 Report Structure

The report comprises descriptions of:

- A project overview (**Section 2**);
- A review of surface water allocation policy (**Section 3**);
- Catchment modelling overview (**Section 4**);
- Analysis of existing hydrological regimes and allocation (**Section 5**);
- Proposed storage reservoir and water takes (**Section 6**);
- Assessment of Environmental Effects (**Section 7**);
- Analysis of impacts on downstream water users (**Section 8**); and
- Summary and conclusions (**Section 9**).

2. Project Overview

2.1 Location

A location overview of the proposed 1.4 Mm^3 TRSWSR is displayed in **Figure 1**. The reservoir is positioned in the upper catchment of the Te Ruaotehauhau Stream, and will be used to service and support local horticultural operations.

Full details of the conceptual design of the reservoir itself are presented in RILEY (2020) *Geotechnical and Site Suitability Assessment Water Storage Reservoir, Ohaewai.*

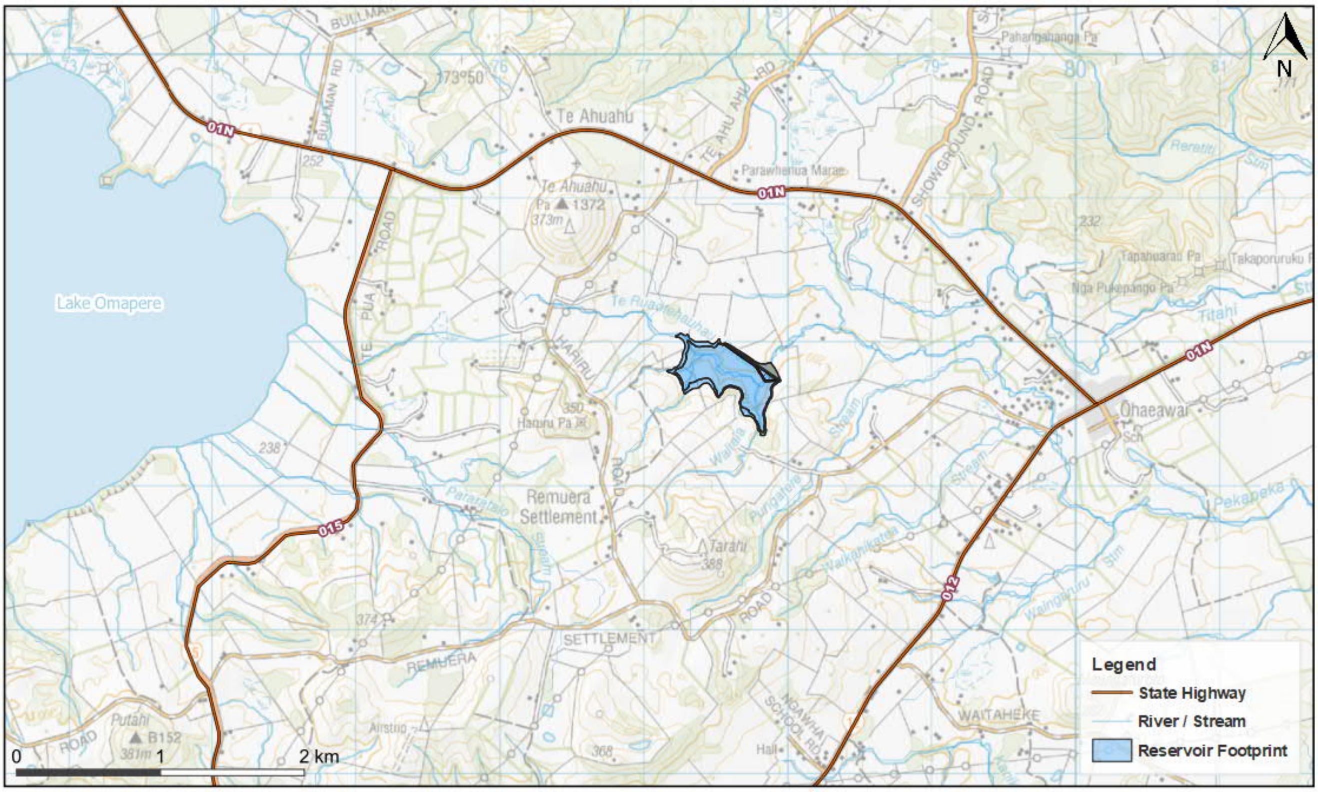


Figure 1. Project location overview map.

2.2 Water Resources

Stored water will arise from the following components:

- The reservoir will be filled through direct catchment inflows. A base flow will be maintained in the stream downgradient of the reservoir.
- It is currently proposed to harvest:
  - High flows above the median, up to two times the standard deviation of flow at all times they are available (and the reservoir is not full), and
  - Low flow core allocation outside of the irrigation season (i.e. winter months) only.

It should be noted, these water takes will be consented separately from the reservoir itself. Details of the two takes are summarised in **Table 1**.

Table 1. Proposed water takes.

Take type	Rate (L/s)	Minimum flow criteria (L/s)	Note
High-flow take	0 - 451	29	Gravity inflow from median to median plus 2x Std. Dev.
Core allocation / low-flow take	3.0	5.9	Gravity inflow during winter only

2.3 Water Use Requirements

The storage reservoir is proposed to service local community irrigation demands. Based on the NWSUP Pre-feasibility Design and Demand Study, the reservoir is expected to support up to approximately 390 hectares of horticultural development (WWLA, 2020 d. in prep). The total aera of land serviced will ultimately depend on community uptake.

This hydrology assessment has been undertaken on the assumption of a maximum daily demand of 16,160 m^3/day during the irrigation season.

3. Regulatory Framework

This section provides an overview of key policy regarding surface water allocation and takes from the Proposed Regional Plan Northland (PRPN).

3.1 Allocation Limits

Allocation limits for streams are set to protect the health of aquatic ecosystems by capping the amount of water that can be taken from a water body above a minimum flow or level for lakes. This enables natural fluctuations in stream flow to occur, while providing somewhat for security of supply. An allocation limit along with a minimum flow criterion is defined, with restrictions applying when stream flow reduces below the minimum flow rate.

3.1.1 Core Allocation / Low-flow

NRC grouped networks of streams into freshwater management units based on common values of the water bodies and the sensitivity of the values to change in flow as follows:

- Large River;
- Small River;
- Coastal River; and
- Outstanding Value River.

All rivers and streams of interest to this study are classified as small rivers, which implies minimum flow of 80% MALF and an allocation limit of 40% of the MALF are relevant (**Table 2**).

Policy H.4.3 of the Proposed Regional Plan for Northland states, the quantity of river flow available for abstraction below the median must not exceed the criteria outlined in **Table 2**, provided a minimum river flow is maintained (**Policy H.4.1**).

Table 2. Minimum flow criteria and allocation limits for Northland's rivers.

Management Unit	Minimum Flow (% of 7-day MALF)	Allocation Limit (% of 7-day MALF)
Outstanding rivers	100%	10%
Coastal rivers	90%	30%
Small rivers	80%	40%
Large river	80%	50%

3.1.2 High Flow

When river flow is above the median flow, **Policy C.5.1.10** states that the taking and use of water for a river that is not a permitted or controlled activity, is a restricted discretionary activity. Matters of discretion include:

1. The timing, rate and volume of the take to avoid or mitigate effects on existing authorised takes and aquatic ecosystem health.
2. Measures to ensure the reasonable and efficient use of water.
3. The positive effects of the activity.

4. Catchment Modelling

The following section details the catchment modelling undertaken to characterise the existing hydrological regime of the rivers and streams of interest.

The catchment model detailed in the sections below was based on the catchment model developed as part of the NWSUP: Pre-Feasibility, and further refined for this increased detail assessment and calibrated against newly available flow monitoring data.

Full details on the development of the original catchment model are provided WWLA (2020) NWSUP – Volume 2: Water Resources Analysis.

4.1 Available Data

The following sections summarise the available data used during the development of the catchment flow model relevant to the TRSWSR hydrology study.

4.1.1 Climate Data

The nearest rain gauge to TRSWSR from NRC's rain gauge network is the Waitangi at Ohaeawai gauge, located approximately 1.5 kilometres to the south-east. This met station has fifteen-minute rainfall data covering the period from 25 June 1998 to present.

In order to provide a consistent method of supplying long-term (i.e. 1972 to present) rainfall and evaporation data to all sub-catchment in the catchment model (i.e. including sub-catchments where no rain gauges exist), the National Institute of Water and Atmospheric Research (NIWA) virtual climate station network (VCSN) data were used.

The VCSN data provides estimates of daily rainfall and potential evapotranspiration on a 5 km regular grid, covering all of New Zealand. Estimates of climate parameters are produced for each VCSN point on a daily time-step based on spatial and temporal interpolation of recorded observation data at the nearest reliable meteorological sites. A comparison of measured rainfall from NRC's Waitangi at Ohaeawai gauge and the nearest VCSN station is provided in WWLA (2020b), and showed good agreement between the two datasets.

Given the relatively small spatial scale of interest, a single VCSN point (Station ID: 30694), located approximately three-kilometres northwest of the proposed TRSWSR, was used for the hydrology assessment. Average monthly rainfall and evaporation for this location are displayed in **Figure 2**.

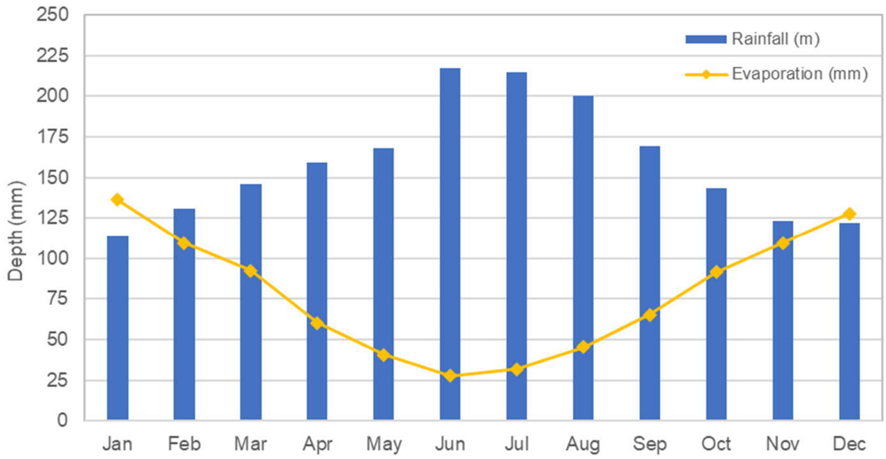


Figure 2. Average monthly rainfall and evaporation.

4.1.2 Flow Data

Observed flow data were available from two locations downstream of the TRSWSR. These are summarised in **Table 3** and there locations shown in **Figure 3**. The two monitoring sites were used to provide a degree of verification to the accuracy of simulated flows from the catchment model.

Table 3. Summary of available flow data.

Dataset	Location Relative to TRSWSR	Description	Source
Pungatere at Sheehan	Approx. 1.8 km downstream	1 spot gauging taken on 18/12/1991	NRC
Waiaruhe at SH1 Bridge	Approx. 9.1 km downstream	58 spot gaugings taken between 04/1978 and 03/2019	NRC

Figure 3. Location of available gauged flow data. (Refer A3 attachment at rear).

4.1.3 Consented Water Takes

A summary of consented water takes in close proximity to TRSWSR are displayed in **Table 4** and **Figure 4**. Of the four takes, two (highlighted in red) are located on the Te Ruaotehauhau Stream, downstream of the proposed reservoir. The remaining two are in neighbouring catchments, and therefore will not be impacted (either positively or negatively) by the reservoir.

Table 4. Consented water takes downstream of TRSWSR.

IRIS ID	Source	Purpose	Annual Take per Year (m^3)
AUT.017199.02.01	Dam Water	Irrigation - Horticulture	3,850
AUT.017199.01.02	Surface Water	Irrigation - Horticulture	7,150
AUT.017643.01.02	Surface Water	Irrigation - Horticulture	15,960
AUT.028688.01.02	Surface Water	Irrigation - Horticulture	28,800

Figure 4. Consented water takes downstream, or in close proximity to TRSWSR. (Refer A3 attachment at rear).

4.2 Soil Moisture Water Balance Model

In order to quantify the volume of water available for harvesting and storage, catchment models were developed for Te Ruaotehauhau Stream.

The following subsections describe the available data used in developing the catchment flow models and the development and calibration of these catchment flow models.

4.2.1 Overview

The Soil Moisture Water Balance Model (SMWBM) was utilised as the rainfall runoff model for this project. The SMWBM is a semi-deterministic model that is parameterised via relationships to catchment physical characteristics. Model functionality incorporates daily rainfall disaggregation and computation on an hourly timestep during rain events, interception storage, surface runoff, surface ponding, soil infiltration, soil moisture storage, sub-soil drainage, vadose zone flow and groundwater discharges for differing land physical characteristics and use types. The model also contains an irrigation demand module. The vadose zone and irrigation demand modules were not used in this assessment.

The SMWBM incorporates parameters characterising the catchment in relation to the following characteristics, with a conceptual diagram of the SMWBM structure and functionality described in more detail in **Appendix A**.

- Interception storage;
- Evaporation losses;
- Soil moisture storage;
- Surface runoff;
- Soil infiltration;
- Sub-soil drainage;
- Stream base flows; and
- The recession and/or attenuation of ground and surface water flow components.

4.3 Model Verification

The catchment models developed for NWSUP – Volume 2: Water Resources Assessment were utilised for this assessment. Full details of the catchment model development and initial calibration are provided in the NWSUP – Volume 2: Water Resources report (WWLA, 2020b).

The sub-sections below detail the model verification to available spot gauge data (Pungatere at Sheehan and Waiaruhe at SH1 bridge) within the catchment of the TRSWSR.

Flow monitoring is currently being undertaken in the Te Ruaotehauhau Stream, at the location of the reservoir wall. The catchment models will be further verified against the new data prior to submission of the water take consents associated with the reservoir.

4.3.1 Pungatere at Sheehan

A comparison of modelled and observed flow at the Pungatere at Sheehan monitoring site is presented in **Figure 5** and **Figure 6**, on a linear and log-y axis respectively. In general, there is good agreement to the single low-flow spot gauging. However, the lack of data points and absence of high flow measurements prevents firm conclusions from being made on model calibration at this location.

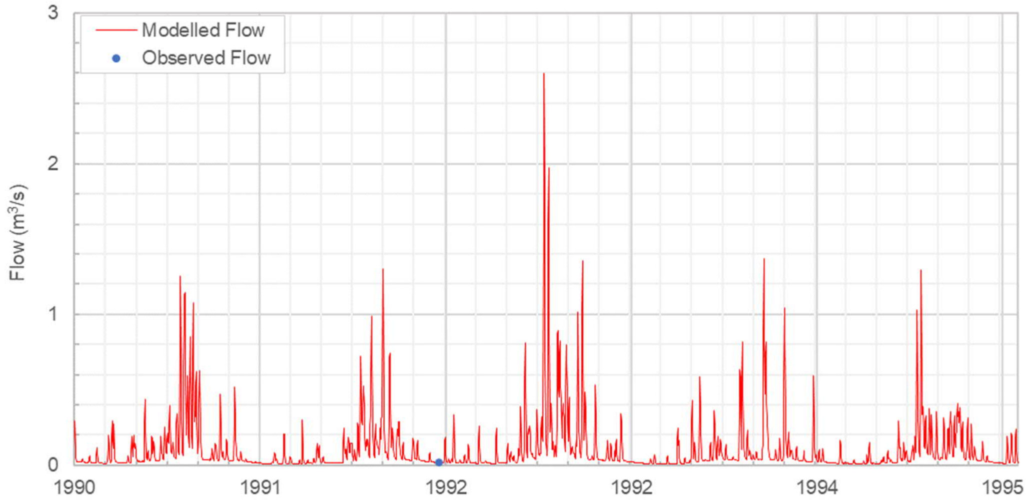


Figure 5. Comparison of modelled and observed flow at Pungatere at Sheehan.

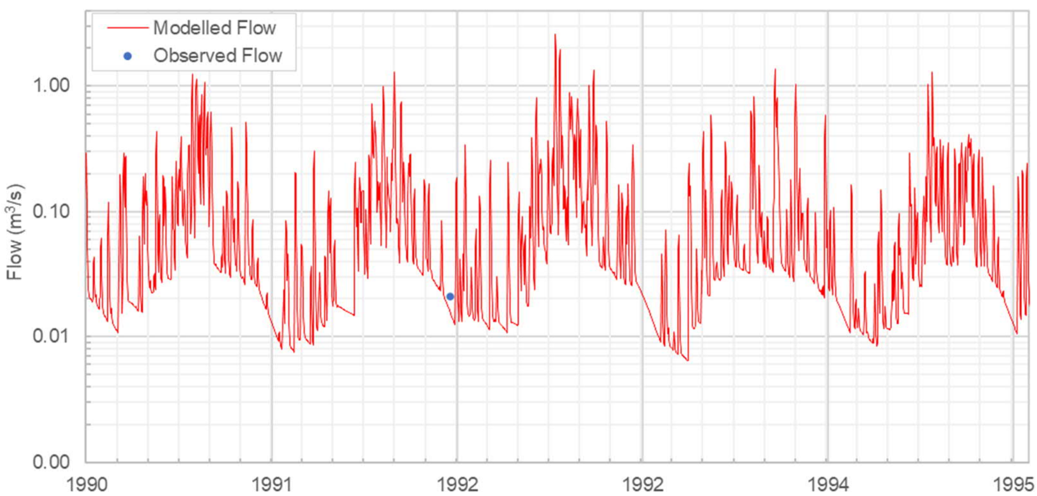


Figure 6. Comparison of modelled and observed flow at Pungatere at Sheehan on a logarithmic y-axis.

4.3.2 Waiaruhe at SH1 Bridge

A comparison of modelled and observed flow at the Waiaruhe at SH1 Bridge monitoring site is presented in **Figure 7** and **Figure 8**, on a linear and log-y axis respectively. In general, there is good agreement to the flow gaugings. The simulated flow demonstrated good agreement to available low and medium-high flow spot gauging data points.

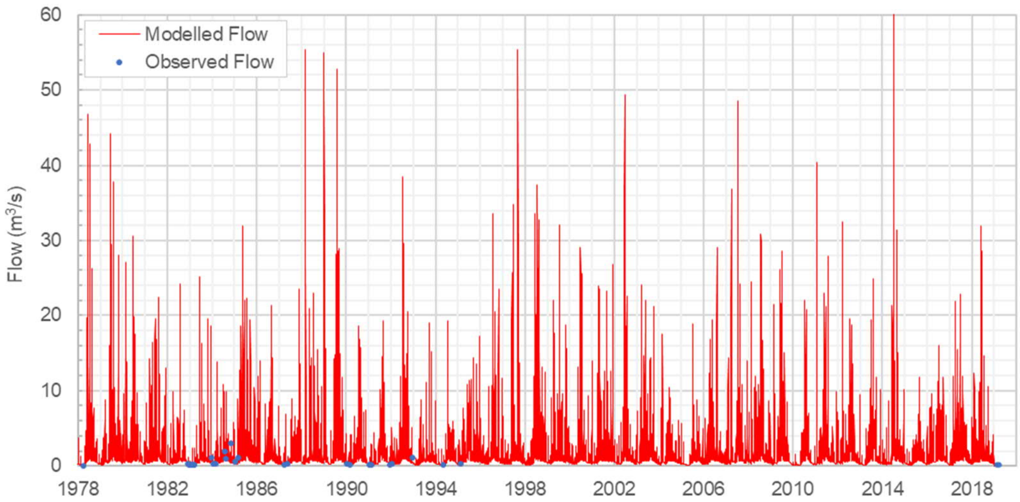


Figure 7. Comparison of modelled and observed flow at Waiaruhe at SH1 Bridge.

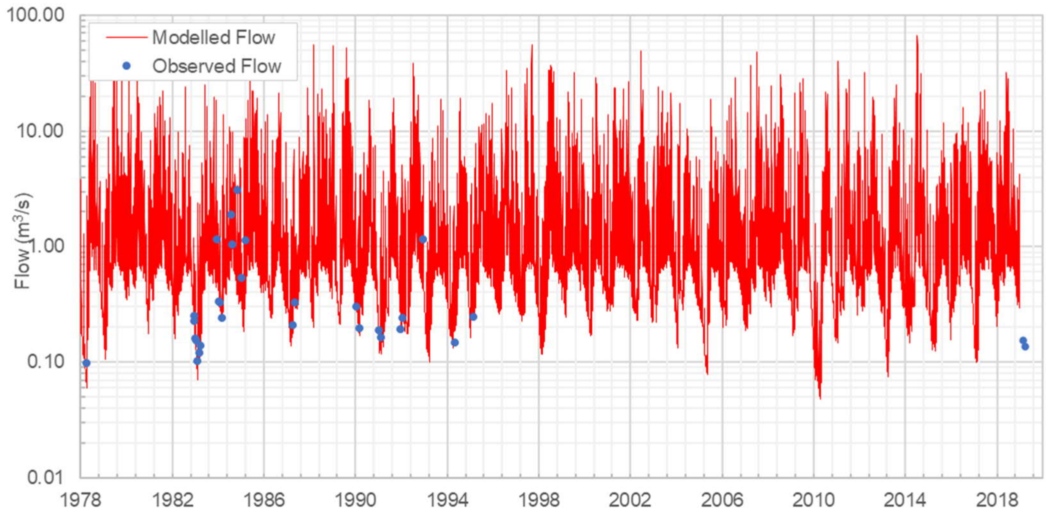


Figure 8. Comparison of modelled and observed flow at Waiaruhe at SH1 Bridge on a logarithmic y-axis.

4.3.3 Overall Statement on Model Verification

The catchment flow model is considered to have demonstrated good agreement to the available spot gauge data at Pungatere at Sheehan and Waiaruhe at SH1 Bridge. However, due to the lack of available flow gaugings, quantifiable model performance metrics (e.g. PBIAS and NSE) could not be calculated.

In addition, as the SMWBM simulates a closed water balance system, and there is good confidence in the rainfall input data (as described in WWLA, 2020b – Appendix B), this provides additional confidence in the overall volume of water simulated (groundwater + surface water) is held by the modelling team.

Overall, the model is considered to provide appropriate representation of daily streamflow dynamics for the purpose of this consent application. Flow monitoring data is currently being collected at the location of the reservoir wall and will be used to further verify the catchment model prior to submitting the water take consent application associated with the reservoir.

5. Existing Hydrological Regimes

The catchment models described in **Section 4** were used to simulate streamflow from 1972 to present at three representative reference locations in order to characterise the existing flow regimes of the Te Ruaotehauhau and Pekapeka Streams. A similar analysis is presented and compared in **Section 7.1** on flows simulated representing post construction of the reservoir and water takes.

The analysis includes the following component for each assessment location:

The analysis includes the following components for each assessment location:

- **Flow hydrographs and flow duration curves:** used to visually demonstrate change, along with standard statistics such as the 7-day mean annual low-flow (7-day MALF), and FRE3 (annual average number of flow events exceeding 3x the median flow).
- **The 7-Day MALF statistic:** is important as it forms the basis of low-flow allocation regulations under the PRPN, with the minimum flow criteria and allocable flow being defined as a proportion on the 7-Day MALF.
- **The FRE3 statistics:** is the number of floods per period of interest (year or season) greater than three times the relevant median flow. FRE3 provides an index of flow variability that is ecologically relevant i.e. the frequency of eco-system disturbance that is needed for a balanced ecosystem composition (periphyton, macro-invertebrates and other biota to co-habitat). Larger values of FRE3 are more desirable than smaller values.

5.1 Flow Assessment Locations

Three representative flow assessment locations were selected to compare the existing streamflow regime (this section) and post reservoir and streamflow take construction (**Section 7.1**). These locations are displayed in

Figure 9, and are described as follows:

- **Proposed TRSWSR Embankment Wall:** This assessment site represents the location immediately downstream of the TRSWSR embankment wall, and thus the location of greatest impact from harvest direct catchment inflows;
- **1,200 m Downstream of TRSWSR:** This assessment site represents the location 1,200 m downstream of the proposed reservoir Embankment wall; and
- **Downstream of Waikahikatea Confluence:** This assessment site represents the location immediately downstream of the Waikahikatea confluence.

Figure 9. Representative assessment locations and their catchments. (Refer A3 attachment at rear).

The existing flow regimes of these assessment locations are summarised in the sections below.

5.1.1 TRSWSR Embankment Wall

The hydrograph and flow duration curve for Te Ruaotehauhau Stream downstream of the embankment wall assessment location are presented in **Figure 10** and **Figure 11**, respectively and summary flow statistics are presented in **Table 5**.

Simulated historic streamflow at this location ranges from approximately 2.1 L/s to a maximum of 3,188 L/s, with a median of 28.9 L/s.

High flow events occur in response to rainfall events, while stream baseflow exhibits a seasonal pattern, with higher baseflow occurring during winter, and low-flows during summer.

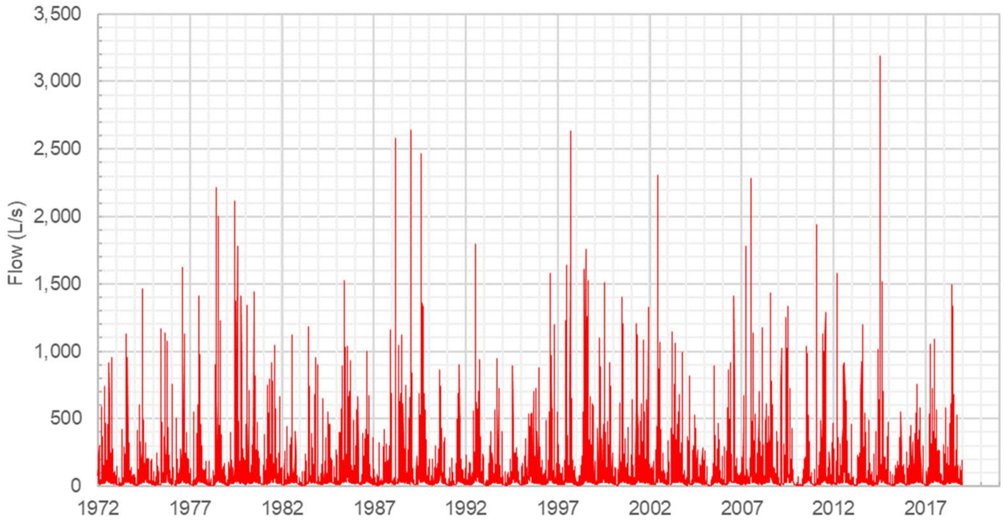


Figure 10. Simulated flow hydrograph for TRSWSR Embankment Wall assessment location.

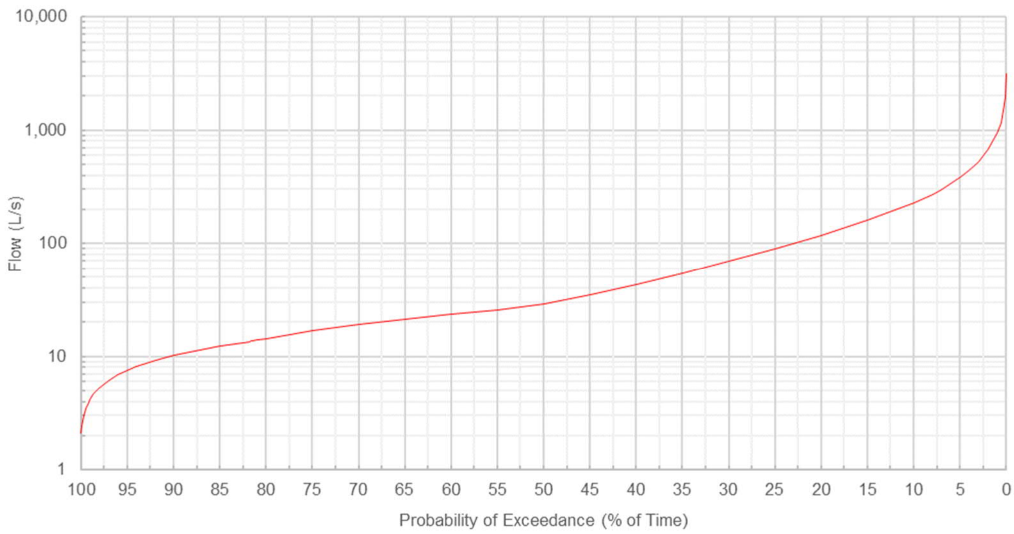


Figure 11. Simulated flow duration curve for TRSWSR Embankment Wall assessment location.

Table 5. Flow statistics for TRSWSR Embankment Wall assessment location.

Statistic	Value
Minimum (L/s)	2.1
Median (L/s)	28.9
Maximum (L/s)	3,188
7-Day MALF (L/s)	7.5
FRE3 (count)	22

5.1.2 1,200 m Downstream of TRSWSR

The hydrograph and flow duration curve for Te Ruaotehauhau Stream at the 1,200 m downstream of TRSWSR assessment location are presented in **Figure 12** and **Figure 13**, respectively, and summary flow statistics presented in **Table 6**.

Simulated historic streamflow at this location ranged from 2.8 L/s to 4,287 L/s, with a median flow of 38.8 L/s.

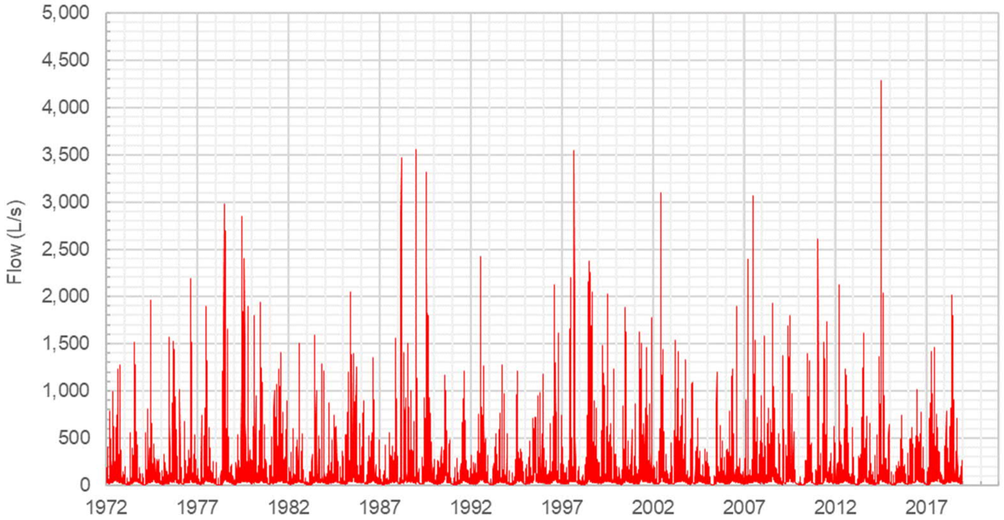


Figure 12. Simulated flow hydrograph for 1,200 m Downstream of TRSWSR assessment location.

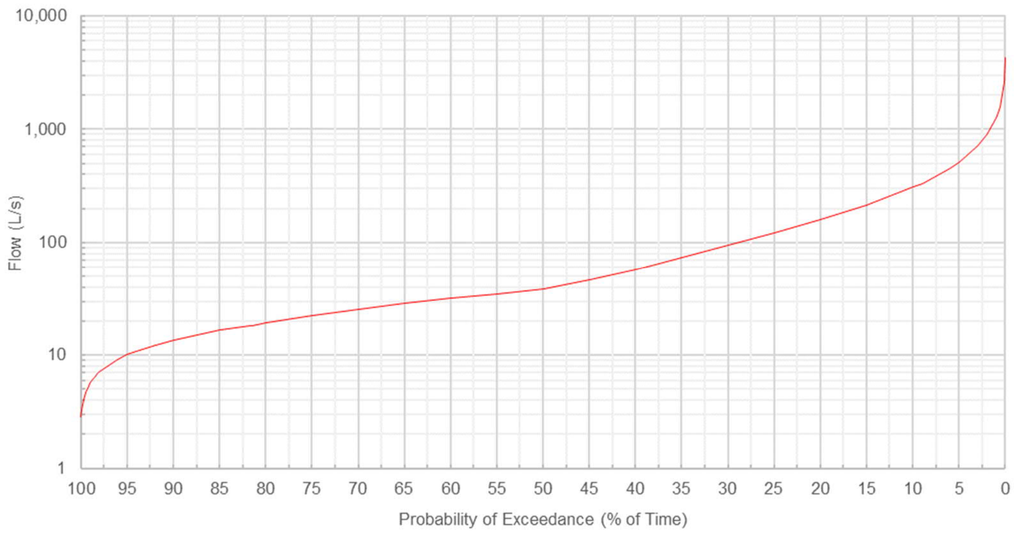


Figure 13. Simulated flow duration curve for 1,200 m Downstream of TRSWSR assessment location.

Table 6. Flow statistics for 1,200 m Downstream of TRSWSR assessment location.

Statistic	Value
Minimum (L/s)	2.8
Median (L/s)	38.8
Maximum (L/s)	4,287
7-Day MALF (L/s)	10.1
FRE3 (count)	22

5.1.3 Downstream of Waikahikatea Confluence

The hydrograph and flow duration curve for the Downstream of Waikahikatea Confluence assessment location are presented in **Figure 14** and **Figure 15**, respectively, and summary flow statistics presented in **Table 7**.

Simulated historic streamflow at this location ranged from 5.3 L/s to 7,998 L/s with a median flow of 72.4 L/s.

Streamflow at this location is approximately twice that of the upstream assessment location, owing to the larger catchment areas associated with the Pungatere Stream and Waikahikatea Stream that enter upstream of this assessment location.

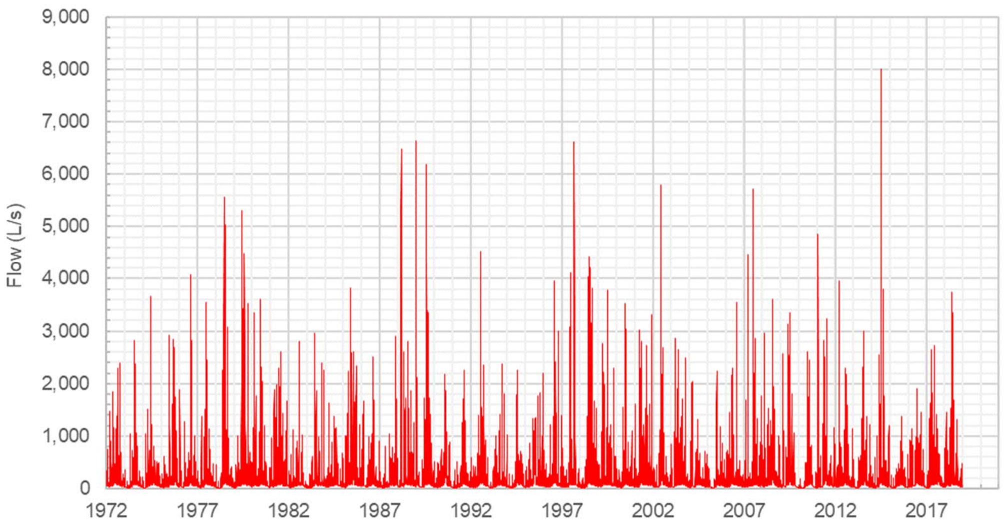


Figure 14. Simulated flow hydrograph for Downstream of Waikahikatea Confluence assessment location.

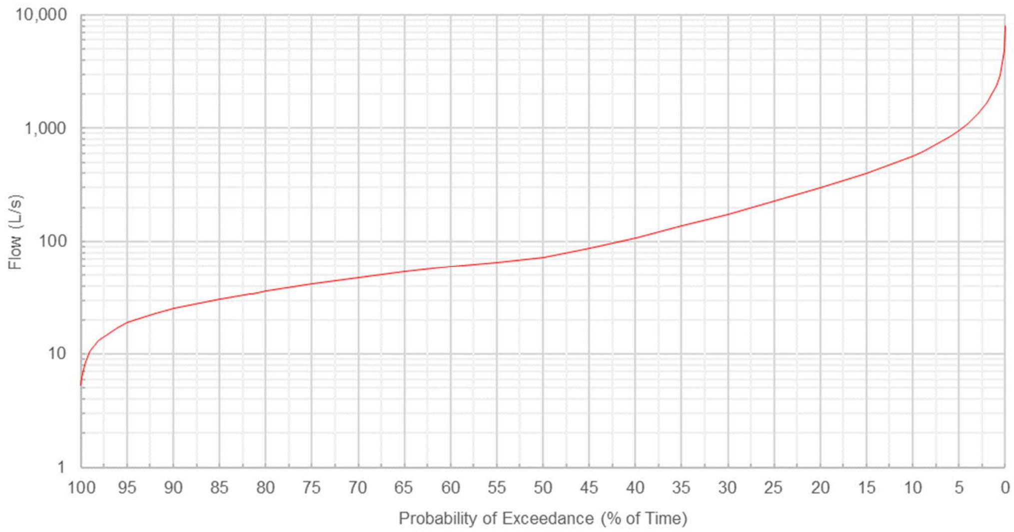


Figure 15. Simulated flow duration curve for Downstream of Waikahikatea Confluence assessment location.

Table 7. Flow statistics for Downstream of Waikahikatea Confluence assessment location.

Statistic	Value
Minimum (L/s)	5.3
Median (L/s)	72.4
Maximum (L/s)	7,998
7-Day MALF (L/s)	18.8
FRE3 (count)	22

5.2 Flow Regime Summary

A summary of daily average flow statistics along with key water take consenting metrics for each of the assessment sites are presented in **Table 8**.

Table 8. Summary of existing daily average flow regime statistics for key assessment locations.

Statistic	TRSWSR Embankment	1,200 m Downstream TRSWSR	Downstream of Waikahikatea Confluence
Catchment Area (km^2) [ha]	3.0 [301]	4.1 [408]	7.6 [762]
Minimum (L/s)	2.1	2.8	5.3
Median (L/s)	28.9	38.8	72.4
Maximum (L/s)	3,187	4,287	7,998
7-Day MALF (L/s)	7.5	10.1	18.8
Minimum Flow Criteria (80% MALF)	6.0	8.3	15.0
Run of River Allocation Limit (40% MALF)	3.0	4.0	7.5
FRE3 (count)	22	22	22

6. Proposed Storage Reservoir

Full details of the conceptual design of the reservoir itself are provided in RILEY (2020) *Geotechnical and Site Suitability Assessment Water Storage Reservoir, Ohaewai.* The design of reservoir is shown **Figure 16**, with key physical dimensions summarised in **Table 9**.

Figure 16. Reservoir design drawing. (Refer A3 attachment at Rear).

Table 9. Reservoir characteristics.

Property	Value
Dam crest Level (m)	207 m RL
Fully supply level (m)	205 m RL
Storage at full supply level (m^3)	1,400,000
Max. water depth at full supply (m)	17
Emergency spillway width (m)	40 (at base)

7. Assessment of Environmental Effects

The following sections detail the assessment of hydrological environmental impacts associated operation of the proposed TRSWSR water storage reservoir on downstream surface water flow regimes.

7.1 Impacts on Surface Water Flow Regimes

The impacts on surface water flow regimes were characterised by comparing a simulation of the existing flow regime (**Section 5**) with the flow regime post completion of the reservoir at the three representative flow assessment locations (**Section 5.1**).

7.1.1 Reservoir Operation

The conceptualised historic operation of the storage reservoir is presented in **Figure 17**, in regards to key inflow and outflow volumes, and changes in reservoir storage. The impact of these takes and release on the downstream flow regime at the three representative locations are then discussed in the sections below.

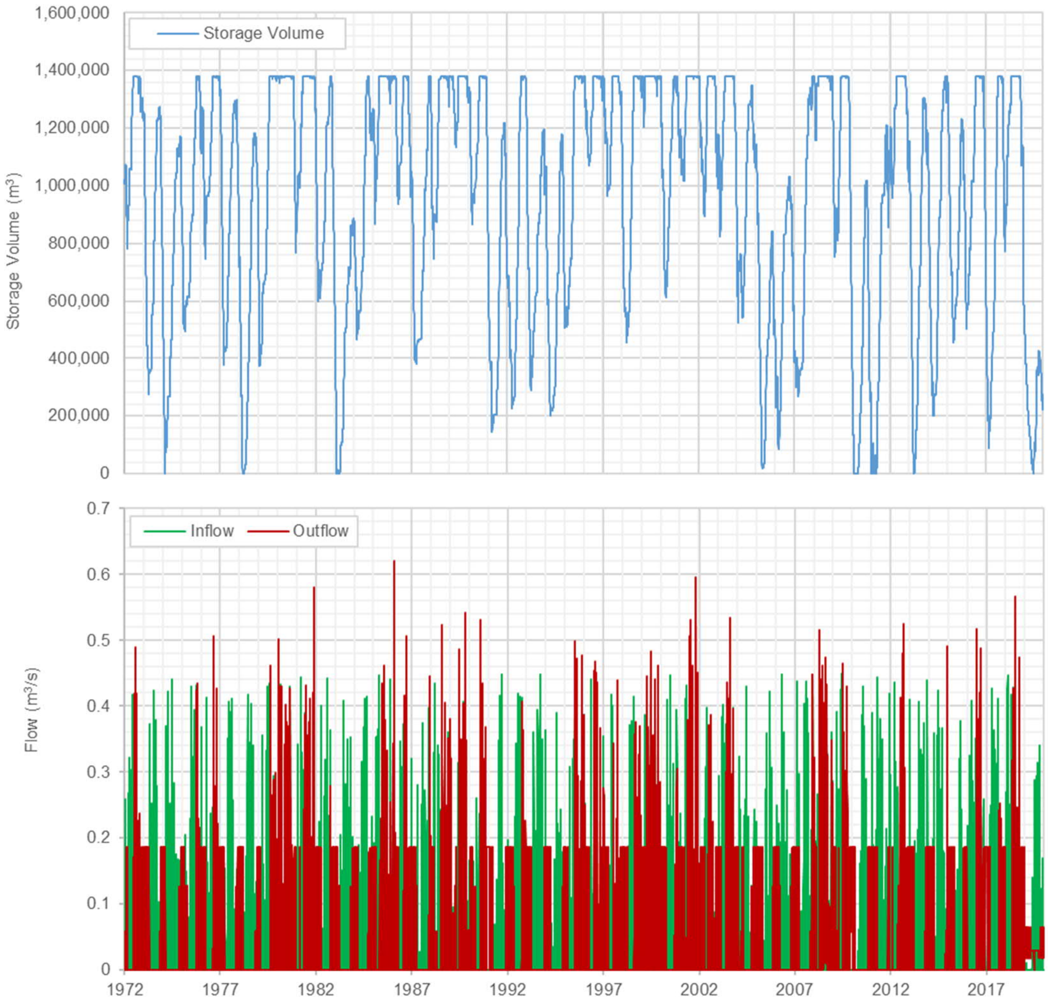


Figure 17. Reservoir operation – change in storage volume (top), and storage inflows and releases (bottom).

7.1.2 TRSWSR Embankment Wall

Comparisons of the flow duration curve and flow hydrograph under natural flow (simulated existing regime) and flow with the reservoir present are presented in **Figure 18** and **Figure 19**, respectively. As this location is immediately downstream of the reservoir, it represents the location of largest impact due to the storage of above median direct catchment inflows.

As indicated in **Figure 18**, a significant proportion of high flow is captured (harvested) by the reservoir. This has the effect of reducing high flow variability and frequency of flushing flows immediately downstream of the reservoir. The frequency of spills, or flushing flows from the reservoir will largely depend on the management regime and weather systems (i.e. back to back high flows during winter when the reservoir is full).

As demonstrated by the next downstream representative assessment location (**Section 0**), the proportional change in flow regime quickly diminishes with increasing distance downstream, as lateral catchment inflows increase and additional tributaries join the Te Ruaotehauhau Stream.

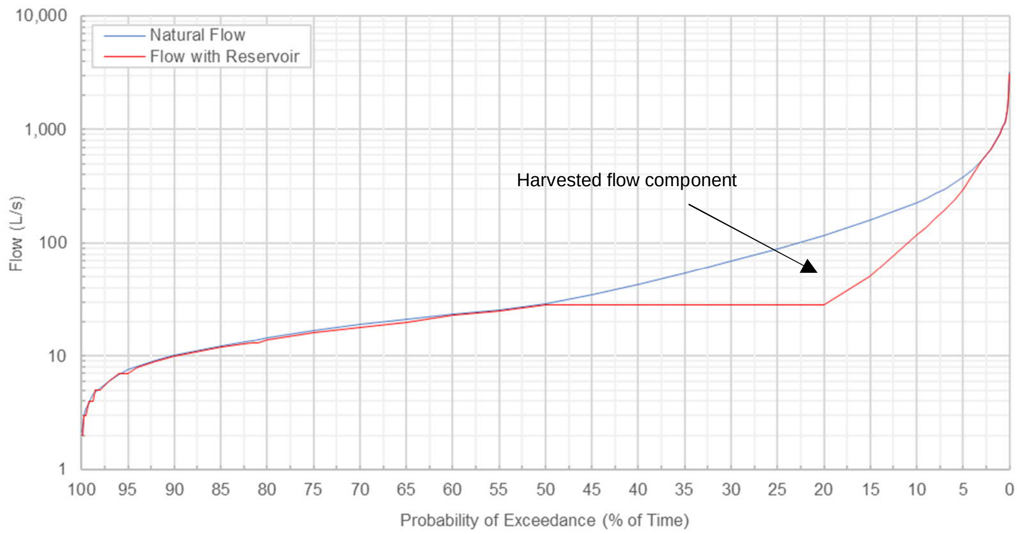


Figure 18. Comparison flow duration curve at the TRSWSR Embankment Wall assessment location.

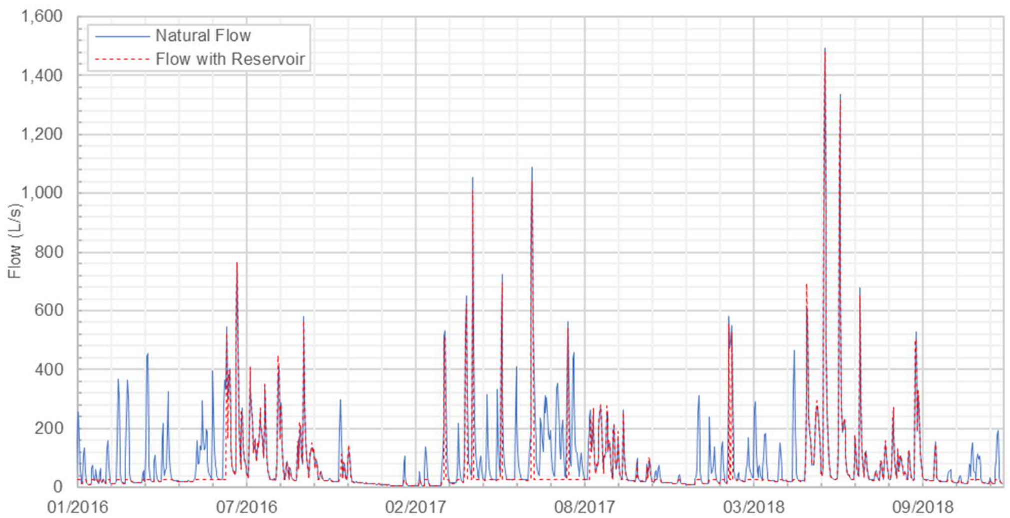


Figure 19. Example sub-set comparison of flow hydrographs at the TRSWSR Embankment Wall assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 10**.

Table 10. TRSWSR Embankment Wall assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	2.1	2.0
Median (L/s)	28.9	25.0
Maximum (L/s)	3,188	3,051
7-Day MALF (L/s)	7.5	7.1
FRE3 (count)	22	12

7.1.3 1,200 m Downstream TRSWSR

Comparisons of the flow hydrograph and flow duration curve under natural flow (simulated existing regime) and flow with the reservoir present, at 1,200 m downstream of the TRSWSR reservoir, are presented in **Figure 20** and **Figure 21**, respectively. The impact of capturing above high flows in the reservoir as a proportion of total flow at this location has further reduced in comparison to upstream location.

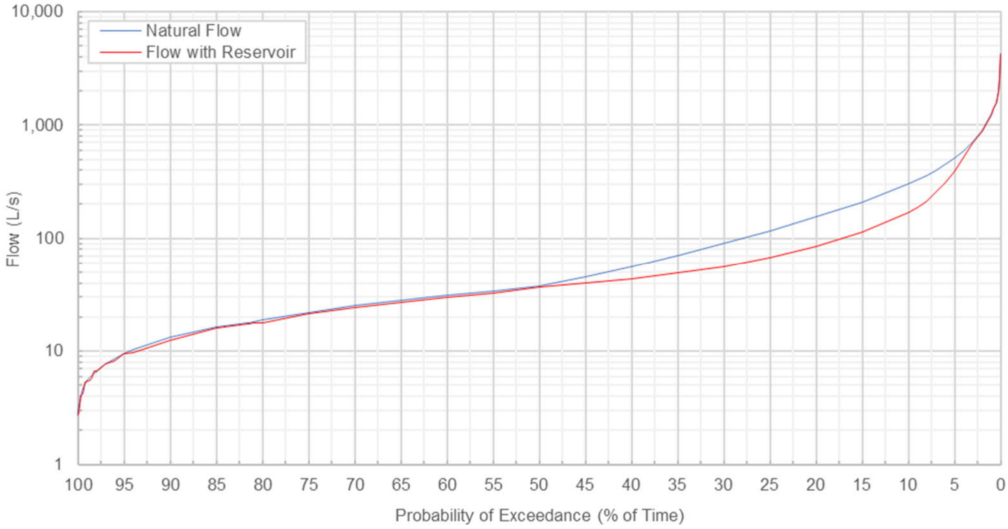


Figure 20. Comparison flow duration curve at the 1,200 m Downstream TRSWSR assessment location.

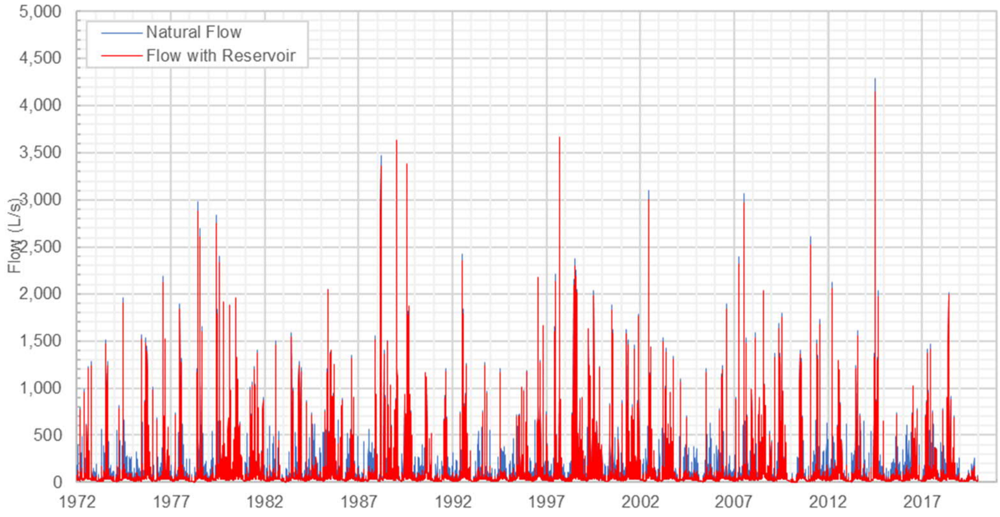


Figure 21. Comparison of flow hydrographs at the 1,200 m Downstream TRSWSR assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 10**.

Table 11. 1,200 m Downstream TRSWSR assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	2.8	2.7
Median (L/s)	38.8	35.5
Maximum (L/s)	4,287	4,151
7-Day MALF (L/s)	10.1	9.8
FRE3 (count)	22	15

7.1.4 Downstream Waikahikatea Confluence

Comparisons of the flow hydrograph and flow duration curve under natural flow (simulated existing regime) and flow with the reservoir present, at one kilometre downstream of the reservoir, are presented in **Figure 22** and **Figure 23**, respectively. The impact of capturing high flows in the reservoir is minimal at this location as demonstrated by a small change in the FRE3 value from 22 to 19 with the reservoir.

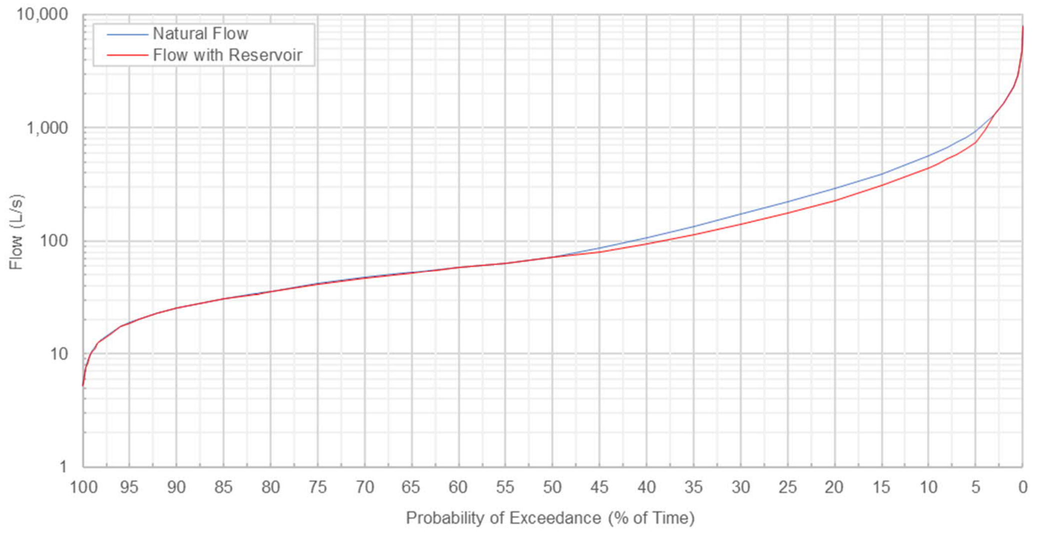


Figure 22. Comparison flow duration curve at the Downstream Waikahikatea Confluence assessment location.

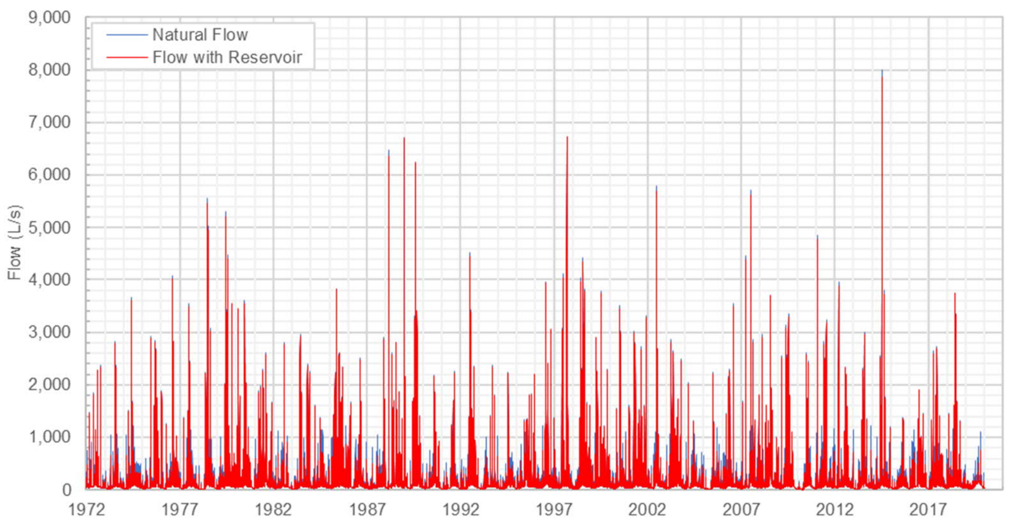


Figure 23. Comparison of flow hydrographs at the Downstream Waikahikatea Confluence assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 10**.

Table 12. Downstream Waikahikatea Confluence assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	5.3	5.2
Median (L/s)	72.4	69.7
Maximum (L/s)	7,998	7,861
7-Day MALF (L/s)	18.8	18.7
FRE3 (count)	22	20

7.2 Impacts on Interactions with Groundwater

The reservoir may cause a small localised rise in groundwater levels due to reservoir seepage. If so, this would be considered to have a positive environmental impact, as it would act to increase stream baseflow. While this positive environmental impact is identified, such impacts are still considered to be minor.

8. Impact on Downstream Water Users

The following sections provide detail on the potential effect on downstream water users associated with the presence and operation of the proposed TRSWSR only, and does not detail those associated with proposed pumped water takes, as these are to be consented separately.

There are two currently consented surface water take downstream of the proposed reservoir (**Figure 4** and **Table 13**). The purpose of these consents is listed as "to take water for pasture irrigation". No other consented surface water takes occur downstream until directly before the outlet to the ocean.

Table 13. Consented water takes downstream of TRSWSR.

Consent Number	Purpose	Max. Rate (L/s)	Annual Allocation (m^3/yr)
AUT.017199.01.02	Irrigation	2.08	7,150
AUT.028688.01.02	Irrigation	3.33	28,800

8.1 Impact of Core Allocation (Low-flow) Take

The proposed core allocation take for direct inflows to the reservoir will only occur during winter. As the downstream consented takes (**Table 13**) are for irrigation of pasture, the consents would only be utilised during summer. Therefore, it is considered there will be no effect on downstream consented water takes associated with a winter core allocation take for direct inflows to TRSWSR.

8.2 Impact of High-Flow Take

The harvesting of high flows will not negatively affect the downstream consented water take. The reservoir high flow take will only occur during times of above median flow at the reservoir (> 29 L/s), and therefore, there will be at least 23.6 L/s in excess of the consented take rate passing downstream of the reservoir during periods of high flow harvesting. In addition, the consented irrigation take is not likely to be operational during times of high-flow taking (i.e. wet periods).

In terms of takes permitted under a Regional Plan or by Section 14(3)(b) of the Resource Management Act 1991, total daily take per property downstream of the lowest point of proposed taking is estimated at:

a) 10 cubic meters (equivalent to 0.116 L/s), or

b) 30 cubic metres (equivalent to 0.347 L/s) for the purposes of dairy shed wash down and milk cooling water,

Flows below the median (up to 28 L/s) will not be harvested and will bypass the reservoir. Therefore, significant water remains available for permitted takes during periods of high flow harvesting. The median flow of 29 L/s at the location immediately downstream of TRSWSR embankment is equivalent to 250 permitted takes at 0.116 L/s, or 83 permitted takes at 0.347 L/s. In addition, catchment flow increases with increasing distance downstream as additional lateral inflows occur and tributaries join.

Based on the above, the potential negative impacts on downstream water users are considered to be no more than minor.

9. Summary

This hydrology study considered the hydrological impacts of:

- the operation of the proposed TRSWSR;
- harvesting of high flow direct catchment inflows into the reservoir, from the median up to two times the standard deviation of flow;
- a core allocation (low-flow) take of direct catchment inflows, during winter only.

The following key conclusions were drawn from the hydrology study:

- The largest impact on streamflow in Te Ruaotehauhau Stream is directly downstream of the reservoir due to the capture of above median flows within the reservoir upstream. As all below median flow is bypassed, there is no change in streamflow during periods of below median flow (50% of the time). During winter there will be a small reduction (3.0 L/s) due to the core allocation take.
- The change in streamflow as a proportion of the total flow, due to upgradient capture of direct inflows, decreases with increasing distance downstream of the reservoir as lateral catchment inflows occur and additional tributaries join. The general variation in streamflow is largely similar to the simulated natural streamflow regime at the Waikahikatea Confluence assessment location.
- There are two consented water takes downstream of TRSWSR, both for pasture irrigation. These consented takes will not be negatively impacted by the proposed winter core allocation, or the high flow take.

10. References

Clausen, B., Biggs, B.J.F. 1997. Relationships between benthic biota and hydrological indices in New Zealand streams. Freshwater Biology 38, 327-342

RILEY. 2020 *Geotechnical and Site Suitability Assessment MN06 Water Storage Reservoir, Ohaewai.* RILEY Report Reference 190416-A.

WWLA. 2020a. Northland Water Storage and Use Project – Volume 1: Command Area Refinement and Analysis. Consultancy Report prepared for Northland Regional Council by Williamson Water & Land Advisory.

WWLA. 2020b. Northland Water Storage and Use Project – Volume 2: Water Resources Assessment. Consultancy Report prepared for Northland Regional Council by Williamson Water & Land Advisory and RILEY Consultants.

WWLA. 2020c. Northland Water Storage and Use Project – Volume 3: Conceptual Design and Costing. Consultancy Report prepared for Northland Regional Council by Williamson Water & Land Advisory and RILEY Consultants.

WWLA. 2020d. Northland Water Storage and Use Project – Kaipara Optimisation Study. Consultancy Report prepared for Te Tai Tokerau Water by Williamson Water & Land Advisory and RILEY Consultants.

Appendix A. SMWBM Parameters

Parameter	Name	Description	Calibrated Value
ST (mm)	Maximum soil water content	ST defines the size of the soil moisture store in terms of a depth of water.	448
SL (mm)	Soil moisture content where drainage ceases.	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.	0
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity	Together with POW, FT (mm/day) controls the rate of percolation to the underlying aquifer system from the soil moisture storage zone. FT is the maximum rate of percolation through the soil zone.	0.5
ZMAX (mm/hr)	Maximum infiltration rate	ZMAX and ZMIN are nominal maximum and minimum infiltration rates in mm/hr used by the model to calculate the actual infiltration rate ZACT. ZMAX and ZMIN regulate the volume of water entering soil moisture storage and the resulting surface runoff. ZACT may be greater than ZMAX at the start of a rainfall event. ZACT is usually nearest to ZMAX when soil moisture is nearing maximum capacity.	5.2
ZMIN (mm/hr)	Minimum infiltration rate		0
POW (>0)	Power of the soil moisture-percolation equation	POW determines the rate at which sub-soil drainage diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of drainage and hence baseflow, as well as the total yield from a catchment.	2
PI (mm)	Interception storage capacity	PI defines the storage capacity of rainfall that that is intercepted by the overhead canopy or vegetation and does not reach the soil zone.	2
AI (-)	Impervious portion of catchment	AI represents the proportion of the catchment that is impervious and directly linked to surface water drainage pathways.	0
R (0,1)	Evaporation – soil moisture relationship	Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. Two different relationships are available. The rate of evapotranspiration is estimated using either a linear (0) or power-curve (1) relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches, full, evaporation occurs at a near maximum rate based on the daily pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases according to the predefined function.	0
DIV (-)	Fraction of excess rainfall allocated directly to pond storage	DIV has values between 0 and 1 and defines the proportion of excess rainfall ponded at the surface due to saturation of the soil zone or rainfall exceeding the soils infiltration capacity to eventually infiltrate the soil, with the remainder (and typically majority) as direct runoff.	0.8
TL (days)	Routing coefficient for surface runoff	TL defines the attenuation and time delay of surface water runoff.	1
GL (days)	Groundwater recession parameter	GL governs the attenuation in groundwater discharge or baseflow from a catchment.	1

Parameter	Name	Description	Calibrated Value
QOBS (m^3/day)	Initial stream volume	QOBS defines the initial volume of water in the stream at the model start period and is used to precondition the soil moisture status.	126,900
AA, BB	Coefficients for rainfall disaggregation.	Used to determine the rainfall event duration and pattern.	0.22, 0.216

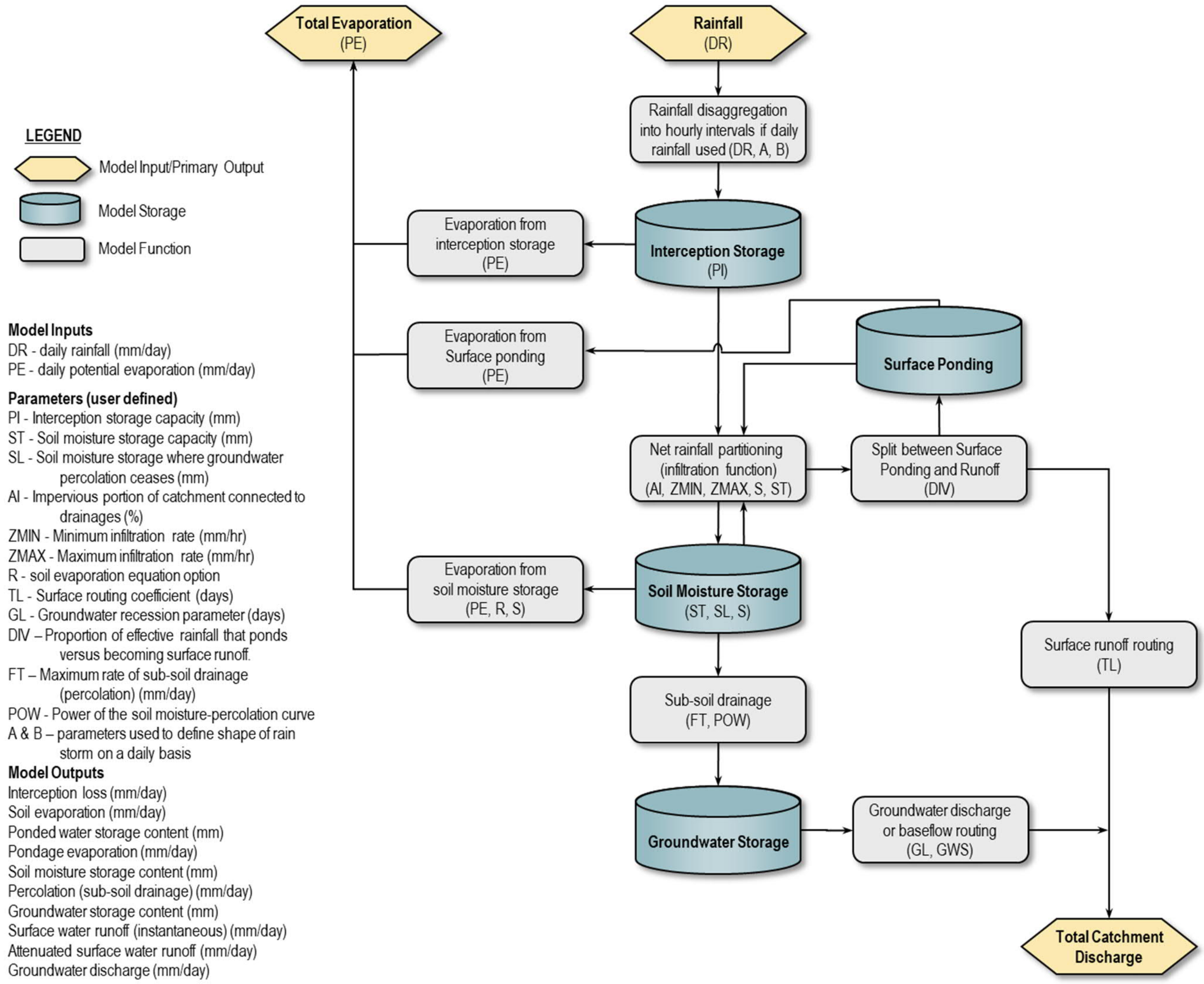


Figure 24. Schematic overview of the SMWBM.

Appendix B. SOURCE Modelling

The SOURCE modelling framework was utilised to model the conceptual operation of the storage reservoir and effects on the downstream flow regime. SOURCE is a hydrological modelling platform developed by the Australian research and not for profit organisation eWater. The platform is comprised of an interface integrating various models (as plugins) and internal tools designed to simulate and extract results for all aspects of water resource systems at a range of spatial and temporal scales.

The schematic modelling component of SOURCE was used to model the conceptual storage operation. The schematic model comprises of a series of linked nodes, representing individual components of the scheme, and rules and constraints on the transfer of water between nodes.

A schematic of the SOURCE model setup is shown in **Figure 25**.

The key node types used in the scheme storage optimisation modelling included:

- **Storage Nodes –** are used to represent storages such as dams, reservoirs, weirs and ponds. Storage Nodes calculate the daily water balance and are governed and constrained by inflows, physical limits on discharges (i.e. outflow pipe or pump capacities), downstream demands and gains (direct rainfall on reservoirs) and losses (evaporation for the reservoir surface). The storage node was configured based on the current conceptual design of the reservoir (WWLA, 2020c).
- **Inflow Nodes –** provide a source (inflow) of water to Storage Nodes. Inflow Nodes were configured with time series extracted from the catchment models (**Section 4Error! Reference source not found.**), representing direct catchment inflows to the reservoir and take locations.
- **Supply Point Nodes –** define a location where water can be extracted to meet a demand required by Water User Nodes. Supply Point Nodes provide a means of constraining extractions (takes) based on physical constraints such a maximum pumping capacity, or when reservoir storage volumes are above or below a specified level.
- **Water User Nodes –** define a water take demand profile, and are always located immediately downstream of a Supply Point Node. Water user nodes simply represent a water take (demand) from a Storage Node, on the condition that sufficient volume of water is available within the storage, and the take is within the constraints of the upstream Supply Point Node. A water user node was configured for the irrigation take. The irrigation take was defined based on the outputs of the SMWBM_Irr model (WWLA, 2020a), for a 100-hectare irrigable area, and a peak application rate of 4.3 mm/day.
- **Pipe Junction Nodes –** are used to transfer water between locations, and to represent pump stations in a water supply system. They operate using a rules-based ordering system. Pipe junction nodes were configured to represent the harvesting of water to storage in the reservoir. Pipe junctions were used to simulate the harvesting of above median flows from the Te Ruaotehauhau Stream, upstream of the reservoir.

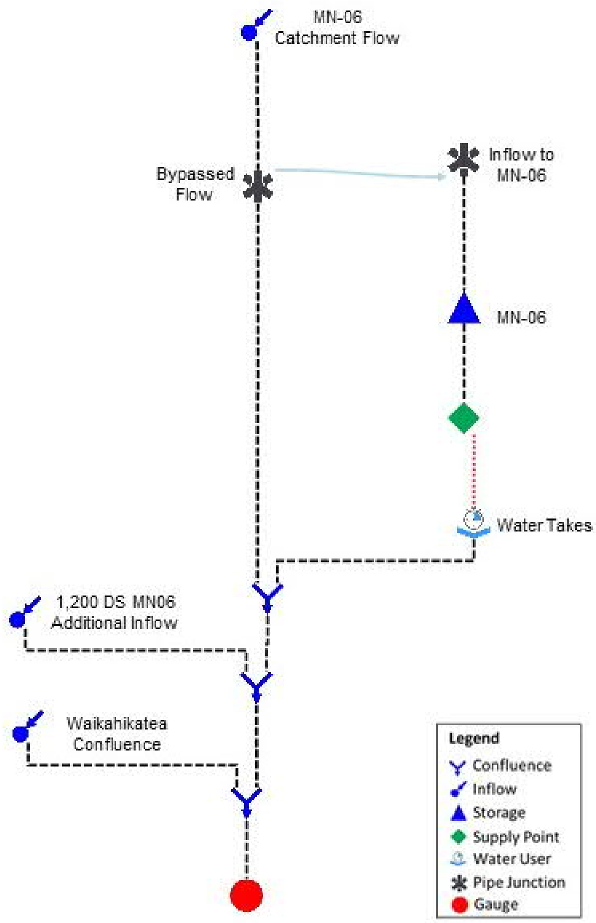
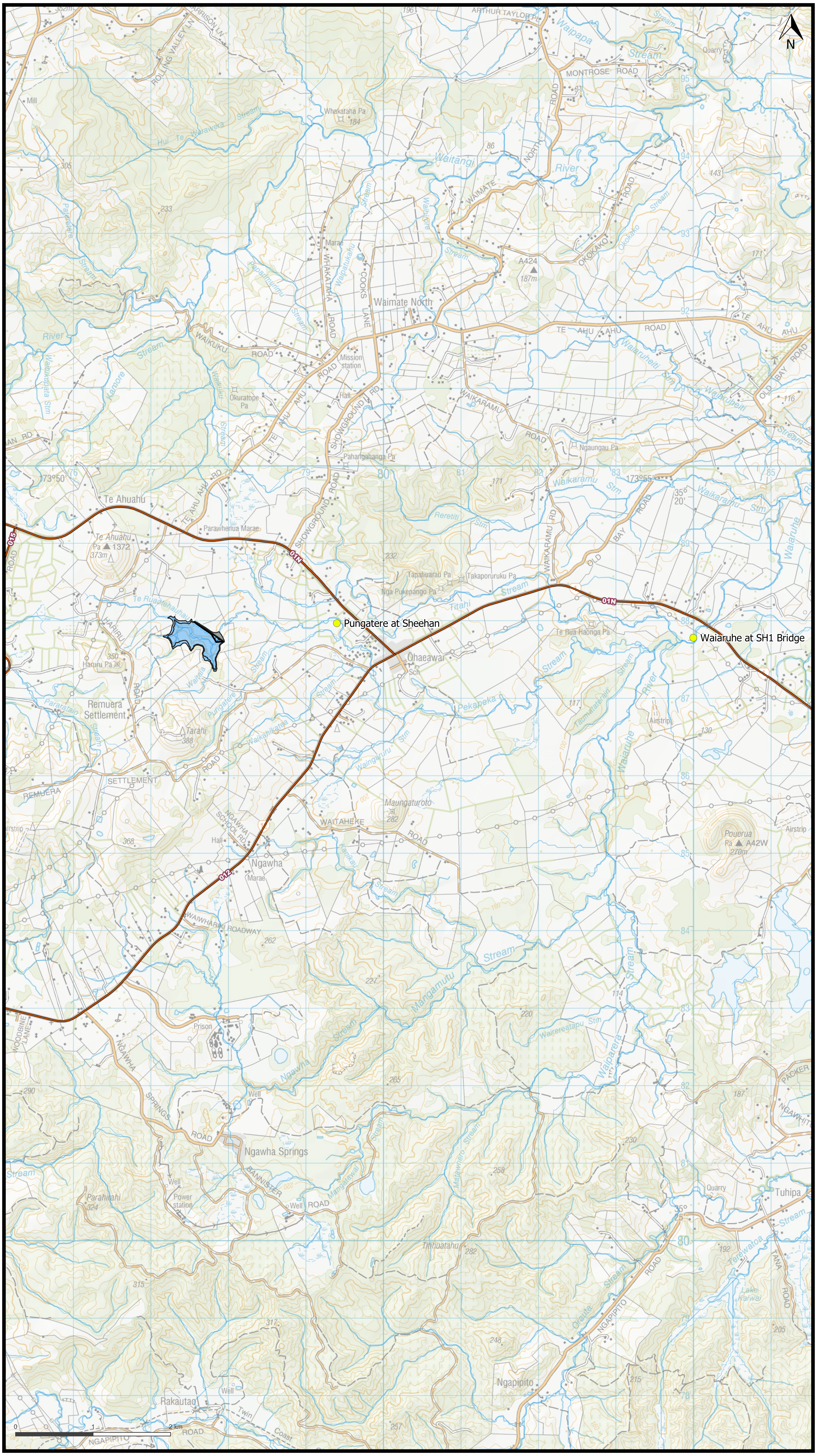


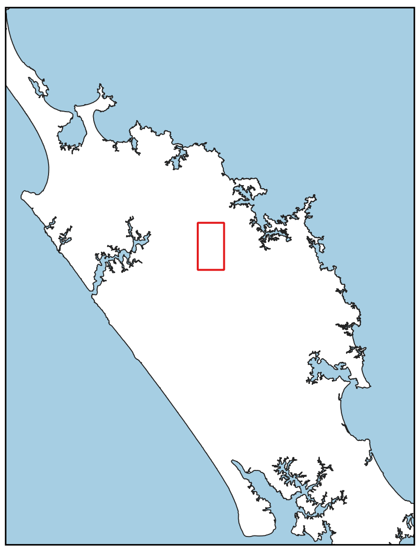
Figure 25. SOURCE model schematic.



Map Title:
Available Flow Gauging Locations

Project:
Te Ruaotehauhau Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



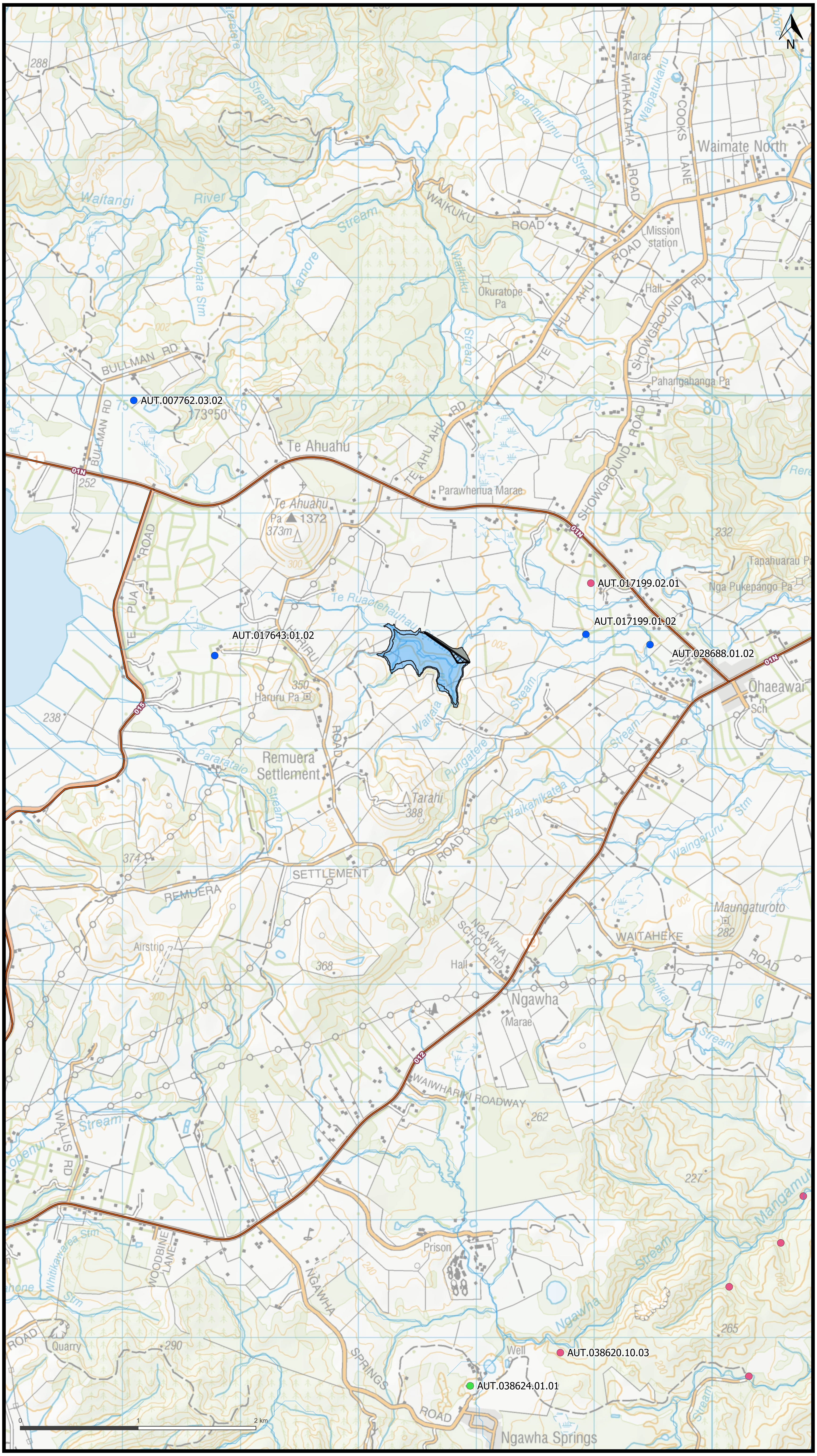
Legend

- **Flow Gauging Locations**
- **River / Stream**
- **State Highway**
- **Reservoir Footprint**

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Flow Gauge Locations
MN-06_Hydrology_Study_Report EL.qgz

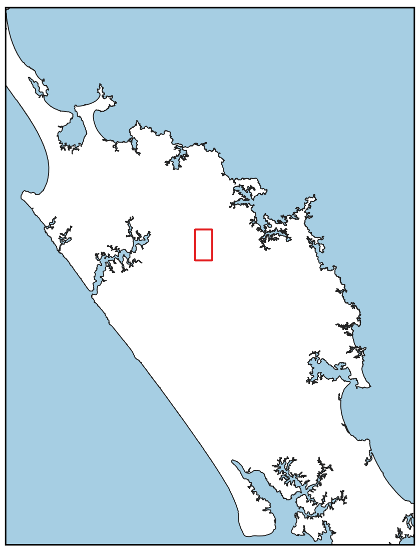
Figure 03.



Map Title:
Consented Water Takes

Project:
Te Ruaotehauhau Stream Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



Legend
- Dam Water Take
- Geothermal Fluid Take
- Surface Water Take
- State Highway
- River / Stream
- Lake
- Reservoir Footprint

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Consented Water Takes
MN-06_Hydrology_Study_Report EL.qgz

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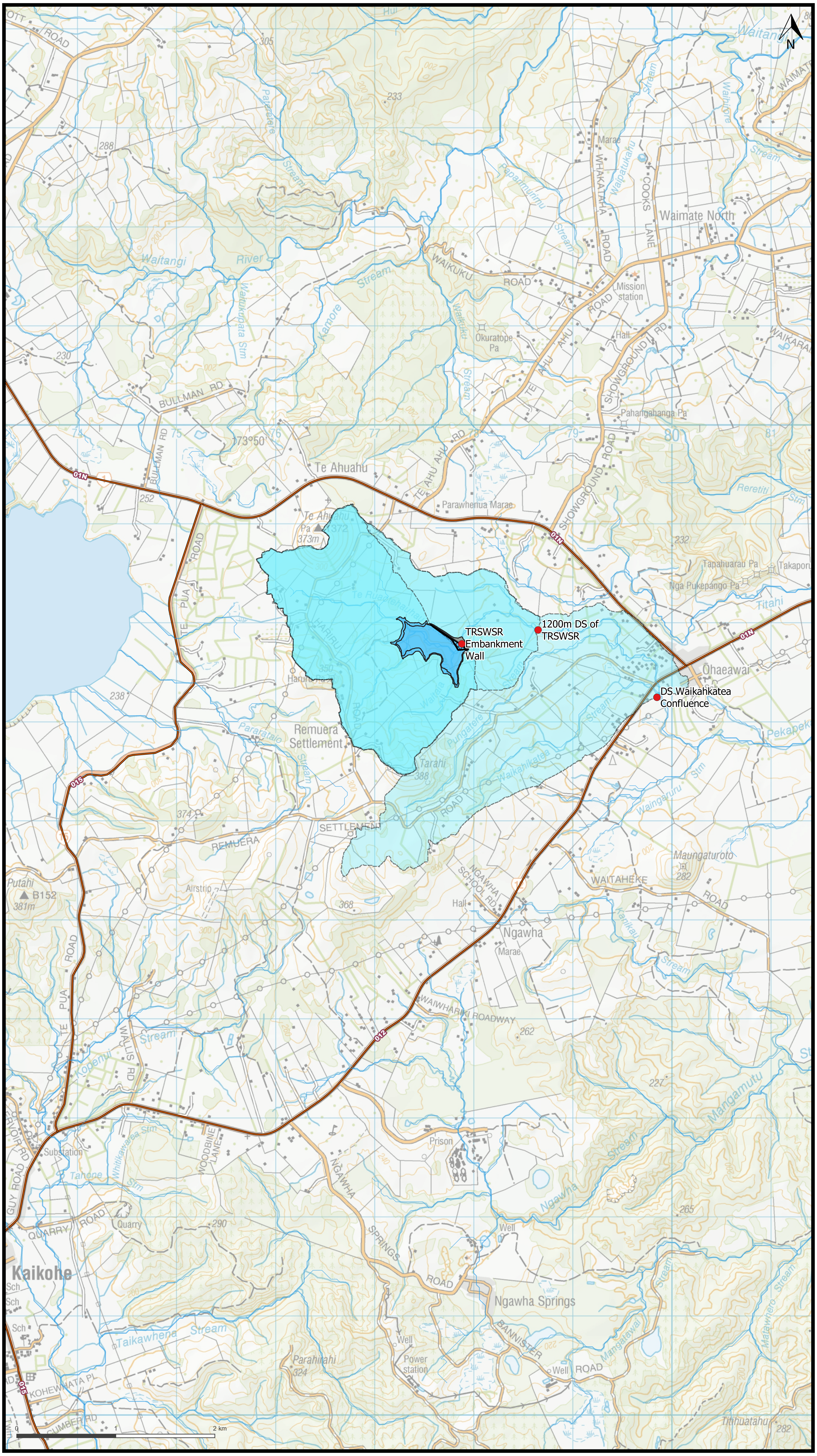
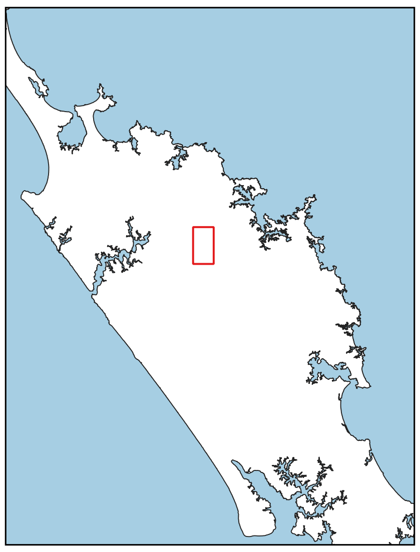
Figure 04.



Map Title:
Representative Assessment Locations

Project:
Te Ruoteahuahu Stream Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



Legend

- Assessment Location
- River / Stream
- State Highway
- Assessment Location Catchment
- Reservoir Footprint

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Assessment Locations
MN-06_Hydrology_Study_Report EL.qgz

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Figure 09.

LEGEND

- 5m CONTOURS
- PROPERTY BOUNDARY
- STREAM CHANNELS
- INUNDATION TO FULL SUPPLY LEVEL (FSL)
- TP1 TEST PIT
- CPT1 CONE PENETROMETER TEST

REFERENCE NOTES:

1. CONTOURS AND AERIAL PHOTO SOURCED FROM 2019 NORTHLAND REGIONAL COUNCIL LIDAR.
2. MAXIMUM INUNDATION AREA ILLUSTRATES THE AREA LIKEY TO BE INNUNDATED ASSUMING A NOMINAL 20m BUFFER.

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FOR CONSENT

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DESIGN	DES CHECK	APPROVED FOR ISSUE
EM		
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MP		
DATE DRAWN		ISSUE DATE
AUG. 2020		05 / 08 / 20

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CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND
PROJECT	DAM MN06 WATER STORAGE AND USE PROJECT
SHEET TITLE	SITE PLAN AND INVESTIGATIONS

ACENZ

ISO 9001 GCS

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