C

APPENDIX C

Hydrology Report – Tonkin & Taylor

REPORT

Tonkin+Taylor

Reconsenting of Motukawa Hydroelectric Power Scheme

Hydrology Report

Prepared for
Trustpower Ltd
Prepared by
Tonkin & Taylor Ltd
Date
November 2021
Job Number
1008726 Phase 100

Note: Since the lodgement of the resource consent applications for the Motukawa Hydro-Electric Power Scheme in November 2021 (being the application to which this technical assessment relates), the proposal by Manawa Energy has been amended to retain the consented maximum water take from the Manganui River as 5.2 m^3/s. The Assessment of Environmental Effects lodged with the resource consent applications has been amended to reflect this change, but the technical assessments associated with the application (including this one) have not been amended. However, all effects on the environment will either be the same or less than previously assessed in the lodged technical assessments.

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1 Introduction

1.1 Context

Trustpower Ltd (TrustPower) owns and operates the Motukawa Hydroelectric Power Scheme (Motukawa HEPS, or "MTK") which is located mid-catchment in the Waitara catchment, between the main stems of the Manganui and Waitara Rivers.

The majority of the current resource consents for the operation of the Scheme were originally granted by Taranaki Regional Council (TRC) on 19 September 2001. Further consents were granted on 27 July 2004 to enable the diversion and use of water for hydroelectric power generation purposes along the Motukawa Race, and on 7 December 2005, to allow water to be abstracted from the Mangaotea Stream to the Motukawa Race. Two older consents for the Mangaotea Aqueduct were granted on 19 August 1999. All 23 resource consents expire on 1 June 2022. Consequently, Trustpower has commenced a process to obtain replacement consents to permit operation of the Scheme for a further term. This report, which is one of a series of technical assessment reports, addresses the hydrological aspects of the Scheme.

1.2 Scope of assessment

The scope of the hydrological assessment includes the following:

i Description of the general hydrological setting of the Motukawa HEPS, including a detailed assessment of the existing flow regime of the Waitara River as well as its major tributary, the Manganui River

ii Description of the existing operational regime of the Motukawa HEPS, including diversion from the Manganui River, Lake Ratapiko levels, and daily flow fluctuations at the Power Station

iii Description of the proposed operational regime of the Motukawa HEPS, including the proposed increase in the maximum take from the Manganui River

iv A summary of the predicted effects of projected climate change on the Manganui River flow regime and Scheme operation

v Description of the hydrological changes resulting from the Scheme and its operation.

1.3 Scheme description

The Motukawa HEPS has a nominal capacity of 5 MW and is orientated around Lake Ratapiko, a man-made lake that was created for water storage and conveyance for hydro-electric generation. The lake is formed by a 14 m high dam (Ratapiko Dam) across the Mako Stream built in 1927.

Most of the inflow (88%) to Lake Ratapiko is sourced from a diversion on the Manganui River that comprises a low (4 m high) concrete weir across the river and a 4.6 km long water race (the Motukawa Race) that discharges to the western end of the lake. The balance of the lake inflow is derived from unnamed tributaries to the lake (8%), minor drainage channels intercepted by the water race (3.5%), and pumped flow from the Mangaotea Stream (<1%)[1]. Water is returned to the Waitara River upstream of the settlement of Tarata, after passing through the power intake at the eastern end of the lake, a 2.8 km long tunnel, a steel penstock, the Motukawa Power Station and tailrace which discharges to the Makara Stream (a minor tributary of the Waitara River). The main components of the Scheme are labelled in Figure 1.1.

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[1] Based on historical operation between October 2009 and December 2020, pumping from the Mangaotea Stream contributed 0.8% of the overall lake inflow volume. On a year-by-year basis, the maximum contribution from Mangaotea Stream was 1.9%, which occurred in 2014. Operation of the pump station ceased in March 2019.

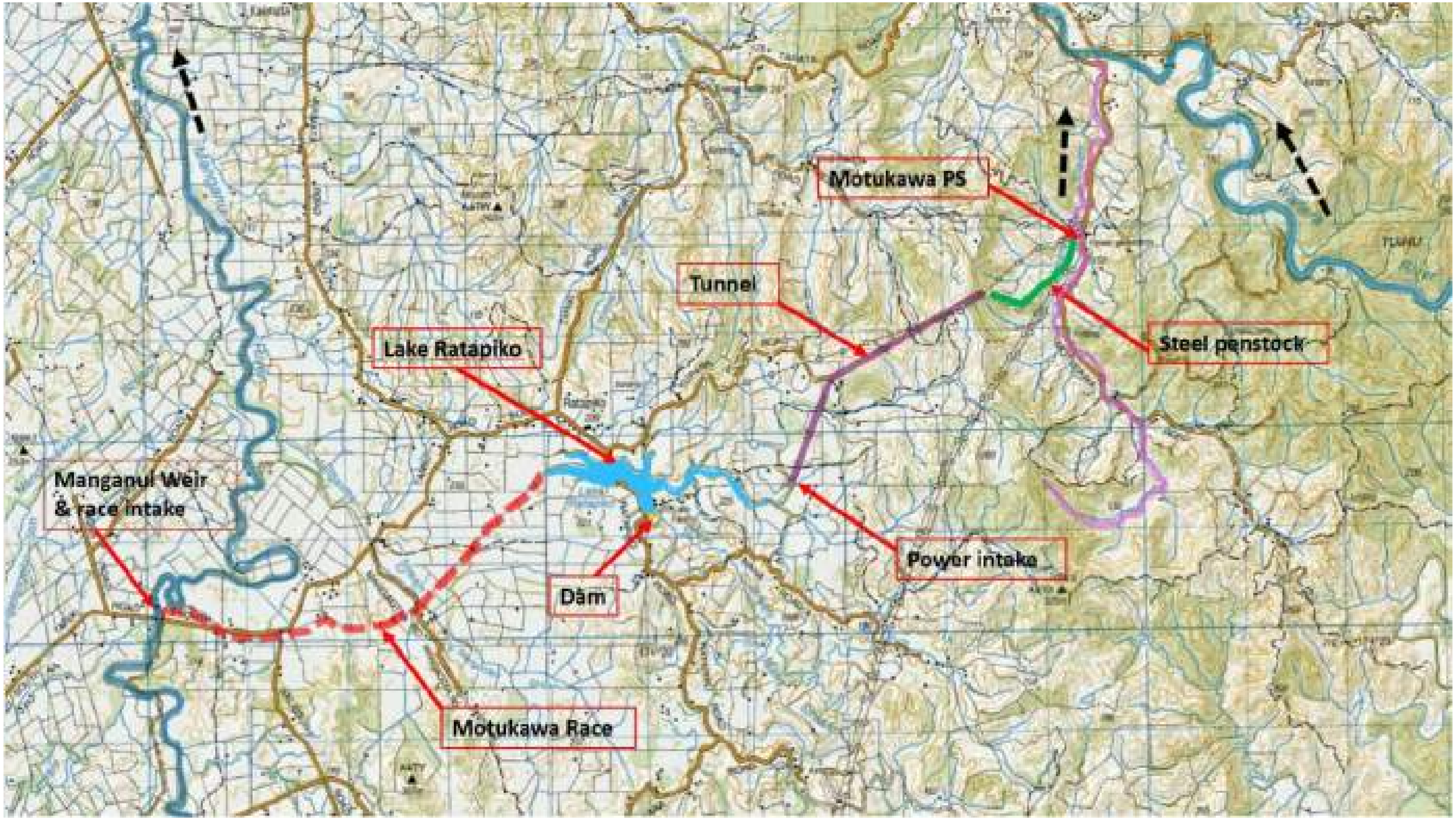


Figure 1.1 Components of the Motukawa HEPS on LINZ's topomap base

A residual flow of at least 400 l/s is maintained in the Manganui River below the intake weir at all times, and this residual flow is provided via fish passes on the left bank (older) and right bank (newer) of the river.

Flow in the residual reach of the Manganui River is incrementally augmented by inflow from the many tributaries downstream of the weir, particularly on the left bank, which drain the slopes of Mount Taranaki. The Manganui River discharges into the Waitara River approximately 25 km downstream of the intake weir.

There is no residual flow, other than spillway discharges and seepage, down the Mako Stream, which was dammed to form Lake Ratapiko. However, the Mako Stream is joined by other tributaries before its flow eventually enters the Waitara River.

1.4 Hydrological nodes

Figure 1.2 shows the full extents of the Manganui and Waitara catchments within which the Motukawa HEPS is located. It also shows the key locations or “hydrological nodes” for potential assessment as well as the five operational flow recording sites in the Waitara catchment. The Manganui River is a major tributary of the Waitara River and flows into the latter about 10 km upstream of Bertrand Road. Below Ratapiko Dam, the Mako Stream flows into the Makara Stream (which is different from the stream with same name at the Power Station) that joins up with the Makino Stream, a comparatively smaller tributary of the Waitara River.

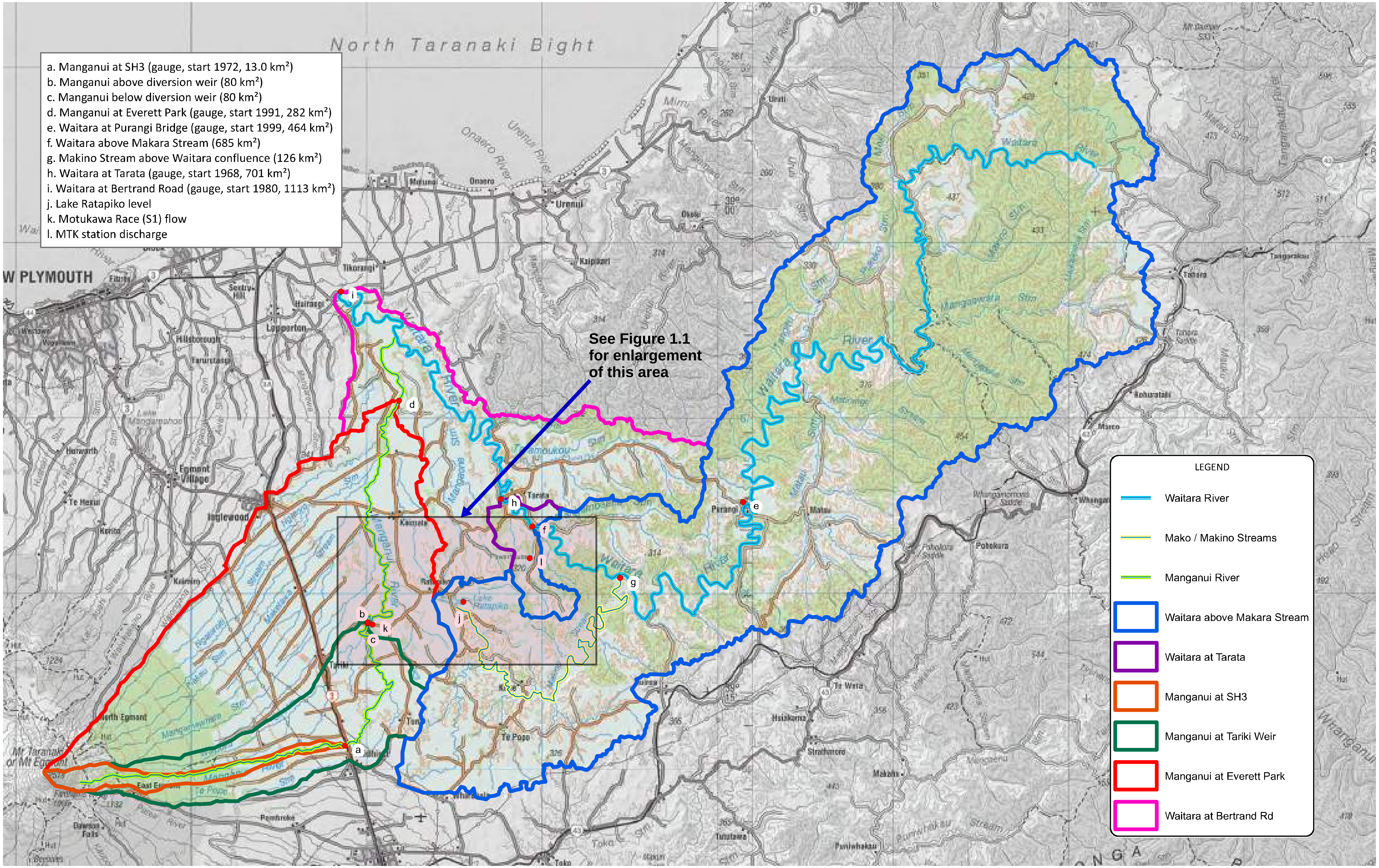
Details of these twelve hydrological nodes, labelled *a.* to *l.* and the rationale for their inclusion, are provided in Table 1.1.

Table 1.1 Description of potential nodal locations for hydrological assessments

	Description	Catchment (km^2)	Reason for selection and record type
a.	Manganui River at SH3	13.0	Long-term gauge with good quality flow record from 1972; indicative of inflow pattern to Manganui Weir
b.	Manganui River above intake weir	80	Manganui River flow upstream of diversion to Motukawa Race (synthetic record)
c.	Manganui River below intake weir	80	Residual river flow in the Manganui River downstream of race diversion (synthetic record)
d.	Manganui River at Everett Park	282	Long-term gauge with flow record from 1991; residual river flow in the lower Manganui River above confluence with Waitara River
e.	Waitara River at Purangi Bridge	464	Gauge with flow record from 1999; analysis not presented because of questionable data reliability in the medium to low flow range
f.	Waitara River above Makara Stream	685	Waitara River flow upstream of MTK power station discharge (synthetic record)
g.	Makino Stream above Waitara confluence	126	The Mako Stream below Lake Ratapiko is a tributary of the Makino Stream; analysis not presented here noting that the dammed catchment (8.5 km^2) is relatively small
h.	Waitara River at Tarata	701	Long-term gauge with good quality flow record from 1968; represents river flow immediately downstream of MTK discharge
i.	Waitara River at Bertrand Road	1113	Long-term gauge with good quality flow record from 1980; represents flow in the lower Waitara River downstream of the confluence with Manganui River; specific reference to this gauge in one MTK consent condition
j.	Lake Ratapiko	12.4 *	Shows lake level operation regime (Trustpower record). (* Area includes local race catchment but excludes Manganui diversion)
k.	Motukawa Race (S1)	N/A	Diverted flow from the Manganui River (Trustpower record)
l.	MTK station discharge	N/A	Outflow from Lake Ratapiko to Makara Stream; shows MTK power station operation regime (Trustpower record)

Of the twelve potential nodal locations in the table above, hydrological information is presented in this report for ten nodes. These comprise of four flow records maintained by TRC or NIWA (nodes *a., d., g.* and *h*., rows in the table shaded blue), three records maintained by Trustpower (nodes *j., k.* and *l.*, rows shaded green), and three synthetic flow records derived from recorded data (nodes *b., c.* and *f*., rows shaded beige).

As noted in the table above, information from the Purangi Bridge flow gauge (node *e.*) was not used principally because of the questionable data reliability in the medium to low flow range. Instead, a synthetic record for node *f.,* the Waitara River above Makara Stream, was created to represent the river flow regime upstream of the Scheme. Node *g.*, the Makino Stream above its confluence with the Waitara River, was not considered further because of the relatively small proportion of its catchment (6.7%) intercepted by the Ratapiko Dam.



a. Manganui at SH3 (gauge, start 1972, 13.0 km²)
b. Manganui above diversion weir (80 km²)
c. Manganui below diversion weir (80 km²)
d. Manganui at Everett Park (gauge, start 1991, 282 km²)
e. Waitara at Purangi Bridge (gauge, start 1999, 464 km²)
f. Waitara above Makara Stream (685 km²)
g. Makino Stream above Waitara confluence (126 km²)
h. Waitara at Tarata (gauge, start 1968, 701 km²)
i. Waitara at Bertrand Road (gauge, start 1980, 1113 km²)
j. Lake Ratapiko level
k. Motukawa Race (S1) flow
l. MTK station discharge

See Figure 1.1 for enlargement of this area

LEGEND

- Waitara River
- Mako / Makino Streams
- Manganui River
- Waitara above Makara Stream
- Waitara at Tarata
- Manganui at SH3
- Manganui at Tariki Weir
- Manganui at Everett Park
- Waitara at Bertrand Rd

Notes:

A3 SCALE 1:200,000

0 2 4 6 8 10 (km)

Location Plan

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APPROVED		
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SCALE (AT A3 SIZE) 1:200,000		
PROJECT No. 1008726.000		

TRUSTPOWER LTD
Motukawa HEPS Hydrology Report
Location Map and Catchment Extents

FIGURE No. Figure 1.2

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2 Catchment characteristics and water resources

2.1 Waitara catchment

Commanding an area of 1,139 km^2, the Waitara catchment is one of the three largest catchments within the Taranaki Region, the others being the Waitotara catchment (1162 km^2) and the Patea catchment (1048 km^2). It drains the north-eastern slopes of Mount Taranaki via its major tributary, the Manganui River (see Section 2.2), and large portions of eastern hill country. Figure 1.2 shows the extents of the Waitara catchment and its sub-catchments.

The source of the Waitara River (main stem) lies in the steep inland hill country of Moki and Makino forests west of Tahora, and initially heads broadly in a south-westerly direction towards central Taranaki. North of Huiroa, the river changes direction and flows generally north-west towards the Tasman Sea, exiting at the coastal town of Waitara. It is joined by the Manganui River about 18 km from the coast.

2.2 Manganui catchment

The Manganui River is the largest tributary of the Waitara River, by catchment area (295 km^2, 26% of Waitara) as well as by flow contribution (about 36% of the mean flow of Waitara). It provides the bulk of water for the Motukawa HEPS through the Manganui Weir and Motukawa Race intake located just downstream of Tariki Road bridge at a point where the river has a catchment area of 80 km^2. Its major tributaries include the Ngatoro Stream (75 km^2), Waitepuke Stream (27 km^2), Mangamawhete Stream (28 km^2) and Waipuku Stream (25 km^2). The Mangaotea Stream (12.3 km^2), from which water has previously been abstracted for the Scheme, is also a tributary of the Manganui River. Figure 1.2 shows the extents of the Manganui catchment.

The headwaters of the Manganui River lie on the north-eastern slopes of Mount Taranaki in Egmont National Park, have elongated catchments like the other mountain streams in the region, and initially drain in an easterly/north-easterly direction before joining the main stem of the Manganui River which flows in a predominantly northerly direction.

The streams coming off the slopes of Mount Taranaki have eroded a dendritic drainage pattern, radiating out from the summit, at elevation 2,518 m above mean sea level. Geology of the ring plain is dominated by past and present volcanic centres, with a large Pouakai ring plain being overlaid by formations arising from the present cone (TRC, 2011). Layers of conglomerates, breccia and tephra have been deposited over lahars and debris flows. The laharic deposits are very mixed and vary from concreted blocks through to uncompacted sands.

A more detailed description of the geology and soils of the Manganui and Waitara catchments is provided in another technical report by Tonkin & Taylor (T+T, 2021) “Lake Ratapiko Sediment Assessment”.

2.3 Rainfall

Heavy rainfall events centred on Egmont National Park are a climatic feature of Taranaki. The main cone and the adjoining ranges are a prominent feature causing and attracting rainfall which may otherwise pass over the surrounding relatively low altitude landscape (TRC, 2011). These geographic features often result in very high rainfall intensities of relatively short duration, resulting in high flood yields in all of the catchments draining onto the ring plain from the Egmont National Park.

Rainfall intensity varies significantly across the Waitara catchment. The eastern headwaters of the Waitara (viz. the Manganui River headwaters) on the slopes of Mount Taranaki are in a mountainous region which is characterised by very high annual rainfall of up to 8,000 mm per annum. Near the coast the mean annual rainfall drops to less than 1,400 mm, illustrating the steepness of the rainfall gradient caused by the orographic influence of Mount Taranaki. The mean annual rainfall in the middle and western parts of the Waitara catchment is comparatively more uniform, ranging generally between 1,800 mm and 2,200 mm.

Based on the recorded mean flow at the Bertrand Road gauge (54.2 m^3/s between 2010 and 2020), the catchment-wide mean annual rainfall for the Waitara catchment is expected to be about 2,200 mm. A catchment-wide mean annual rainfall of about 3,200 mm is estimated for the Manganui River based on the recorded mean flow at Everett Park (19.5 m^3/s).

In a normal year, significant rainfall occurs in every month of the year, with the three months from January to March receiving roughly 30% less rainfall than other months on average. This lower rainfall period coupled with the higher temperatures and evapo-transpiration rates in summer results in a distinct low flow season from January to March in most years.

2.4 Hydrometric data

Hydrometric data fundamental for characterising the hydrological environment are comprised of water level and flow records. Other hydrometric and climatic data such as rainfall, soil moisture, temperature, wind speed and direction, evaporation, and solar radiation are less significant, except to provide background and setting. This is because hydro-electric power schemes such as the Motukawa HEPS have the potential to alter the river flow regime. The Scheme is not expected to have a material effect on other hydrometric variables.

Table 2.1 lists the flow recording sites in the Waitara catchment and the period data that is available. This inventory is based on the national index of hydrological recording sites maintained by NIWA and also includes long-term sites managed by the TRC. For this report, except for the Ngatoro Stream, data for the entire available record at all currently operational sites were obtained, i.e. from the record start date generally up to December 2020 (the last time a data “top-up” was requested from the relevant agency). NIWA’s predecessor previously operated a flow recording station on the Manganui River at Tariki Road (NIWA site no. 39504) between 1962 and 1974. This record was also obtained from NIWA.

It should be noted that the catchment areas shown in this table differ from that shown in Table 1.1 previously. The catchment areas in Table 1.1 are considered more reliable as they are determined from a LINZ digital topographic map layer.

Table 2.1 Flow recording sites in the Waitara catchment as listed in NIWA’s national site index

Number	Sitename	Start date	End date	Recording authority	NZMS260	Catchment (km^2)
39501	Waitara at Tarata	18-Dec-68	current	NIWA	Q19:278271	725
39503	Waitara at Bertrand Rd	7-Feb-80	current	Taranaki Regional Council	Q19:187389	1120
39504	Manganui at Tariki Rd	1-Feb-62	11-Jan-74	NIWA	Q19:202201	80
39506	Motukawa at Tail Race	31-May-72	6-Jan-94	NIWA	Q19:293236	
39508	Manganui at SH3	31-May-72	current	NIWA	Q20:189130	11.3
39509	Ngatoro at Bedford Rd	16-Apr-75	3-Nov-80	NIWA	Q19:123230	9.86
39510	Ngatoro at SH3	18-Jun-75	current	Taranaki Regional Council	Q19:151250	11.6
39511	Maketawa at SH3	13-Oct-80	22-Jan-97	Taranaki Regional Council	Q19:159225	18.7
39545	Ngatoro at Bushline	14-Apr-92	5-Jan-00	Taranaki Regional Council	P20:086194	
39594	Waitara at Mangaoapa Rd	16-May-91	31-Oct-98	Taranaki Regional Council	Q19:408223	
39595	Manganui at Everett Park	13-Jun-91	current	Taranaki Regional Council	Q19:219326	200
39597	Waitara at Purangi Br	11-Feb-99	current	Taranaki Regional Council	Q19:416269	

The longest available flow records are for the Manganui at SH3, with continuous data available from 31 May 1972 (i.e. 48.5 years of data) and for the Waitara at Tarata, with continuous data from 18

December 1968 (i.e. 52 years of data). The other long-term flow recording sites of note are Waitara at Bertrand Road (40.5 years of data) and Manganui at Everett Park (29.5 years of data). Figure 1.2 shows the location of the flow recording sites.

Records from these sites have been analysed to characterise the flow regime of the Manganui and Waitara Rivers. The Manganui at SH3 site is representative of the upper reaches of the Manganui River above the diversion, while the Everett Park site represents the lower reach of the Manganui River which is subject to the influence of the Scheme (viz. the residual river). Both the Tarata and Bertrand Road gauges on the Waitara River are downstream of the Power Station tailrace and the recorded flows reflect the diurnal generation pattern of the Scheme.

In addition to the listed water level recorders in Table 2.1, Trustpower operates several other recorders as part of its SCADA (supervisory control and data acquisition) and operational control systems for the Motukawa HEPS. Of relevance are the water level and flow recorders at the Manganui Weir, Motukawa Race, Lake Ratapiko and the Motukawa Power Station. Details of the electronic records supplied by Trustpower for the current assessment are listed in Table 2.2.

Table 2.2 Selected time-series data for the Motukawa Scheme provided by Trustpower

Variable	Description	Record Start Date	Comment
MTK_H15LT_006	Lake Ratapiko level	17-Jul-2001	Lake level record
MTK_STN_LOAD	Motukawa Power Station discharge	12-Jul-2001	MW output converted into flow
MTK_H16PEN_FLOW	Motukawa penstock flow	31-Oct-2001	Penstock flow measured by ultrasonic sensor. Gap from Dec-2002 to Mar-2008
MTK_H14LT_WEIRL	Manganui Weir water level	2-Feb-2005	Full range flood levels only after 10-Oct-2009
MTK_S1RACE_Q	Motukawa Race flow (S1)	12-Jul-2001	Measured flow in Motukawa Race at 1300 m downstream of the race inlet
MTK_H14T_FPQ	Total fish pass flow at Manganui Weir	14-Dec-2007	Combined left bank and right bank (fish pass) residual flow
MTK_MGP	Pumped flow from Mangaotea Stream	30-Oct-2008	Flow pumped from Big Mangaotea Stream into Motukawa Race. Pumps last used in March 2018
MTK_MGP_S_TQ	Total residual below Mangaotea Pump	30-Oct-2008	Combined flow in the Big and Little Mangaotea streams below the pump station

The above records have not been generally audited or maintained to the same standards as adopted by TRC and NIWA, and contain periods of missing data (often as unmarked gaps) and drop-outs.

Furthermore, all flow records contain a certain amount of intrinsic uncertainty, and this should be recognised when making interpretations from flow records. A comprehensive audit of the completeness and reliability of individual records has not been undertaken in this study. Nevertheless, it is understood that TRC and NIWA have an objective to maintain their river flow records to particular quality standards and have well-established procedures for auditing recorded flows.

2.5 Water use in the catchment

The list of all current consents (as at August 2019) for taking, diverting or damming surface water in the Waitara catchment is presented in Table 2.3. Figure 2.1 shows the location of these consents in the catchment.

Water take from the streams and rivers in the catchment is dominated by the Motukawa HEPS, which has consents to divert up to 5,200 l/s from the Manganui River and abstract up to 450 l/s from the Mangaotea Stream (a tributary of the Manganui River) into the Motukawa Race. Water abstracted by the Scheme is returned to the Waitara River after passing through the Power Station or the spillway at Ratapiko Dam. Further details of Trustpower's water use associated with the Scheme, including the conditions of consent that govern the takes, are provided in Section 3.

Excluding the consents for the Motukawa HEPS, the sum of the consented takes in the Waitara catchment is 691 l/s (instantaneous take rate), of which 68% (472 l/s) is Methanex Limited's take from the lower Waitara River for its methanol plants. Other energy sector users, Nova Energy Ltd, Todd Enery Ltd, TAG Oil (NZ) Ltd, and Greymouth Petroleum Ltd, have a combined take of 95.5 l/s (14%). Municipal water supply use by New Plymouth District Council (NPDC) and Stratford District Council accounts for another 10% (66 l/s). On a volumetric basis, the sum of all these takes (excluding Trustpower's consents) amount to a consented maximum of 52,644 m^3/day.

There are two relatively small consented takes upstream of the Scheme's intake at the Manganui Weir, viz. Kathdan Trust Ltd (13 l/s) and Stratford District Council (5 l/s). There are no current consented takes on the Waitara River upstream of the Scheme's tailrace discharge (enters above Tarata).

Table 2.3 Surface water takes in the Waitara catchment

Consent holder	Stated location	Stated purpose	Consented quantity	
			Rate	Volume
Methanex Motunui Ltd	Waitara Valley Intake Structure, Mamaku Road and Motunui Intake structure, East Bank, Waitara River	Petrochemical processing: to take water from two sites on the Waitara River for use at the Waitara Valley methanol plant	83.3 l/s	300 m^3/hr
Methanex Motunui Ltd	Motunui Intake Structure, East Bank, Waitara River	Petrochemical processing: To take water from the Waitara River for use at the Motunui plant	388.9 l/s	1400 m^3/hr
Kathdan Trust Limited	York Road, Midhirst	Dairy farm: to take, divert and use water from an unnamed tributary of the Waipuku Stream a tributary of the Manganui River	13 l/s	1080 m^3/day
Stratford District Council	Mountain Road, Midhirst	Municipal water supply: to take water from the Te Popo Stream a tributary of the Manganui River for Midhirst community public water supply purposes	5 l/s	90,000 m^3/year
Nova Energy Limited	McKee Oil Field, Bristol Road, Inglewood	Petrochemical processing: to take water from the Mangaone Stream for use in a gas fired Power Station	36 l/s	12,000 m^3/week
Trustpower Limited	Manganui River, Downstream of Tariki Road Bridge, Inglewood	Power generation – hydro: to take and use up to 5200 litres/second of water from the Manganui River for hydroelectric power generation purposes	5200 l/s	-
New Plymouth District Council	Dudley Road, Inglewood	Municipal water supply: to take water as a contingency supply and for farm supply purposes from an intake weir in the Ngatoro Stream	5 l/s	400 m^3/day & 5000 m^3/day contingency
Waitara Golf Club Inc	Mouatt Street, Waitara	Recreational: to take water from an unnamed tributary of the Waitara River for golf course irrigation purposes	5 l/s	70 m3/day
New Plymouth District Council	Dudley Road, Inglewood	Municipal water supply: to take and use water from the Ngatoro Stream a tributary of the Manganui River, for Inglewood urban water supply	56 l/s	4850 m^3/day
Trustpower Limited	Lake Ratapiko, Ratapiko Road, Ratapiko, Inglewood	Power generation - hydro: to take and use up to 7787 litres/second of water from Lake Ratapiko for hydroelectric power generation purposes	7787 l/s	-

Consent holder	Stated location	Stated purpose	Consented quantity	
			Rate	Volume
Trustpower Limited	Lake Ratapiko, Ratapiko Road, Ratapiko, Inglewood	Power generation - hydro: to take and use water from the Mangaotea Stream, a tributary of the Manganui River, for hydroelectric power generation purposes	450 l/s	38,880 m^3/day
JW & MT Hamblyn Family Trusts	107 Faull Road, Tikorangi	To take and use water from the Waitara River for pasture irrigation purposes	27 l/s	2098 m^3/day
Estate Ian Mantey Family Trust & Sally Mantey Family Trust	Mountain Road, Tariki	Dairy farm: to take and use water from the Mangatengehu and Mangamawhete Streams, both tributaries of the Manganui River for pasture irrigation	12 l/s	1036 m^3/day
Todd Energy Limited	Mangahewa-D wellsite, Rimutauteka Road, Inglewood [Property owner: KV & SJ Collins]	Petrochemical processing: to take water from the Manganui River for wellsite and well drilling activities during hydrocarbon exploration and production operations at the Mangahewa-D wellsite	25 l/s	100 m^3/day
Todd Energy Limited	Mystone-A wellsite, Rimutauteka Road, Inglewood [Property owner: NB & HR Dunlop]	Petrochemical processing: to take water from the Manganui River for wellsite and well drilling activities during hydrocarbon exploration and production operations at the Mystone-A wellsite	25 l/s	100 m^3/day
TAG Oil (NZ) Limited	Sidewinder wellsite, 323 Upper Durham Road, Inglewood [Property owner: B.F.F Limited]	Hydrocarbon processing: to take and use water from the Piakau Stream for hydrocarbon exploration activities at the Sidewinder wellsite	5 l/s	350 m^3/week
Greymouth Petroleum Limited	Ngatoro-G wellsite, Bedford Road, Inglewood [Property owner: RJ & GW Moffitt]	Petrochemical processing: to take water from the Ngatoronui Stream and an unnamed tributary of the Ngatoronui Stream for wellsite and well drilling during hydrocarbon exploration and production activities at the Ngatoro-G wellsite	4.5 l/s	100 m^3/week

LEGEND

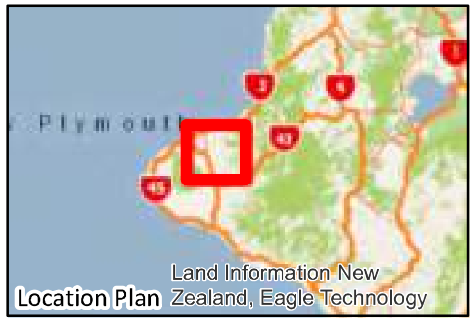
- ● Flow measurement locations

Water Take - Volume (l/s)

- ● less than 50
- ● 50 - 500
- ● 500 - 1000
- ● 5000 - 10000
- 🟩 Surface Water Zone: Waitara

A3 SCALE: 1:130,000

0 1 2 3 4 5 (km)



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Notes:

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ARCFILE
20210716_Waiwhakaiho Waitara

SCALE (AT A3 SIZE)
1:130,000

PROJECT No.
1008776

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

Waitara Catchment

Surface Water Takes and
Flow Measurement Locations

Figure 2.1

2.6 Manganui River flows

2.6.1 Derivation of Manganui River flows at the intake weir

The flow at the Manganui Weir is not currently monitored and has not been since 1974. As noted earlier, there is a 12-year flow record for this location (Site No. 39504, Manganui at Tariki Road) from January 1962 to January 1974. However, to understand the hydrological alterations caused by the Motukawa HEPS it is necessary to derive a contemporary flow record for the Manganui Weir that corresponds with the current operation of the Scheme.

Two methods were trialled to generate such a synthetic record:

A. By correlating the recorded flows at Tariki Road (Site No. 39504) and SH3 (Site No. 39508)
B. By reconstituting the individually recorded flow components at the weir being the race flow, weir overflow and the fish pass flows.

Method A. Correlation of Tariki Road and SH3 flows

The flow recording site at SH3 (Site No. 39508) is located about 14.5 km upstream of the weir where the catchment area (13.0 km^2) is one sixth that at the weir (80 km^2). The former flow recording site at Tariki Road (Site No. 39504) was apparently located at the Manganui intake weir. Flows at SH3 have been monitored from 31 May 1972, thus there is an overlap of about 19 months between this record and the Tariki Road record. Figure 2.2 shows the strong correlation ($R^2 > 0.82$) in the hourly flows recorded at the two sites, with the Tariki Road flows offset (lagged) by two hours.

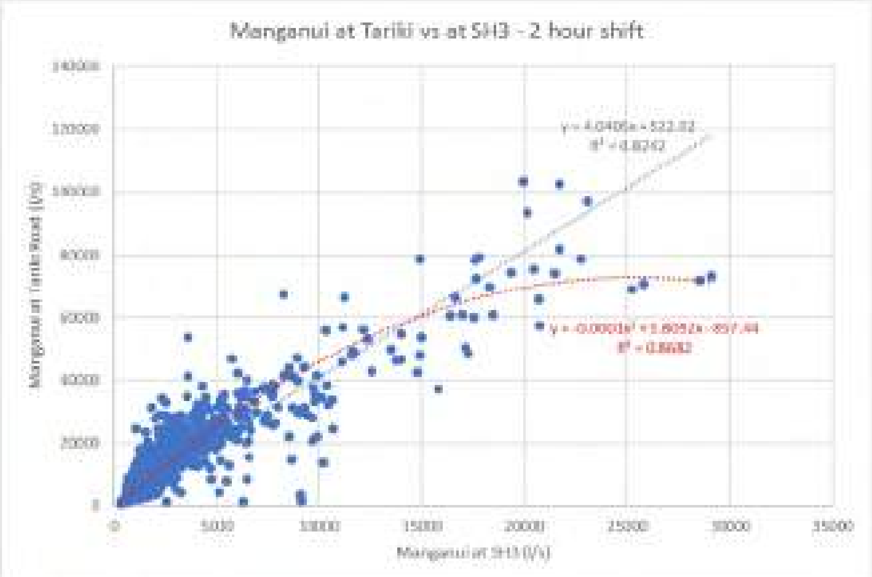

Figure 2.2 Correlation of hourly Tariki Road and SH3 flows (the latter occurring 2 hours earlier)

On the strength of this correlation a synthetic flow record for Tariki Road from 1972 to 2020 was generated using a vector transform approach. Figure 2.3 provides a comparison of the recorded and synthetic flow hydrographs at Tariki Road (equivalently, Manganui Weir). However, comparison of the mean flow from this synthetic record against both Method B. below (recombined weir inflow record) and a rainfall-based catchment water balance (see Section 3.2) indicated a 16% overestimation. Even after adjusting the transformation parameters (within reasonable bounds that is), an overestimation of about 7% remained. The reasons for this are unclear and are likely related to errors in the stage-discharge rating curve in the Tariki Road record and/or the fact that the short overlapping period was a very dry period (67% of the long-term mean flow at SH3) and not sufficiently representative for projection. Therefore, this method was not adopted.

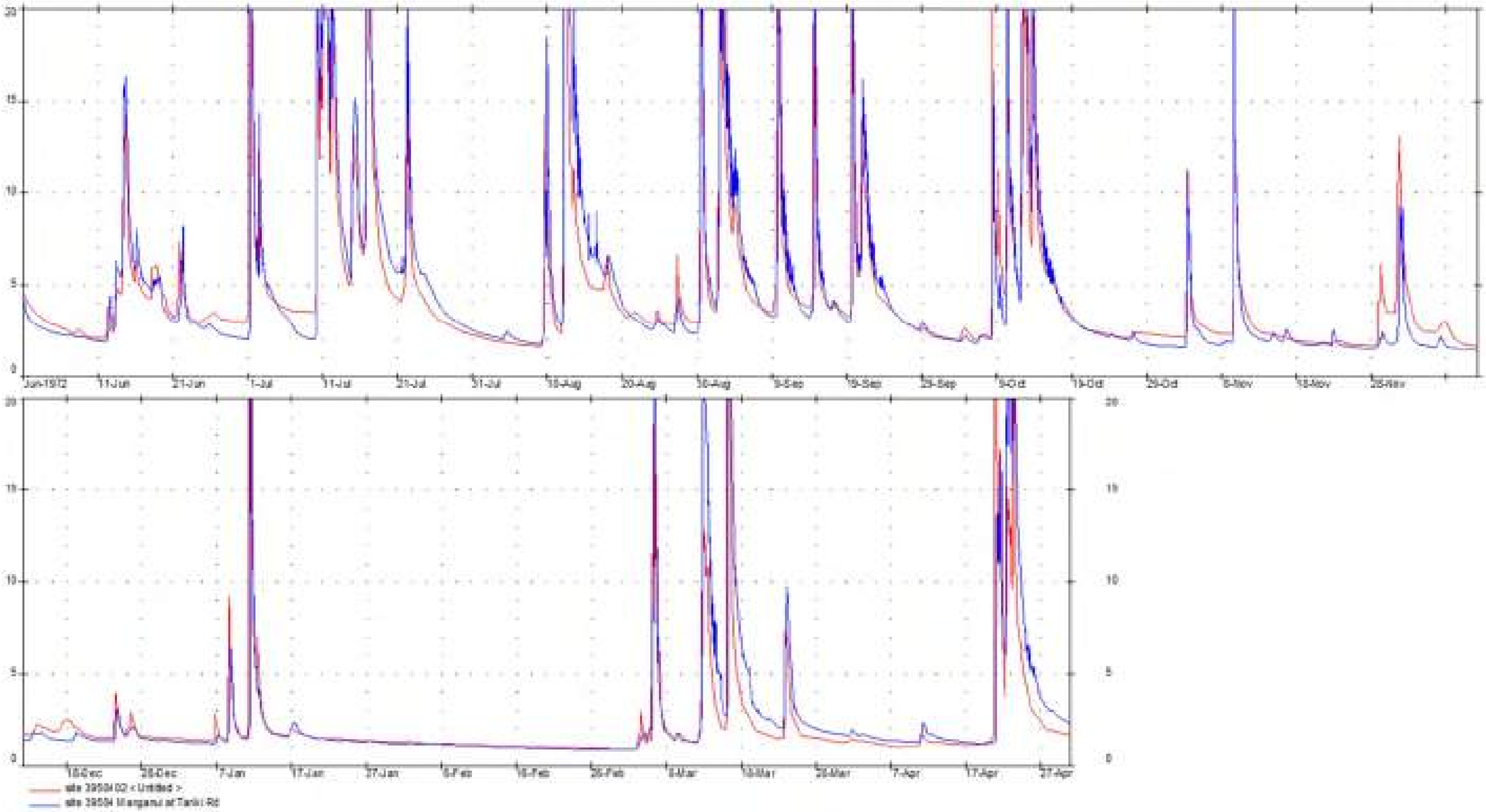

Figure 2.3 *Comparison of recorded (blue trace) and synthetic (red trace) flow hydrographs for Manganui at Tariki Road, the latter derived from Manganui at SH3 data, June 1972 to April 1973*

Nevertheless, this synthetic record provided a very useful check on the hydrographs generated using Method B (viz. coherence in terms of both magnitude and timing of flow events).

Method B. Reconstituting flow components at the weir

Inflow to the weir may be back-calculated by using the principle of mass conservation, that is, the inflow can be computed as:

Inflow = Sum of Outflows + Rate of Change of Pond Storage
where
Sum of outflows = Weir Overflow + Combined L/R Residual Flow + Motukawa Race Flow

The storage impounded by the Manganui Weir is relatively small, being about 35 m wide and 500 m long (exposed riffles can be seen in satellite imagery about 500 m upstream of the weir). The operating water level range at the weir is very small (generally less than 0.2 m when not in flood). Therefore, the weir operates as a true "run-of-river" and the small changes in the pond storage are negligible when hourly or longer averaging intervals are used to back-calculate inflow. In generating this "reconstituted" weir inflow record, it was necessary to rectify or edit out obvious anomalies in the residual flow record and the Motukawa Race flow record.

A stage-discharge rating curve for the weir was calculated from a historical drawing by Taranaki Electric Power Board of the weir profile (ogee-crested with design head of about 1.83 m and non-negligible approach velocity) and a measured weir length of 34 m, with a crest level of RL 210.82 m. Weir overflows were computed by applying the rating curve to the recorded water levels at the weir.

Mean flow from the reconstituted inflow record agreed well with the catchment water balance (see Section 3.2). The reconstituted inflow hydrograph was found to be very coherent with the synthetic flow record from Method A. Subsequent water balance analyses and hydrological assessments are based on this reconstituted inflow record.

Appendix A presents the time-series plot of the entire reconstituted inflow record for the Manganui Weir. The earliest start date of the record, 10 October 2009, is constrained by the availability of the full range weir water level record. Prior to this date (February 2005 to October 2009) levels higher than 0.8 m above the weir crest were not recorded.

2.6.2 Manganui River flows and seasonality

Appendix B presents time-series plots of the entire flow record for the two current long-term flow recording stations on the Manganui River, i.e. at SH3 (Site No. 39504) and at Everett Park (Site No. 39595), and also for the defunct Tariki Road station (Site No. 39504).

Figures 2.4 and 2.5 are plots of the superimposed flow records for three locations on the Manganui River (SH3, Manganui Weir and Everett Park) for the period 2009 to 2020, which is the period used for the Motukawa HEPS water balance assessment (as described in Section 3.2). As expected, all three records are closely correlated in terms of timing and relative magnitude of floods and freshes.

The following should be noted:

- The recorded flows at Everett Park are affected by the diversion of Manganui River flows into the Motukawa Race. This is discussed in more detail in Section 3
- Unlike the SH3 and Everett Park records, flow data for the Manganui Weir is synthetic, derived by reconstituting the recorded flow components at the weir (as outlined earlier).

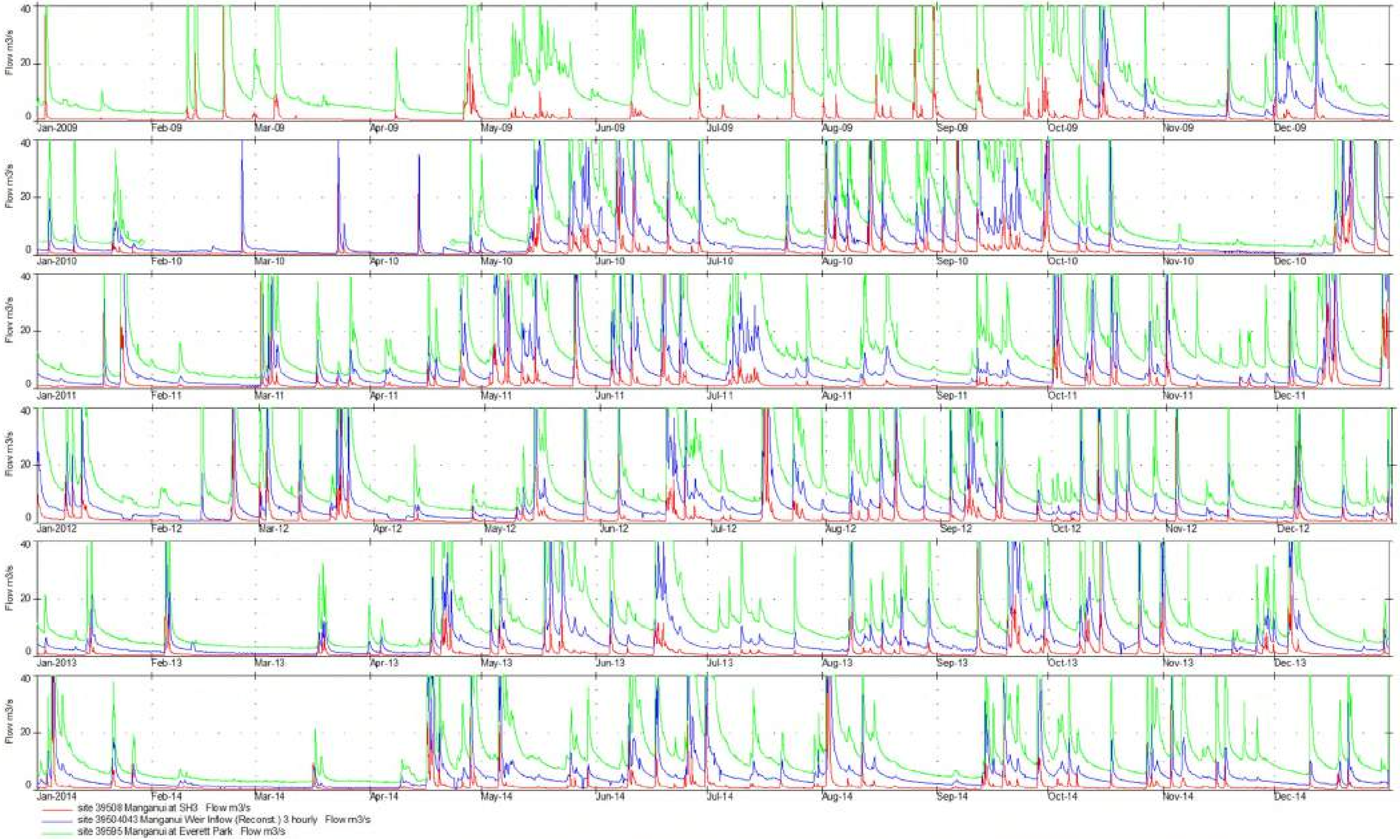

Figure 2.4 Manganui River flow time series at SH3 (red hydrograph), Manganui Weir (blue hydrograph) and Everett Park (green hydrograph) from 2009 to 2014

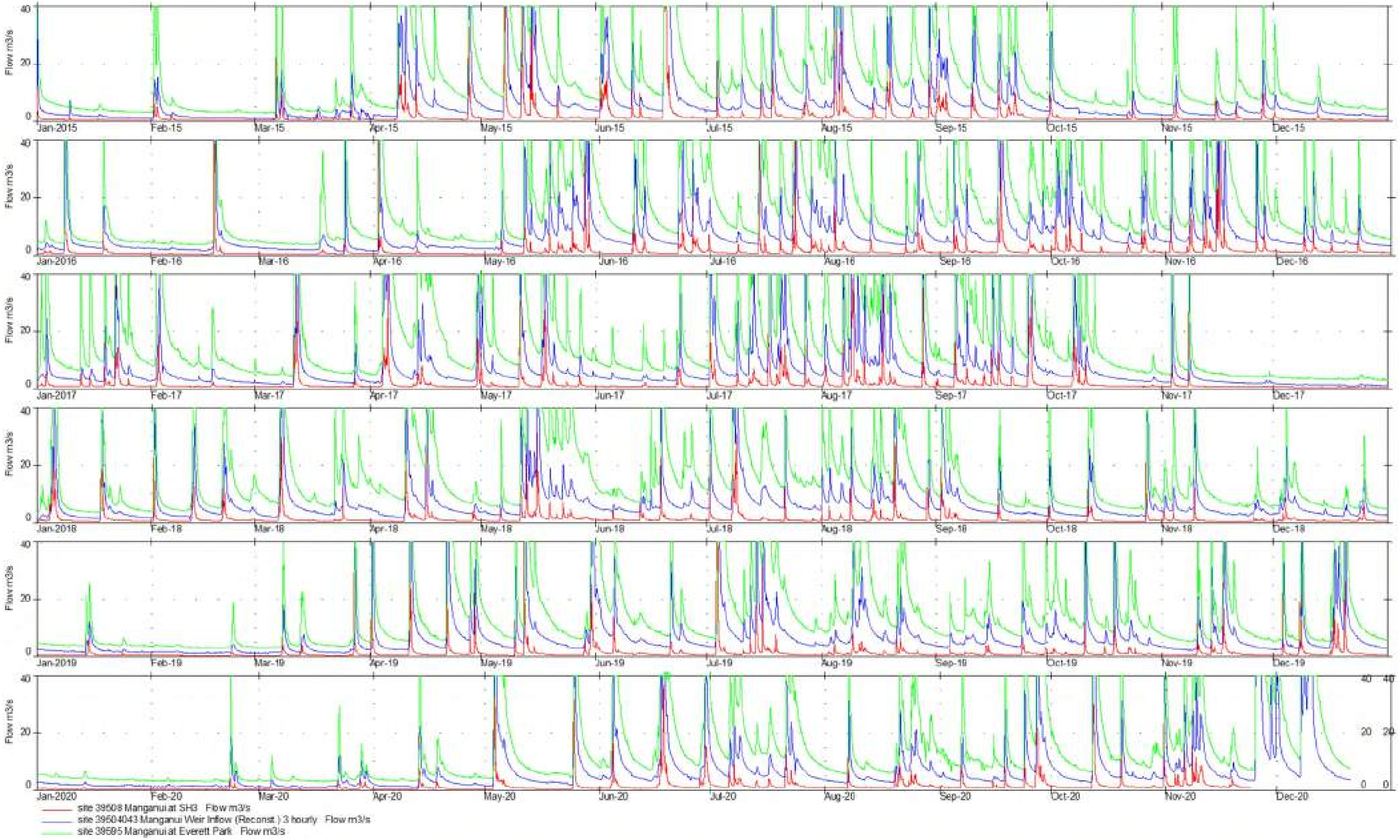

Figure 2.5 Manganui River flow time series at SH3 (red hydrograph), Manganui Weir (blue hydrograph) and Everett Park (green hydrograph) from 2015 to 2020

Tables 2.4, 2.5 and 2.6 provide tabulations of the mean monthly flows at SH3, Manganui Weir and Everett Park respectively for their entire available records. Figure 2.6 is a histogram plot of the monthly mean flow (mean flow for a particular month averaged across all years) for all three sites for their overlapping period (2010 to 2020), which shows the seasonal pattern in the flow behaviour.

Table 2.4 Manganui River at SH3 mean monthly flows for full record 1972 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Manganui at SH3 (Node a): Mean monthly river flow (m^3/s)												
1972	-	-	-	-	-	0.86	1.72	1.20	1.34	1.03	0.75	0.66	-
1973	0.65	0.40	0.80	0.76	1.22	1.54	0.72	1.86	1.56	1.00	1.48	0.75	1.06
1974	0.52	0.59	0.44	1.68	1.22	0.89	4.02	1.76	1.82	2.54	1.07	0.92	1.46
1975	0.57	0.53	1.42	1.51	1.87	1.46	1.35	2.13	1.34	1.75	0.98	0.75	1.31
1976	2.02	1.24	0.83	0.89	1.51	2.62	1.72	1.68	1.22	1.18	1.23	1.67	1.48
1977	1.06	1.05	0.67	1.04	2.30	2.20	2.07	1.84	1.81	1.76	1.81	1.17	1.57
1978	0.57	0.47	0.53	1.31	2.48	1.33	2.50	1.29	2.05	1.72	1.33	0.93	1.38
1979	0.60	1.31	1.45	1.91	2.61	0.89	2.08	1.40	1.56	2.28	1.63	1.78	1.63
1980	2.24	1.02	2.07	1.72	1.34	2.40	1.77	1.63	1.82	1.21	1.25	1.05	1.63
1981	0.75	0.53	1.33	1.01	1.03	2.27	1.78	1.45	1.45	2.09	1.69	1.38	1.40
1982	0.75	0.86	0.97	0.82	1.50	1.83	0.96	0.67	2.03	0.84	0.96	2.77	1.25
1983	1.12	0.61	0.51	2.16	1.85	1.07	1.57	1.65	1.97	2.31	2.27	1.59	1.56
1984	0.94	0.76	1.44	0.79	1.18	0.95	2.72	1.34	0.85	1.11	1.30	1.50	1.24
1985	1.57	0.60	0.91	1.29	0.74	2.26	2.20	1.68	1.37	0.98	1.33	2.00	1.42
1986	3.02	1.99	0.90	1.28	1.70	1.42	1.81	2.35	2.02	1.72	0.80	0.89	1.66
1987	1.00	0.62	2.00	1.79	1.97	1.35	0.75	1.61	1.46	2.19	1.10	1.67	1.47
1988	0.77	0.79	1.33	0.66	1.73	1.51	2.48	2.21	2.06	2.36	1.67	1.18	1.57
1989	1.38	1.65	1.22	1.31	1.33	2.99	2.31	1.10	1.00	2.48	1.58	1.37	1.64
1990	1.73	0.66	3.41	1.48	1.53	1.36	1.65	2.79	1.12	1.88	2.25	0.82	1.73
1991	1.59	1.36	0.69	1.87	0.71	1.13	1.48	3.20	1.27	1.80	0.96	0.90	1.41
1992	1.07	1.77	1.27	0.61	1.15	0.97	2.16	2.56	1.32	2.68	1.12	1.92	1.55
1993	1.07	0.75	1.01	1.14	2.74	2.38	0.70	0.97	1.56	1.53	1.10	0.82	1.32
1994	0.76	0.67	1.30	0.82	1.40	2.93	1.45	2.06	1.80	1.22	3.35	0.99	1.56
1995	1.03	1.54	1.67	3.04	1.28	1.81	1.74	1.86	2.21	2.20	1.76	1.41	1.79
1996	1.51	1.35	1.12	2.04	1.34	1.46	2.24	2.10	2.27	2.35	1.65	1.95	1.78
1997	1.13	0.81	1.02	1.04	0.78	1.51	1.18	1.63	1.16	2.10	1.16	2.23	1.32
1998	1.36	1.40	1.29	1.11	1.38	1.99	5.43	1.61	2.78	7.55	1.70	1.55	2.44
1999	1.82	0.94	1.12	1.18	2.73	1.95	1.68	2.25	1.49	1.32	2.88	1.81	1.77
2000	2.10	0.78	0.52	1.81	2.05	1.60	1.42	1.43	2.36	2.92	0.74	1.07	1.57
2001	0.59	0.55	0.51	0.54	1.32	1.49	1.28	2.08	0.89	2.41	2.50	2.86	1.43
2002	1.08	1.38	1.00	0.87	1.37	2.43	1.58	1.93	2.29	1.23	1.01	1.88	1.51
2003	0.60	0.41	0.91	0.89	1.92	2.41	1.66	1.03	2.94	2.64	1.32	1.33	1.51
2004	1.30	5.61	1.41	1.59	1.77	3.02	1.83	1.70	2.49	1.80	1.01	1.20	2.04
2005	1.40	0.79	1.13	0.64	2.15	1.45	1.95	0.85	1.06	1.53	0.53	1.13	1.22
2006	1.11	0.56	0.60	1.01	1.07	1.46	1.88	2.24	0.83	1.63	3.05	1.21	1.39
2007	0.96	0.56	0.74	0.60	1.01	1.57	2.23	1.51	0.92	2.13	0.66	0.89	1.15
2008	0.57	0.52	0.93	1.66	1.15	1.24	3.52	2.01	1.21	2.32	1.87	1.48	1.55
2009	0.92	1.59	1.05	1.56	1.41	1.29	1.72	2.61	2.06	1.95	0.90	1.20	1.52
2010	0.89	0.65	0.65	0.71	2.06	2.67	0.91	3.12	3.95	1.57	0.65	2.63	1.71
2011	1.70	0.75	1.64	1.33	3.05	2.63	1.79	1.08	1.04	2.89	1.40	3.73	1.93
2012	2.11	1.69	2.41	0.82	1.90	2.12	2.76	1.64	2.23	1.78	1.04	1.36	1.83
2013	0.90	1.30	0.74	1.51	1.87	1.82	0.90	1.43	2.63	2.74	1.29	1.62	1.56
2014	1.79	0.67	0.62	2.11	1.46	2.55	1.19	2.85	1.88	1.45	1.33	1.12	1.59
2015	0.68	0.75	0.98	2.40	3.13	4.11	2.16	3.06	2.55	1.09	1.15	0.76	1.90
2016	1.14	1.28	0.76	0.89	1.85	1.67	2.08	1.55	2.29	1.79	3.12	1.45	1.65
2017	1.82	1.19	1.63	2.18	2.16	1.04	3.00	3.21	2.91	1.63	1.17	0.63	1.89
2018	1.85	1.66	1.47	1.71	2.30	1.48	2.03	1.82	1.35	1.07	0.96	1.02	1.56
2019	0.71	0.53	0.87	1.97	1.71	1.40	2.35	1.40	1.03	1.35	1.34	1.82	1.38
2020	0.56	0.55	0.61	0.75	1.86	2.47	1.90	1.64	2.24	2.14	3.51	2.49	1.73
Minimum	0.52	0.40	0.44	0.54	0.71	0.86	0.70	0.67	0.83	0.84	0.53	0.63	1.06
Average	1.20	1.04	1.12	1.33	1.69	1.82	1.92	1.84	1.77	1.94	1.48	1.46	1.56
Maximum	3.02	5.61	3.41	3.04	3.13	4.11	5.43	3.21	3.95	7.55	3.51	3.73	2.44

Table 2.5 Manganui Weir mean monthly inflows for period 2009 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Manganui River above Intake Weir (Node b): Mean monthly flow (m^3/s)												
2009	-	-	-	-	-	-	-	-	-	-	3.23	6.58	-
2010	2.97	2.32	1.84	1.57	8.81	11.32	3.18	11.40	14.82	6.01	1.58	8.16	6.18
2011	6.02	2.05	5.29	4.81	12.26	11.01	8.13	4.56	3.80	10.91	4.73	11.48	7.14
2012	6.45	4.23	8.05	2.42	6.45	8.53	12.44	7.90	8.67	6.95	3.95	4.22	6.71
2013	3.20	3.41	1.68	4.86	8.90	8.12	3.82	5.86	11.11	9.99	5.24	5.85	6.01
2014	6.39	1.71	1.20	6.55	6.04	9.63	5.50	11.51	6.96	5.54	5.56	3.34	5.85
2015	2.44	2.12	2.57	8.88	12.83	15.90	7.13	11.88	9.26	4.02	3.85	3.21	7.02
2016	4.58	4.67	2.80	3.89	10.63	9.04	11.24	8.49	11.15	9.24	12.76	5.19	7.81
2017	5.80	4.42	4.92	9.97	9.36	4.25	13.55	14.77	12.66	5.68	3.77	1.51	7.58
2018	4.92	5.87	6.92	7.24	10.47	6.90	11.11	10.45	6.28	4.97	4.99	4.54	7.07
2019	2.32	1.63	2.93	9.61	8.56	7.77	13.34	8.51	5.76	7.85	5.91	7.97	6.88
2020	1.94	1.96	2.10	2.88	8.85	11.09	8.53	6.50	8.93	8.21	14.67	13.27	7.42
Minimum	1.94	1.63	1.20	1.57	6.04	4.25	3.18	4.56	3.80	4.02	1.58	1.51	5.85
Average	4.27	3.13	3.66	5.70	9.38	9.41	8.91	9.26	9.04	7.21	5.85	6.28	6.88
Maximum	6.45	5.87	8.05	9.97	12.83	15.90	13.55	14.77	14.82	10.91	14.67	13.27	7.81

Table 2.6 Manganui River at Everett Park mean monthly inflows for period 1991 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Manganui River at Everett Park (Node d): Mean monthly river flow (m^3/s)												
1991	-	-	-	-	-	-	24.03	44.20	12.05	19.78	7.77	7.80	-
1992	17.11	31.54	15.82	6.84	13.69	11.45	31.01	34.90	17.83	28.64	8.05	22.23	19.96
1993	8.96	3.92	6.68	12.14	33.23	24.94	5.31	9.19	15.45	17.94	12.38	7.78	13.20
1994	6.69	5.19	13.61	11.20	19.24	38.25	19.77	30.37	21.32	15.40	49.18	7.03	19.78
1995	7.97	18.16	19.65	41.87	11.97	22.67	23.83	25.60	29.23	27.05	22.88	11.23	21.79
1996	11.07	16.90	9.22	31.58	16.02	18.43	32.88	24.65	27.91	26.42	18.49	24.33	21.49
1997	8.11	6.69	8.58	8.86	8.54	14.80	11.62	16.14	15.07	30.06	14.59	28.39	14.36
1998	11.66	18.16	10.78	10.55	20.22	25.19	64.50	12.44	29.23	107.68	13.89	13.60	28.33
1999	13.22	6.49	12.47	9.82	33.94	29.10	19.07	27.54	16.38	14.54	35.81	15.95	19.60
2000	18.02	7.01	3.48	15.69	25.16	21.97	15.02	13.76	32.88	45.85	6.97	11.43	18.15
2001	6.22	4.27	4.34	4.65	14.53	19.51	17.33	27.96	8.06	27.17	34.68	32.67	16.89
2002	12.12	14.36	12.17	7.38	14.37	32.57	21.15	22.51	30.77	13.13	11.82	18.75	17.58
2003	5.07	3.26	7.04	6.92	22.78	27.00	25.66	9.01	39.93	33.89	15.99	20.53	18.16
2004	11.56	71.22	17.92	13.95	17.28	36.96	20.89	19.83	28.73	24.29	8.06	10.38	23.18
2005	19.13	5.72	8.93	5.84	29.14	17.58	27.39	10.39	13.06	21.63	5.65	13.21	14.93
2006	9.57	5.27	4.42	12.06	16.09	18.59	18.95	29.28	7.69	17.46	43.06	11.69	16.22
2007	7.30	3.74	7.05	4.73	12.78	19.58	33.65	25.43	9.10	28.08	8.55	7.26	14.06
2008	4.19	3.75	9.32	15.77	10.48	14.45	48.53	32.77	16.49	39.14	21.45	13.31	19.24
2009	7.06	20.41	9.20	12.77	15.64	14.19	22.48	29.47	26.60	31.03	9.84	23.65	18.54
2010	7.68	-	-	-	29.34	37.49	10.04	35.19	53.64	15.80	4.24	23.86	19.64
2011	14.72	5.61	13.75	12.50	36.09	36.42	24.66	12.33	11.86	35.43	16.64	38.88	21.73
2012	19.47	17.23	27.34	6.99	18.39	22.57	35.58	23.52	21.43	20.04	10.91	11.26	19.62
2013	8.53	8.45	4.76	13.07	26.30	25.65	12.12	15.23	32.22	28.82	12.28	15.76	16.96
2014	17.16	3.98	3.83	17.58	16.78	26.88	14.79	28.17	15.61	14.35	15.94	11.36	15.59
2015	5.73	6.31	7.21	30.81	35.04	48.44	20.22	36.49	24.27	10.80	11.58	6.93	20.34
2016	9.66	10.51	7.65	11.33	29.28	24.46	33.12	25.39	30.50	25.08	38.29	12.41	21.48
2017	19.64	16.65	12.86	33.76	26.32	10.09	41.61	47.77	37.39	14.58	9.36	3.72	22.86
2018	12.05	13.58	18.15	21.48	31.15	18.29	30.80	24.89	12.52	10.74	12.00	8.64	17.91
2019	4.84	3.91	6.72	23.74	20.18	17.41	35.83	21.63	13.49	18.79	12.87	16.61	16.43
2020	4.28	4.41	4.56	6.21	22.05	28.27	21.10	14.32	23.66	21.38	40.03	36.59	18.92
Minimum	4.19	3.26	3.48	4.65	8.54	10.09	5.31	9.01	7.69	10.74	4.24	3.72	13.20
Average	10.65	12.02	10.27	14.65	21.59	24.25	25.43	24.35	22.48	26.17	17.77	16.24	18.86
Maximum	19.64	71.22	27.34	41.87	36.09	48.44	64.50	47.77	53.64	107.68	49.18	38.88	28.33

Note: Values in red font indicate periods which contain gap filled data.

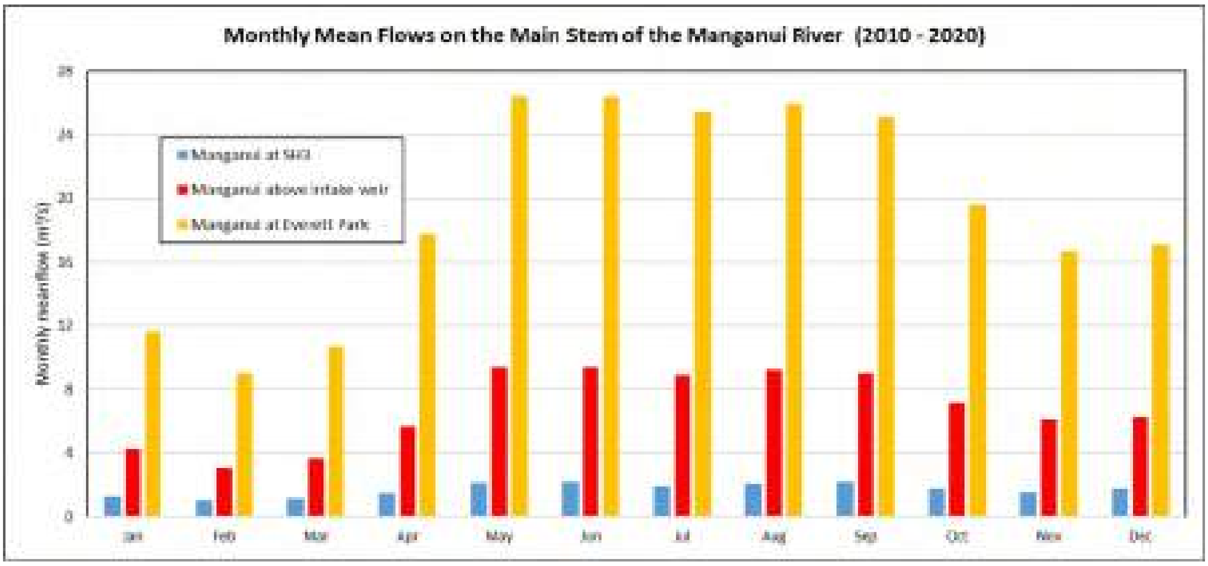

Figure 2.6 Manganui River: mean flow distribution by month-of-year for three locations, period 2010 - 2020

A strong seasonal pattern in the river flows is observed. For example, at the Manganui Weir, the mean flow in the five months from May to September (of 9.2 m^3/s) is almost 1.8 times the mean flow for the other seven months of the year (5.2 m^3/s). The seasonal difference is retained in the lower reaches despite the diversion into the Motukawa Race, i.e. at Everett Park, the mean flow from May to September (25.9 m^3/s) is about 1.7 times the mean flow from October to April (14.7 m^3/s). On average and in round terms, the mean monthly river flow at Everett Park is about 2.8 times that at the Manganui Weir, and the mean monthly flow at the Manganui Weir is about 4 times that at SH3.

The flow records at both SH3 (1972 to 2020) and Everett Park (1991 to 2020) are long enough for a trend analysis of overall water resource availability on a year-to-year basis.

Figure 2.7 shows, for the SH3 record, the significant variability in the yearly mean flows (shown by dark blue bars) and even greater variability in the summer mean flows (taken as the flow averaged over December, January and February each year, and shown by the hatched red bars). The linear trendlines (shown by the dotted and dashed lines) indicate a slight increasing trend in the yearly mean flows (slope roughly 0.4% per year) as well as the summer mean flows. However, this cannot be regarded as conclusive as the correlation is weak ($R^2 = 0.13$ for the yearly mean flows) and the inter-annual variability is large. A similar and slightly stronger increasing trend is observed in the winter mean flows (June, July and August, see Figure 2.8).

Figure 2.9 plots the yearly and summer mean flow series from the Everett Park record. The linear trendline (dotted black line) fitted to the yearly mean flows is near horizontal, indicating no increasing or reducing trend over the record period. The apparent difference in the mean flow trend between the SH3 and Everett Park records can be explained by the fact that the early part of SH3 record 1973 to 1991 was markedly (about 10%) drier than the latter part of the record from 1992 to 2020 and that the Everett Park record only started in mid-1991.

There is no apparent trend in the summer mean flows at Everett Park. However, there appears to be a very weak trend of increasing winter mean flows (June, July and August, see Figure 2.10), which is offset by a weak trend of declining spring flows (September, October and November, see Figure 2.11). Such a declining trend in the mean spring flows was not apparent in the SH3 record.

It is noted that the first four months of 2020 were the driest on record for Everett Park and the second driest at SH3 (a lower mean flow was recorded for the first four months of 2001).

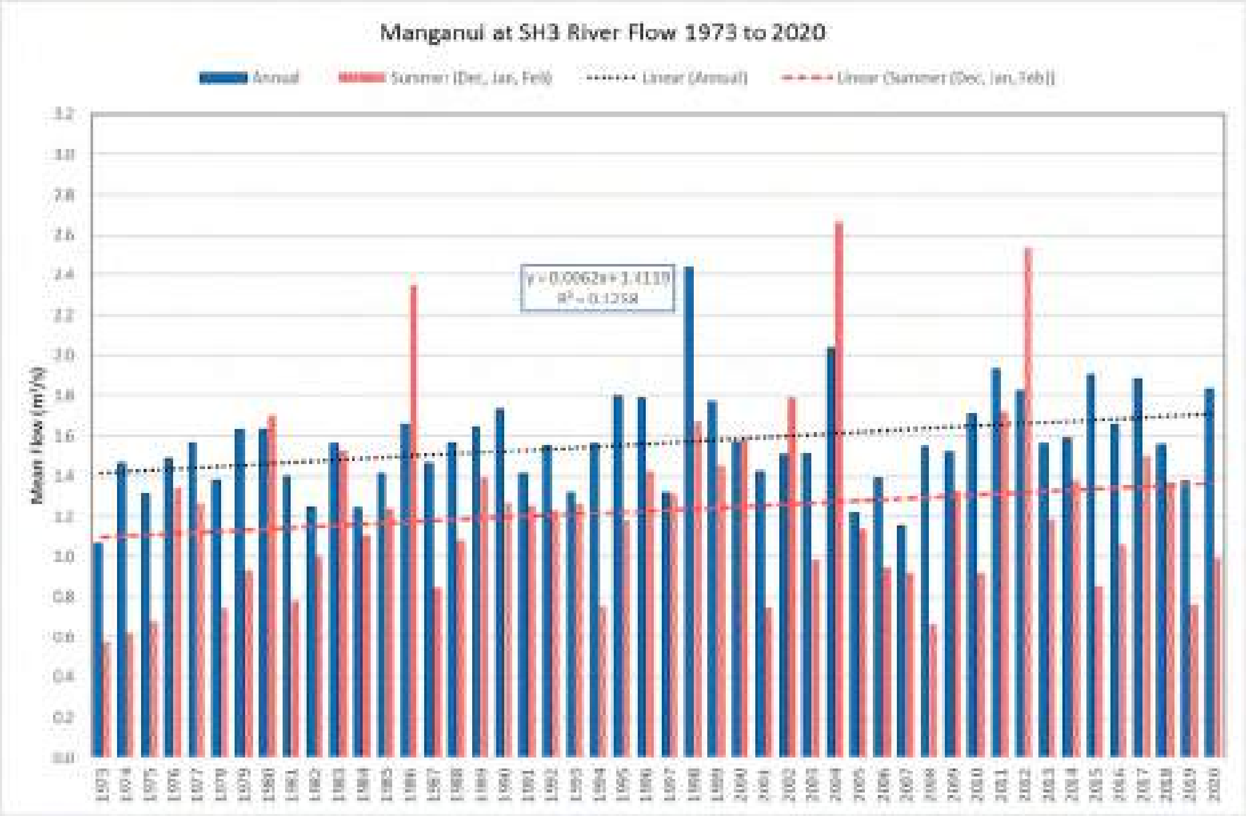

Figure 2.7 Manganui at SH3 annual and summer mean flow series over 48 years, 1973 to 2020

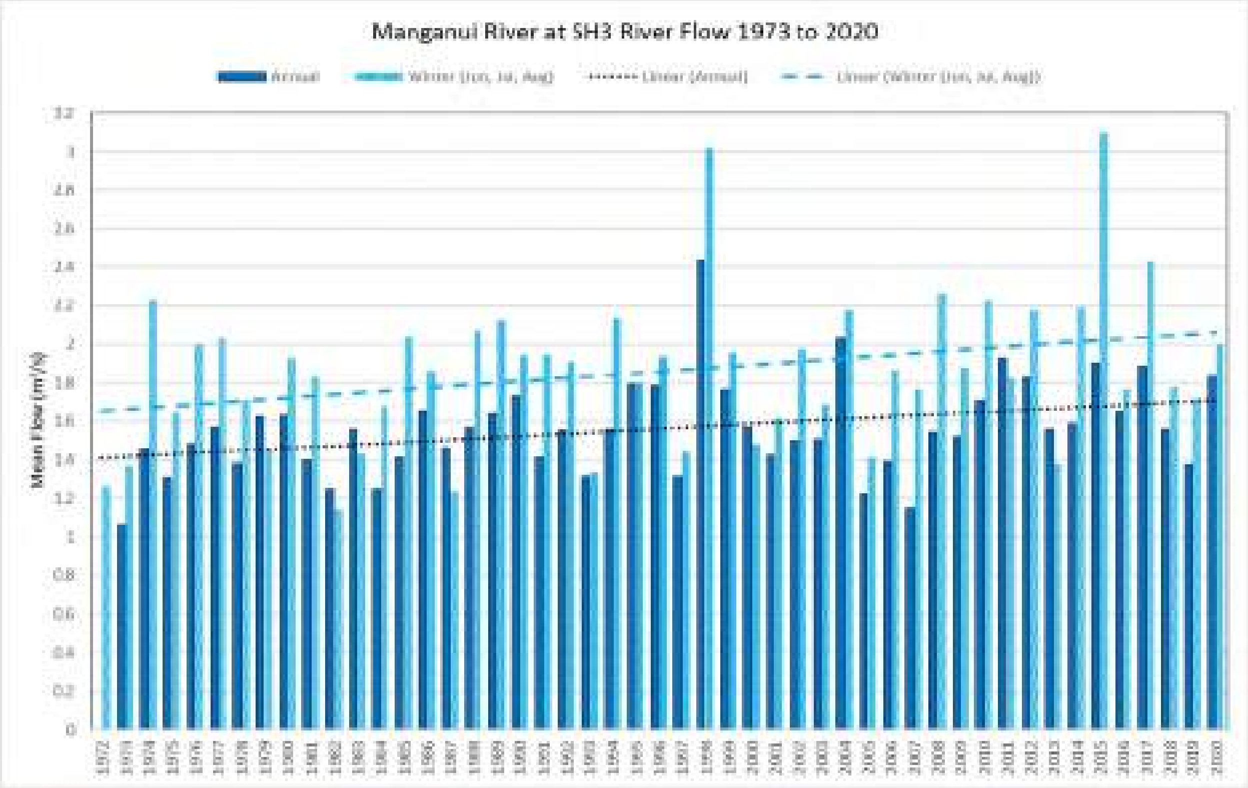

Figure 2.8 Manganui at SH3 annual and winter mean flow series over 48 years, 1973 to 2020

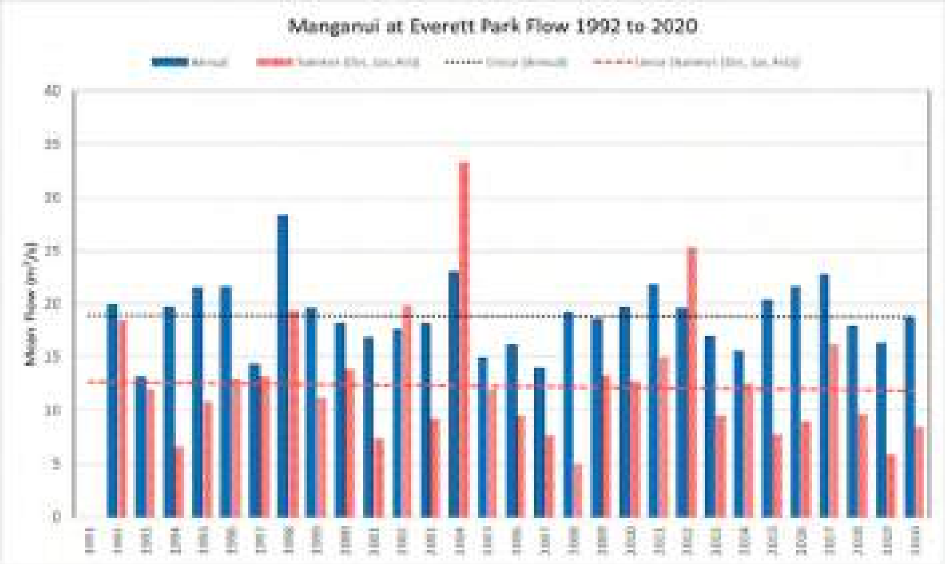

Figure 2.9 Manganui at Everett Park annual and summer mean flow series over 29 years, 1992 to 2020

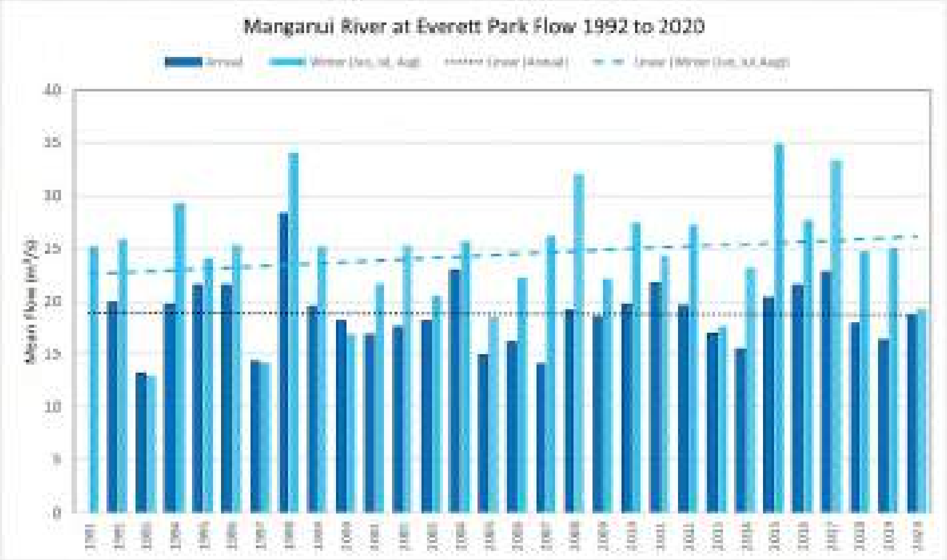

Figure 2.10 Manganui at Everett Park annual and winter mean flow series over 29 years, 1992 to 2020

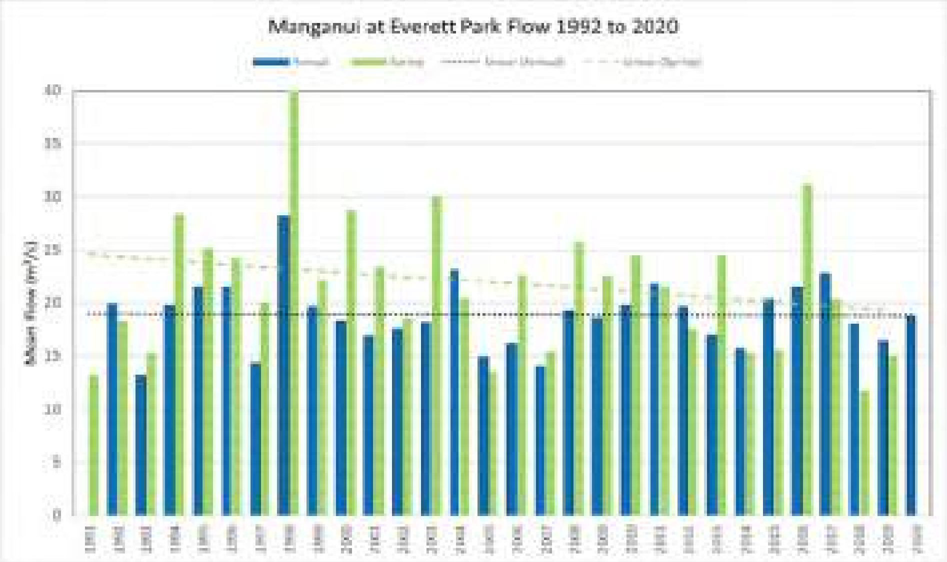

Figure 2.11 Manganui at Everett Park annual and spring mean flow series over 29 years, 1992 to 2020

2.6.3 Manganui River flow duration

Time-series plots of flows (hydrographs) may be condensed into flow duration curves, which are effectively cumulative probability plots of the flow distribution, constructed from a complete ranked series (e.g. from the highest value to the lowest value) of all the recorded flows. This flow duration curve may be considered the unique signature of the flow record. Figure 2.12 presents flow duration plots of the Manganui River at SH3, the Manganui Weir and Everett Park for their overlapping record period i.e. October 2009 to December 2020. In Figure 2.13 and 2.14, a separate flow duration curve for each season (summer = Dec, Jan, Feb; autumn = Mar, Apr, May; winter = Jun, Jul, Aug; and spring = Sep; Oct; Nov) is plotted in addition to the annual (full year) curve for the Manganui Weir and Everett Park respectively.

Table 2.7 tabulates the flow duration ordinates corresponding with the plots on Figures 2.13 and 2.14. The median flow is given by the flow that is exceeded 50% of the time, i.e. 4.17 m^3/s for the Manganui Weir and 10.35 m^3/s for Everett Park. A flow of 5.6 m^3/s at the Manganui Weir, which is the consented maximum take (5,200 l/s) plus the minimum residual flow below the Manganui Weir (400 l/s), is exceeded 32% of the time based on the inflow record from Oct 2009 to Dec 2020.

The flow duration curves and the data in the table indicate that, for both sites, winter (June to August) experiences the highest average flows, followed by spring and then autumn, with summer (December to February) being the driest season.

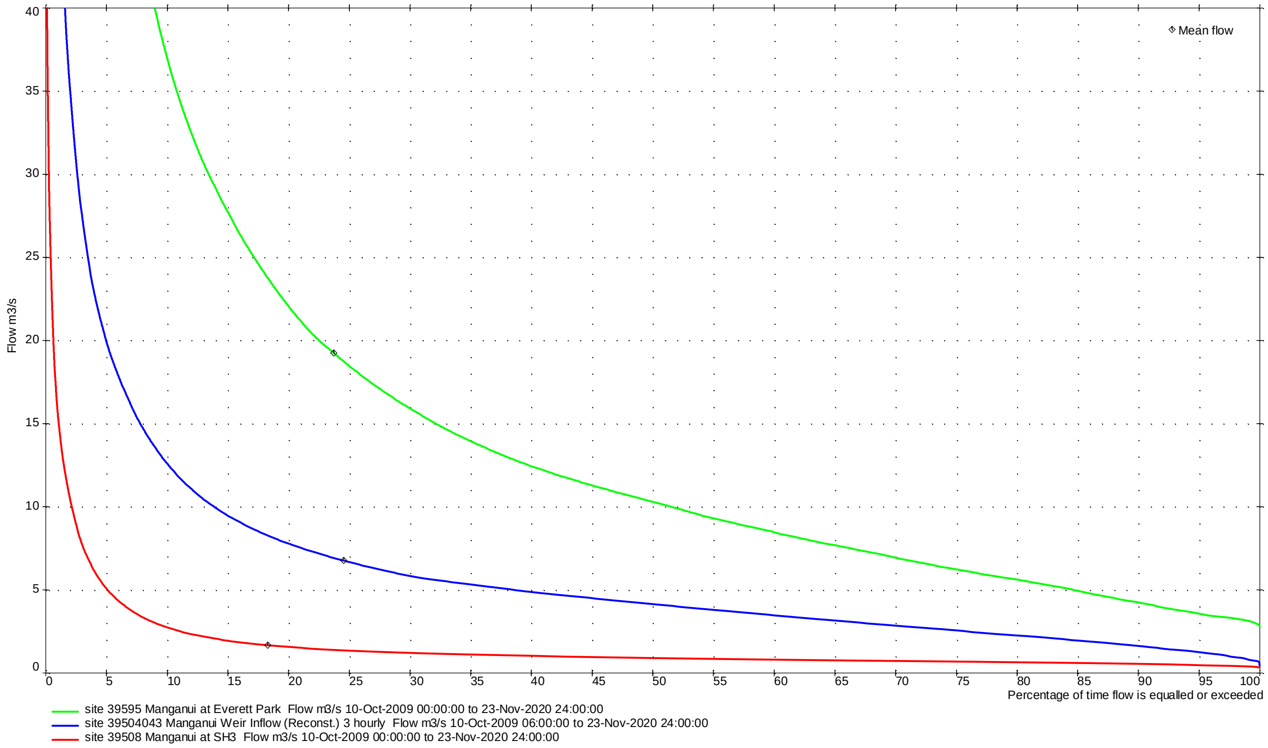

Figure 2.12 Manganui River flow duration curves October 2009 to December 2020. Red curve – SH3; blue curve – Manganui Weir; and green curve – Everett Park. Mean flow on each curve is indicated by diamond marker

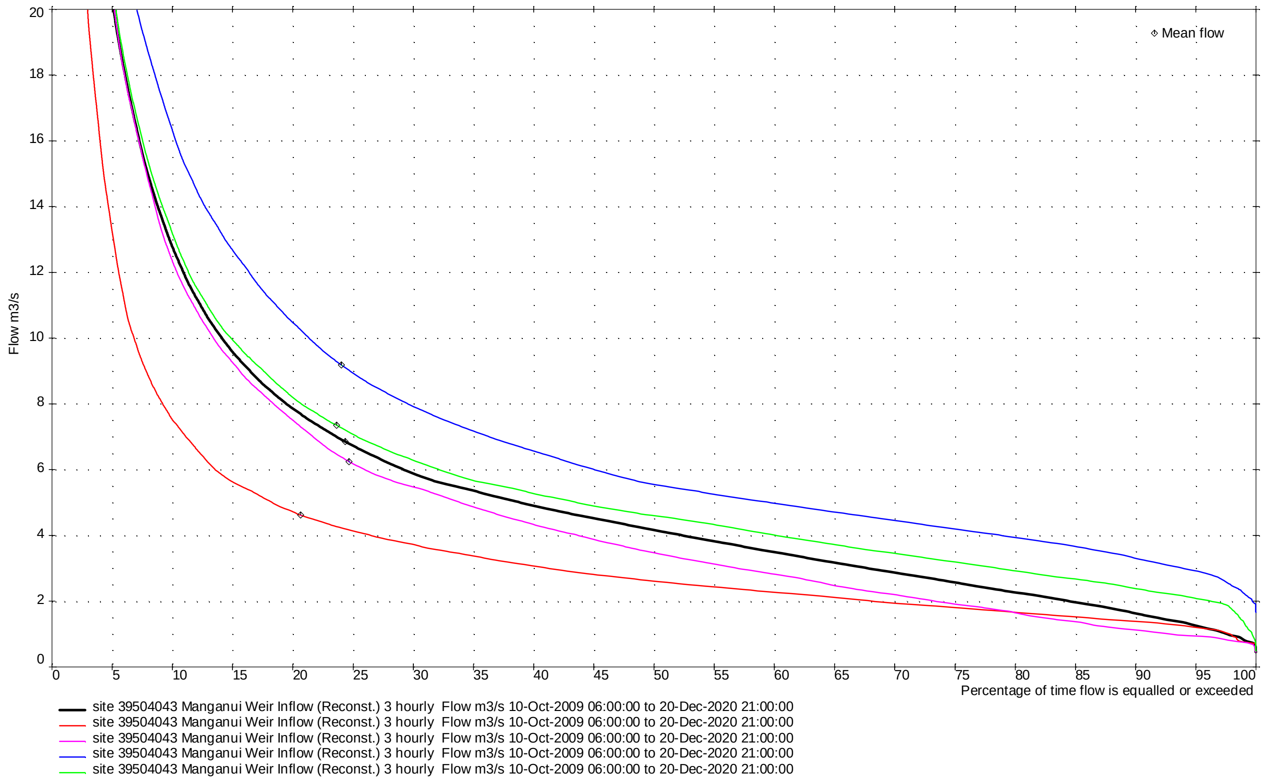

Figure 2.13 Manganui Weir (Manganui above intake weir) flow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker

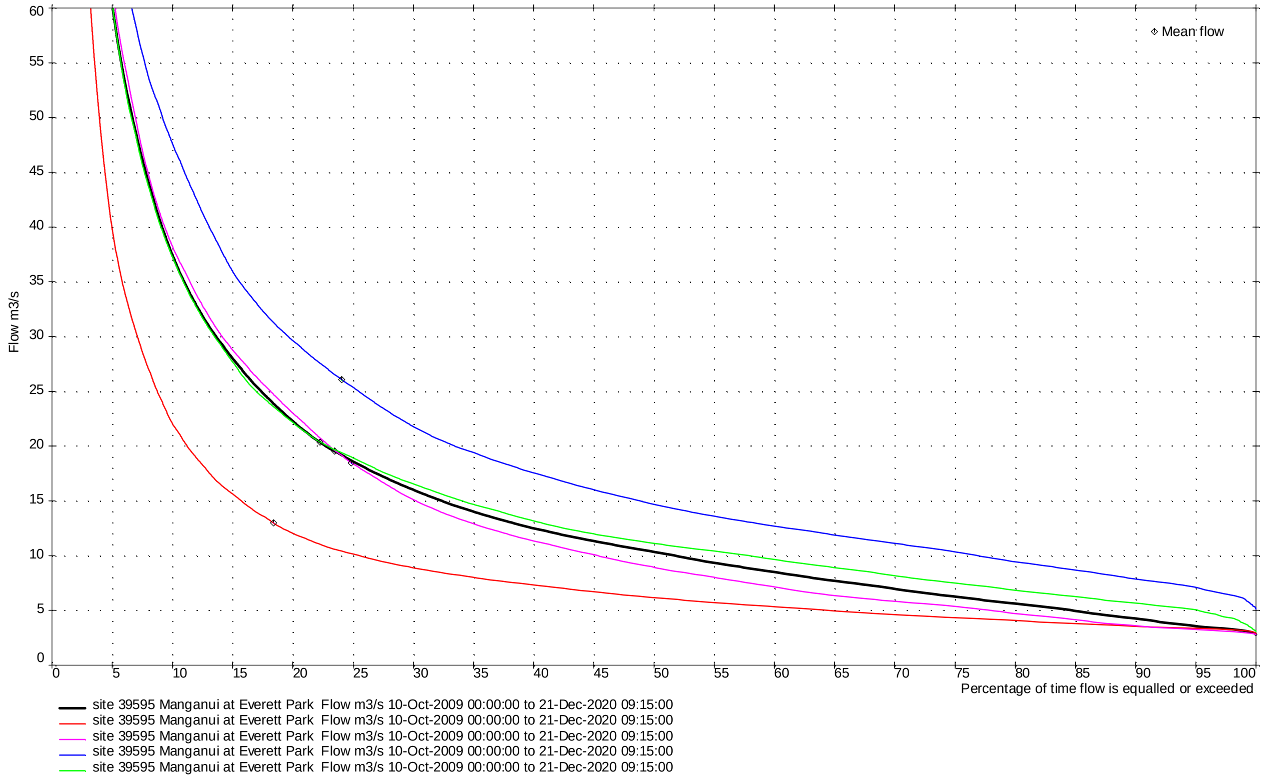

Figure 2.14 Manganui at Everett Park flow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta curve – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker

Table 2.7 Manganui above Weir and at Everett Park flow duration data (Oct 2009 to Dec 2020)

% time flow is exceeded	Manganui Weir inflow (m^3/s)					Manganui at Everett Park (m^3/s)				
	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON
1	55.4	45.8	51.7	70.4	55.1	173.1	148.1	154.9	223.0	179.3
2	36.3	27.9	36.4	42.5	36.5	110.8	86.6	110.8	132.1	111.4
5	20.3	13.3	20.5	24.2	20.8	60.4	39.9	62.3	70.7	60.5
10	12.79	7.53	12.36	16.34	13.20	37.5	22.1	38.3	47.7	37.3
20	7.87	4.73	7.51	10.48	8.21	22.30	12.06	23.03	29.7	22.2
30	5.89	3.73	5.48	7.93	6.30	16.03	8.92	15.13	21.8	16.58
40	4.91	3.07	4.34	6.58	5.28	12.51	7.34	11.35	17.58	13.18
50	4.17	2.62	3.48	5.56	4.61	10.35	6.17	8.96	14.71	11.13
60	3.50	2.28	2.83	4.99	4.02	8.51	5.36	7.15	12.71	9.67
70	2.88	1.95	2.21	4.46	3.46	6.98	4.63	5.86	11.13	8.17
80	2.28	1.67	1.66	3.95	2.93	5.64	4.08	4.74	9.46	6.87
90	1.64	1.39	1.13	3.31	2.38	4.26	3.56	3.62	7.89	5.69
95	1.27	1.21	0.95	2.93	2.09	3.58	3.38	3.27	7.12	5.05
98	0.97	0.99	0.80	2.48	1.76	3.29	3.24	3.06	6.39	4.30
99	0.83	0.77	0.76	2.25	1.36	3.15	3.16	2.98	6.07	3.83

2.6.4 Manganui River low flow characteristics

The long-term flow records for SH3 and Everett Park were analysed to assess the frequency and severity of low flow events. As is standard practice, these assessments are based on frequency analysis of the annual minimum 7-day averaged flows (rather than the minimum daily flow or minimum instantaneous flow).

Figure 2.15 shows the General Extreme Value (GEV) distribution fitted to the annual 7-day low flow series for SH3 from 1973 to 2020. The 7-day mean annual low flow (7-day MALF) based on this series is 0.47 m^3/s, and the 5-year 7-day low flow 0.39 m^3/s. Of the 48 annual minima, 35 (73%) have occurred in the three months from February to April. There is one consented surface water take upstream of SH3 of 13 l/s (refer Section 2.5) which is relatively small compared to the 7-day MALF.

The Everett Park site has a shorter record (29 years) for low flow analysis. Abstraction from the Mangaotea Stream reduces the residual river flow which is recorded at this site. However, the stringent consent conditions attached to the take (see Table 3.1) mean that low flows (e.g., at the mean annual low flow level) are essentially unaffected by the take. The fitted frequency curve to the 7-day annual low flow series is shown in Figure 2.16. No adjustment for surface water abstractions above Everett Park were made and the low flow analysis may not be representative of the natural flow regime. The 7-day MALF based on this unadjusted flow series is 3.47 m^3/s and the 5-year 7-day low flow 2.88 m^3/s. Of the 29 annual minima, 22 (76%) have occurred between the months of January and March.

As noted in Section 2.4, flow at the Manganui Weir was previously monitored for 12 years, between Jan 1962 and Jan 1974 (Site No. 39504 Manganui at Tariki Road). The 7-day MALF from this early period of data is 1.29 m^3/s. The 7-day MALF based on the reconstituted Manganui Weir inflow record (2010 to 2020) is slightly lower at 1.18 m^3/s. The consented water takes upstream of the weir are relatively small (sum of takes is 18 l/s, refer to Section 2.5) and would have made only a minor difference to the 7-day MALF.

To determine if the 7-day MALF from the recent Manganui Weir record (2010 to 2020) is likely to be representative of the longer term, comparisons were made with the 7-day annual low flows from all the long-term sites in the Waitara catchment, viz. Manganui at SH3, Manganui at Everett Park, Waitara at Tarata and Waitara at Bertrand Road. A good correlation with the Tarata record (R^2 of 0.83) was found, with reasonable correlations for the other sites (R^2 from 0.46 to 0.67).

Both the Bertrand Road and Tarata records indicate that the 7-day MALFs between 2010 and 2020 are about 11% lower than their respective long-term 7-day MALFs. Contradictorily, both the SH3 and Everett Park records suggest that the 7-day MALFs between 2010 and 2020 are about 5% *higher* than their long-term 7-day MALFs. The comparisons are thus inconclusive, and perhaps suggest there are different underlying trends in play between the eastern (Manganui sub-catchment) and western (main stem) flanks of the Waitara catchment.

For the current assessment, a 7-day MALF of 1.18 m^3/s for the Manganui Weir, based on the reconstituted inflow record from 2010 to 2020, has been adopted.

The reconstituted inflow record for the Manganui Weir (2010 to 2020) is too short by itself for a meaningful low flow frequency analysis. Therefore, the annual 7-day low flow series from the earlier Tariki Road record (1962 to 1973) was combined with that from the 2010 to 2020 record for an assessment. Figure 2.17 shows the frequency curve fitted to the annual 7-day low flow series from the combined record.

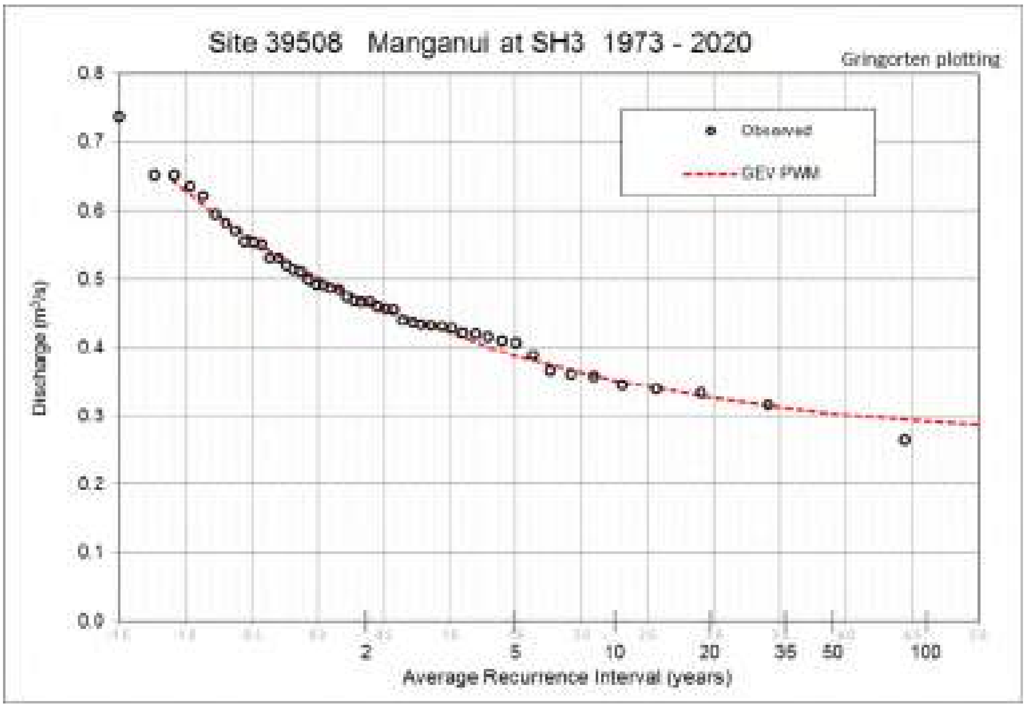

Figure 2.15 Manganui River at SH3 7-day annual low flows, and the best-fit GEV distribution

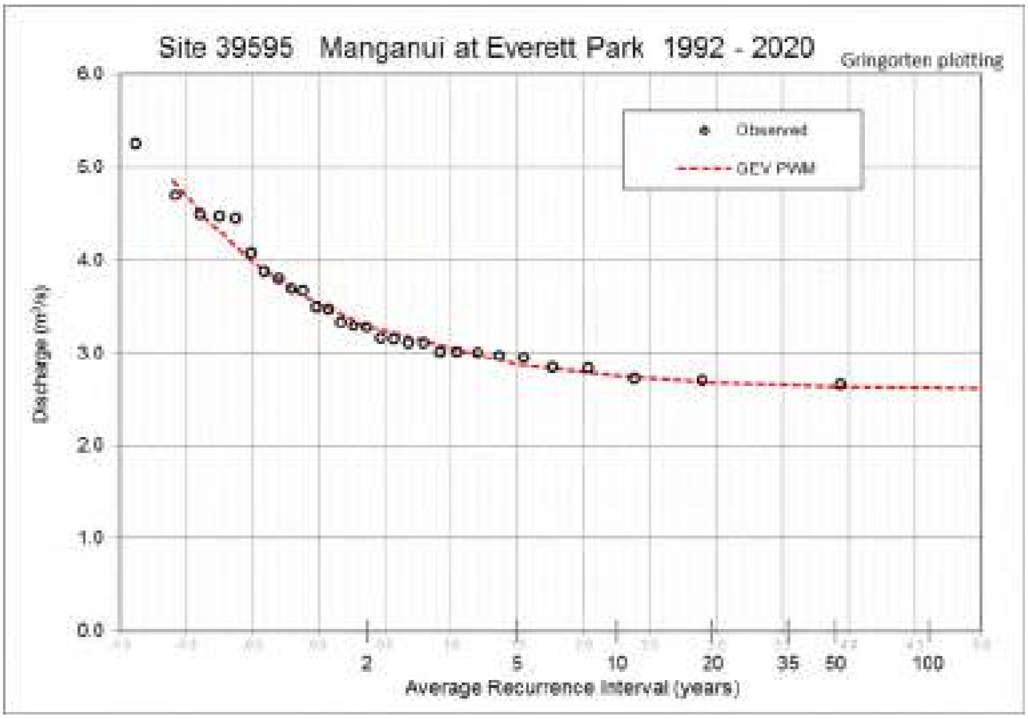

Figure 2.16 *Manganui River at Everett Park frequency analysis of 7-day annual low flows, showing the best-fit General Extreme Value distribution*

Figure 2.17 *Manganui River at Tariki Road / Weir frequency analysis of 7-day annual low flows, showing the best-fit General Extreme Value distribution*

Table 2.8 summarises the low flow estimates for all three sites. The data indicates similar specific low flow yields (low flow per unit catchment area) at Manganui Weir and Everett Park, but a significantly higher specific low flow yield for the upper Manganui catchment above the SH3 site.

Table 2.8 Manganui River low flow frequency at three locations

Location	Catchment Area (km²)	7-day MALF		5-year 7-day low flow		20-year 7-day low flow	
		(m³/s)	(l/s/km²)	(m³/s)	(l/s/km²)	(m³/s)	(l/s/km²)
Manganui at SH3	13.0	0.47	36.5	0.39	30	0.33	25
Manganui Weir	80	1.18	14.8	0.92	11.5	0.74	9.3
Manganui at Everett Park [1]	282	3.47	12.3	2.88	10.2	2.68	9.5

Note [1] No adjustment made for surface water abstractions upstream of Everett Park, including the diversion to the Motukawa Race, i.e., these low flow estimates are not based on "naturalised" flows.

Both the SH3 and Everett Park flow records are long enough for a trend analysis of their annual minimum flow series, and this is shown in Figures 2.18 and 2.19. While there is considerable variability in the annual minima, the linear trendlines (dotted blue line) fitted to both series do not indicate any increasing or decreasing trend. Any potential trend could be significant in the derivation of a statistical index such as the 7-day MALF, which is conventionally determined from historical flow records that are assumed to be statistically stationary (non-trending). It is interesting to note that the apparent (though weak) increasing trend in the mean summer flows at SH3 (shown in Figure 2.7) is not accompanied by an equivalent trend in the 7-day annual low flows.

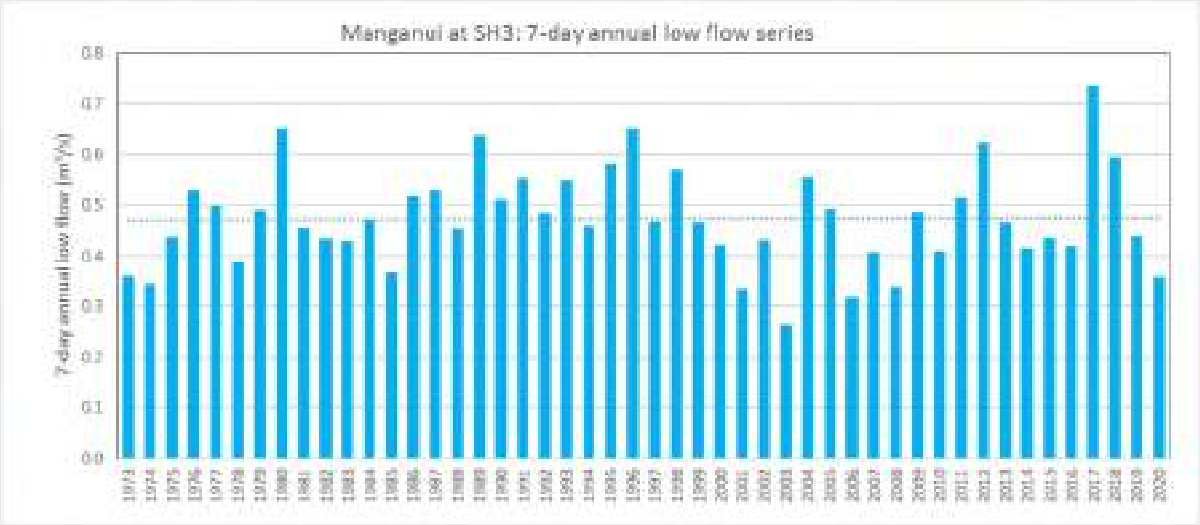

Figure 2.18 Manganui River at SH3 annual 7-day low flow series (July to June year)

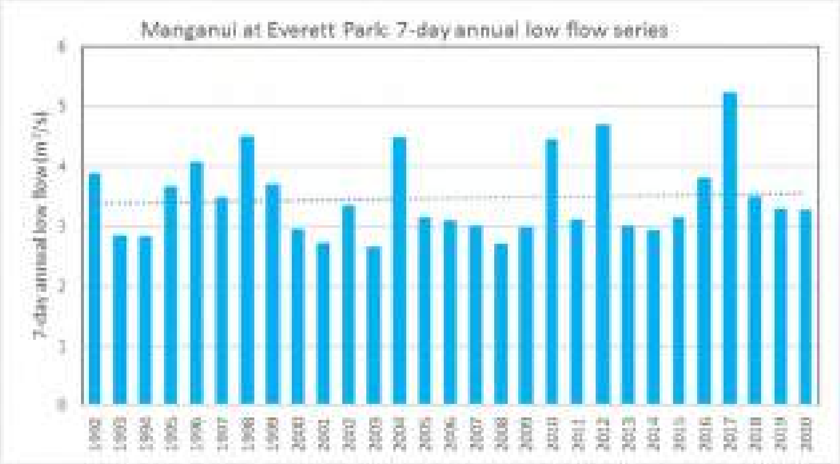

Figure 2.19 Manganui River at Everett Park annual 7-day low flow series (July to June year)

2.6.5 Manganui River flood flow regime

Flow records for the SH3 and Everett Park sites were analysed to determine the frequency and magnitude of flood flows in the Manganui River. These assessments are based on frequency analysis of the annual series of instantaneous maximum flows (i.e. the highest recorded flow for each year).

Figure 2.20 shows the best-fit Extreme Value Type 1 (EV1) frequency distribution applied to the biennial[2] flood series from the Manganui at SH3 record from 1973 to 2020. Figure 2.21 shows the EV1 distribution fitted to the shorter Everett Park biennial flood series from 1991 to 2020. The mean annual flood at SH3 and Everett Park are, respectively, 60 m^3/s and 713 m^3/s. Large floods at the SH3 site can occur at any time of the year, with the period from January to March recording the fewest (10%) annual maxima. Interestingly, at Everett Park, the largest flood in each year typically occurs in a more focused period between August and October (63% of annual maxima).

The reconstituted inflow record for the Manganui Weir (2010 to 2020) is too short by itself for a meaningful flood frequency analysis. Therefore, the annual flood series from the earlier Tariki Road record (1962 to 1973, Site No. 39504) was combined with that from the 2010 to 2020 record for an assessment. The mean annual flood from this combined 23-year record is 201 m^3/s (and 198 m^3/s based on the earlier record and 204 m^3/s based on the recent record). Figure 2.22 shows the EV1 distribution fitted to the biennial flood series from the combined record. Stitching the two flow records, which are separated by a 37-year gap, is considered appropriate as both flow records are for the same site. Furthermore, the flood frequency curve fits the datapoints very well.

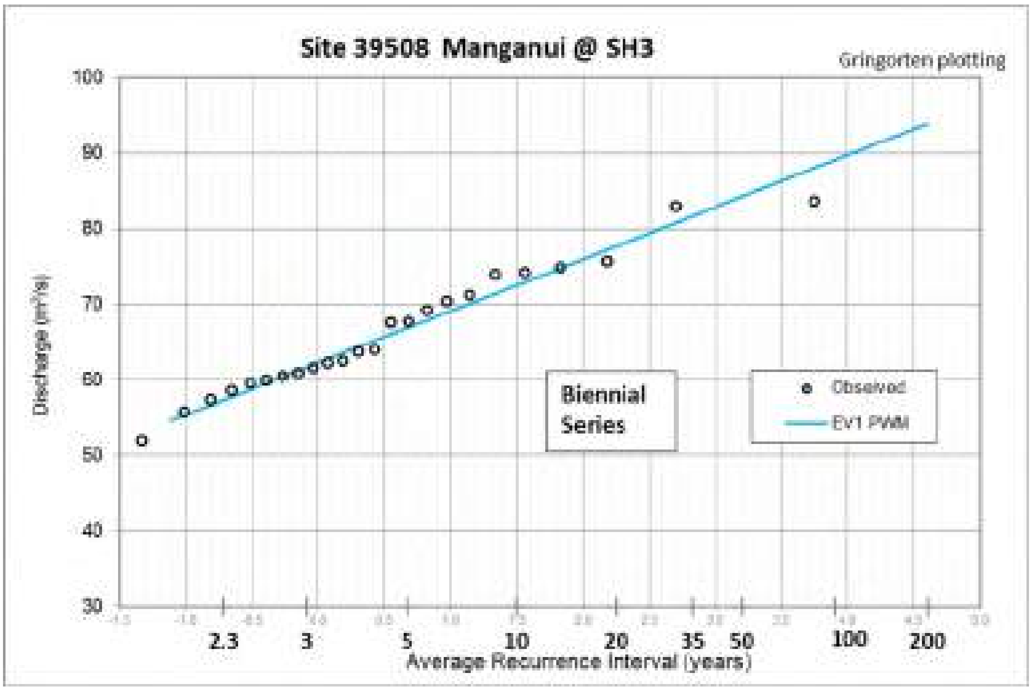

Figure 2.20 Manganui at SH3 flood frequency analysis based on biennial flood series 1973 to 2020

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[2] McKerchar and Pearson (1989) suggest that for some sites there may be an insufficient number of flood events in a one year interval for certain distributions such as the EV1 to apply satisfactorily. In that situation, they propose extending the time interval from one year to two years and examine the biennial maxima using the EV1 fit, and so on (i.e. to three and then four years etc.), until the EV1 is accepted.

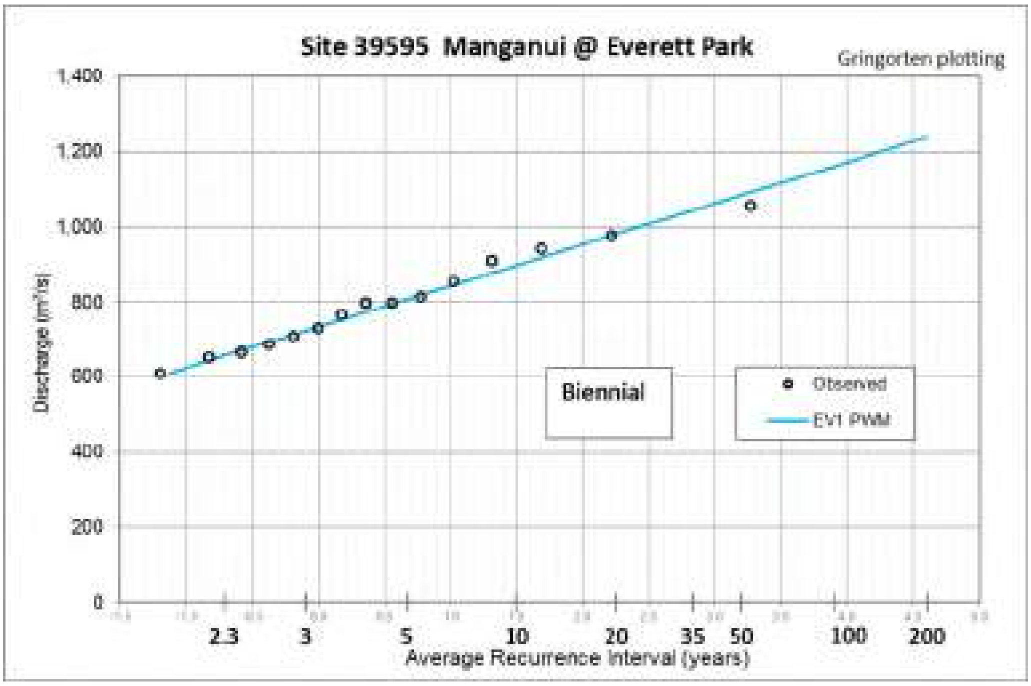

Figure 2.21 Manganui at Everett Park flood frequency analysis, biennial flood series 1991 to 2020

Figure 2.22 Manganui at Tariki Road / Weir flood frequency analysis, biennial flood series 1962 to 1973 and 2010 to 2020

Table 2.9 summarises the peak flow estimates for all three sites. The data indicates a decrease in the flood intensity from the upper catchment (represented by the SH3 site) to the middle part of the catchment (represented by Manganui Weir), which is largely explained by the fall-off in storm rainfall depths and ground slopes from the headwaters of the catchment. However, based on the flood estimates for Everett Park, the flood intensity does not appear to reduce downstream of Manganui Weir. This is possibly because other tributaries that join the mainstem of the Manganui downstream of the weir (e.g. the Ngatoro Stream) have their headwaters in the more exposed north-eastern slopes of Mt Taranaki (more exposed relative to the upper Manganui catchment which is located on the eastern slopes) and receive higher intensity rainfall.

Table 2.9 Manganui River flood frequency at three locations

Location	Catchment Area (km²)	Mean annual flood		5-year ARI flood		20-year ARI flood		100-year ARI flood	
		(m³/s)	(m³/s/km²)	(m³/s)	(m³/s/km²)	(m³/s)	(m³/s/km²)	(m³/s)	(m³/s/km²)
Manganui at SH3	13.0	60	4.62	67	5.15	78	6.0	89	6.8
Manganui Weir	80	201	2.55	234	2.92	294	3.7	357	4.5
Manganui at Everett Park	282	713	2.53	807	2.86	980	3.5	1160	4.1

Plots of the annual flood series recorded for the Manganui River at SH3 and Everett Park are shown in Figures 2.23 and 2.24 respectively. There is possibly a very weak apparent trend of increasing flood flows in the SH3 flood series but no apparent trend in the shorter Everett Park record. The largest flood on record is the February 2004 event.

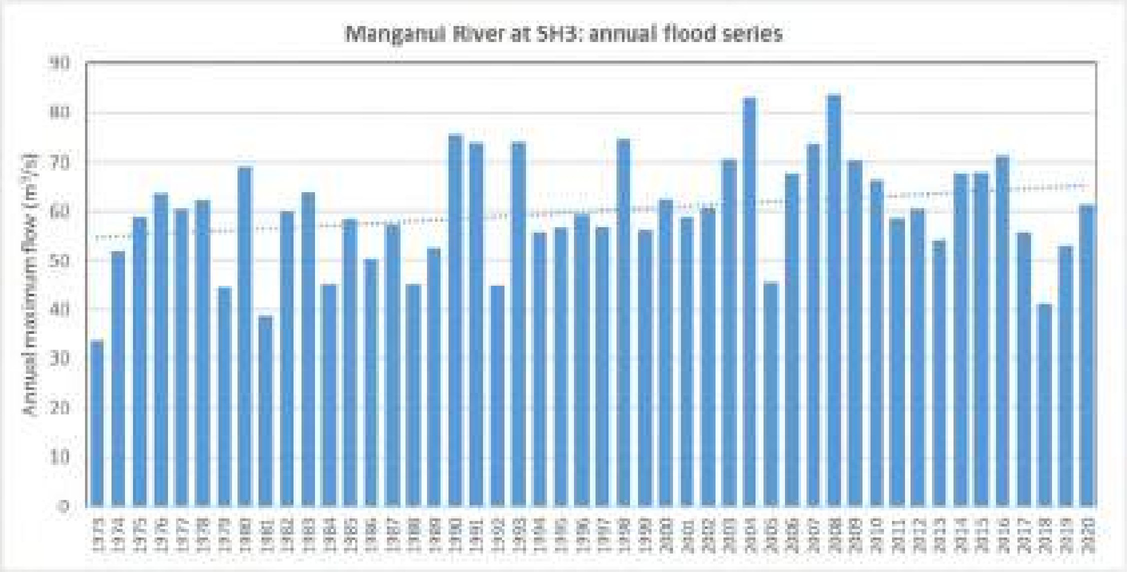

Figure 2.23 Manganui at SH3 annual flood series

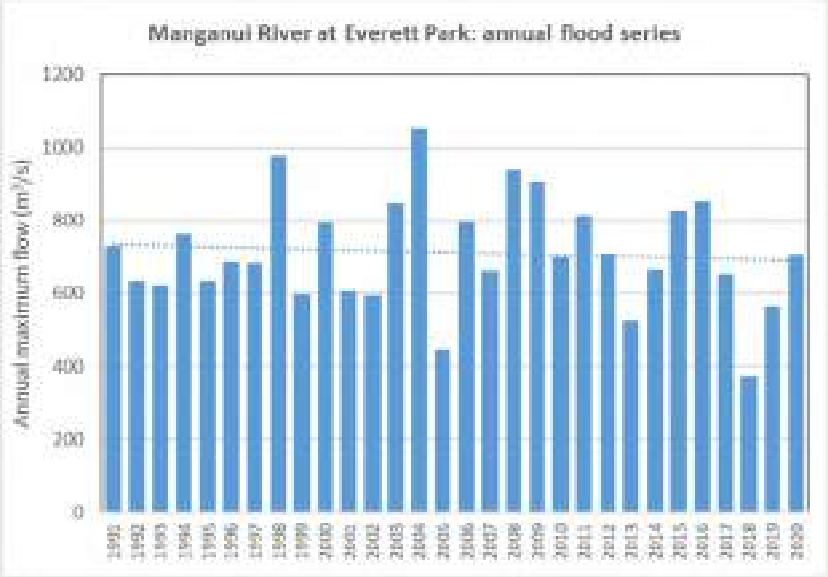

Figure 2.23 Manganui at Everett Park annual flood series

2.7 Waitara River flows

2.7.1 Waitara River flows and seasonality

Appendix C presents time-series plots of the entire flow record for the two current long-term flow recording stations on the main stem of the Waitara River i.e. at Tarata (Site No. 39501) and at Bertrand Road (Site No. 39503). Figures 2.24 and 2.25 are plots of the superimposed flow records for these two sites for the period 2009 to 2020, which is the period used for Motukawa HEPS water balance assessment (as described in Section 3.2). As expected, both flow records are very closely correlated, as one site (Tarata) is located upstream of the other (Bertrand Road) where the catchment area is 59% larger. The influence of the operation of the Motukawa HEPS on river flows may be seen as the high frequency fluctuations during low flow periods and flow recessions (caused by daily peaking operation at the power station). This is discussed in more detail in Section 3.5.2.

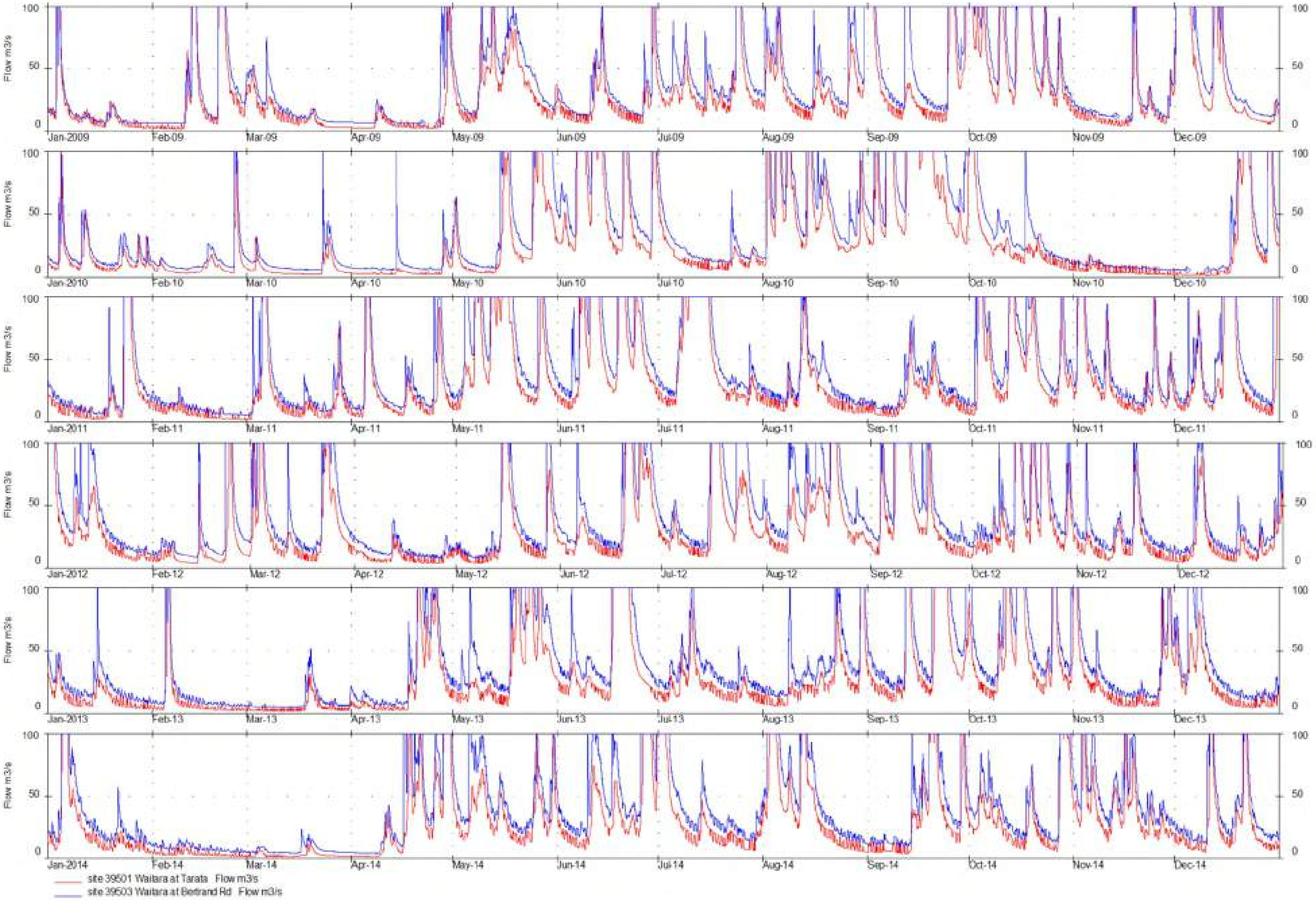

Figure 2.24 Waitara River flow time series at Tarata (red hydrograph) and at Bertrand Road (blue hydrograph) from 2009 to 2014

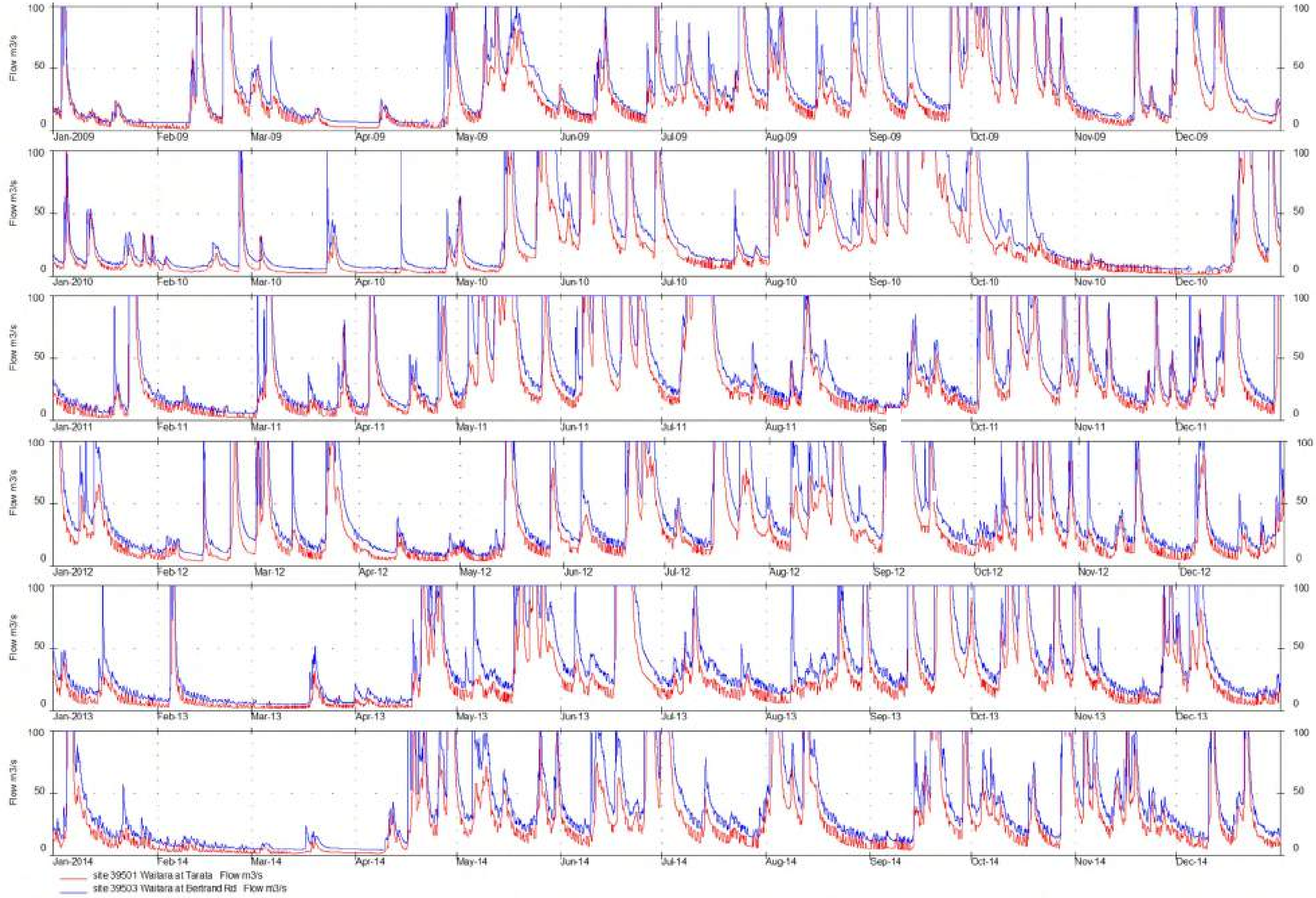

Figure 2.25 Waitara River flow time series at Tarata (red hydrograph) and at Bertrand Road (blue hydrograph) from 2015 to 2020

Tables 2.10 and 2.11 provide tabulations of the mean monthly flows at Tarata and Bertrand Road respectively for their entire available records.

Table 2.10 Waitara at Tarata mean monthly flows for full record 1969 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Waitara at Tarata (Node h): Mean monthly river flow (m^3/s)												
1969	19.37	36.87	9.19	13.16	45.43	28.73	22.49	42.42	32.97	17.04	7.52	12.89	23.94
1970	7.90	2.98	7.02	13.47	32.12	53.54	58.07	41.60	97.03	47.90	24.94	19.20	33.92
1971	27.04	54.54	10.33	9.07	25.50	53.20	19.87	33.89	63.16	76.55	32.30	28.80	36.00
1972	19.22	7.22	34.19	18.32	56.55	17.52	52.55	37.76	30.28	30.44	12.54	9.92	27.40
1973	8.15	2.25	16.87	15.35	44.95	51.00	15.23	50.25	80.22	22.53	51.74	12.99	30.99
1974	8.31	4.80	3.14	9.00	22.46	18.60	112.90	36.72	30.72	58.55	24.64	19.07	29.37
1975	16.74	5.03	16.95	32.50	68.15	45.91	55.38	77.67	43.39	52.87	21.67	19.10	38.24
1976	28.69	27.39	8.63	26.30	55.67	71.86	51.05	51.62	29.00	31.51	16.00	26.05	35.35
1977	26.68	18.14	14.24	20.61	55.91	91.86	40.09	37.71	44.67	26.27	45.98	25.00	37.27
1978	5.29	3.95	3.40	16.61	27.87	29.08	68.64	38.62	39.88	35.55	62.64	15.31	29.02
1979	5.62	22.23	22.38	40.30	75.03	14.00	28.80	37.33	38.58	53.41	32.32	43.39	34.58
1980	58.84	17.81	31.85	48.04	26.66	38.20	49.45	48.10	62.45	26.09	34.48	33.29	39.66
1981	8.69	14.24	14.38	30.02	23.68	69.46	49.42	50.79	45.00	33.95	14.00	32.86	32.27
1982	19.35	11.48	9.53	18.37	46.53	29.71	28.12	21.29	44.51	27.03	22.56	69.23	29.12
1983	27.48	7.17	9.39	41.85	41.80	22.97	25.65	31.50	49.73	47.87	54.85	19.29	31.71
1984	14.69	17.51	40.45	29.80	36.22	22.05	72.33	37.63	21.65	24.73	27.70	44.07	32.56
1985	34.40	10.16	4.55	9.69	6.27	51.06	40.20	40.00	31.46	20.05	15.07	42.85	25.59
1986	49.63	20.64	17.16	13.21	37.28	56.99	61.26	39.96	35.97	54.34	13.09	11.52	34.42
1987	37.21	9.20	12.28	43.11	35.80	37.97	20.93	29.19	43.57	57.74	19.42	49.72	33.17
1988	6.76	10.31	15.56	16.82	44.73	53.76	73.80	67.20	52.55	69.74	45.79	29.03	40.65
1989	25.90	41.79	14.87	14.51	30.02	37.63	61.00	18.22	22.50	68.27	25.43	26.07	32.18
1990	43.70	10.90	95.24	34.13	63.68	50.49	45.18	79.29	22.91	39.41	52.35	14.31	46.32
1991	35.96	39.51	11.37	49.35	24.39	26.49	46.53	95.11	40.08	36.24	20.00	14.11	36.60
1992	27.18	43.92	21.18	12.86	19.94	25.69	87.67	79.83	43.46	35.68	15.56	35.31	37.46
1993	17.85	6.17	5.67	31.88	57.26	51.00	9.93	18.38	24.22	31.62	39.54	17.05	25.92
1994	15.63	7.75	20.77	25.68	49.41	68.95	45.98	57.09	62.08	33.71	121.01	17.64	43.82
1995	12.99	21.23	40.75	76.08	31.47	53.56	69.45	45.46	55.44	50.95	51.61	29.04	44.87
1996	18.67	35.55	26.32	71.50	47.05	39.67	68.54	51.71	55.80	53.25	43.35	60.52	47.67
1997	11.97	12.43	10.83	25.09	20.30	28.16	24.15	35.44	31.69	55.20	40.71	57.86	29.60
1998	23.93	41.55	18.86	25.10	43.98	47.51	105.40	32.73	57.93	188.94	27.84	23.27	53.33
1999	19.27	6.79	9.05	19.62	69.94	57.78	40.93	51.18	36.50	16.08	51.62	20.36	33.39
2000	24.09	12.46	3.97	20.75	33.16	44.53	34.92	25.19	56.19	92.87	11.22	34.31	32.91
2001	10.36	9.03	6.75	15.41	32.29	29.70	25.41	44.91	10.59	26.79	61.60	66.43	28.42
2002	23.15	17.21	20.70	13.28	21.08	56.81	48.49	39.93	65.63	34.00	37.89	46.48	35.45
2003	8.37	2.81	5.96	13.95	41.89	58.16	49.32	9.67	80.65	65.72	43.48	79.44	38.46
2004	17.23	136.42	30.35	20.54	34.22	71.30	35.44	48.30	44.00	57.15	21.21	22.98	44.49
2005	42.99	8.24	21.16	12.81	49.99	33.12	48.39	28.79	30.86	54.30	5.66	36.58	31.38
2006	14.70	9.89	5.70	26.36	30.91	36.01	41.12	64.64	19.21	40.04	76.85	28.24	32.92
2007	14.22	6.46	25.68	7.09	23.83	31.79	59.92	61.64	15.41	49.60	24.09	12.61	27.96
2008	4.15	4.84	6.78	30.48	28.82	40.00	85.50	78.64	35.36	71.48	34.70	18.50	36.79
2009	15.94	37.52	12.72	10.21	37.04	24.04	39.37	41.59	45.04	69.52	16.41	46.16	33.02
2010	14.78	9.60	6.30	4.48	33.13	63.63	15.06	55.88	94.56	37.04	5.37	31.55	31.00
2011	37.70	7.38	21.61	24.93	58.23	68.02	59.05	23.09	19.55	51.39	36.61	48.35	38.25
2012	36.72	14.54	33.34	8.59	32.28	37.59	60.15	46.05	47.12	45.62	17.89	19.93	33.48
2013	12.59	9.72	5.01	24.85	38.37	51.66	21.47	27.39	64.66	71.99	28.64	21.39	31.54
2014	30.41	4.30	3.35	37.19	35.05	38.98	34.82	52.38	32.35	35.81	38.75	29.17	31.20
2015	5.77	6.60	6.85	50.74	66.84	98.20	39.83	73.80	43.25	25.36	27.45	10.27	37.98
2016	16.36	10.58	7.34	10.32	57.86	46.96	55.58	58.06	63.51	45.37	63.43	18.70	37.90
2017	33.28	44.59	16.46	77.64	47.81	17.69	67.90	83.41	71.92	22.17	15.58	5.12	41.90
2018	17.09	15.20	41.72	33.59	70.79	42.46	59.75	49.44	15.86	12.82	22.54	17.55	33.43
2019	5.93	4.12	11.19	28.92	23.53	34.27	65.53	53.31	26.26	36.91	22.84	36.89	29.36
2020	4.51	5.00	8.27	12.39	39.17	40.84	44.58	30.45	58.54	28.46	48.83	74.21	33.01
Minimum	4.15	2.25	3.14	4.48	6.27	14.00	9.93	9.67	10.59	12.82	5.37	5.12	23.94
Average	20.64	18.23	16.88	25.69	40.43	44.43	48.90	46.39	44.42	46.11	33.26	30.46	34.76
Maximum	58.84	136.42	95.24	77.64	75.03	98.20	112.90	95.11	97.03	188.94	121.01	79.44	53.33

Note: Values in red font indicate periods which contain gap filled data.

Table 2.11 Waitara at Bertrand Road mean monthly flows for full record 1980 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Waitara River at Bertrand Road (Node i): Mean monthly river flow (m^3/s)												
1980	-	28.18	56.06	70.90	44.75	82.05	85.39	79.91	97.07	45.17	51.33	51.95	66.57
1981	14.98	22.37	26.88	43.01	33.93	114.04	86.11	82.70	68.21	64.55	30.15	48.14	53.05
1982	27.17	19.22	18.99	30.04	69.42	61.39	43.60	31.84	77.47	38.84	35.08	103.36	46.54
1983	38.26	11.59	13.04	72.16	69.40	36.09	48.48	54.42	83.41	82.48	88.61	34.19	52.82
1984	29.24	30.25	70.76	43.33	57.95	34.33	123.91	60.71	34.36	38.65	44.78	71.13	53.56
1985	58.43	16.50	12.51	20.75	12.23	98.75	73.25	71.28	52.24	31.05	27.80	72.81	45.82
1986	103.60	63.01	27.24	22.98	61.04	82.41	102.48	73.26	66.86	87.42	19.67	17.71	60.76
1987	52.94	15.95	30.32	68.20	63.78	55.62	31.27	48.50	62.06	89.52	31.55	76.36	52.45
1988	11.97	16.12	27.97	23.07	71.95	84.11	114.44	103.03	81.33	106.76	66.73	41.93	62.69
1989	39.32	63.32	25.43	27.42	50.75	108.85	116.82	27.35	32.04	105.81	45.08	35.28	56.43
1990	63.51	17.03	209.54	107.80	140.86	120.93	112.87	161.27	59.45	86.07	107.92	37.70	102.81
1991	70.68	75.78	28.21	95.93	44.45	54.71	83.15	155.26	59.12	61.70	30.98	24.96	65.38
1992	53.83	87.19	43.28	22.91	39.94	44.70	135.83	131.67	70.37	73.08	25.69	61.87	66.02
1993	29.88	10.74	12.91	51.13	97.60	85.13	15.75	29.43	43.71	52.91	55.58	26.98	42.73
1994	23.83	13.76	38.30	42.11	76.34	119.55	75.29	98.79	91.38	56.10	174.86	24.92	69.65
1995	21.63	36.71	63.27	126.64	45.87	80.54	100.22	74.43	88.22	81.35	75.56	39.44	69.50
1996	27.90	51.39	33.75	107.85	63.45	58.96	106.40	79.77	85.90	79.88	59.24	84.09	69.89
1997	18.32	17.20	17.38	31.74	27.89	43.17	34.56	50.91	46.36	89.47	54.47	87.69	43.47
1998	34.00	60.14	27.52	33.46	66.60	74.83	175.30	44.96	86.17	309.15	44.87	36.89	83.26
1999	32.32	12.43	20.85	28.41	106.04	91.72	61.32	79.97	54.64	30.09	86.48	33.30	53.33
2000	39.90	19.15	7.83	37.47	62.24	70.64	51.81	38.86	92.54	151.17	18.04	45.69	53.11
2001	17.66	13.54	11.30	20.56	48.95	54.17	44.39	76.44	19.30	58.46	107.22	106.85	48.50
2002	36.58	35.03	34.45	21.00	36.46	97.93	76.01	66.33	103.31	47.40	45.67	66.54	55.60
2003	12.94	6.44	12.63	20.59	68.01	87.72	80.15	18.55	127.65	109.41	58.61	102.77	59.06
2004	27.95	223.61	53.57	33.95	50.22	113.96	55.90	68.63	72.99	82.22	27.64	30.84	69.37
2005	63.60	13.46	29.44	18.51	81.49	51.17	76.72	39.63	43.65	77.49	11.78	48.34	46.71
2006	22.67	14.22	9.26	35.72	45.59	50.17	56.67	97.25	25.86	56.52	123.67	40.84	48.37
2007	20.01	9.58	32.16	10.78	36.67	49.92	101.93	92.95	26.27	78.00	34.22	18.50	42.99
2008	8.32	8.27	14.65	51.97	44.77	57.37	143.59	120.91	49.13	104.09	49.61	23.93	56.70
2009	19.02	55.05	19.25	19.17	49.20	34.33	59.34	66.43	73.93	98.51	23.14	68.20	48.87
2010	19.87	16.73	12.24	10.03	60.91	102.42	22.83	88.14	155.71	58.29	8.67	56.48	51.11
2011	51.93	11.52	34.39	34.80	98.06	110.46	84.53	32.16	28.28	86.59	49.55	86.70	59.51
2012	58.13	30.44	59.13	14.40	50.46	57.15	103.24	75.96	73.52	69.55	30.27	31.15	54.70
2013	21.62	18.73	9.33	38.28	68.39	84.58	34.09	43.73	105.99	106.46	43.00	39.33	51.21
2014	50.80	8.69	7.16	57.90	52.87	70.07	54.58	86.94	50.46	51.15	55.02	41.57	49.16
2015	12.03	12.99	13.97	89.44	110.19	160.08	61.89	119.91	70.08	36.09	37.58	17.10	61.88
2016	24.55	20.17	13.26	19.53	86.07	69.98	86.59	86.18	91.75	69.86	99.50	33.21	58.47
2017	53.26	61.95	31.24	110.88	75.55	30.38	113.31	132.30	108.69	37.88	24.55	8.49	65.70
2018	26.80	28.09	58.44	56.47	103.28	62.66	92.94	71.93	28.23	23.09	33.47	25.85	51.19
2019	10.46	7.12	17.19	53.71	43.75	52.62	103.76	76.33	39.91	55.79	35.72	52.90	46.09
2020	8.64	8.58	11.84	17.50	60.12	69.69	66.77	47.27	81.72	50.42	88.98	113.07	52.15
Minimum	8.32	6.44	7.16	10.03	12.23	30.38	15.75	18.55	19.30	23.09	8.67	8.49	42.73
Average	33.96	31.52	31.63	44.94	62.86	74.86	80.43	75.27	68.52	76.06	52.74	50.46	57.25
Maximum	103.6	223.6	209.5	126.6	140.9	160.1	175.3	161.3	155.7	309.2	174.9	113.1	102.8

Note: Values in red font indicate periods which contain gap filled data.

Figure 2.26 is a histogram plot of the monthly mean flow for the Waitara River at Tarata and at Bertrand Road for the period 2010 – 2020 (the water balance period adopted for the current assessment), which shows the highly seasonal pattern in the flow behaviour. For both sites, the mean flow in the six months from May to October is about twice the mean flow for the other six months of the year.

In round terms, the mean monthly river flow at Bertrand Road is about 1.6 times that at Tarata, and between 2.3 to 3 times that at Everett Park, depending on month.

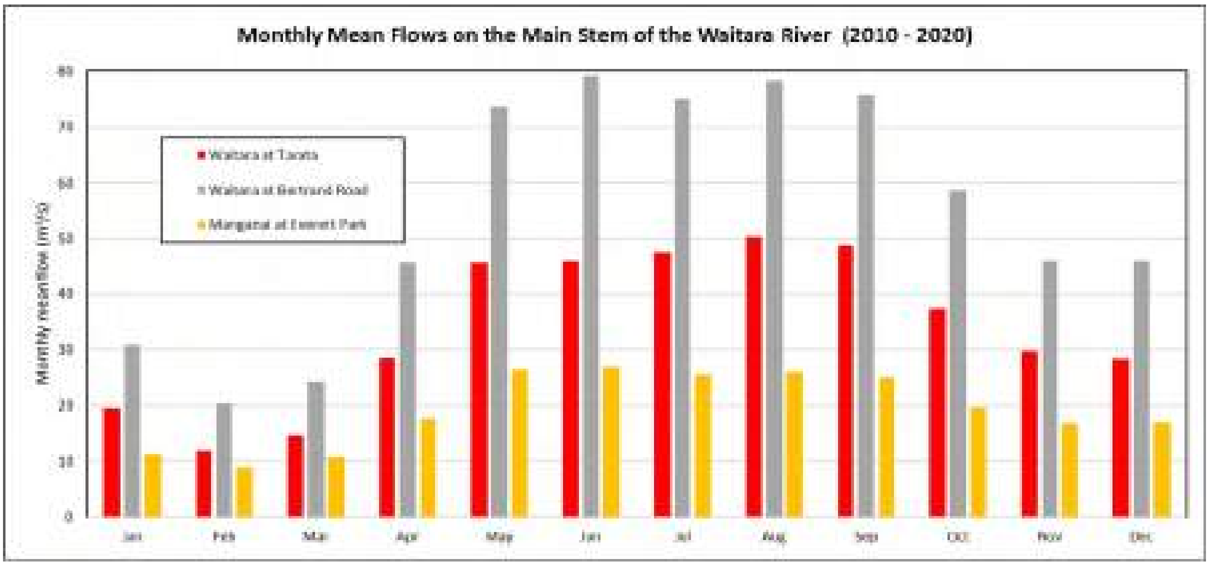

Figure 2.26 Waitara River: mean flow distribution by month-of-year for two locations. Manganui at Everett Park flows also shown to indicate relative magnitude. Period 2010 - 2020

The flow records at both Tarata Road (1969 to 2020) and Bertrand Road (1980 to 2020) are long enough for a trend analysis of overall water resource availability and inter-annual variability.

Figure 2.27 shows, for the Tarata record, the significant variability in the yearly mean flows and even greater variability in the summer mean flows (Dec, Jan, Feb). The linear trendlines (shown by the dotted and dashed lines) do not indicate any long-term trend in either the yearly mean flows or the summer mean flows. However, the summer mean flows pre-1980 and post-2007 appear markedly lower (about a third lower) compared with the period in between (1981 to 2006). This suggests a potential link to the phases of the Interdecadal Pacific Oscillation[3] (IPO), with a tendency for higher summer mean flows during the warm phase of the IPO.

Figure 2.28 compares the annual and winter mean flow series (Jun, Jul, Aug) and trendlines. There is a suggestion of a very weak increasing trend in the winter mean flows.

Figure 2.29 plots the yearly and summer mean flow series from the shorter Bertrand Road record while Figure 2.30 shows the corresponding winter mean flow series. There is an apparent decline in mean summer flows at Bertrand Road. However, reference to the mean summer flow series for Tarata Road in Figure 2.27 indicates that this apparent trend is not a trend but likely to be part of a longer term cycle potentially associated with the IPO. That is, if the Bertrand Road record existed over the same period as the Tarata record (1969 to 2020) then it is likely that the trendline fitted to its summer mean flow series would be close to horizontal also, per the Tarata record.

At Bertrand Road, it is noted that the first four months of 2020 were the driest on record while the summer of 2019/2020 (D, J, F) was the second driest (second after the 2007/2008 summer). However, the longer Tarata record shows that, prior to the start of the Bertrand Road record in 1980, the summer of 1972/1973 and the first four months of both 1974 and 1978 were drier.

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[3] The Interdecadal Pacific oscillation (IPO) is an oceanographic/meteorological phenomenon occurring in a wide area of the Pacific across both hemispheres. The period of oscillation varies from less than 15 years to over 30 years. Positive (warm) phases of the IPO are characterized by a warmer than average tropical Pacific and cooler than average northern Pacific. Negative (cool) phases are characterized by an inversion of this pattern, with cool tropics and warm northern regions. In more recent times, the IPO had a cool phase from 1946 to 1977, and a warm phase from 1978 to 1997. The period 1998 to the present has seen two short cool phases (1998 to 2002 and 2006 to 2014) and a warm phase (2015 to present).

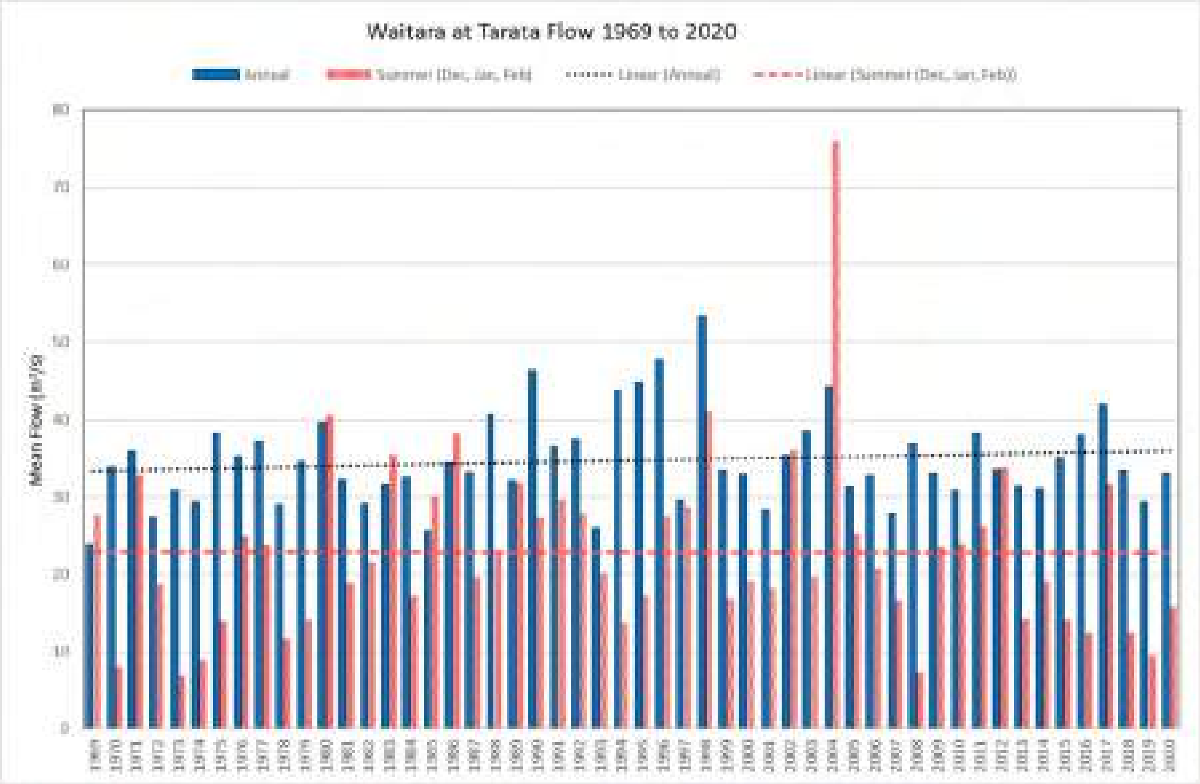

Figure 2.27 Waitara at Tarata annual and summer mean flow series over 52 years, 1969 to 2020

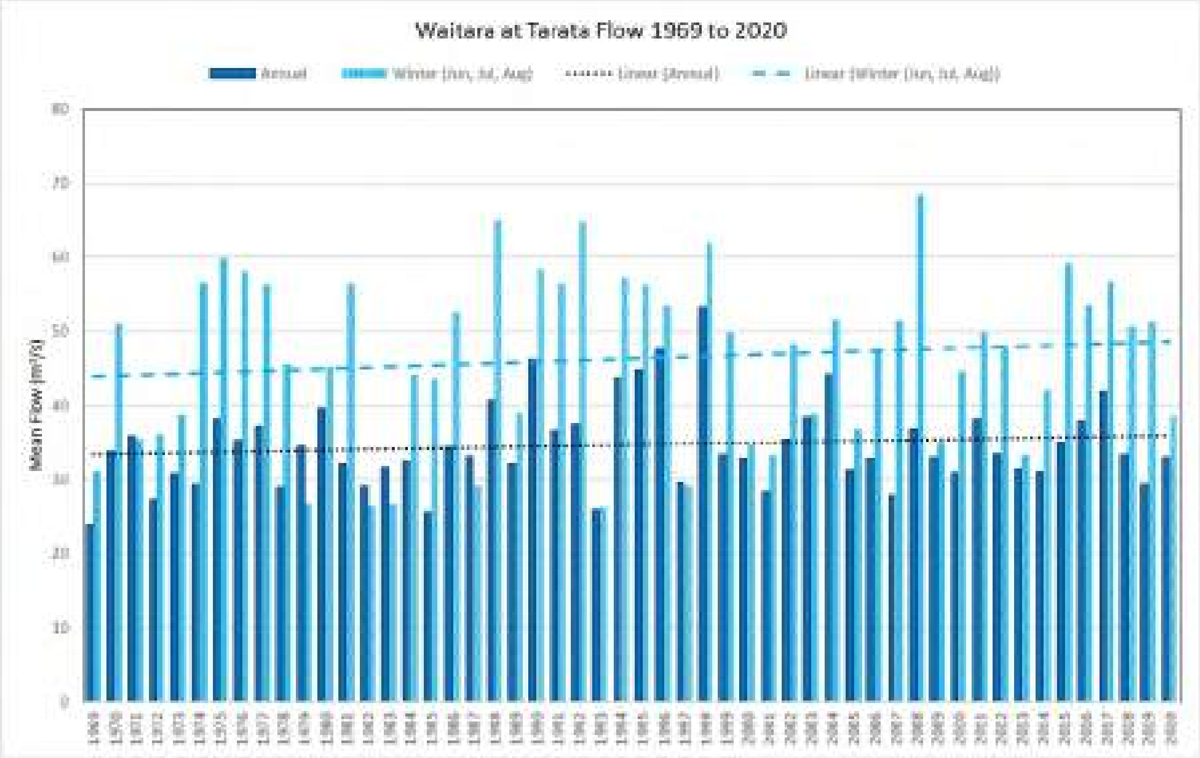

Figure 2.28 Waitara at Tarata annual and winter mean flow series over 52 years, 1969 to 2020

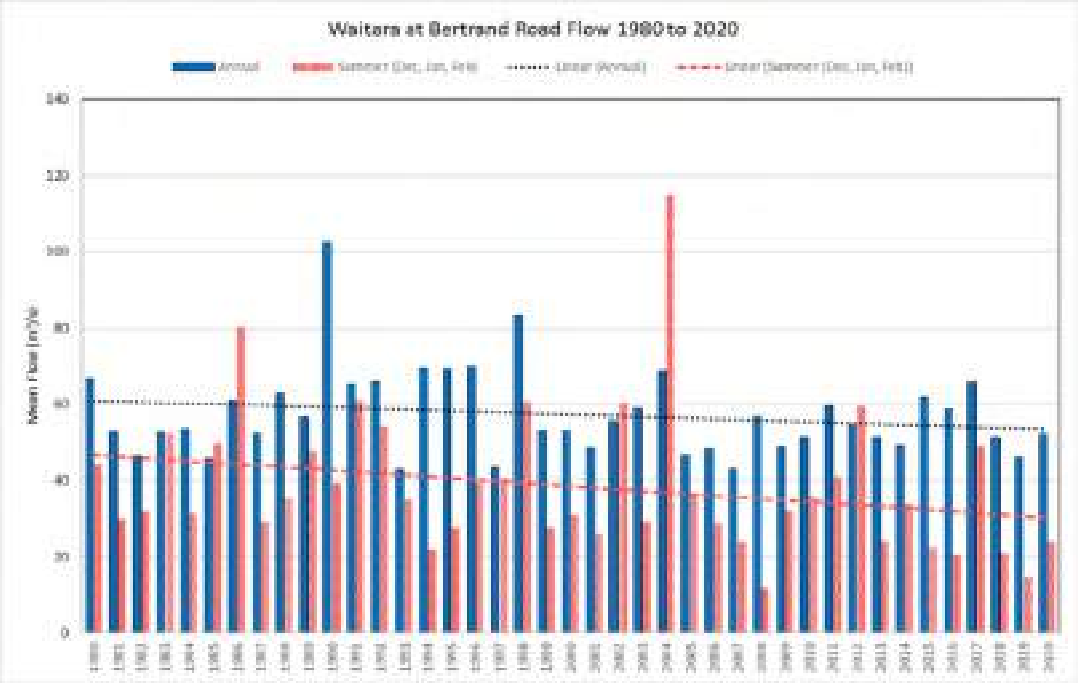

Figure 2.29 *Waitara at Bertrand Road annual and summer mean flow series over 41 years, 1980 to 2020*

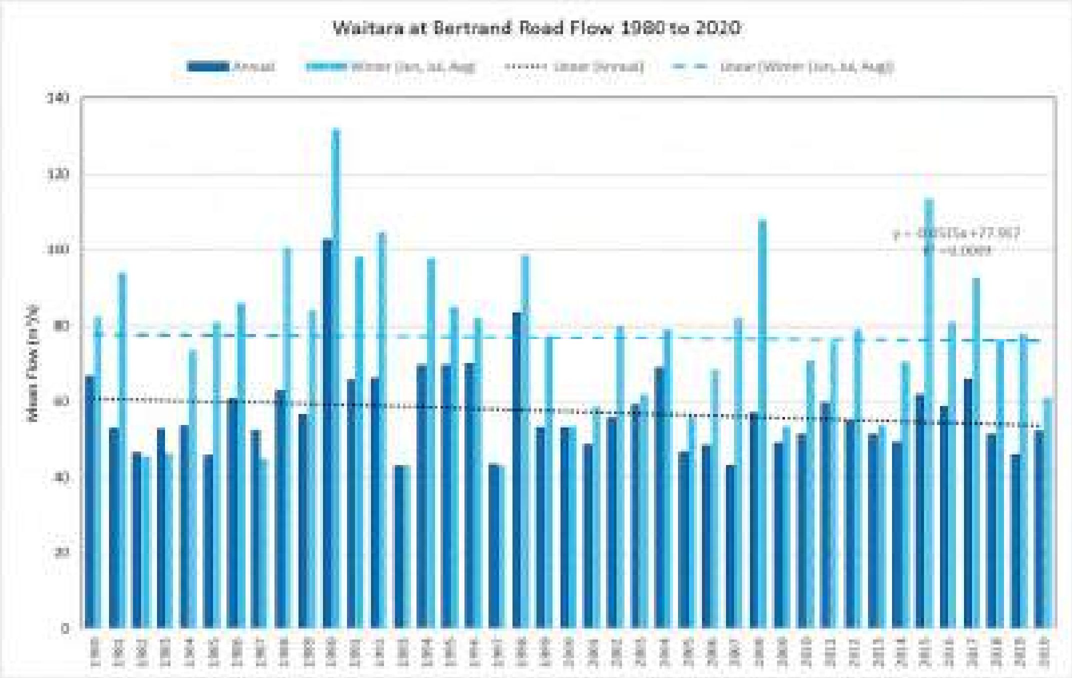

Figure 2.30 *Waitara at Tarata annual and summer mean flow series over 41 years, 1980 to 2020*

2.7.2 Waitara River flow duration

Figure 2.31 presents flow duration plots of the Waitara River at SH3 and at Bertrand Road for the period 2010 to 2020. In Figures 2.32 and 2.33, a separate flow duration curve for each season is plotted in addition to the annual (full year) curve for Tarata and Bertrand Road respectively. Table 2.12 tabulates the flow duration ordinates corresponding with the plots on Figures 2.31 and 2.32. The median flow is given by the flow that is exceeded 50% of the time, i.e. 18.64 m^3/s for Tarata and 29.6 m^3/s for Bertrand Road. While the mean flow ratio between Bertrand Road and Tarata is 1.6

and applies also to much of the flow duration curve, at lower flows the ratio becomes progressively larger, e.g. it is 2.3 at the 99th percentile flow exceedance. This is a direct result of the contribution of the strong baseflows from the Manganui River which joins the Waitara River above Bertrand Road.

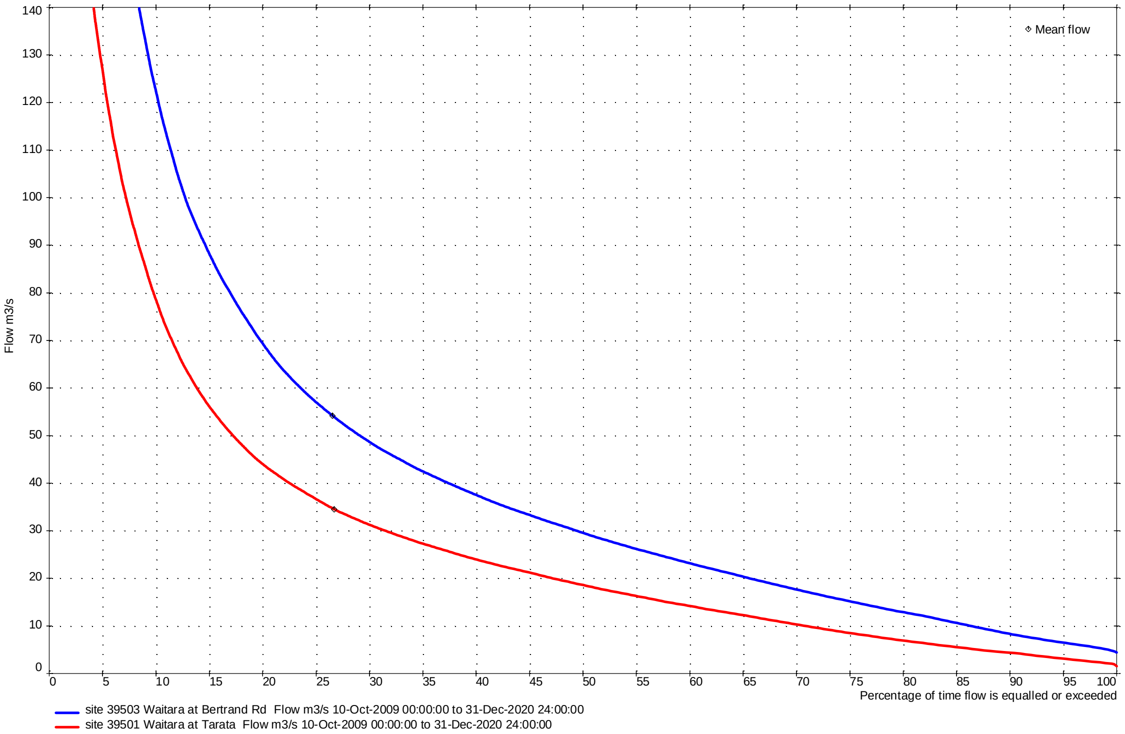

Figure 2.31 Waitara River flow duration curves October 2009 to December 2020. Red curve – Tarata; blue curve – Bertrand Road. Mean flow on each curve is indicated by diamond marker

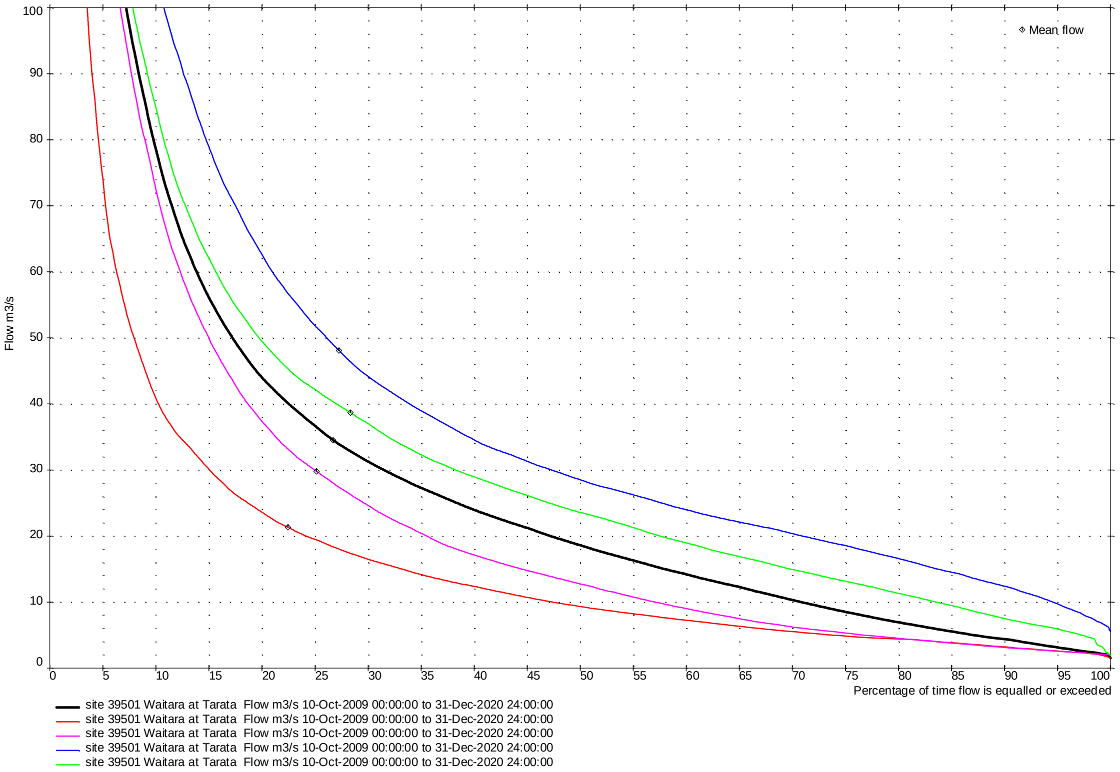

Figure 2.32 Waitara at Tarata flow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker

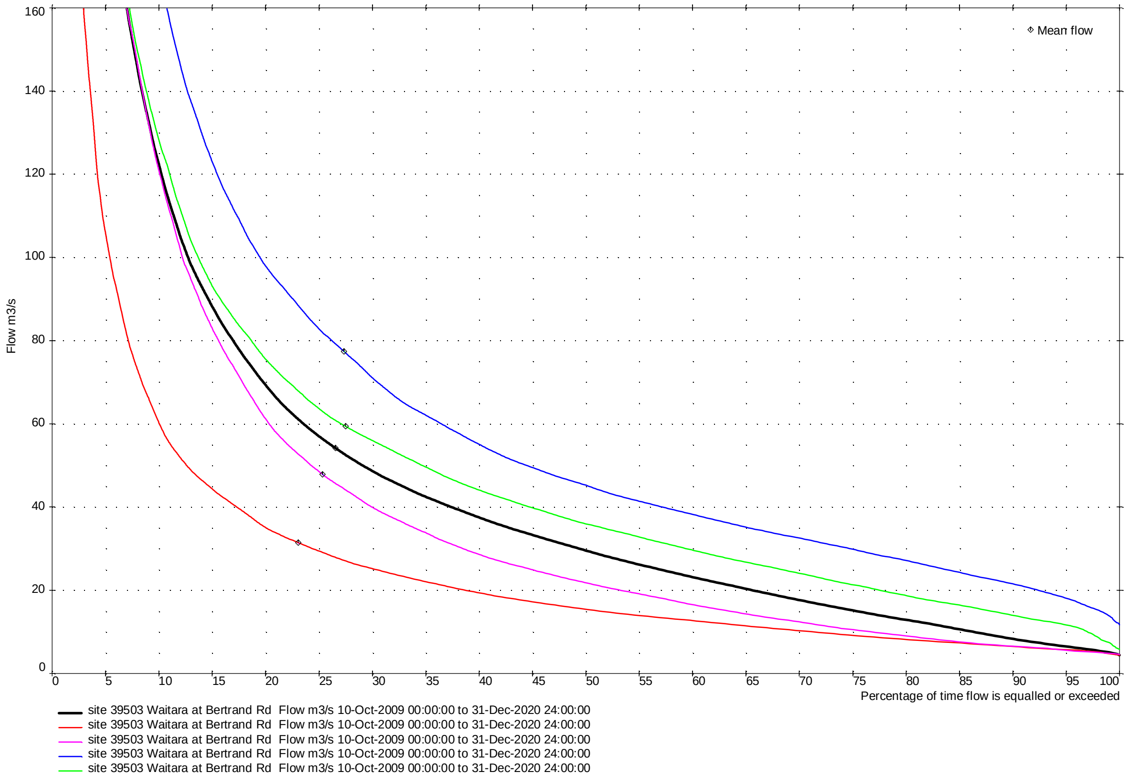

Figure 2.33 Waitara at Bertrand Road flow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker

Table 2.12 Waitara at Tarata and at Bertrand Road flow duration data (Oct 2009 to Dec 2020)

% time flow is exceeded	Waitara at Tarata (m^3/s)					Waitara at Bertrand Road (m^3/s)				
	Annual	Summer D J F	Autumn M A M	Winter J J A	Spring S O N	Annual	Summer D J F	Autumn M A M	Winter J J A	Spring S O N
1	254	226	248	288	231	390	307	368	461	398
2	197	151	194	227	190	300	213	286	364	278
5	127	74.3	123	156	130	195	106	195	246	193
10	78.7	40.9	72.6	105	85.0	123	60.4	121	167	128
20	44.1	23.6	37.4	62.7	49.5	69.4	35.1	61.3	98.0	75.6
30	31.3	16.51	24.7	44.2	37.1	48.7	25.3	40.0	71.1	56.1
40	24.0	12.41	17.17	34.6	29.0	37.6	19.42	28.7	55.1	44.2
50	18.64	9.36	12.78	28.5	23.6	29.6	15.49	21.9	45.3	36.0
60	14.23	7.28	9.04	24.0	18.99	23.2	12.74	16.58	38.3	29.7
70	10.34	5.56	6.25	20.4	14.95	17.70	10.32	12.46	32.6	24.1
80	6.96	4.44	4.54	16.62	11.36	12.92	8.22	9.08	27.2	18.79
90	4.41	3.23	3.15	12.42	7.54	8.36	6.52	6.58	21.6	14.02
95	3.16	2.60	2.57	9.76	5.94	6.52	5.77	5.61	18.14	11.72
98	2.47	2.24	2.25	7.71	4.64	5.51	5.18	5.08	15.29	8.72
99	2.23	2.00	2.15	6.94	3.40	5.12	4.79	4.90	13.96	7.49

2.7.3 Waitara River low flow characteristics

The long-term flow records for Tarata and Bertrand Road were analysed to assess the frequency and severity of low flow events. Figure 2.34 shows the General Extreme Value (GEV) distribution fitted to the annual 7-day low flow series for Tarata from 1969 to 2020. The 7-day mean annual low flow (7-day MALF) based on this series is 3.88 m^3/s, and the 5-year 7-day low flow 2.43 m^3/s. Of the 52 annual minima, 44 (85%) have occurred in the three months from January to March. Apart from the take from Lake Ratapiko for energy generation at the Motukawa Power Station, there are no other consented surface water takes upstream of Tarata (refer Section 2.5).

The fitted frequency curve to the 7-day biennial low flow series at Bertrand Road is shown in Figure 2.35. No adjustment for surface water abstractions above Bertrand Road were made, and the most significant of these is the Methanex Motunui take of up to 389 l/s, noting that under very low flow conditions (5 m^3/s or less), the Motukawa HEPS is required to pass water either over the Manganui Weir or continuously through Lake Ratapiko and the Power Station (refer to Section 3.1). This consent condition effectively prevents alteration of the low flow in either the Manganui or Waitara River by the Scheme. The 7-day MALF based on this unadjusted flow series is 7.93 m^3/s and the 5-year 7-day low flow 5.60 m^3/s. Of the 41 annual minima, 30 (73%) have occurred between the months of January and March.

Table 2.13 summarises the low flow estimates for both sites. The data indicates an appreciably higher specific low flow yield (flow per unit catchment area) at Bertrand Road compared with Tarata. This is a direct result of the substantially higher specific low flow yield of the Manganui River.

Table 2.13 Waitara River low flow frequency at Tarata and Bertrand Road

Location	Catchment Area (km^2)	7-day MALF		5-year 7-day low flow		20-year 7-day low flow	
		(m^3/s)	($l/s/km^2$)	(m^3/s)	($l/s/km^2$)	(m^3/s)	($l/s/km^2$)
Waitara at Tarata [1]	701	3.88	5.53	2.43	3.47	1.92	2.74
Waitara at Bertrand Road [2]	1113	7.93	7.12	5.95	5.35	4.87	4.38

Note 1 No adjustment made for the discharges from the Motukawa power station (not based on “naturalised” flows).

2 No adjustment made for surface water takes upstream of Bertrand Road or the discharges from Motukawa power station, i.e. these low flow estimates are not based on “naturalised” flows.

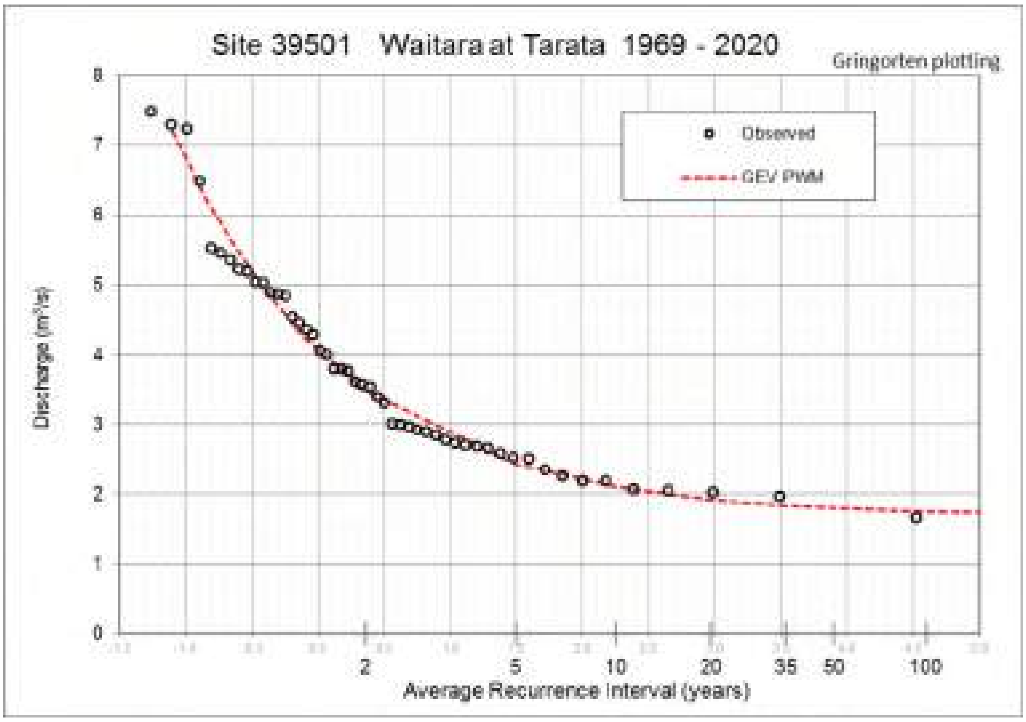

Figure 2.34 Waitara River at Tarata: 7-day annual low flows, and the best-fit GEV distribution

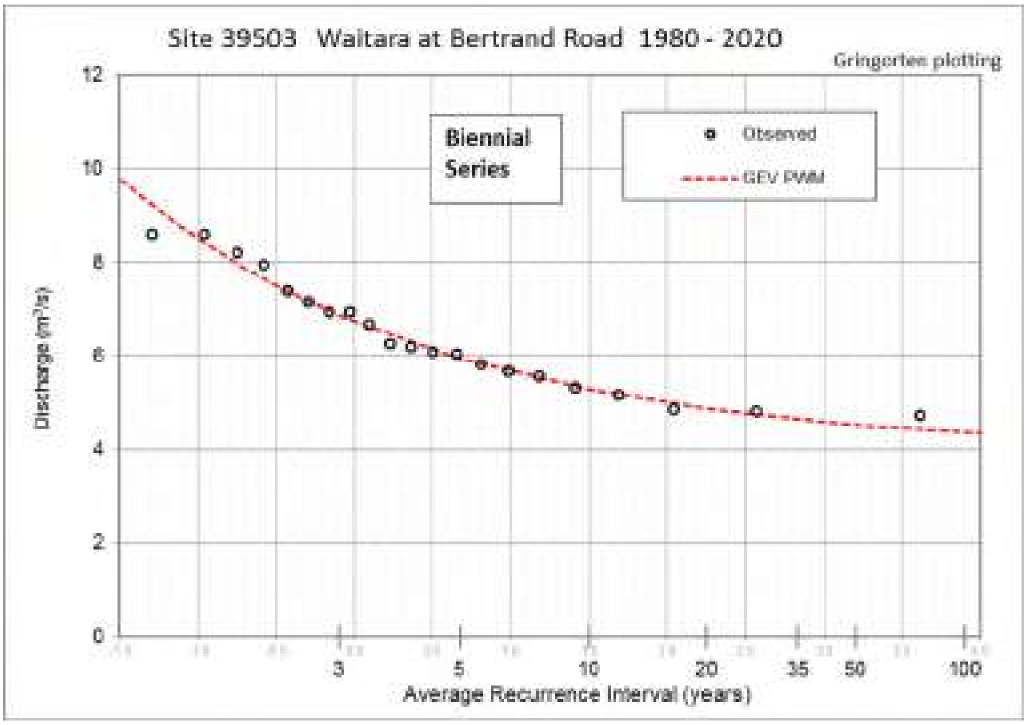

Figure 2.35 Waitara River at Bertrand Road: 7-day biennial low flows, and the best-fit GEV distribution. A biennial series was selected over an annual series for better fit to the flows below 5 m^3/s

Special Condition 4 of Consent 3369-2 (and also Special Condition 1 of Consent 3372-2) is triggered when flow at Bertrand Road is equal to or less than 5,000 l/s (refer to Section 3.1). Figure 2.36 is a partial hydrograph plot of the flow below 8 m^3/s (8,000 l/s) at Bertrand Road between 1980 and 2020. In summary, flows below 5,000 l/s occurred:

- Twice in the 1980s decade

- At no time in the 1990s decade
- Once between 2000 and 2012
- Eight times since the beginning of 2013 to 2020.

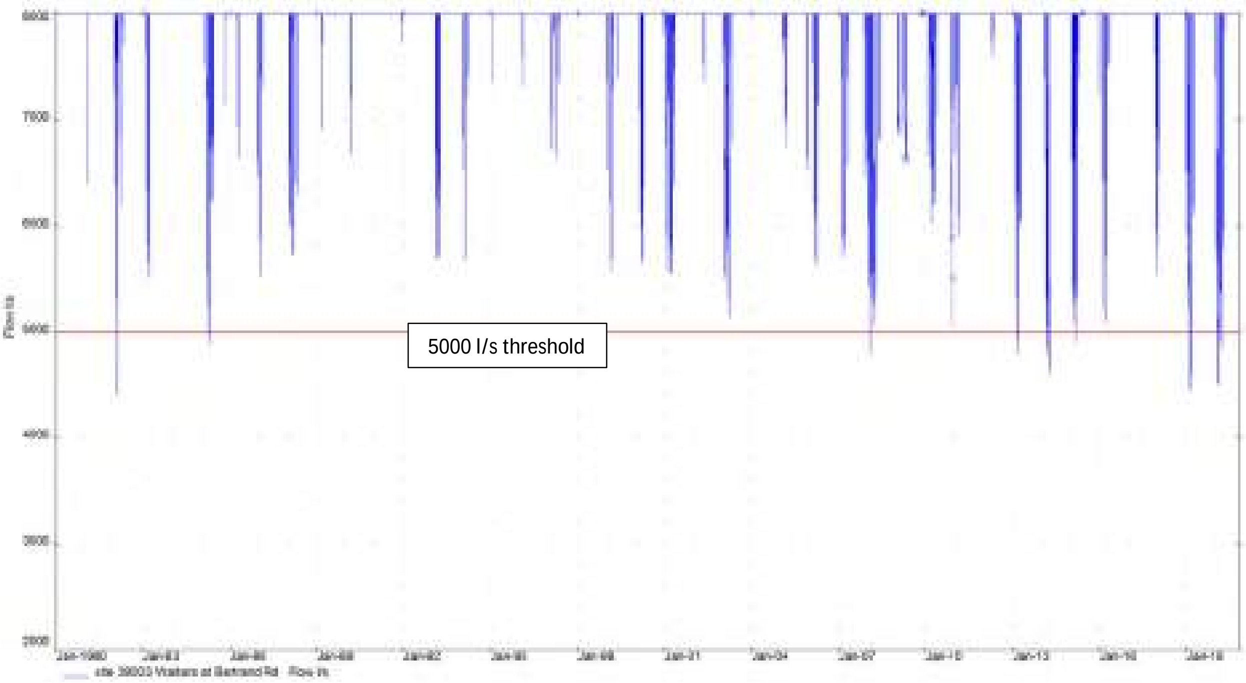

Figure 2.36 Hydrograph showing occurrences of flow below 5000 l/s at Bertrand Road 1980 to 2020

Both the Tarata and Bertrand Road flow records are long enough for a trend analysis of their annual minimum flow series, and this is shown in Figures 2.37 and 2.38. While there is considerable variability in the annual minima, the linear trendline (dotted blue line) fitted to the longer Tarata series does not indicate any increasing or decreasing trend. There is an apparent weak declining trend in annual low flows in the Bertrand Road record. However, as explained earlier, this pattern could also be part of a longer term cycle (possibly associated with the IPO, refer to Section 2.7.1).

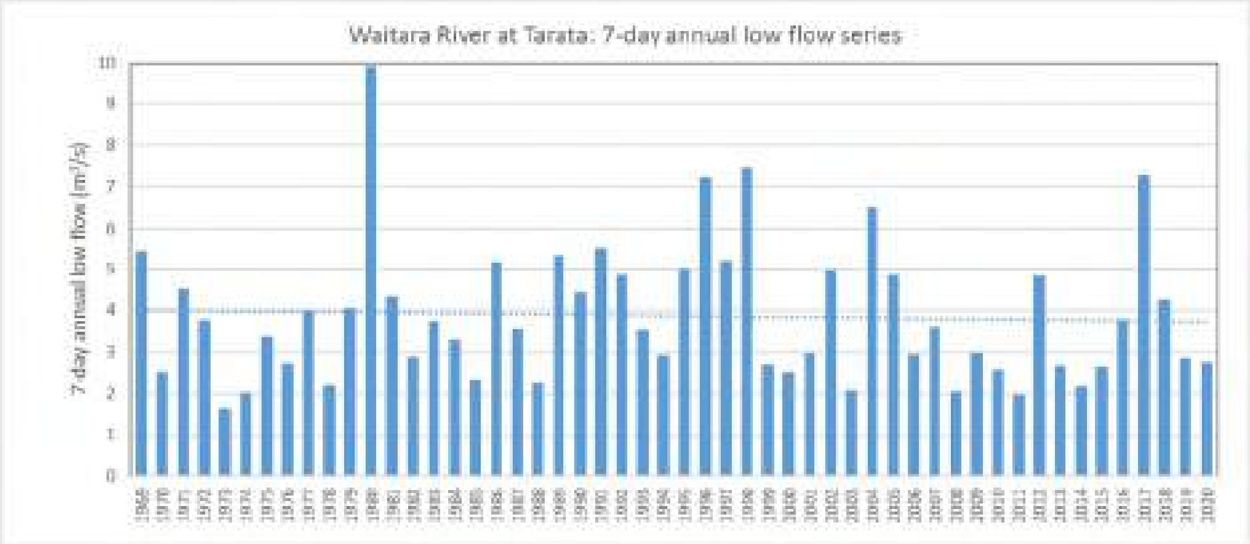

Figure 2.37 Waitara at Tarata annual 7-day low flow series (July to June year)

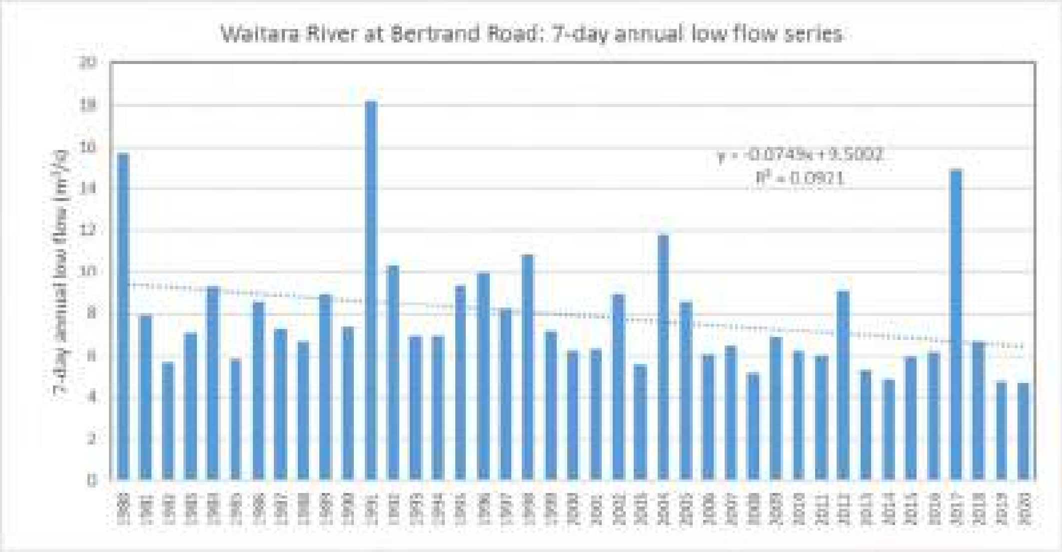

Figure 2.38 Waitara at Bertrand Road annual 7-day low flow series (July to June year)

2.7.4 Waitara River flood flow regime

Flow records for the Tarata and Bertrand Road sites were analysed to determine the frequency and magnitude of flood flows in the main stem of the Waitara River. These assessments are based on frequency analysis of the annual series of instantaneous maximum flows (i.e. the highest recorded flow for each year).

Figure 2.39 shows the best-fit Extreme Value Type 1 (EV1) frequency distribution applied to the biennial flood series from the Waitara at Tarata record from 1969 to 2020. Figure 2.40 shows the EV1 distribution fitted to the Bertrand Road biennial flood series from 1980 to 2020. The mean annual flood at Tarata and Bertrand Road are, respectively, 619 m^3/s and 970 m^3/s.

Large floods at the Tarata site can occur at any time of the year, and there are no particularly flood-prone months (compared with other months of the year) in terms of occurrence of the largest flood in each year (the annual flood). At the Bertrand Road site though, the annual flood has occurred in the month of July a total of six times (15%) and in the month of October a total of ten times (24%) in the 41-year record.

Table 2.14 summarises the peak flow estimates for Tarata and Bertrand Road. The data shows that the flood yield (flood discharge per unit catchment area) at both sites are very similar. Floods at the Bertrand Road site include the contribution from the Manganui catchment which experiences significantly higher flood intensities than the remainder (eastern flank) of the Waitara catchment (refer to Table 2.9).

Table 2.14 Waitara River flood frequency at Tarata and Bertrand Road

Location	Catchment Area (km^2)	Mean annual flood		5-year ARI flood		20-year ARI flood		100-year ARI flood	
		(m^3/s)	($m^3/s/km^2$)	(m^3/s)	($m^3/s/km^2$)	(m^3/s)	($m^3/s/km^2$)	(m^3/s)	($m^3/s/km^2$)
Waitara at Tarata	701	619	0.88	740	1.06	1000	1.43	1270	1.82
Waitara at Bertrand Road	1113	970	0.87	1190	1.07	1630	1.46	2090	1.88

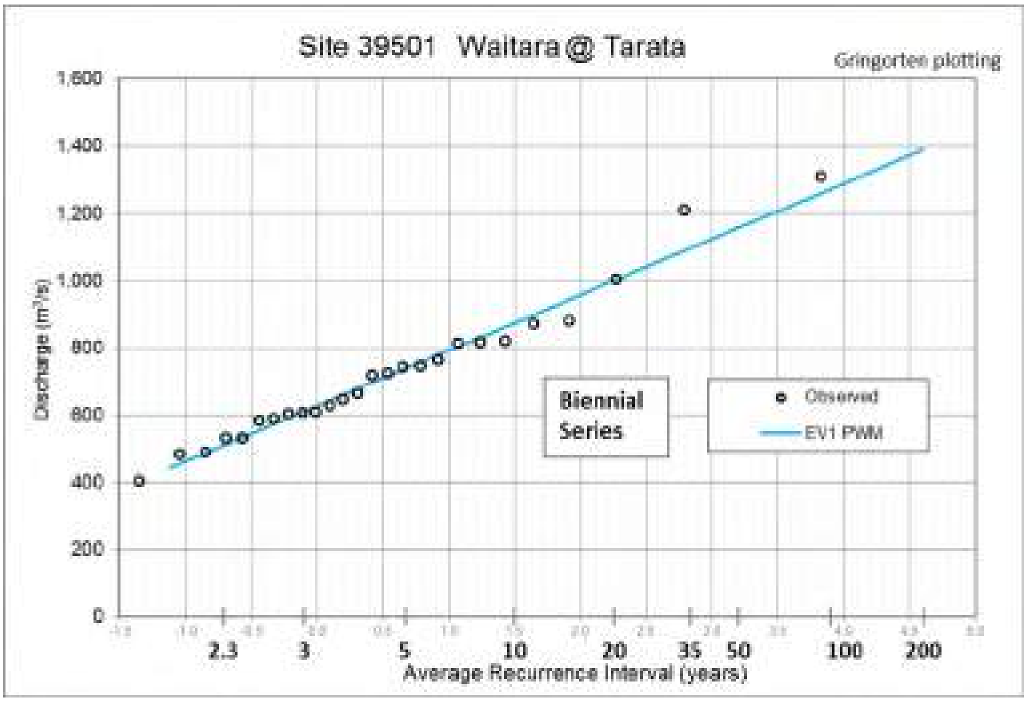

Figure 2.39 Waitara at Tarata flood frequency analysis, biennial flood series 1969 to 2020

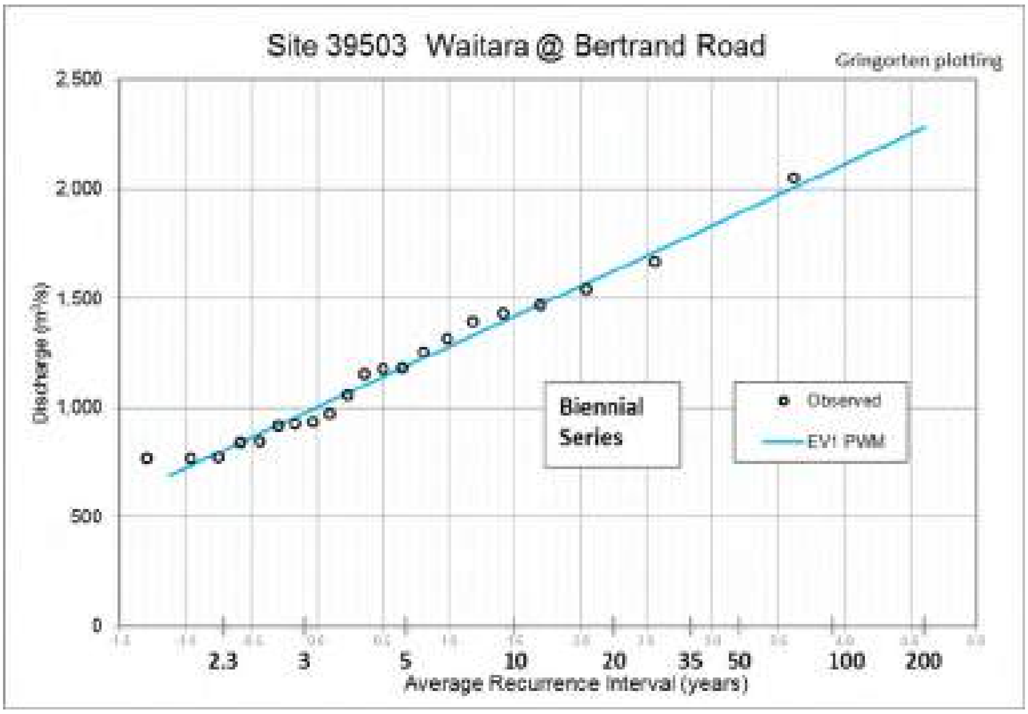

Figure 2.40 Waitara at Bertrand Road flood frequency analysis, biennial flood series 1980 to 2020

Plots of the annual flood series recorded for the Tarata and Bertrand Road are shown in Figures 2.41 and 2.42 respectively. There are no apparent trends of increasing or decreasing flood flows in either record. At both sites the two largest floods on record are the 10 March 1990 and 20 June 2015 events.

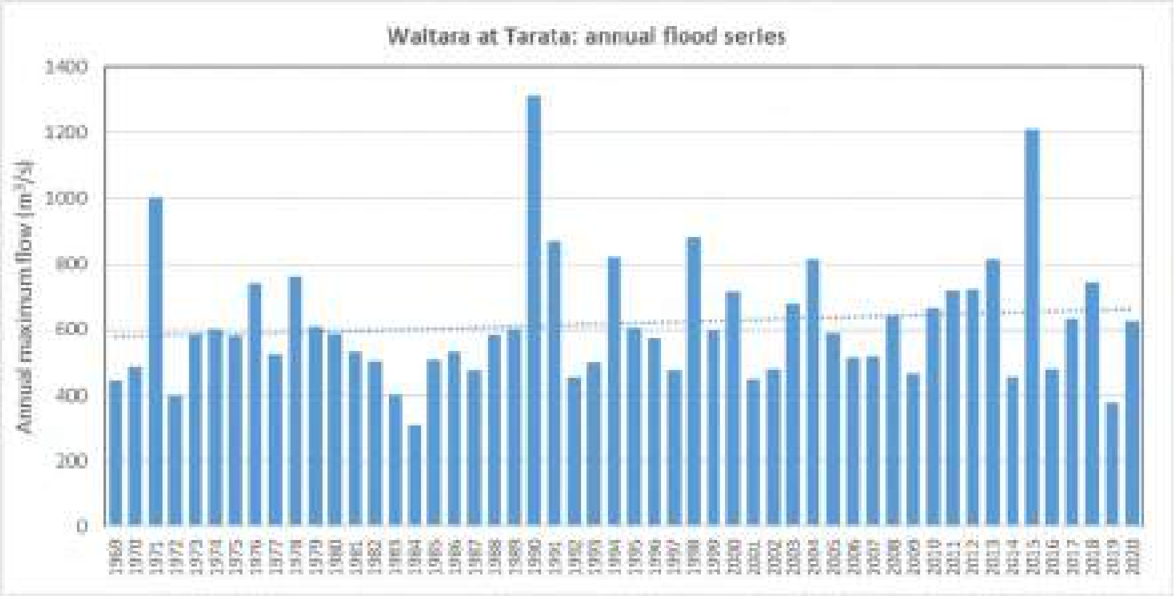

Figure 2.41 Waitara at Tarata annual flood series

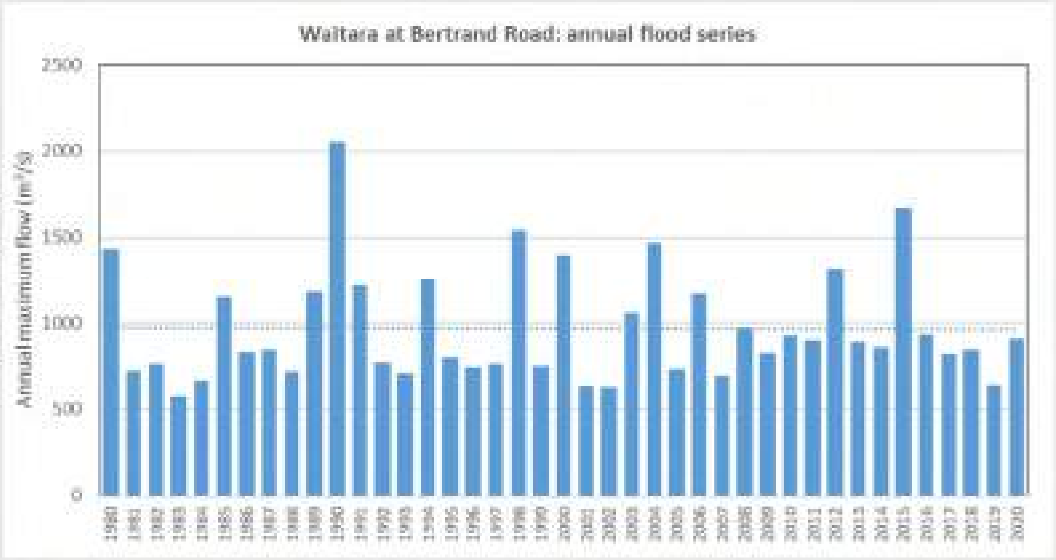

Figure 2.23 Waitara at Bertrand Road annual flood series

2.8 Summary flow statistics

Table 2.15 overleaf collates the key flow statistics for both the Manganui and Waitara rivers at their long- term flow recording sites and includes the Manganui Weir derived (reconstituted) inflow record. As the statistics are influenced by the period of record used, values for their common (overlapping) periods are also presented in the table in addition to statistics based on the full available record.

Table 2.13 Summary of flow statistics for the Manganui and Waitara rivers

Site and Record Period	Flow Statistic					
Manganui at SH3 (Catchment = 13.0 km^2)	100-year ARI Flood (m^3/s)	Mean Annual Flood (m^3/s)	Mean Flow (m^3/s)	Median Flow (m^3/s)	7-day MALF (m^3/s)	7-day 5 Year Low Flow (m^3/s)
Full Record: 31/5/1972 – 20/12/2020	89	60	1.56	0.86	0.47	0.33
Overlap with Everett Park: 13/06/1991 – 20/12/2020	-	63	1.63	0.89	0.47	-
[1] Water balance period: 10/10/2009 – 20/12/2020	-	60	1.69	0.91	0.49	-
Manganui Weir (Catchment = 80 km^2)	100-year ARI Flood (m^3/s)	Mean Annual Flood (m^3/s)	Mean Flow (m^3/s)	Median Flow (m^3/s)	7-day MALF (m^3/s)	7-day 5 Year Low Flow (m^3/s)
[1] Water balance period: 10/10/2009 – 20/12/2020	[2] ~360	[2] 201	6.86	4.17	1.18	[3] 0.92
Manganui at Everett Park (Catchment = 282 km^2)	100-year ARI Flood (m^3/s)	Mean Annual Flood (m^3/s)	Mean Flow (m^3/s)	Median Flow (m^3/s)	7-day MALF (m^3/s)	7-day 5 Year Low Flow (m^3/s)
Full Record: 13/06/1991 – 19/5/2020	1160	713	19.0	9.22	3.47	2.88
[1] Water balance period: 10/10/2009 – 20/12/2020	-	672	19.5	10.35	3.68	-
Waitara at Tarata (Catchment = 701 km^2)	100-year ARI Flood (m^3/s)	Mean Annual Flood (m^3/s)	Mean Flow (m^3/s)	Median Flow (m^3/s)	7-day MALF (m^3/s)	7-day 5 Year Low Flow (m^3/s)
Full Record: 18/12/1968 – 15/01/2021	1270	619	34.7	18.4	3.88	2.43
Overlap with Bertrand Road: 8/02/1980 – 20/12/2020	-	622	35.3	18.9	4.03	-
[1] Water balance period: 10/10/2009 – 20/12/2020	-	678	34.6	18.65	3.44	-
Waitara at Bertrand Road (Catchment = 1113 km^2)	100-year ARI Flood (m^3/s)	Mean Annual Flood (m^3/s)	Mean Flow (m^3/s)	Median Flow (m^3/s)	7-day MALF (m^3/s)	7-day 5 Year Low Flow (m^3/s)
Full Record: 8/02/1980 – 20/12/2020	2090	970	57.2	29.9	7.93	5.95
[1] Water balance period: 10/10/2009 – 20/12/2020	-	974	54.8	29.6	6.79	-

[1] Refer to Section 3.2 regarding the water balance period.

[2] Flood frequency assessment for the Manganui Weir includes the derived inflow record and Manganui at Tariki Rd record 1962 to 1973.

[3] Low flow assessment for the Manganui Weir includes the derived inflow record and Manganui at Tariki Rd record 1962 to 1973.

3 Current Motukawa HEPS Operating Regime

3.1 Existing consents

Figure 3.1 presents a schematic layout of the Motukawa HEPS that shows the main components of the Scheme and the consent conditions for their operation that are associated with taking, diverting, using and damming surface water. Table 3.1 provides a summary of these consent conditions. All consents expire on 1 June 2022.

Table 3.1 Consent conditions relevant to hydrological operation of the Motukawa Scheme

Consent number	Purpose	Relevant Special Conditions	Comment
3369 – 2	To take and use up to 5,200 litres/second of water from the Manganui River in the Waitara catchment for hydroelectric generation purposes	1. That the abstraction shall be managed to ensure that a residual flow of not less than 400 litres/second is maintained, at all times in the Manganui River below the weir 4. That the abstraction shall be managed so as to ensure that when the flow in the Waitara River, as measured at the Bertrand Road hydrology gauging site, is less than or equal to 5000 litres/second, the flow in the upper Manganui River, above the weir will either: (a) pass directly over the weir into the Manganui River; or (b) pass continuously through Lake Ratapiko [with provision for the residual flow in the Manganui River] and the power station into the Makara Stream, and thence the lower Waitara River; in order to mitigate the effects of low flows in the Waitara River. The Taranaki Regional Council shall notify the consent holder when flows at the Bertrand Road site are equal to 5000 litres/second. 5. That the consent holder shall pass 400 litres/second for three hours daily over the weir, if the weir licensed by consent 5080 is not naturally overtopped by flows in the Manganui River, of the same or larger volume, for a continuous period of 30 days. 7. That the consent holder shall, as far as is practicable, maintain a residual flow of 150 litres/second in the race during maintenance periods. During periods when it is not practicable, the consent holder shall arrange for a fish salvage operation to relocate stranded fish from the race.	Consent was granted 19 September 2001.
3371 – 2.1	To divert and use up to 8,000 litres/second of stormwater run-off and the entire flow of various unnamed watercourses draining into the race and into Lake Ratapiko in the Waitara catchment for hydroelectric power supply purposes	2. That the consent holder shall manage the water in the race so as to avoid or minimise the potential for flooding of adjacent farmland attributable to the activities of the consent holder by ensuring a maximum race water level (metres), above mean sea-level, of: 205.20 at Salisbury Road (NZTM: 1711773E-5658233N); 199.30 at Mangaotea (NZTM: 1712685E-5658307N); 199.25 at the Mangaotea Aqueduct (NZTM: 1712760E-5658335N); 199.15 at Lower Mangaotea (NZTM: 1713893E-5659542N).	Consent was granted 19 September 2001 and varied on 7 July 2016.

Consent number	Purpose	Relevant Special Conditions	Comment
		4. That a five-yearly monitoring survey of the race be completed by the consent holder to identify any maintenance requirements in order to maintain a race capacity of 8000 litres/second, for the purpose of avoiding flooding adjacent farmland, any required maintenance shall occur within 12 months of the completion of the survey.	
3372 – 2	To discharge up to 7,787 litres per second from the Motukawa HEPS into the Makara Stream	1. That the abstraction shall be managed so as to ensure that when the flow in the Waitara River, as measured at the Bertrand Road hydrology gauging site, is less than or equal to 5000 litres/second, the flow in the upper Manganui River, above the weir will either: (a) pass directly over the weir into the Manganui River; or (b) pass continuously through Lake Ratapiko [with provision for the residual flow in the Manganui River] and the power station into the Makara Stream, and thence the lower Waitara River; in order to mitigate the effects of low flows in the Waitara River. The Taranaki Regional Council shall notify the consent holder when flows at the Bertrand Road site are equal to 5000 litres/second.	
3373 – 2	To dam the Mako Stream a tributary of the Makino Stream in the Waitara catchment to form Lake Ratapiko for hydroelectric power generation purposes, including the spillway structure	5. That the consent holder shall ensure that a minimum lake water level of 194 metres above mean sea level, is retained at all times, except during periods of maintenance, for the purpose of maintaining aquatic habitat. 6. That the consent holder shall ensure the maximum level, under normal operating conditions, of Lake Ratapiko does not exceed 198.7 metres above mean sea level.	Consent was granted 19 September 2001 and varied on 4 November 2002.
5082 – 1	To discharge, under emergency conditions, up to 2,000 litres/s of overflow water from the Mangaotea Aqueduct into the Mangaotea Stream a tributary of the Manganui River	2. That emergency conditions constitute a period when local stormwater runoff to the race is required to be discharged to the Mangaotea Stream in order to avoid the race flooding adjoining land.	Consent was granted 19 August 1999.
5084 – 1	To discharge up to 55,000 litres/second of water, during adverse weather conditions, via spillways and lake drainage valves from Lake Ratapiko into the Mako Stream a tributary of the Makino Stream in the Waitara catchment	No relevant special conditions.	Consent was granted 19 September 2001.
5087 – 1	To take and use up to 7,787 litres/second of water from Lake Ratapiko in the Waitara catchment for hydroelectric power generation purposes	1. That the consent holder shall ensure a minimum lake level of 194 metres above mean sea level is retained at all times, except during periods of maintenance, for the purpose of maintaining aquatic habitat. 2. That the consent holder shall, for lake maintenance purposes, draw the level of Lake Ratapiko down gradually, over a 7-day period, in order to avoid or minimise fish stranding, and shall notify the Taranaki	Consent was granted 19 September 2001.

Consent number	Purpose	Relevant Special Conditions	Comment
		Regional Council and Fish and Game New Zealand at the commencement of the draw down period. 3. That the consent holder shall ensure that the maximum level, under normal operating conditions, of Lake Ratapiko does not exceed 198.7 metres above mean sea level. 4. That the consent holder shall manage lake levels so as to avoid or minimise the potential for the flooding of land adjoining the lake and race attributable to the activities of the consent holder.	
5088 – 1	To discharge up to 2,000 litres/second of water from the surge chamber of the Motukawa hydroelectric power station during maintenance periods into an unnamed tributary of the Makara Stream in the Waitara catchment	No relevant special conditions.	Consent was granted 19 September 2001.
6381 – 1	To take and use water from the Mangaotea Stream, a tributary of the Manganui River in the Waitara catchment, for hydroelectric power generation purposes	3. The volume of water abstracted shall not exceed 38,880 cubic metres per day at a rate not exceeding 450 litres per second. 4. For the first two years following the exercise of this consent the abstraction authorised by this consent shall cease when the flow in the Mangaotea Stream immediately downstream of the confluence with the Little Mangaotea Stream located at Q19: 227-201 (GPS E2622779 N6220149) is equal to or less than 94 litres per second. If at this site flows are greater than 94 litres per second, the abstraction shall cease when the flow in the Mangaotea Stream immediately downstream of the abstraction point (GPS E2622836 N6220071) is equal to or less than 35 L/s. 5. Two years after the exercise of this consent, and following assessment of monitoring conducted as per special conditions 8, if a review of the residual flows detailed in special condition 4 is required (as per condition 9), residual flows shall be based on 55% of the median flow immediately downstream of the confluence with the Little Mangaotea Stream, and at the point of abstraction shall be 35 L/s or mean annual low flow whichever is higher. 6. That if a flushing flow (defined as three times the median flow) has not occurred within a continuous period of 20 days, the consent holder shall cease abstraction for 8 hours during the next naturally occurring flushing flow, so as to enhance water quality downstream of the abstraction point. 8. In the first two years following the exercise of this consent, a monitoring programme designed in consultation with submitters and the Taranaki Regional Council, shall be commissioned and implemented by the consent holder to determine hydrological and ecological effects on the Mangaotea Stream and Manganui River downstream of the Mangaotea Stream confluence, and whether the residual flow is appropriate. Following the completion of monitoring, the consent holder shall forward the report(s) of these	Consent was granted 7 December 2005.

Consent number	Purpose	Relevant Special Conditions	Comment
		investigations to the Taranaki Regional Council and submitters within 6 weeks.	

Among the special conditions, the most operationally significant ones are for the diversion from the Manganui River into the Motukawa Race; the residual flow that must remain downstream of the diversion; race water level limits; and Lake Ratapiko operational limits.

Abstraction of up to 450 l/s from the Mangaotea Stream authorised by Consent No. 6381 – 1 commenced in November 2008. The pump station ceased to operate in March 2019, and Trustpower does not intend to renew the consent for this take.

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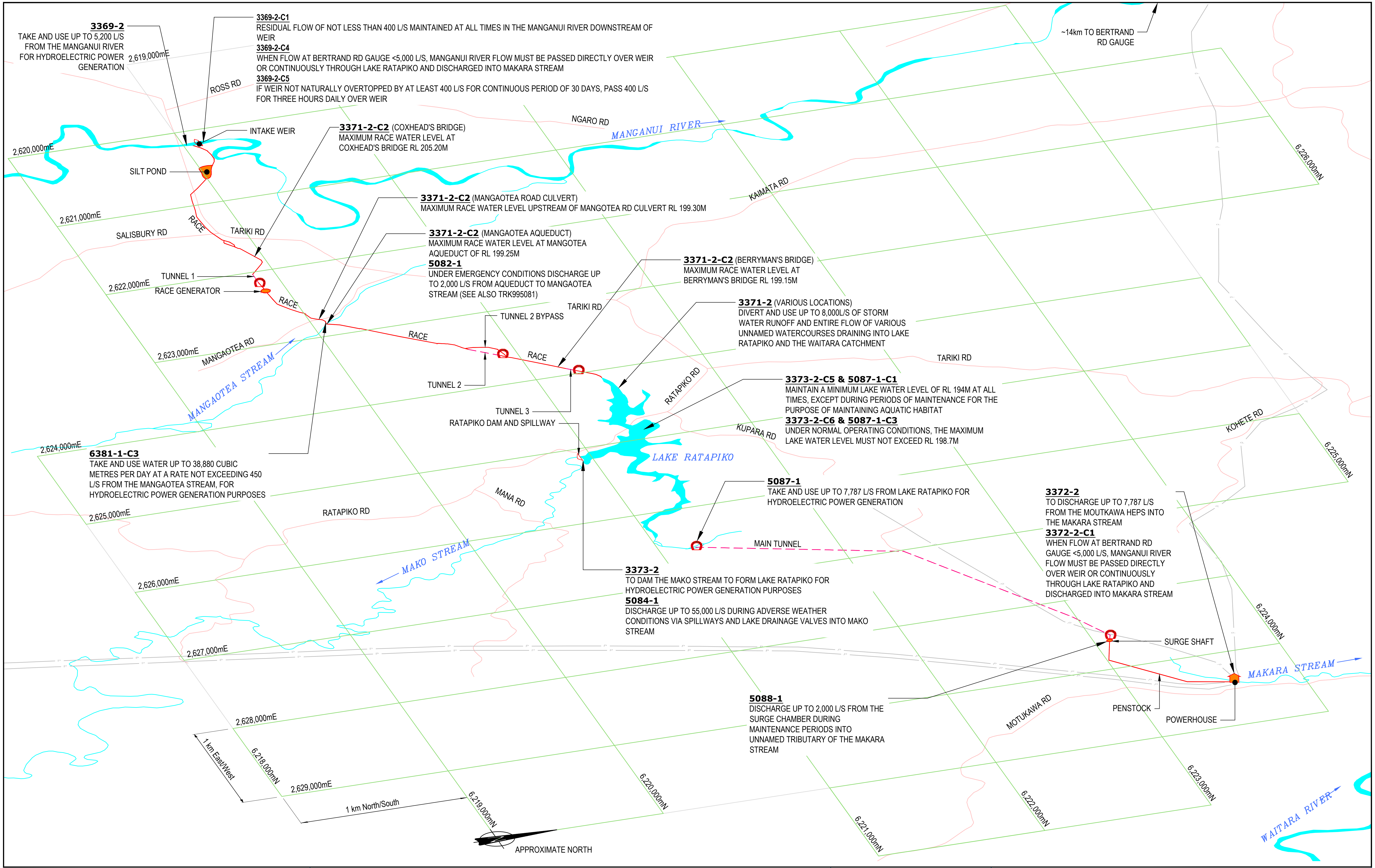

3369-2
TAKE AND USE UP TO 5,200 L/S FROM THE MANGANUI RIVER FOR HYDROELECTRIC POWER GENERATION

3369-2-C1
RESIDUAL FLOW OF NOT LESS THAN 400 L/S MAINTAINED AT ALL TIMES IN THE MANGANUI RIVER DOWNSTREAM OF WEIR

3369-2-C4
WHEN FLOW AT BERTRAND RD GAUGE <5,000 L/S, MANGANUI RIVER FLOW MUST BE PASSED DIRECTLY OVER WEIR OR CONTINUOUSLY THROUGH LAKE RATAPIKO AND DISCHARGED INTO MAKARA STREAM

3369-2-C5
IF WEIR NOT NATURALLY OVERTOPPED BY AT LEAST 400 L/S FOR CONTINUOUS PERIOD OF 30 DAYS, PASS 400 L/S FOR THREE HOURS DAILY OVER WEIR

~14km TO BERTRAND RD GAUGE

3371-2-C2 (COXHEAD'S BRIDGE)
MAXIMUM RACE WATER LEVEL AT COXHEAD'S BRIDGE RL 205.20M

3371-2-C2 (MANGAOTEA ROAD CULVERT)
MAXIMUM RACE WATER LEVEL UPSTREAM OF MANGOTEA RD CULVERT RL 199.30M

3371-2-C2 (MANGAOTEA AQUEDUCT)
MAXIMUM RACE WATER LEVEL AT MANGOTEA AQUEDUCT OF RL 199.25M

5082-1
UNDER EMERGENCY CONDITIONS DISCHARGE UP TO 2,000 L/S FROM AQUEDUCT TO MANGAOTEA STREAM (SEE ALSO TRK995081)

3371-2-C2 (BERRYMAN'S BRIDGE)
MAXIMUM RACE WATER LEVEL AT BERRYMAN'S BRIDGE RL 199.15M

3371-2 (VARIOUS LOCATIONS)
DIVERT AND USE UP TO 8,000L/S OF STORM WATER RUNOFF AND ENTIRE FLOW OF VARIOUS UNNAMED WATERCOURSES DRAINING INTO LAKE RATAPIKO AND THE WAITARA CATCHMENT

3373-2-C5 & 5087-1-C1
MAINTAIN A MINIMUM LAKE WATER LEVEL OF RL 194M AT ALL TIMES, EXCEPT DURING PERIODS OF MAINTENANCE FOR THE PURPOSE OF MAINTAINING AQUATIC HABITAT

3373-2-C6 & 5087-1-C3
UNDER NORMAL OPERATING CONDITIONS, THE MAXIMUM LAKE WATER LEVEL MUST NOT EXCEED RL 198.7M

6381-1-C3
TAKE AND USE WATER UP TO 38,880 CUBIC METRES PER DAY AT A RATE NOT EXCEEDING 450 L/S FROM THE MANGAOTEA STREAM, FOR HYDROELECTRIC POWER GENERATION PURPOSES

5087-1
TAKE AND USE UP TO 7,787 L/S FROM LAKE RATAPIKO FOR HYDROELECTRIC POWER GENERATION

3372-2
TO DISCHARGE UP TO 7,787 L/S FROM THE MOUTKAWA HEPS INTO THE MAKARA STREAM

3372-2-C1
WHEN FLOW AT BERTRAND RD GAUGE <5,000 L/S, MANGANUI RIVER FLOW MUST BE PASSED DIRECTLY OVER WEIR OR CONTINUOUSLY THROUGH LAKE RATAPIKO AND DISCHARGED INTO MAKARA STREAM

3373-2
TO DAM THE MAKO STREAM TO FORM LAKE RATAPIKO FOR HYDROELECTRIC POWER GENERATION PURPOSES

5084-1
DISCHARGE UP TO 55,000 L/S DURING ADVERSE WEATHER CONDITIONS VIA SPILLWAYS AND LAKE DRAINAGE VALVES INTO MAKO STREAM

5088-1
DISCHARGE UP TO 2,000 L/S FROM THE SURGE CHAMBER DURING MAINTENANCE PERIODS INTO UNNAMED TRIBUTARY OF THE MAKARA STREAM

APPROXIMATE NORTH

GRID IN TERMS OF NEW ZEALAND MAP GRID (NZMG) AND GEODETIC DATUM NZDG49.
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DRAWN	RHTA	Nov.21
CHECKED		
APPROVED	DATE	

CLIENT **TRUSTPOWER LTD**
PROJECT **RECONSENTING OF MOTUKAWA HYDRO-ELECTRIC POWER SCHEME**
TITLE MOTUKAWA HYDRO-ELECTRIC POWER SCHEME
SCHEMATIC LAYOUT
SCALE (A3) N.T.S FIG No. FIGURE 3.1 REV 1

3.2 Scheme water balance assessment

To understand the implications of the Scheme's operation on river hydrology and to broadly gauge the reliability of the various flow records for subsequent assessments, separate water balance analyses were completed for Lake Ratapiko and the Manganui Weir. In these analyses, the sum of inflows from all sources is tallied with the sum of the outflows for a particular time span. If there is a significant discrepancy, then it is likely that there is a systematic error or bias in one or more of the flow records used in the water balance.

The longest period for which the key flow records are all available is limited by availability of the Manganui Weir overflow (spill) record, i.e. the common period is 10 October 2009 to 20 December 2020, spanning just over 11 years. However, a longer period is available for reconciling the inflows and outflows at Lake Ratapiko viz. July 2001 to December 2020. Table 3.2 summarises the water balance for Lake Ratapiko for both periods. Differences in lake storage at the start and end of the accounting period do not affect the water balance because of the relatively small size of the lake (surface area of full lake = 0.26 km^2) and limited typical operating range (less than 4 m).

Table 3.2 Water balance analysis for Lake Ratapiko for two accounting periods

		Jul 2001 to Dec 2020	Oct 2009 to Dec 2020	
ID	Item	Mean Flow (l/s)		Notes/description
A	Diverted river flow into Motukawa Race	3035	3161	Flow measured near upstream end of Motukawa Race (Tariki Road)
B	Mangaotea Stream take	19	29	Pumped flow from Big Mangaotea Stream to Motukawa Race. The pumping station operated between November 2008 and March 2018 and the mean flow reflects this
C	Local catchment inflow (excluding flow diverted from Manganui River)	~ 413	~ 413	This is an approximation (± 40 l/s) based on a catchment area of ~12.4 km^2 and assessed mean annual runoff of 1050 mm. Includes flow intercepted by the race and local tributaries of Lake Ratapiko as well as direct rainfall on the lake surface
D	Sum of inflows = A + B + C	3467	3603	
E	Power station discharge	3347	3562	Discharge converted from station load using rating curve
F	Spill flow from dam	~ 57	~83	Estimate based on lake level duration above the crest of the spillway flashboards (RL 198.67 m) and the spillway geometry and operation advised by Trustpower (see Table 3.4 also)
G	Seepage and other losses	~ 5	~ 5	Rough order estimate based on recorded seepage plus an allowance
H	Sum of outflows = E + F + G	3409	3650	For both periods, the difference compared with the sum of inflows is less than 60 l/s, i.e. apparent error less than 2%

There is excellent agreement (<2% difference) between the total inflow into and total outflow from Lake Ratapiko for both accounting periods, which provides confidence in the reliability of the component mean flows. This difference is less than the expected uncertainty in the major components of the water balance, such as the power station discharge which is derived from load (power output) versus water discharge rating curves.

On an annual basis, take from the Mangaotea Stream peaked at 58 l/s in 2014, and it that year represented about 1.9% of the total race inflow into Lake Ratapiko. However, over the 11-year water balance period (October 2009 to December 2020), it contributed 0.9% of the race inflow volume.

Table 3.3 presents the water balance analysis for the Manganui Weir for the common period 10 October 2009 to 20 December 2020. Several estimates of the mean flow at the Manganui Weir (Tariki Road) based on different methods are presented. From the comparison, the mean flow at Manganui Weir based on the reconstituted flow components (Method B, refer to Section 2.6.1) of 6.86 m^3/s is well supported.

Based on the SH3 record (1972 to 2020), the long term mean flow could be up to 8% lower than the period mean selected for this assessment (2010 to 2020) (refer to Table 2.13 for period flow statistics). Analysis of the SH3 flow record appears to indicate a weak trend of increasing mean flows over the years, and, to an extent, the same pattern can be reasonably expected in the Manganui Weir flows.

Table 3.3 Water balance comparison for Manganui Weir for the period Oct 2009 to Dec 2020

ID	Item	Mean Flow (l/s)	Notes/Description
I	Diverted river flow into Motukawa Race	3161	Measured near upstream end (Tariki Road) of the Motukawa Race
J	Combined L/R residual flow	513	Sum of left bank & right bank residual/fish pass flows at intake weir
K	Manganui Weir overflow	3184	Computed using weir equation applied to recorded weir water levels
L	Total inflow at intake weir = I + J + K	6858	This is the river flow arriving at the Manganui Weir before diversion (Method B, refer to Section 2.6.1)
M	Manganui at Tariki Road flow record Jan 1962 to Dec 1973	6707	Mean flow at NIWA Site 39504, for comparison with item L above, noting that the recorded mean flow is likely overestimated but also that the data period contained a very dry spell (1972 and 1973)
N	Manganui at Tariki Road mean flow from catchment water balance	6900	Calculated from catchment-averaged rainfall of 3350 mm p.a. and losses of 625 mm p.a., the latter based on comparative losses back-calculated from recorded mean flows at other gauges
O	Manganui at Tariki Road synthetic record from Manganui at SH3 record	7320 (Oct 09 to Dec 20) 6717 (long-term mean)	Mean flow estimated based on correlation between Tariki Road and SH3 time-series flows for their overlapping data period 1972/73 (Method A, refer to Section 2.6.1). The long-term mean is also shown and corresponds with the full SH3 data period 1972 to 2020

3.3 Diversion from Manganui River

3.3.1 Intake headworks

Figure 1.1 shows the location of the river intake on the Manganui River (the Manganui Weir) and the alignment of the diversion race (Motukawa Race) to Lake Ratapiko. The river intake comprises a concrete weir about 4 m high built in the 1920s across the full width of the river (see photo in Figure 3.2), fish passes on left and right banks of the weir, and the diversion race inlet.

The weir is ungated and allows free overflow over its 34 m wide ogee-shaped crest that has a crest level of RL 210.82 m (and an estimated design head of 1.83 m). At the downstream toe of the weir is a concrete lined energy dissipating basin. On the right bank about 25 m upstream of the weir is the inlet to the diversion race. There are two fish passes that release residual flow past the Manganui Weir: an older fish pass on the left abutment of the weir and a more recently constructed stepped naturalised channel on the right bank of the weir (see Figure 3.3). The impoundment formed by the Manganui Weir is relatively small, being only as wide as the river channel (25 to 35 m wide) and extending about 550 m upstream.

Figure 3.2 The Manganui Weir, wide angle view from right bank. Tariki Road bridge visible on the left of the photo (photo credit: Trustpower)

Figure 3.3 Left bank fish pass shown in the left frame. The right frame presents a vertical aerial view of the intake works; the intake weir and right bank fish pass channel are labelled

Water levels at the weir have been monitored by Trustpower since at least February 2005 (refer to Table 2.2), but up until 10 October 2009, the maximum recorded level was truncated at 0.8 m above the weir crest. Given that the water level at the mean annual flood (201 m^3/s, refer to Table 2.13) is 1.87 m above the weir crest, the peak discharge prior to 10 October 2009 cannot be determined from the water level record. Appendix D presents the raw (unaudited) water level record at the Manganui Weir from 2010 to 2020. The maximum recorded level is RL 212.975 m, which is 2.155 m above the weir crest and corresponds with a discharge of 254 m^3/s. Figure 3.4 presents the water level duration curve at the Manganui Weir while Figure 3.5 shows the corresponding flow duration curves (annual and seasonal) of the weir overflow. Overflows occur for just over 50% of the time on average and the mean discharge over the weir is 3.18 m^3/s.

Section 3.7 provides further information on the river flow regime downstream of the intake weir, which incorporates the residual (fish pass) flow and the weir overflow, and includes tables of mean monthly flows and analysis of seasonality.

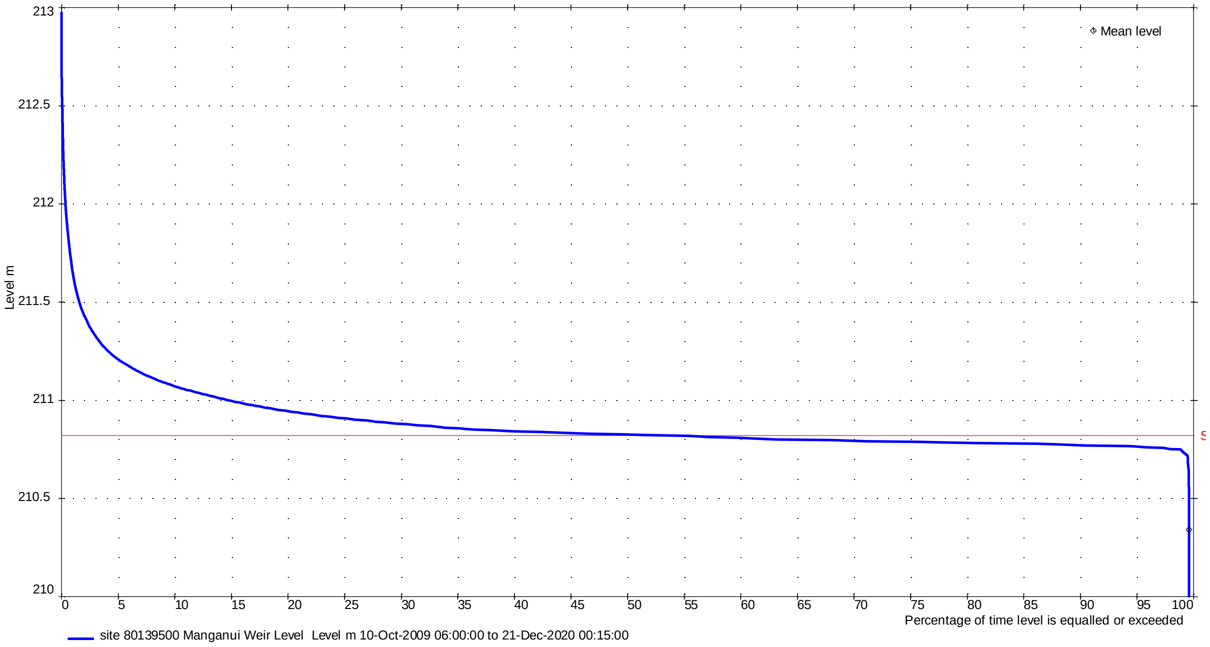

Figure 3.4 *Manganui Weir water level duration curve, Oct 2009 to Dec 2020. Weir crest level indicated by red line. Levels lower than the 99th percentile exceedance level comprise of dropouts in the data*

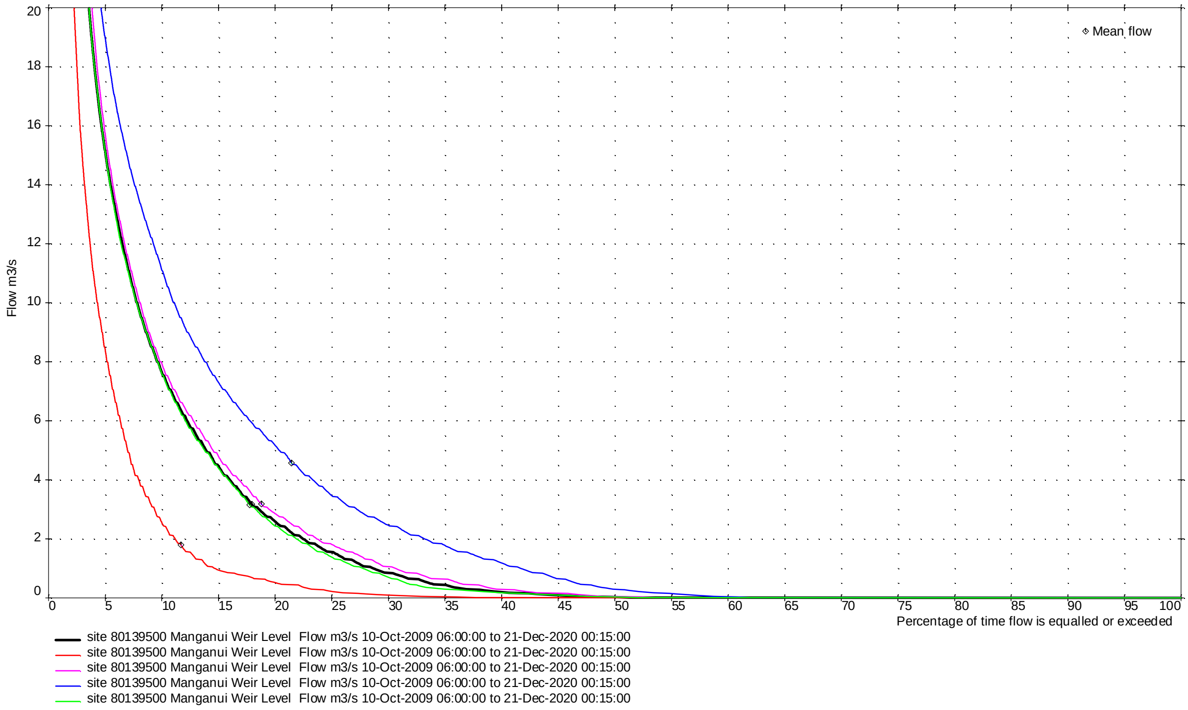

Figure 3.5 *Manganui Weir overflow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker*

3.3.2 Fish pass flows

A minimum residual flow of 400 l/s is required below the intake weir at all times (Consent 3369 – 2 Special Condition 1). The discharge in both fish passes contribute to this residual flow and is continuously monitored by Trustpower (refer to Table 2.2). Appendix D includes hydrograph plots of the combined fish pass flow (i.e. sum of the left bank and right bank fish pass flows) for the period 2010 to 2020. The combined fish pass flow is strongly correlated with the water level at the Manganui Weir as can be seen in Figure 3.6, which plots the recorded (hourly-averaged) flows against the weir water levels for the 2020 year, particularly for water levels less than RL 211.00 m (r^2 = 96.6%). There is a linear relationship between the combined fish pass flow and weir water level for levels up to about RL 211.00 m, followed by a step reduction in the flow (given by another relationship between flow and level) for higher water levels. In this plot, flows less than 400 l/s do not indicate that the residual flow is less than 400 l/s. This is because, at above RL 210.82 m, the weir overflow starts to contribute strongly to the overall residual flow below the weir.

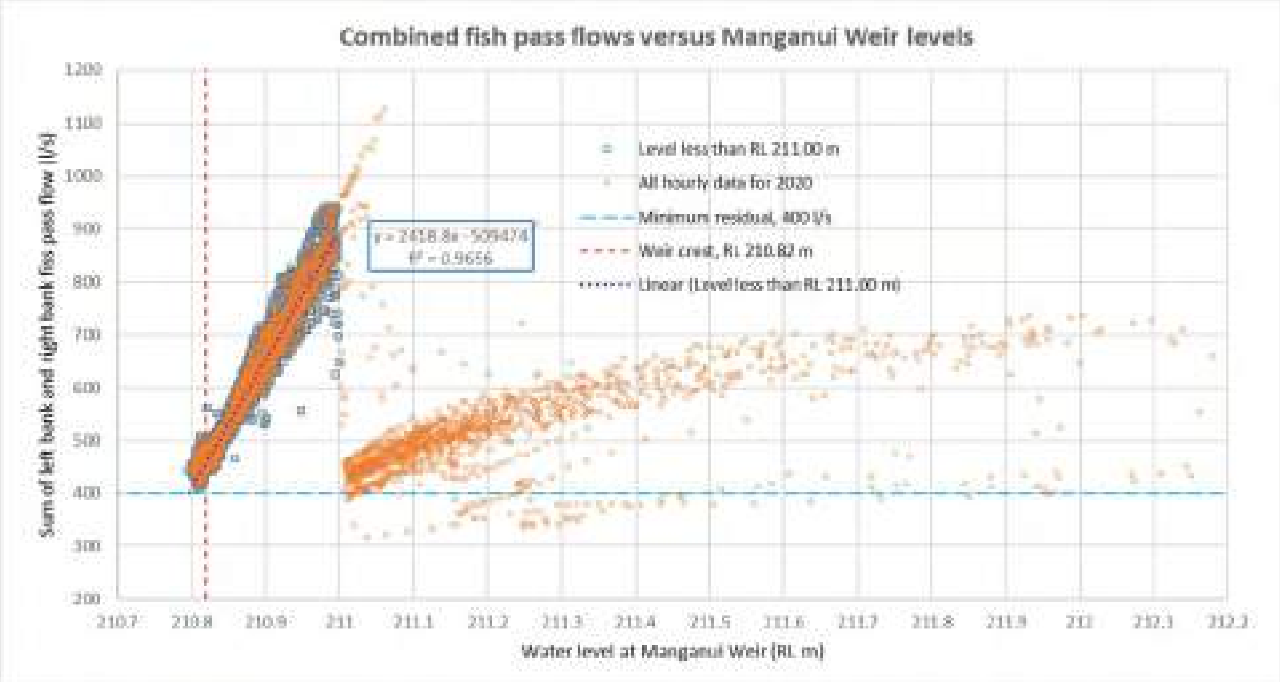

Figure 3.6 Relationship between total fish pass flow and weir water level based on hourly data for 2020

Figure 3.7 presents the combined fish pass flow duration curve based on the unaudited flow record (but with negative values removed) for the water balance period October 2009 to December 2020. Dropouts (missing data) in the raw flow record contribute to values below 400 l/s in the low flow end of the curve (greater than the 95th percentile exceedance). The curve for the last year of record (2020), which is more complete, is separately plotted and shows that the total fish pass flow does not fall below 300 l/s. The mean flow for the full period is 513 l/s and for 2020 alone is 532 l/s.

Section 3.7 provides further information on the river flow regime downstream of the intake weir which includes the residual (fish pass) flow as well as the weir overflow.

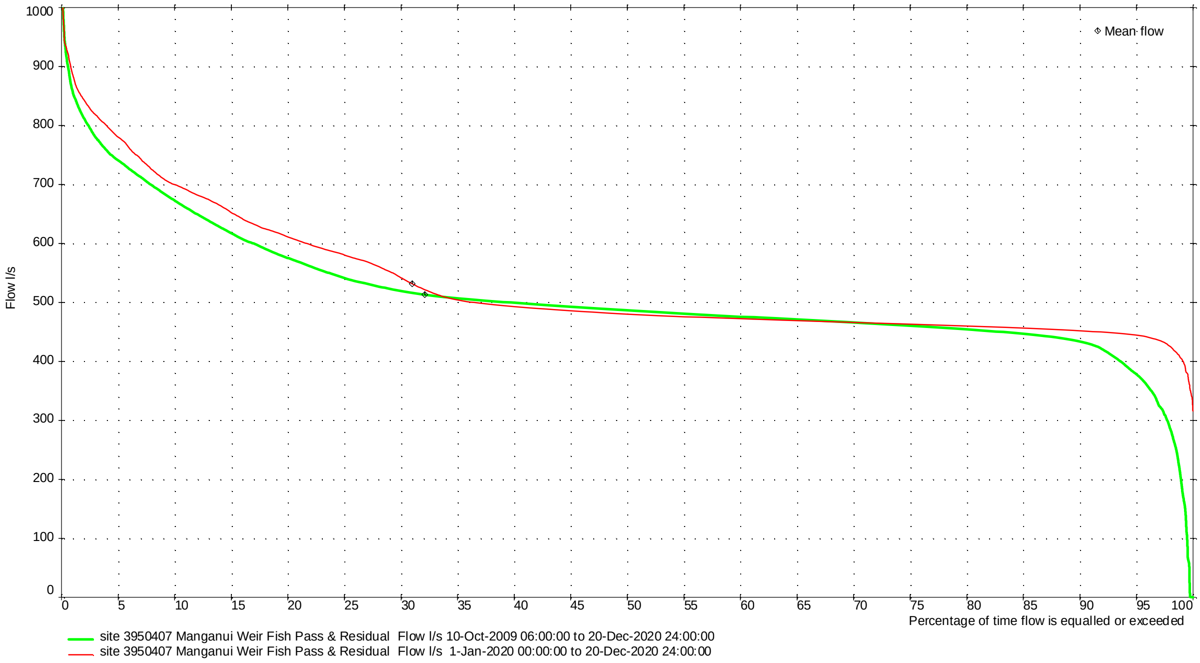

Figure 3.7 Flow duration curves of the total fish pass flow, for Oct 2009 to Dec 2020 (green curve) and for 2020 alone (red curve). Note that the residual flow below the weir is greater than the combined fish pass flow when weir overflow occurs, which is greater than 50% of the time on average

3.3.3 Motukawa Race flows

Riley (2021) provides a detailed description of the Motukawa Race and its features, including:

- It is approximately 4.6 km long, generally between 3 m and 9 m in width and mainly in cut, and the bed elevation drops 13 m over this distance (from RL 208.20 m at the upstream end to RL 195.18 m at the downstream end)
- Along its alignment are three short tunnel sections, an in-race generator and an aqueduct (Mangaotea Aqueduct) where it crosses over the Mangaotea Stream
- Within the first 500 m at the upstream end is a screened inlet followed by an intake structure (CH105) with twin vertical gates and a pond for settling out sand-sized sediments i.e. the Silt Pond (CH290 to CH520)
- There is a pump station at the Mangaotea Aqueduct (CH2855) that is consented to abstract up to 450 l/s from the Mangaotea Stream into the race.

Figure 3.8 is a drawing of the longitudinal section of the Motukawa Race, which shows that the race invert falls unevenly. The chainages (CH) referred to in this section are shown in this drawing.

Flow in the Motukawa Race is primarily monitored by Trustpower at the Tariki Weir (CH725) which is about 200 m downstream of the Silt Pond. As described in Riley (2021), the two main tributaries that feed directly into the Race are the Salisbury Drain (CH1300) and an unnamed drain at CH3400, which are both downstream of the race flow monitoring point. Furthermore, abstracted flows from the Mangaotea pump station have previously entered the race at CH2855. Thus the recorded race flows do not include any substantial local catchment inflows.

There are several other water level sensors along the race that do not measure flow but are used by Trustpower to manage the Scheme in accordance with Consent 3371 – 2.1 Special Condition 2 (refer to Table 3.1, viz. to avoid or minimise the potential for flooding of adjacent farmland).

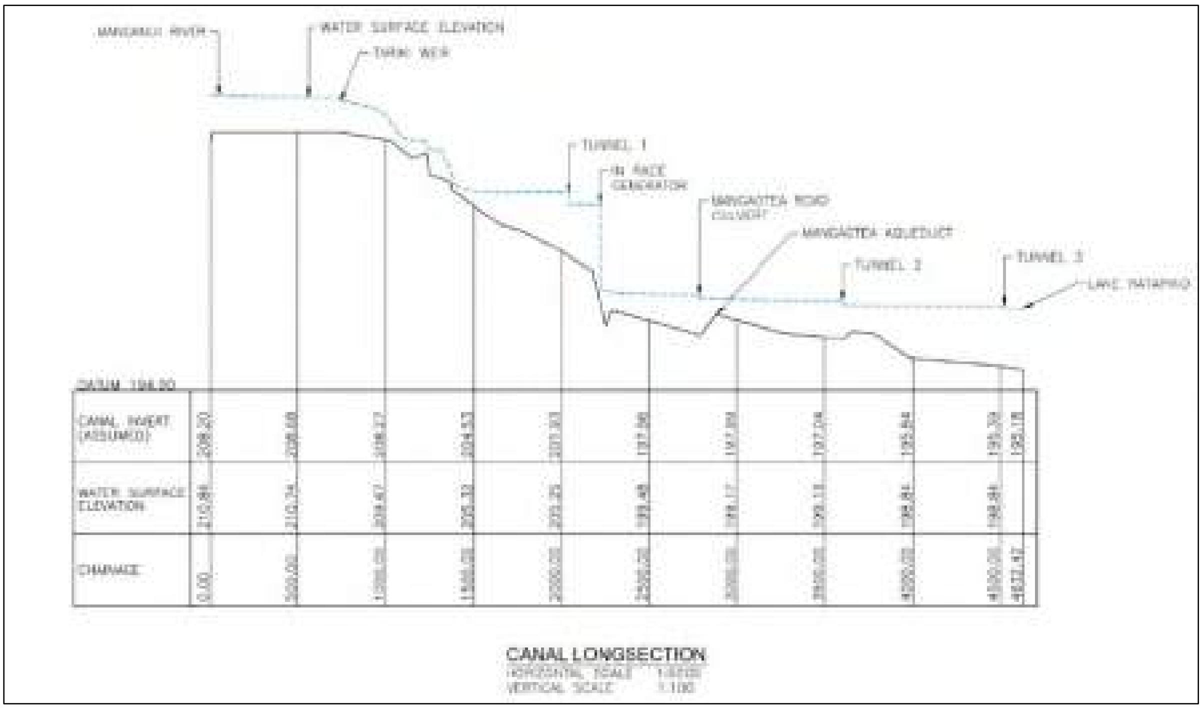

Figure 3.8 *Motukawa Race longsection with estimated water level profile for a flow of 7.5 m^3/s. Extracted from Drawing 18MTK/ENH-92 Rev1 by Riley Consultants*

Appendix D presents the unaudited Motukawa Race flow record for the water balance period 2010 to 2020. Figure 3.9 presents the corresponding race flow duration curves (annual and seasonal). The mean race flow over this period is 3.16 m^3/s and the median 3.33 m^3/s. The maximum race flow is 5.2 m^3/s (0.1% exceedance), equal to the maximum consented take (5,200 l/s, per Consent 3369 – 2), while a flow of 5.0 m^3/s is exceeded 13% of the time on average.

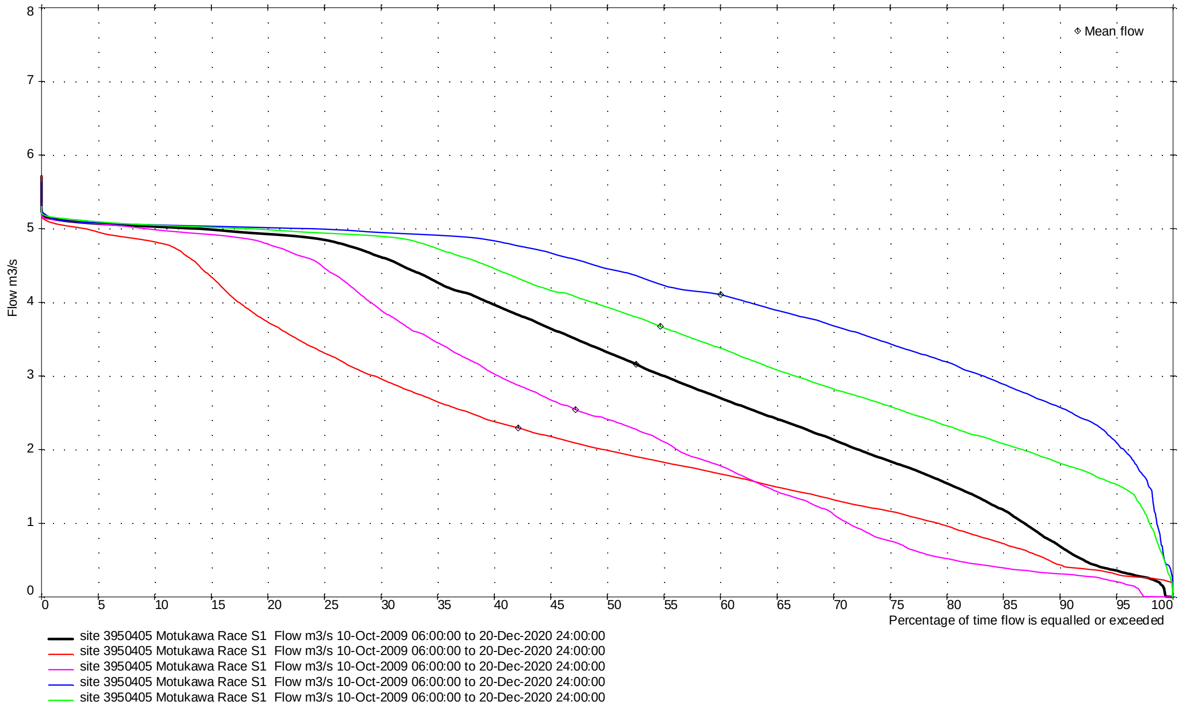

Figure 3.9 *Motukawa Race flow duration curve, Oct 2009 to Dec 2020. Red curve – summer (D, J, F); magenta – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. Mean flow on each curve is indicated by diamond marker*

Section 3.6 provides further assessment of the Scheme inflows and outflows, and presents tables of mean monthly flows and analysis of seasonality.

3.3.4 Pumping from Mangaotea Stream

Consents were granted to Trustpower for taking water from the Mangaotea Stream on 7 December 2005. Records of abstraction begin in October 2008 and show that the pump station (photo in Figure 3.10) ceased operation in March 2018. Figure 3.11 is a time series plot of the abstracted flows from 2009 to 2018.

Figure 3.10 The pump station for abstracting water from Mangaotea Stream to the Motukawa Race

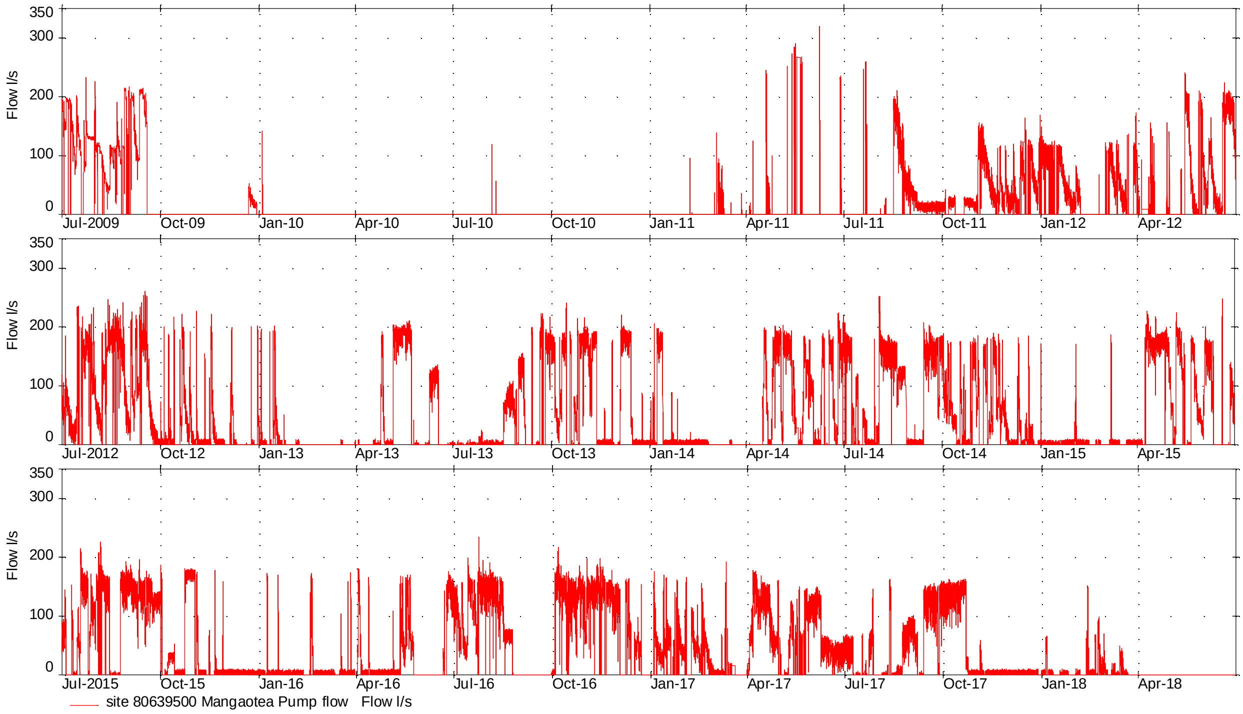

Figure 3.11 Time-series of flows pumped from the Mangaotea Stream into the Motukawa race 2009 to 2018

The hydrograph plot shows a maximum take of 320 l/s (cf. a maximum consented take of 450 l/s per Consent 6381 – 1). However, the average take over the water balance period (October 2009 to December 2020) is only 29 l/s. The year 2014 recorded the highest annual average take of 58 l/s.

Section 3.6 provides a tabulation of the mean monthly abstracted flow from the Mangaotea Stream.

3.4 Lake Ratapiko

3.4.1 General description

Lake Ratapiko (the Lake) is a man-made lake created in 1927, through damming of the Mako Stream, for hydro-electric generation purposes. A 12 m high embankment dam, the Ratapiko Dam, impounds Lake Ratapiko. The dam is served by a service and an auxiliary (or "flood") spillway, the latter equipped with a fuse plug that activates (washes out) to provide more flood capacity when the reservoir level exceeds RL 199.22 m (0.52 m higher than the consented maximum normal operating level).

It is understood that the 14 m wide auxiliary spillway has operated (partially fused) three times, in September 2000, February 2004 and June 2015, since its construction in 1994.

The service spillway has a crest width of 19.59 m. In 2014, five tipping flashboards, each 3.9 m long and 300 mm high, were installed on the top of the concrete weir crest (RL 198.37 m). Thus, in their normal (upright position), the effective crest level for onset of spill is RL 198.67 m. It is understood these flashboards tip over when there is more than 30 mm of overflow (i.e. above RL 198.70 m) and spring back into the upright position after the spill event.

A more detailed description of the dam and its flood passage performance is provided in reports prepared by Riley Consultants for Trustpower's dam safety management programme.

Figure 3.12 shows photos of Ratapiko Dam and its service spillway. Table 3.4 summarises the key levels associated with the lake management and operation.

Table 3.4 Lake Ratapiko key threshold levels for Trustpower's operation of the Scheme

Elevation (RL m)	Significance of level	Comment
199.625	Dam crest level	The max. normal operating level is 0.925 m below the crest
199.55	Peak reservoir level in the 100-year ARI flood	This gives a freeboard to the dam crest of 0.07 m
199.22	Fuse plug crest level at auxiliary (flood) spillway	Based on 2018 LiDAR survey
198.96	Effective crest level of flood spillway after fusing	Based on 2018 LiDAR survey
198.70	Consented maximum normal operating level	Consents 3373 -2 & 5087 -1 (see Table 3.1). In flood conditions when spill occurs the reservoir level will be higher
198.67	Crest level of tipping flashboards (in their upright position) on the service spillway	There are five tipping flashboards affixed to the concrete spillway crest (RL 198.37 m)
198.47	Effective crest level of service spillway after the flashboard has tipped over	It is understood these flashboards return to the upright position after the spill event
194.00	Consented minimum normal operating level	Consent 3373 -2 & 5087 -1 (see Table 3.1). Level may be lower for maintenance, including for maintaining aquatic habitat

Figure 3.13 shows the lake volume and surface area versus water level relationship for Lake Ratapiko based on a bathymetric survey in May 2008. The useable lake storage between the minimum and maximum consented normal operating levels is 695,000 m^3. At the maximum consented level of RL 198.70 m, the lake surface area is 0.26 km^2.

Figure 3.12 The left frame shows a vertical aerial view of the dam and its spillways (labelled). The right frame shows the service spillway and its flashboards

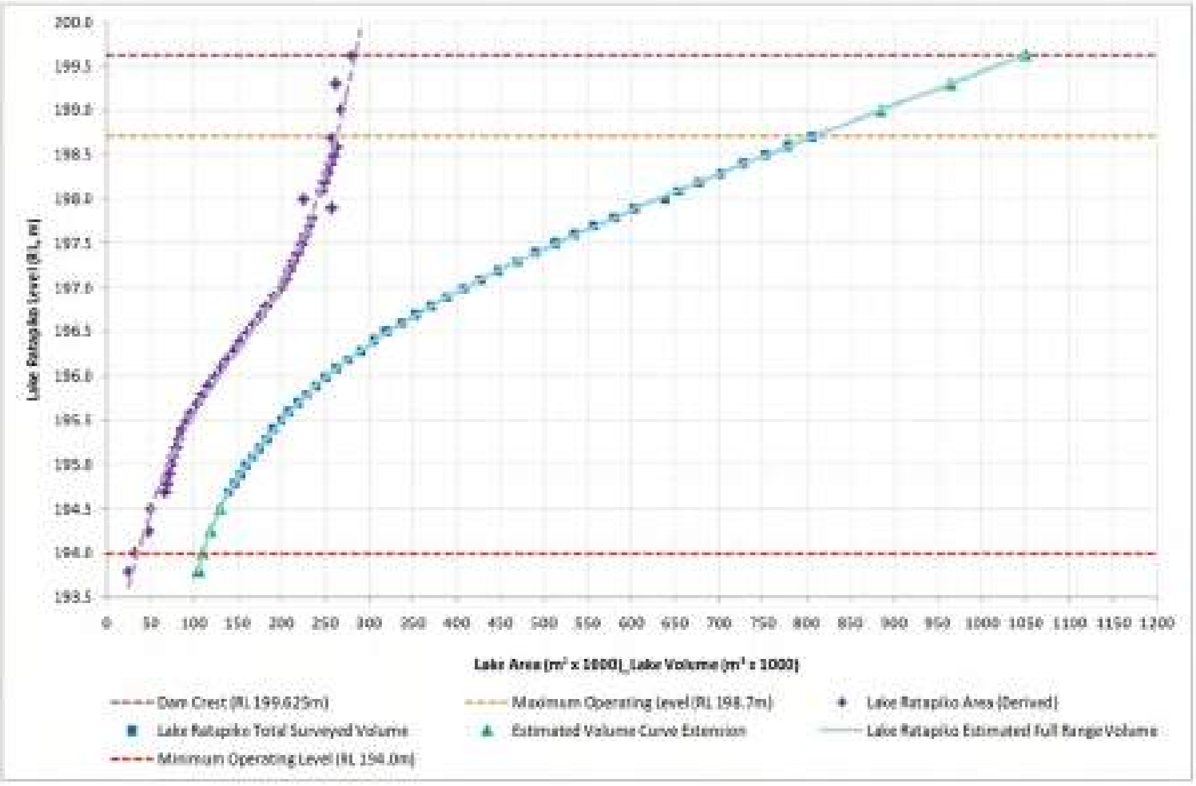

Figure 3.13 Water level versus lake storage and surface area curves for Lake Ratapiko

3.4.2 Lake level fluctuations

Figure 3.14 presents a plot of the water level time-series for Lake Ratapiko for the last five years (2016 to 2020). The full unaudited record, available from July 2001 to December 2020, is plotted in Appendix D. There are numerous dropouts (unmarked gaps and missing data) in the full record, particularly in 2001, 2006, 2013 and 2014. Threshold lines in the plots indicate the consented minimum (red) and maximum (cyan) normal operating levels. The green threshold line marks the top 1 metre of the operating range within which the lake level is generally held between November and late March.

Figure 3.14 Lake Ratapiko water level time-series from January 2016 to December 2020. The lower threshold line (red) represents minimum normal operating level (RL 194.0 m), the upper threshold line (cyan) the maximum normal operating level (RL 198.7 m), and the middle threshold line (green) marks the level within 1 m of full (RL 197.7 m)

In addition, Trustpower has voluntarily endeavoured to operate lake levels (for the benefit of recreational lake users) within 0.5 m of full storage level during weekends and special event days over the summer months (generally extending to late March and accommodating Easter where possible (refer to Greenaway (2021) for more detail).

In most years, the lake is lowered significantly for maintenance purposes in the month of April. However, the intact water level record shows that the level has not dropped below the minimum consented level of RL 194 m since at least July 2001. Spill events occur when the water level exceeds the top of the service spillway flashboards (RL 198.67 m). Further detail is provided in Section 3.4.4.

The high frequency fluctuations in the lake level time-series have a diurnal (daily) frequency and reflect the pattern of generation at the Motukawa Power Station to meet power demand on a daily basis. To illustrate this, Figure 3.15 shows a segment of the water level time-series for a 3-month period September to November 2020. The amplitude of the daily fluctuations is typically between 0.25 m and 0.4 m. For some periods of the year, there is also a pattern of weekday/weekend cycling in which lake levels are progressively lowered from Monday to Thursday or Friday and recovering (rising) over the following two to three days, as can be seen for the month of September 2020 in Figure 3.13. The amplitude of the weekly cycling, when it occurs, is typically around 1.5 m to 2 m.

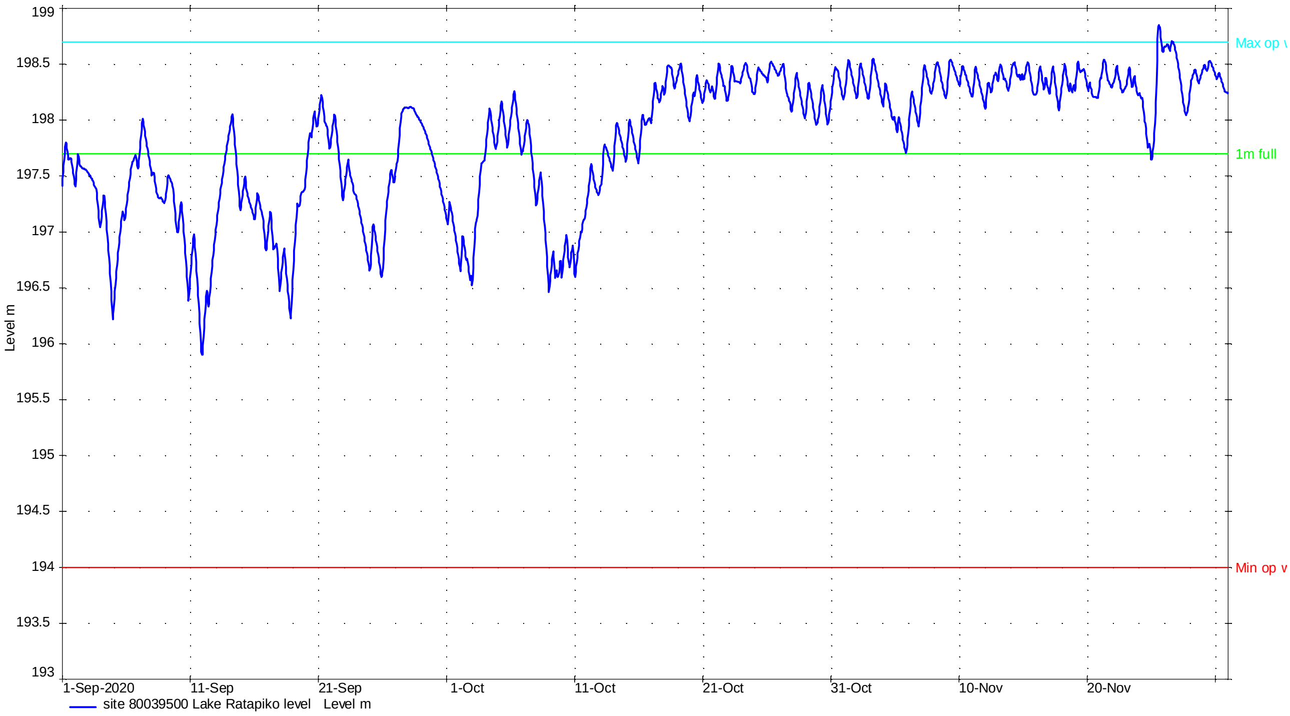

Figure 3.15 Lake Ratapiko water level Sep 2020 to Nov 2020. Low threshold line (red) is minimum normal operating level (RL 194.0 m), upper threshold (cyan) the maximum normal operating level (RL 198.7 m), and middle threshold (green) marks the level within 1 m of full (RL 197.7 m)

3.4.3 Lake level duration and seasonality

Figure 3.16 presents a level duration plot of Lake Ratapiko water levels based on the unaudited record for the water balance period (October 2009 to December 2020). Separate level duration curves for each season are plotted in addition the annual (full year) curve.

Overall, the lake levels have generally fluctuated within a 4.2 m operating range between RL 194.5 m and RL 198.7 m. Comparison of the seasonal level duration curves indicate significant differences across the seasons, particularly between summer (D, J, F), when the lake level is maintained near full, and autumn (M, A, M) when the lake is lowered for maintenance in most years. Over the summer months the lake level has been within 0.5 m of the maximum operating level for 87% of the time and within 1.0 m of the maximum operating level for more than 99% of the time (also noting that some of the lower levels occurring for this period are spurious dropouts in the data).

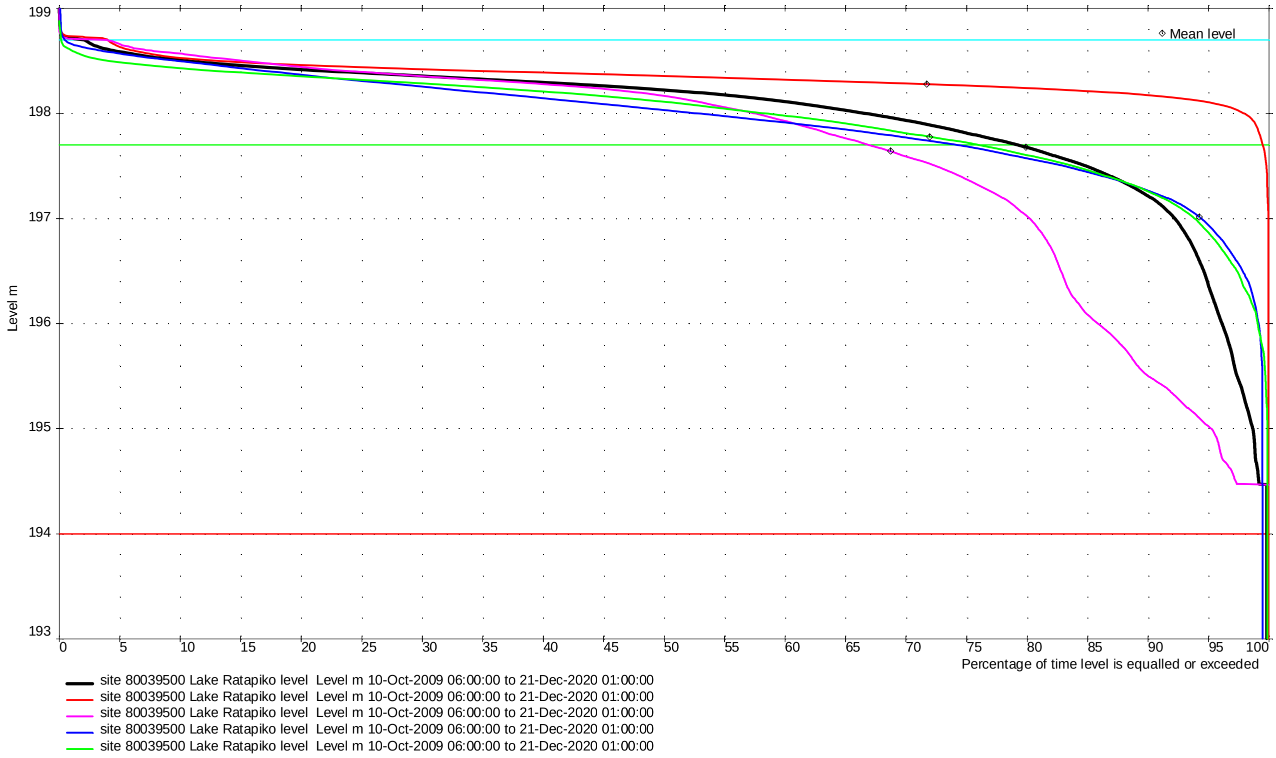

Figure 3.16 Lake Ratapiko level duration curves (in RL m), Oct 2009 to Dec 2020. Red - summer (D, J, F); magenta - autumn (M, A, M); blue - winter (J, J, A); green - spring (S, O, N); black - full year. Low threshold line (red) is the min. normal level (RL 194.0 m), upper threshold (cyan) the max. normal level (RL 198.7 m), and middle threshold (green) marks the level within 1 m of full (RL 197.7 m)

3.4.4 Flood management

Flood inflows to Lake Ratapiko are derived from two sources:

- Runoff from the local catchment draining to Lake Ratapiko, comprising the upper Mako Stream and its tributaries (catchment area 8.46 km^2 including the lake surface)
- Flows conveyed by the Motukawa Race to the lake, which come from:
  - the two drains that feed directly into the race (catchment area 3.92 km^2)
  - the Manganui River (catchment area 80 km^2), although when the water level in the race and/or reservoir level is high, the race intake gates are partially closed so that only a modest flow (typically less than 0.5 m^3/s) is let through
  - the floodplain of the Mangaotea Stream (noting that the stream normally flows under the race/aqueduct); in an extreme flood event, flow from the Mangaotea Stream floodplain has been observed to enter the race and also spill out of the race at numerous locations

Figure 3.17 shows the extents of the sub-catchments draining to Lake Ratapiko (excluding the Manganui River) as described above.

A detailed hydraulic assessment of the Motukawa Race under normal operating conditions (and for a diverted flow of up to 7.5 m^3/s) as well as flood conditions is provided in Riley (2021). The interaction between the Mangaotea floodplain and the Motukawa Race in an extreme flood (100-year ARI event) was previously also modelled by Riley Consultants.

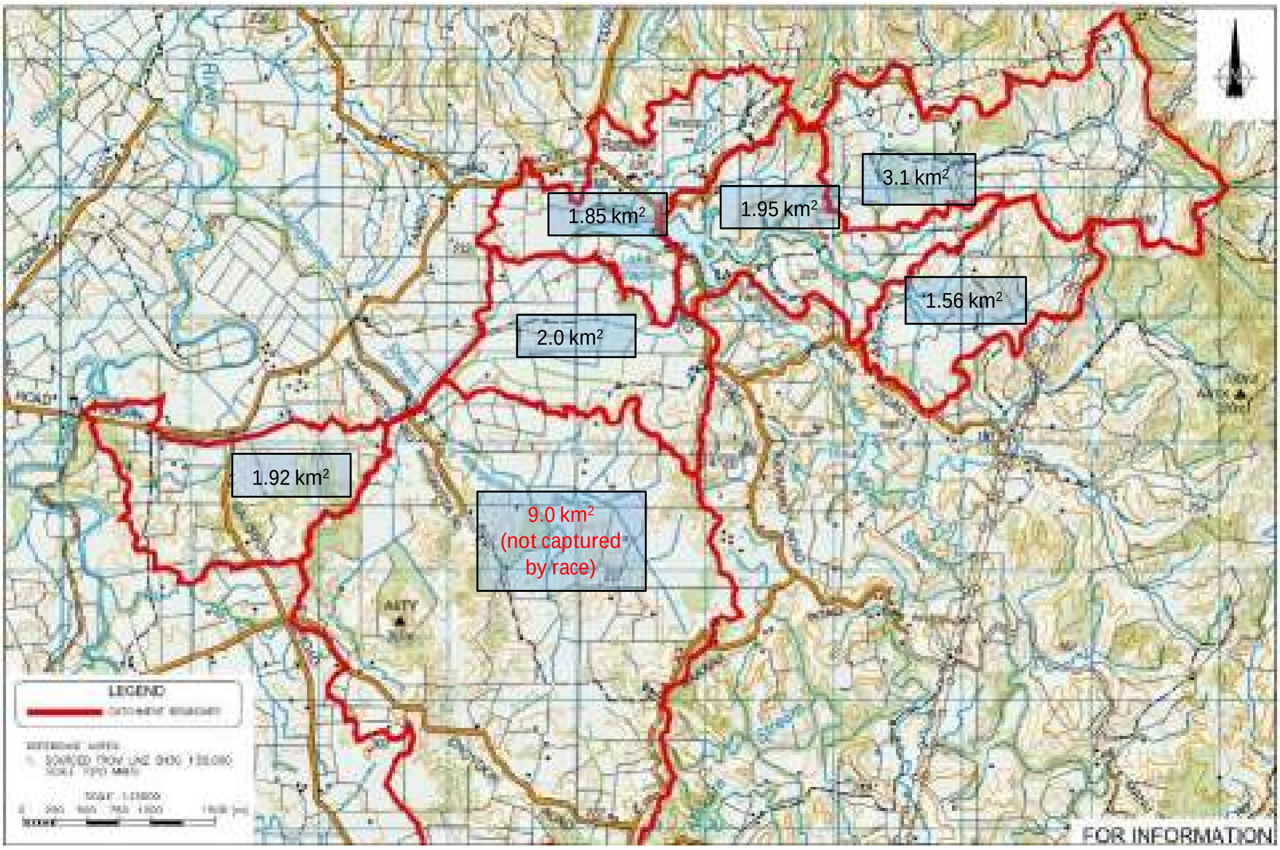

Figure 3.17 Sub-catchments of Lake Ratapiko (catchment boundaries determined by Riley Consultants from a 2018 LiDAR survey)

Key conclusions from Trustpower-commissioned flood assessments of Lake Ratapiko are as follows:

- The spillways at Ratapiko Dam are able to convey the 100-year ARI flood with a freeboard of 0.07 m to the dam crest, with the conservative assumption that no discharge through the Power Station is possible (station outage assumed) and an initial lake level of RL 198.70 m (the consented maximum normal operating level)
- Based on the same conservative assumptions, the 1,000 year ARI flood cannot be passed by the spillways without overtopping the dam crest (viz. modelled peak water level of RL 200.07 m, i.e. a 0.45 m higher dam crest needed)
- In the 1,000-year ARI flood, the peak inflow from the critical 6-hour duration storm is estimated at 115 m^3/s and the peak outflow 101 m^3/s, comprising discharges of 75 m^3/s from the service spillway and 26 m^3/s from the auxiliary spillway.

It is noted that the peak outflow of 101 m^3/s in a 1,000-year ARI flood is 84% greater than the consented maximum flood discharge from the lake to Mako Stream of 55 m^3/s (Consent 5084 – 1, refer to Table 3.1).

3.4.5 Spill flow and residual flow

For the water balance analysis (see Section 3.2), an approximate record of 3-hourly spill flow from Ratapiko Dam was developed from the lake level record by applying a level versus discharge rating curve and assuming that the flashboards all tip over when the lake level exceeds RL 198.70 m (i.e. at 0.03 m above the crest of the flashboards in their (normally) upright position). This is a simplification because tipping of the flashboards results in an effective weir crest elevation that varies with time. Furthermore, the five flashboard sections are understood to be operated in two independent groups. Significant spill events, in descending order, occurred in June 2015 (~25 m^3/s peak spill), February 2004 and July 2012.

Figure 3.18 presents the flow duration curve of spill flow from Ratapiko Dam for the water balance period October 2009 to December 2020. Note that the plot only covers the 0% to 10% exceedance range (zero flows for exceedance greater than 2.4%). The mean spill flow over this period is 0.083 m^3/s. However, the bulk of this spill volume occurred between February and May of 2010, and this was a consequence of station upgrades at the time (i.e. a new runner and guide vane being installed). Ignoring these months results in a lesser historical mean spill of 0.031 m^3/s. The corresponding flow duration curve is also plotted in Figure 3.16 and shows that the dam spills about 0.3% of the time on average (that is, excluding the period prior to July 2010). Excluding 2010, the dam spills, on average, 4.9 days per year. Table 3.5 summarises the number of days that spill has occurred, on a monthly as well as yearly basis, between 2010 and 2020. A tabulation of the mean monthly spill flows is presented in Section 4.3.3.

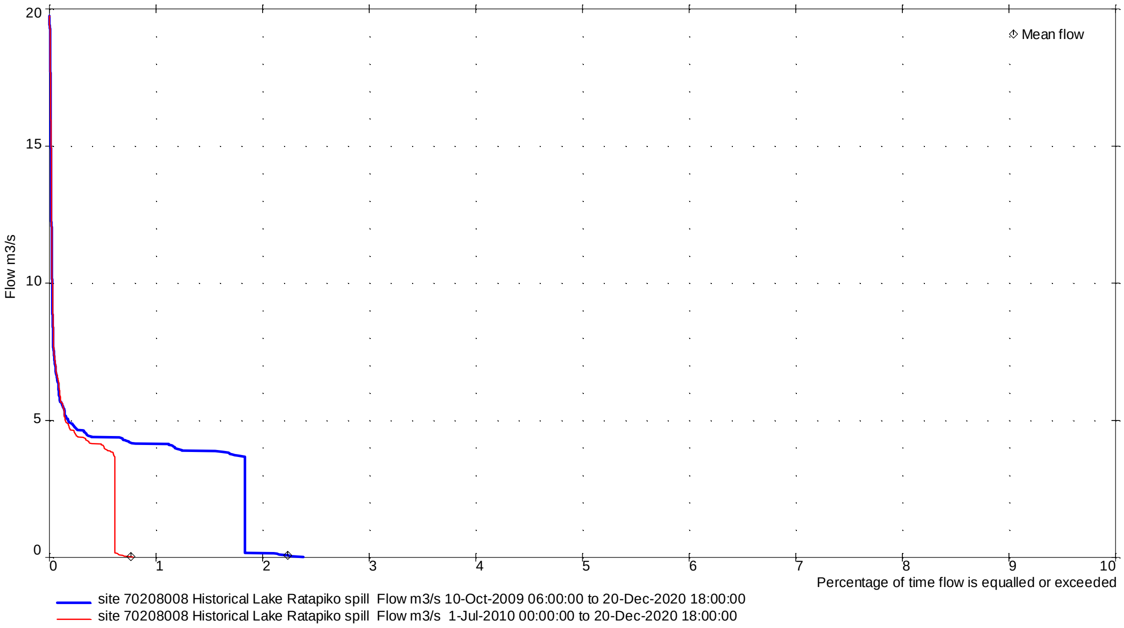

Figure 3.18 Flow duration curve of the approximated spill flow to Mako Stream from Ratapiko Dam, for Oct 2009 to Dec 2020 (blue curve) and for the period Jul 2010 to Dec 2020 (red curve). The difference shows that the bulk of the historical spill occurred prior to July 2010

Table 3.5 Number of spill days from historical Lake Ratapiko level record 2010 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
2010	0	24	31	8	8	3	1	7	3	1	0	0	86
2011	1	0	0	0	0	2	0	0	0	1	0	0	4
2012	0	16	5	0	0	0	1	0	0	0	0	0	22
2013	0	0	0	0	0	0	0	0	1	0	0	0	1
2014	0	0	0	0	0	1	0	1	0	0	0	2	4
2015	0	0	2	0	0	2	0	1	0	0	0	0	5
2016	0	0	0	0	0	0	1	0	0	0	0	0	1
2017	0	0	0	0	0	0	1	1	0	0	0	0	2
2018	0	1	0	0	0	1	0	0	0	0	0	0	2
2019	0	0	0	1	0	0	3	0	0	0	0	0	4
2020	0	0	0	0	0	0	0	0	0	0	2	2	4
Averages*	0.1	1.7	0.7	0.1	0	0.6	0.6	0.3	0.1	0.1	0.2	0.4	4.9

Note: * The averages shown exclude the 2020 year in which spilling occurred over an extended period because of station upgrade works.

No residual flow is required below Ratapiko Dam. Nevertheless, apart from spill flow described above, contributing to the residual flow in the Mako Stream are seepage losses from the dam embankment and lakebed and any leakage at the flashboards on the spillway crest. Seepage is monitored at the toe of the embankment dam as part of Trustpower's dam safety management system, and is typically less than 3 l/s (as per correspondence from Trustpower's Dam Safety Team).

3.5 Motukawa power station

3.5.1 Power station flows

At the current time the Motukawa Power Station can produce an output of 5.05 MW from a maximum generation discharge of 7.02 m^3/s. Appendix D presents time-series plots of the Power Station discharge (generation flow) for the water balance period October 2009 to December 2020. The generation flow is derived from station load (in MW) using a series of power output versus discharge rating curves. For periods prior to April 2019, the peak generation flow appeared to reach the consented maximum of 7.787 m^3/s (per Consent 5087 – 1). A tabulation of the mean monthly generation flows is provided in Section 3.6.

Figure 3.19 presents the flow duration curves of the generation discharge. Separate flow duration curves are provided for summer (Dec, Jan, Feb), autumn (Mar, Apr, May), winter (Jun, Jul, Aug) and spring (Sep, Oct, Nov). There is a significant difference in the discharged flow volume across the seasons, for example the median (50th percentile) winter flow is 2.7 times the median summer flow. Generation ceases for about 30% of the time on average. There are also a series of intermediate steps or "set points" in each of the curves below the maximum, notably at around 2 m^3/s, 4.2 - 4.5 m^3/s and 6.4 m^3/s, which are related to the characteristics of the generating machinery.

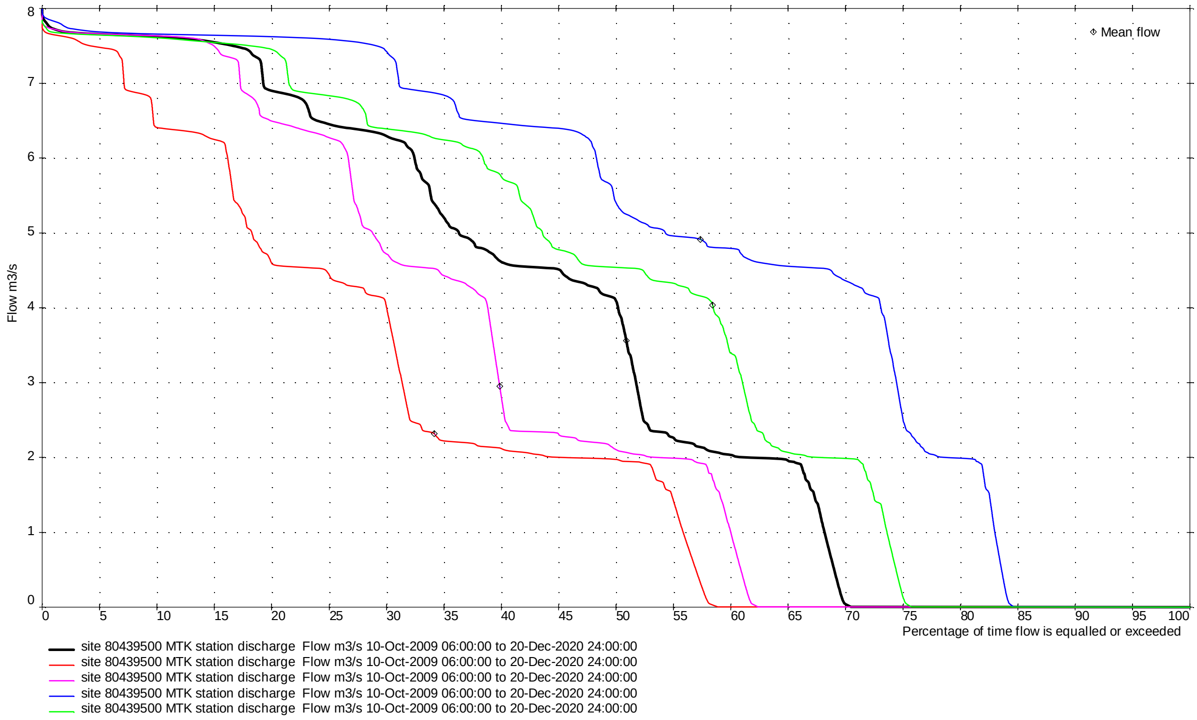

Figure 3.19 Motukawa generation flow duration curves (in m^3/s), Oct 2013 to Dec 2020. Red curve – summer (D, J, F); magenta curve – autumn (M, A, M); blue curve – winter (J, J, A); green curve – spring (S, O, N); black curve – full year. The mean flow for each curve is indicated by the diamond marker.

3.5.2 Daily flow ramping

Figure 3.20 is a hydrograph plot of the Motukawa Power Station discharges for a 2-week period in July 2020 that illustrates the typical generation pattern during winter when river flows are generally higher. The contemporaneous flow in the Waitara at Tarata and Waitara at Bertrand Road gauges located respectively about 7.5 km and 45 km downstream of the Power Station, is also plotted in Figure 3.20. Figure 3.21 shows the Motukawa generation flows for a 2-week period in

February/March 2019 that illustrates the typical operation during a summer low flow period. Figures 3.20 and 3.21 have the same vertical and horizontal scale.

It can be seen that the generation regime is characterised by a strong diurnal (daily peaking) pattern, with a period of zero or reduced generation at night (typically midnight to 6 am) on most days. These zero generation periods extend for a longer duration each day when inflows to Lake Ratapiko are low. The generation pattern is clearly reflected in the recorded Waitara River flow at Tarata and at Bertrand Road further downstream (typically with a lag of 2 - 3 hours to Tarata and a further lag of 10 – 15 hours to Bertrand Road) accompanied by attenuation (smoothing) of the generation pulse. The lag in the river's response to ramping at the station becomes longer as the river flow decreases.

The current consents do not set any constraints on generation flow ramping at the Motukawa Power Station.

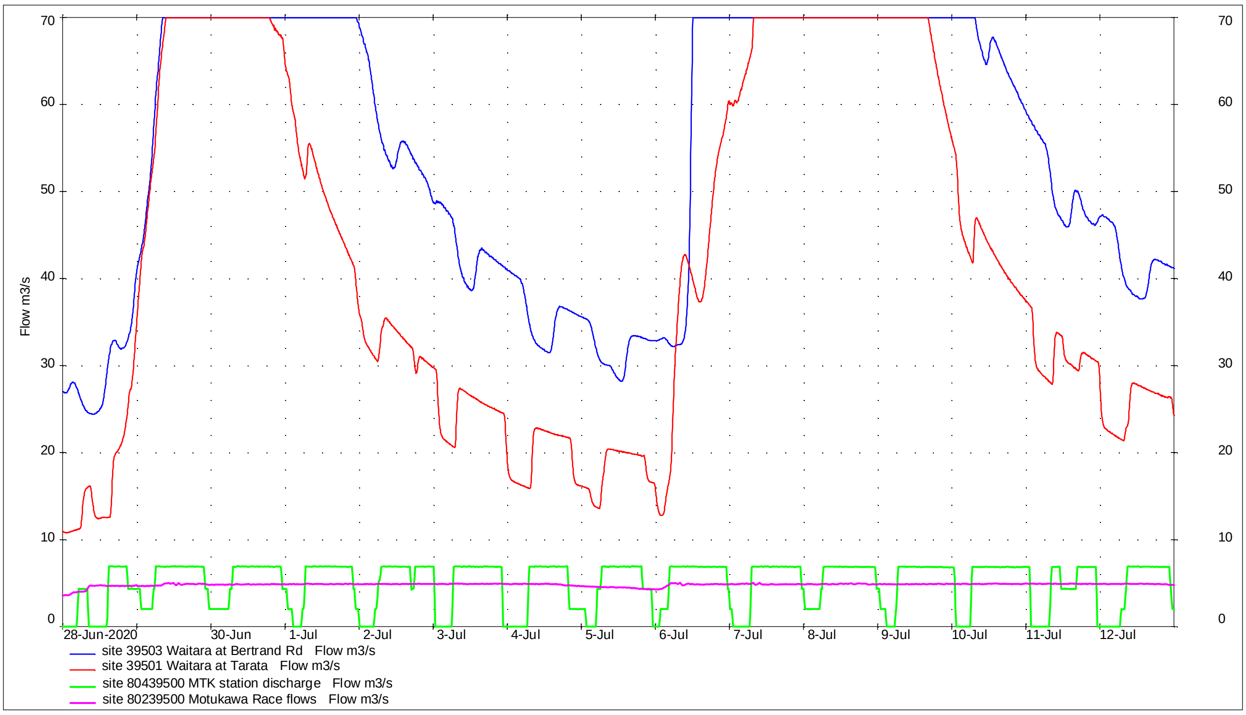

Figure 3.20 Motukawa Power Station discharge (green) versus Waitara at Tarata (red) and at Bertrand Road (blue) for 2-week period 28 Jun to 13 Jul 2020. Diverted flow from Manganui River in magenta

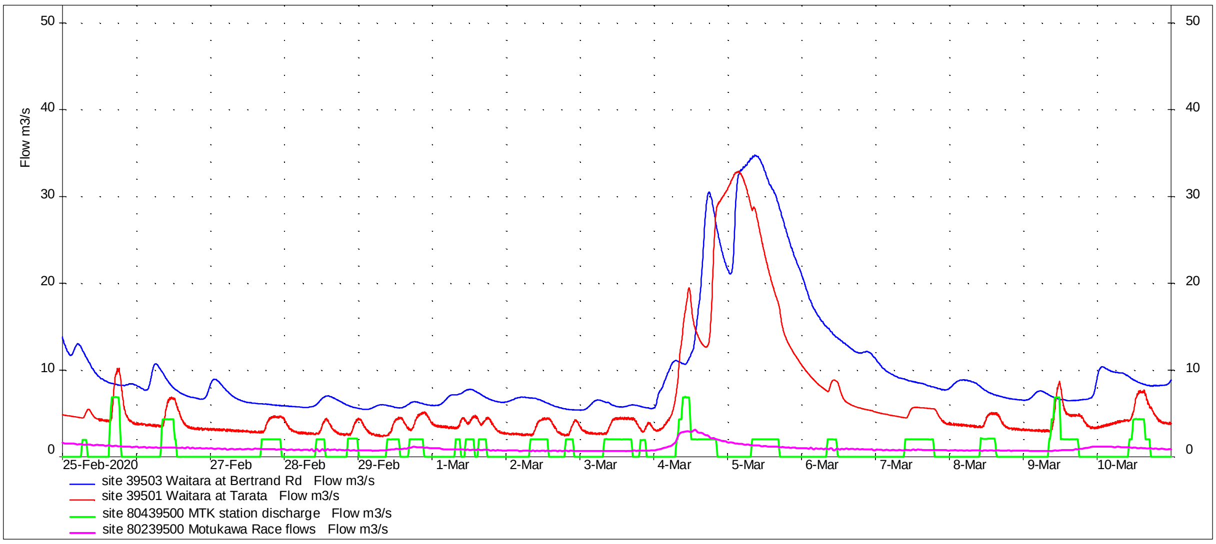

Figure 3.21 Motukawa Power Station discharge (green) versus Waitara at Tarata (red) and at Bertrand Road (blue) for 2-week period 25 Feb to 13 Mar 2020. Diverted flow from Manganui River in magenta

3.6 Scheme inflows and outflows

Table 3.7 overleaf provides a tabulation of the mean monthly flows for 2010 to 2020 for five key locations associated with the Motukawa Scheme, i.e.

- Manganui River at the intake weir (node *b.*), representing the inflow to Manganui Weir
- Motukawa Race S1 (node *k.*), the flow measured near the upstream end of the race
- Manganui Weir spill flow (weir overflow)
- Combined left bank fish pass and right bank fish pass flow at the Manganui Weir
- Motukawa Power Station discharge (node *l.*)

Table 3.6 below shows the mean monthly abstracted flows from the Mangaotea Stream during the period it was operational (October 2008 to March 2018). With an average flow of 29 l/s (0.029 m^3/s) over the water balance period it is significantly smaller than the other component scheme flows.

Figure 3.22 is a histogram plot of the monthly mean flows (flow for a particular month averaged across all years) for each location, which shows the seasonal pattern in the flow behaviour. A seasonal pattern similar to the river inflow is seen in the Motukawa Race flow, where the mean race flow from May to October of 4.0 m^3/s is 1.7 times the mean for the other six months of the year. Over the water balance period (October 2009 to December 2020), 46% of the river inflow volume to the Manganui Weir was diverted into the Motukawa Race.

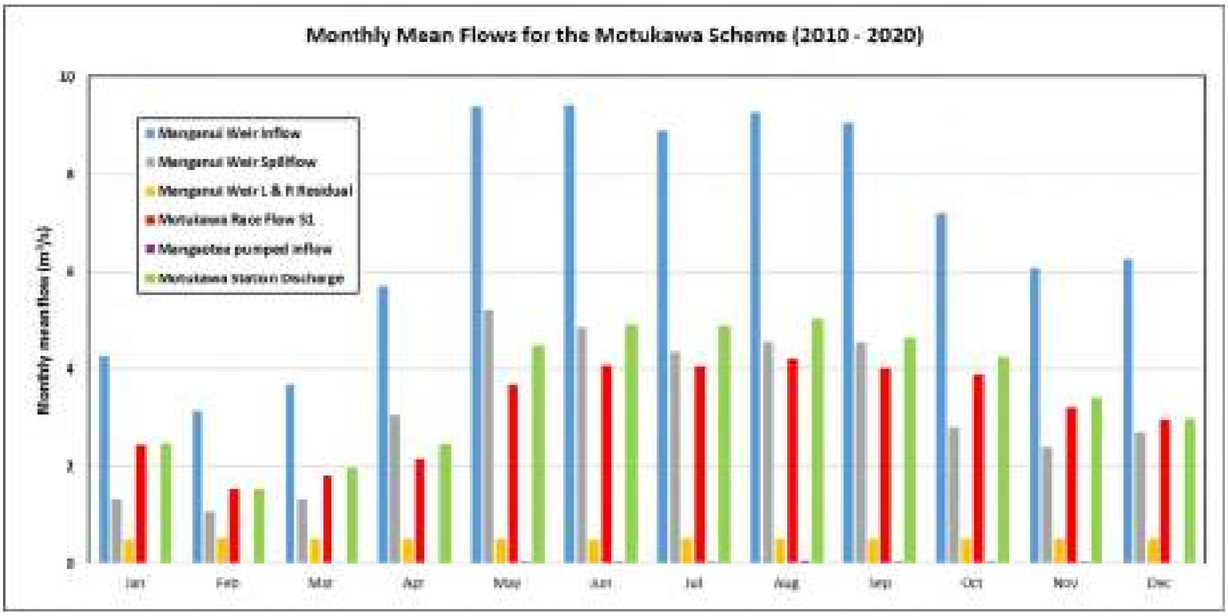

Figure 3.22 Motukawa Scheme: mean flow distribution by month-of-year

Table 3.6 Mean monthly pumped flows from Mangaotea Stream 2008 to 2018

Year	Pumped Flow from Big Mangaotea Stream: Mean monthly flow (m^3/s)												Annual mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2008	-	-	-	-	-	-	-	-	-	0.000	0.001	0.001	-
2009	0.001	0.002	0.008	0.002	0.054	0.049	0.129	0.095	0.085	0.000	0.000	0.006	0.036
2010	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.004	0.004	0.036	0.009	0.003	0.053	0.019	0.013	0.062	0.053	0.021
2012	0.059	0.008	0.045	0.009	0.050	0.094	0.098	0.128	0.094	0.038	0.018	0.014	0.055
2013	0.015	0.000	0.000	0.013	0.105	0.032	0.001	0.030	0.074	0.097	0.068	0.060	0.042
2014	0.040	0.002	0.000	0.050	0.106	0.080	0.050	0.120	0.088	0.062	0.077	0.014	0.058
2015	0.003	0.003	0.004	0.128	0.086	0.063	0.073	0.093	0.138	0.059	0.019	0.002	0.056
2016	0.006	0.009	0.004	0.016	0.036	0.032	0.118	0.087	0.000	0.127	0.129	0.035	0.050
2017	0.040	0.038	0.008	0.100	0.051	0.063	0.021	0.025	0.086	0.100	0.003	0.002	0.045
2018	0.003	0.013	0.004	-	-	-	-	-	-	-	-	-	-
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.017	0.008	0.008	0.036	0.058	0.047	0.055	0.070	0.065	0.050	0.038	0.019	0.040
Maximum	0.059	0.038	0.045	0.128	0.106	0.094	0.129	0.128	0.138	0.127	0.129	0.060	0.058

Table 3.7 Motukawa Scheme mean monthly flows 2010 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Manganui River Above Intake Weir (Node b.): Mean monthly flow (m^3/s)												Mean
2010	2.97	2.32	1.84	1.58	8.81	11.32	3.17	11.41	15.07	5.76	1.58	8.17	6.18
2011	6.02	2.04	5.29	4.81	12.27	11.01	8.13	4.56	3.80	10.92	4.72	11.54	7.14
2012	6.39	4.22	8.06	2.42	6.45	8.53	12.44	7.90	8.67	6.95	3.94	4.23	6.71
2013	3.19	3.41	1.68	4.86	8.90	8.11	3.82	5.87	11.13	10.06	5.16	5.83	6.01
2014	6.39	1.71	1.20	6.56	6.03	9.69	5.45	11.50	6.97	5.54	5.55	3.36	5.85
2015	2.41	2.12	2.57	8.89	12.83	15.90	7.13	11.89	9.25	4.02	3.86	3.20	7.02
2016	4.58	4.67	2.80	3.89	10.64	9.06	11.23	8.48	11.15	9.23	12.76	5.19	7.82
2017	5.80	4.42	4.92	9.99	9.34	4.24	13.56	14.77	12.66	5.67	3.77	1.51	7.58
2018	4.92	5.88	6.92	7.24	10.47	6.89	11.11	10.45	6.28	4.98	4.99	4.54	7.07
2019	2.32	1.63	2.93	9.62	8.59	7.73	13.34	8.51	5.78	7.83	5.91	7.97	6.88
2020	1.94	1.96	2.10	2.88	8.85	11.11	8.51	6.50	8.94	8.25	14.70	13.27	7.44
Minimum	1.94	1.63	1.20	1.58	6.03	4.24	3.17	4.56	3.80	4.02	1.58	1.51	5.85
Average	4.27	3.13	3.66	5.70	9.38	9.42	8.90	9.26	9.06	7.20	6.09	6.25	6.88
Maximum	6.39	5.88	8.06	9.99	12.83	15.90	13.56	14.77	15.07	10.92	14.70	13.27	7.82
Year	Motukawa Race Flow S1 (Node k.): Mean monthly flow (m^3/s)												Annual
2010	1.72	0.42	0.26	0.32	1.54	2.92	2.14	3.65	3.92	3.51	1.07	2.31	1.99
2011	2.71	1.56	3.05	3.17	4.64	4.49	4.25	3.52	3.08	4.30	3.00	3.28	3.44
2012	3.48	0.77	3.82	1.82	3.32	4.12	4.16	4.30	4.11	3.75	2.61	2.63	3.26
2013	2.43	1.46	0.97	2.62	4.10	3.95	3.16	3.70	3.52	4.11	3.19	3.17	3.04
2014	3.17	1.19	0.31	2.26	3.58	4.23	3.87	4.00	3.56	3.98	4.00	2.23	3.04
2015	1.60	1.35	1.51	3.71	4.38	3.94	4.01	4.56	4.77	2.96	2.91	2.58	3.20
2016	2.71	2.31	1.45	1.89	4.23	4.60	4.76	4.67	4.89	4.78	4.90	4.00	3.77
2017	3.66	3.00	2.43	1.98	4.66	3.37	4.69	4.70	4.67	3.77	2.45	1.01	3.37
2018	2.48	3.32	3.33	2.18	4.20	4.44	4.82	4.93	3.58	3.04	3.56	3.26	3.60
2019	1.59	0.61	1.52	1.64	2.53	4.34	3.97	4.40	4.09	4.51	3.31	3.73	3.03
2020	1.25	0.85	1.36	2.02	3.07	4.35	4.70	3.81	3.96	4.14	4.23	4.22	3.08
Minimum	1.25	0.42	0.26	0.32	1.54	2.92	2.14	3.52	3.08	2.96	1.07	1.01	1.99
Average	2.44	1.53	1.82	2.14	3.66	4.07	4.05	4.20	4.01	3.89	3.20	2.95	3.17
Maximum	3.66	3.32	3.82	3.71	4.66	4.60	4.82	4.93	4.89	4.78	4.90	4.22	3.77
Year	Manganui Weir Spillflow: Mean monthly flow (m^3/s)												Annual
2010	0.77	1.36	1.10	0.77	6.85	7.94	0.53	7.32	10.62	1.74	0.00	5.33	3.70
2011	2.82	0.00	1.74	1.14	7.15	6.03	3.42	0.56	0.23	6.14	1.23	7.76	3.22
2012	2.36	2.82	3.74	0.04	2.61	3.92	7.78	3.10	4.04	2.71	0.85	1.10	2.93
2013	0.26	1.34	0.23	1.76	4.30	3.70	0.18	1.69	7.11	5.39	1.44	2.15	2.46
2014	2.73	0.02	0.32	3.77	1.89	4.91	1.09	6.98	2.89	1.02	1.04	0.62	2.28
2015	0.31	0.27	0.56	4.67	7.93	11.43	2.57	6.78	3.92	0.57	0.45	0.10	3.30
2016	1.35	1.83	0.79	1.46	5.75	3.93	5.93	3.29	5.73	3.93	7.30	0.68	3.50
2017	1.64	0.91	2.04	7.50	4.20	0.42	8.37	9.56	7.43	1.41	0.85	0.02	3.71
2018	1.94	2.00	2.97	4.47	5.78	1.94	5.79	4.98	2.21	1.47	0.94	0.77	2.95
2019	0.24	0.53	0.93	7.48	5.50	2.88	8.86	3.59	1.17	2.79	2.09	3.72	3.33
2020	0.18	0.58	0.25	0.40	5.24	6.21	3.26	2.15	4.47	3.59	9.87	7.40	3.64
Minimum	0.18	0.00	0.23	0.04	1.89	0.42	0.18	0.56	0.23	0.57	0.00	0.02	2.28
Average	1.33	1.06	1.33	3.04	5.20	4.85	4.34	4.55	4.53	2.79	2.37	2.70	3.18
Maximum	2.82	2.82	3.74	7.50	7.93	11.43	8.86	9.56	10.62	6.14	9.87	7.76	3.71
Year	Manganui Weir Left Plus Right (Fish Pass) Residual: Mean monthly flow (m^3/s)												Annual
2010	0.48	0.54	0.48	0.49	0.42	0.46	0.50	0.45	0.54	0.51	0.51	0.52	0.49
2011	0.48	0.49	0.51	0.50	0.47	0.49	0.46	0.48	0.49	0.48	0.49	0.50	0.49
2012	0.55	0.63	0.49	0.55	0.52	0.49	0.50	0.51	0.52	0.49	0.49	0.50	0.52
2013	0.51	0.60	0.49	0.48	0.50	0.47	0.47	0.48	0.50	0.56	0.53	0.50	0.51
2014	0.50	0.50	0.58	0.54	0.50	0.54	0.49	0.53	0.52	0.54	0.51	0.51	0.52
2015	0.50	0.50	0.50	0.51	0.52	0.53	0.55	0.55	0.55	0.49	0.50	0.51	0.52
2016	0.51	0.53	0.56	0.55	0.66	0.53	0.54	0.52	0.54	0.52	0.56	0.51	0.54
2017	0.49	0.52	0.46	0.52	0.49	0.46	0.50	0.52	0.57	0.49	0.47	0.49	0.50
2018	0.50	0.56	0.62	0.58	0.49	0.51	0.50	0.54	0.48	0.47	0.49	0.51	0.52
2019	0.48	0.50	0.48	0.50	0.56	0.51	0.51	0.53	0.51	0.54	0.51	0.52	0.51
2020	0.51	0.53	0.49	0.47	0.54	0.55	0.55	0.53	0.50	0.53	0.60	0.56	0.53
Minimum	0.48	0.49	0.46	0.47	0.42	0.46	0.46	0.45	0.48	0.47	0.47	0.49	0.49
Average	0.50	0.54	0.51	0.52	0.52	0.50	0.51	0.51	0.52	0.51	0.51	0.51	0.51
Maximum	0.55	0.63	0.62	0.58	0.66	0.55	0.55	0.55	0.57	0.56	0.60	0.56	0.54
Year	Motukawa Power Station Discharge (Node. l.): Mean monthly flow (m^3/s)												Annual
2010	1.58	0.02	0.01	0.21	1.93	3.93	2.96	4.54	5.22	3.90	1.15	2.69	2.36
2011	3.15	1.55	3.31	3.34	5.61	5.75	5.12	3.89	3.32	5.13	3.46	3.90	3.98
2012	4.06	1.45	4.47	1.82	3.59	4.77	5.17	4.98	4.49	4.05	2.67	2.71	3.70
2013	2.57	1.52	1.32	3.16	5.89	6.01	4.09	4.92	5.73	5.78	3.82	3.81	4.06
2014	3.78	1.15	0.43	2.71	5.21	5.34	4.91	5.16	4.33	4.45	4.70	2.26	3.71
2015	1.46	1.23	1.76	4.99	5.99	5.36	4.79	6.09	5.87	2.80	2.70	1.95	3.76
2016	2.03	1.70	1.08	1.26	4.50	4.94	5.40	5.26	4.95	5.23	5.56	3.53	3.80
2017	3.76	3.72	2.80	3.35	5.93	3.75	6.00	6.44	6.02	3.85	2.14	0.76	4.05
2018	2.27	3.23	3.71	2.51	4.82	5.00	5.79	5.40	3.35	2.86	3.47	2.96	3.79
2019	1.33	0.44	1.33	1.77	2.50	4.44	4.51	4.67	3.75	4.43	2.94	3.41	2.97
2020	1.00	0.69	1.34	1.60	3.07	4.44	4.84	3.63	4.00	3.96	4.81	4.49	3.17
Minimum	1.00	0.02	0.01	0.21	1.93	3.75	2.96	3.63	3.32	2.80	1.15	0.76	2.97
Average	2.45	1.52	1.96	2.43	4.46	4.88	4.87	5.00	4.64	4.22	3.40	2.95	3.58
Maximum	4.06	3.72	4.47	4.99	5.99	6.01	6.00	6.44	6.02	5.78	5.56	4.49	4.06

3.7 River flow regime downstream of Motukawa Scheme

3.7.1 Synthetic time-series flows for ungauged locations

Three of the hydrological nodes selected for assessment (refer to Section 1.4) are not gauged and so do not have direct at-site flow records. These are:

- Manganui River above intake weir (Node *b.*)
- Manganui River below intake weir (Node *c.*)
- Waitara River above Makara Stream (Node *f.*)

Nodal locations are shown in Figure 1.2.

Derivation of the synthetic Manganui River flow record above the intake weir (Node *b.*) was described in detail in Section 2.6.1. The adopted method involved simply adding (reconstituting) the flow components at the intake, being the flow in the Motukawa Race (at S1), the combined left and right bank fish pass flow, and the weir overflow, and removing clearly anomalous data points.

The residual flow below the intake weir (Node *c.*) was computed as the sum of the combined left and right bank fish pass flow and the weir overflow.

To estimate the Waitara River flow above the Makara Stream, the historical Motukawa station discharge (with a lead time of two hours) was subtracted from the Waitara River flow recorded at Tarata. From this a further flow subtraction was made for the estimated contribution of the local catchment between Makara Stream and the Tarata gauge (viz. mainly the Makara Stream flow). This synthetic record was smoothed by taking 6-hourly averages. However, some of the diurnal generation signal in the resulting record (which is spurious upstream of the Makara Stream) remained.

3.7.2 Manganui River nodes

Table 3.8 provides a tabulation of the mean monthly flows for the water balance period (2010 to 2020) for the four nodal locations on the Manganui River, i.e. at SH3 (Node *a.*), above the Manganui Weir (Node *b.*), below the Manganui Weir (Node *c.*) and at Everett Park (Node *d.*). Figure 3.23 is a histogram plot of the monthly mean flows (flows for a particular month averaged across all years) for each location, which shows the seasonal pattern in the flow behaviour, and for a particular month, the average change in mean flow from upstream (SH3) to downstream (Everett Park).

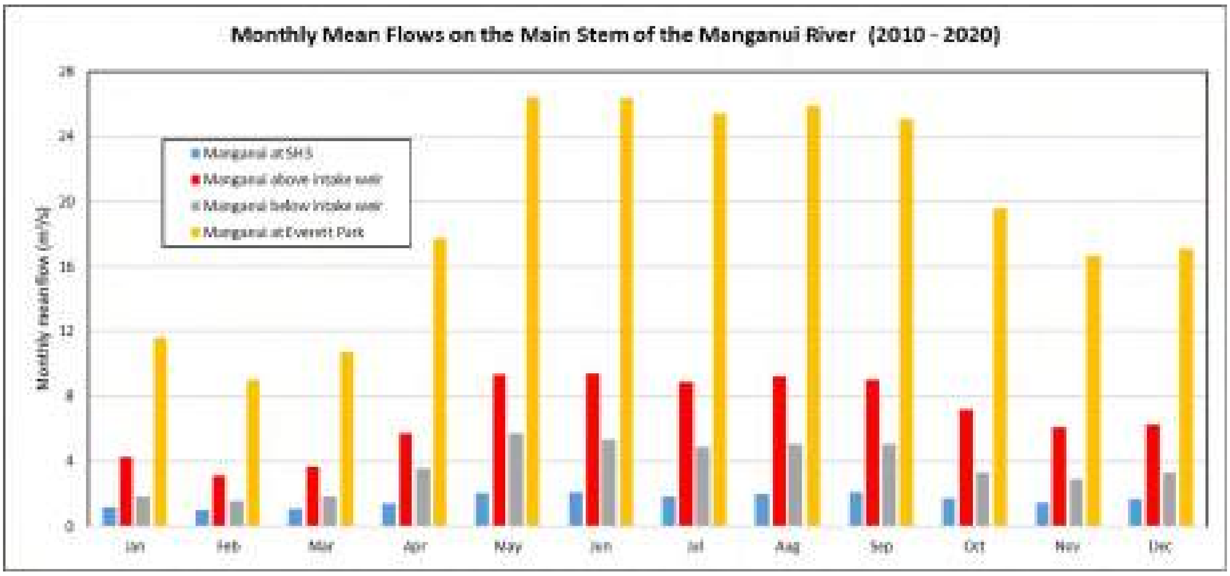

Figure 3.23 Manganui River: mean flow distribution by month-of-year for four nodal locations

Table 3.8 Manganui River mean monthly flows at four locations

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Manganui River at SH3 (Node a.): Mean monthly river flow (m^3/s)												
2010	0.89	0.65	0.65	0.71	2.06	2.67	0.91	3.12	3.95	1.57	0.65	2.63	1.71
2011	1.70	0.75	1.64	1.33	3.05	2.63	1.79	1.08	1.04	2.89	1.40	3.73	1.93
2012	2.11	1.69	2.41	0.82	1.90	2.12	2.76	1.64	2.23	1.78	1.04	1.36	1.83
2013	0.90	1.30	0.74	1.51	1.87	1.82	0.90	1.43	2.63	2.74	1.29	1.62	1.56
2014	1.79	0.67	0.62	2.11	1.46	2.55	1.19	2.85	1.88	1.45	1.33	1.12	1.59
2015	0.68	0.75	0.98	2.40	3.13	4.11	2.16	3.06	2.55	1.09	1.15	0.76	1.90
2016	1.14	1.28	0.76	0.89	1.85	1.67	2.08	1.55	2.29	1.79	3.12	1.45	1.65
2017	1.82	1.19	1.63	2.18	2.16	1.04	3.00	3.21	2.91	1.63	1.17	0.63	1.89
2018	1.85	1.66	1.47	1.71	2.30	1.48	2.03	1.82	1.35	1.07	0.96	1.02	1.56
2019	0.71	0.53	0.87	1.97	1.71	1.40	2.35	1.40	1.03	1.35	1.34	1.82	1.38
2020	0.56	0.55	0.61	0.75	1.86	2.47	1.90	1.64	2.24	2.14	3.51	2.49	1.73
Minimum	0.56	0.53	0.61	0.71	1.46	1.04	0.90	1.08	1.03	1.07	0.65	0.63	1.38
Average	1.29	1.00	1.13	1.49	2.12	2.18	1.91	2.07	2.19	1.77	1.54	1.69	1.70
Maximum	2.11	1.69	2.41	2.40	3.13	4.11	3.00	3.21	3.95	2.89	3.51	3.73	1.93
Year	Manganui River Above Intake Weir (Node b.): Mean monthly river flow (m^3/s)												Annual
2010	2.97	2.32	1.84	1.58	8.81	11.32	3.17	11.41	15.07	5.76	1.58	8.17	6.18
2011	6.02	2.04	5.29	4.81	12.27	11.01	8.13	4.56	3.80	10.92	4.72	11.54	7.14
2012	6.39	4.22	8.06	2.42	6.45	8.53	12.44	7.90	8.67	6.95	3.94	4.23	6.71
2013	3.19	3.41	1.68	4.86	8.90	8.11	3.82	5.87	11.13	10.06	5.16	5.83	6.01
2014	6.39	1.71	1.20	6.56	6.03	9.69	5.45	11.50	6.97	5.54	5.55	3.36	5.85
2015	2.41	2.12	2.57	8.89	12.83	15.90	7.13	11.89	9.25	4.02	3.86	3.20	7.02
2016	4.58	4.67	2.80	3.89	10.64	9.06	11.23	8.48	11.15	9.23	12.76	5.19	7.82
2017	5.80	4.42	4.92	9.99	9.34	4.24	13.56	14.77	12.66	5.67	3.77	1.51	7.58
2018	4.92	5.88	6.92	7.24	10.47	6.89	11.11	10.45	6.28	4.98	4.99	4.54	7.07
2019	2.32	1.63	2.93	9.62	8.59	7.73	13.34	8.51	5.78	7.83	5.91	7.97	6.88
2020	1.94	1.96	2.10	2.88	8.85	11.11	8.51	6.50	8.94	8.25	14.70	13.27	7.44
Minimum	1.94	1.63	1.20	1.58	6.03	4.24	3.17	4.56	3.80	4.02	1.58	1.51	5.85
Average	4.27	3.13	3.66	5.70	9.38	9.42	8.90	9.26	9.06	7.20	6.09	6.25	6.88
Maximum	6.39	5.88	8.06	9.99	12.83	15.90	13.56	14.77	15.07	10.92	14.70	13.27	7.82
Year	Manganui River Downstream of Intake Weir (Node c.): Mean monthly river flow (m^3/s)												Annual
2010	1.25	1.90	1.58	1.26	7.27	8.40	1.03	7.76	11.15	2.24	0.51	5.85	4.19
2011	3.30	0.49	2.24	1.64	7.62	6.52	3.88	1.04	0.72	6.62	1.72	8.26	3.71
2012	2.91	3.45	4.24	0.60	3.13	4.41	8.28	3.61	4.56	3.20	1.34	1.60	3.45
2013	0.76	1.94	0.72	2.24	4.80	4.17	0.65	2.17	7.61	5.95	1.97	2.65	2.97
2014	3.22	0.52	0.89	4.31	2.40	5.45	1.58	7.51	3.41	1.56	1.55	1.13	2.80
2015	0.82	0.77	1.06	5.19	8.45	11.96	3.12	7.33	4.47	1.06	0.95	0.62	3.82
2016	1.87	2.36	1.35	2.00	6.41	4.46	6.47	3.81	6.26	4.46	7.86	1.19	4.04
2017	2.13	1.43	2.49	8.01	4.69	0.88	8.87	10.08	8.00	1.90	1.32	0.51	4.21
2018	2.44	2.56	3.59	5.06	6.27	2.46	6.29	5.52	2.69	1.93	1.43	1.28	3.47
2019	0.72	1.02	1.41	7.99	6.06	3.39	9.37	4.12	1.68	3.33	2.60	4.24	3.85
2020	0.69	1.11	0.74	0.86	5.78	6.76	3.81	2.69	4.97	4.11	10.47	9.06	4.26
Minimum	0.69	0.49	0.72	0.60	2.40	0.88	0.65	1.04	0.72	1.06	0.51	0.51	2.80
Average	1.83	1.60	1.85	3.56	5.71	5.35	4.85	5.06	5.05	3.31	2.88	3.31	3.71
Maximum	3.30	3.45	4.24	8.01	8.45	11.96	9.37	10.08	11.15	6.62	10.47	9.06	4.26
Year	Manganui River at Everett Park (Node d.): Mean monthly river flow (m^3/s)												Annual
2010	7.68	-	-	-	29.34	37.49	10.04	35.19	53.64	15.80	4.24	23.86	-
2011	14.72	5.61	13.75	12.50	36.09	36.42	24.66	12.33	11.86	35.43	16.64	38.88	21.72
2012	19.47	17.23	27.34	6.99	18.39	22.57	35.58	23.52	21.43	20.04	10.91	11.26	19.62
2013	8.53	8.45	4.76	13.07	26.30	25.65	12.12	15.23	32.22	28.82	12.28	15.76	16.95
2014	17.16	3.98	3.83	17.58	16.78	26.88	14.79	28.17	15.61	14.35	15.94	11.36	15.58
2015	5.73	6.31	7.21	30.81	35.04	48.44	20.22	36.49	24.27	10.80	11.58	6.93	20.33
2016	9.66	10.51	7.65	11.33	29.28	24.46	33.12	25.39	30.50	25.08	38.29	12.41	21.51
2017	19.64	16.65	12.86	33.76	26.32	10.09	41.61	47.77	37.39	14.58	9.36	3.72	22.86
2018	12.05	13.58	18.15	21.48	31.15	18.29	30.80	24.89	12.52	10.74	12.00	8.64	17.91
2019	4.84	3.91	6.72	23.74	20.18	17.41	35.83	21.63	13.49	18.79	12.87	16.61	16.42
2020	4.28	4.41	4.56	6.21	22.05	28.27	21.10	14.32	23.66	21.38	40.03	39.27	19.18
Minimum	4.28	3.91	3.83	6.21	16.78	10.09	10.04	12.33	11.86	10.74	4.24	3.72	15.58
Average	11.61	9.06	10.68	17.75	26.45	26.91	25.44	25.90	25.15	19.62	16.74	17.16	19.21
Maximum	19.64	17.23	27.34	33.76	36.09	48.44	41.61	47.77	53.64	35.43	40.03	39.27	22.86

At SH3, the mean flow in the 6 months from May to October is about 1.5 times the mean flow for the other six months of the year. The difference is amplified in the lower reaches, e.g. at both the Manganui Weir and Everett Park, the mean flow from May to October is around 1.8 times the mean flow from November to April.

The following flow duration curves (FDCs) are presented in this section for the common period October 2009 to December 2020:

- Figure 3.24: FDCs for the four nodal locations on the Manganui River on the same plot. (This is similar to Figure 2.12 but with the addition of the residual flow below the intake weir)
- Figure 3.25: Separate FDCs for each season and for the full year for the Manganui River below the weir. (Similar seasonal FDCs for the other nodes are provided in Section 2.6.3)
- Figure 3.26: FDCs of the Manganui Weir flow components i.e. Manganui Weir inflow, combined left and right bank fish pass flow, Motukawa Race flow, Manganui Weir overflow

Figures 3.27 and 3.28 present hydrograph plots that compare the Manganui Weir inflow with the residual flow below the weir for the period 2010 to 2020.

Table 3.9 presents the ordinates corresponding with the flow duration curves shown in Figure 3.25 (for the Manganui River below the intake weir). The flow duration data for the Manganui River above the intake weir (weir inflow) are also shown for comparison.

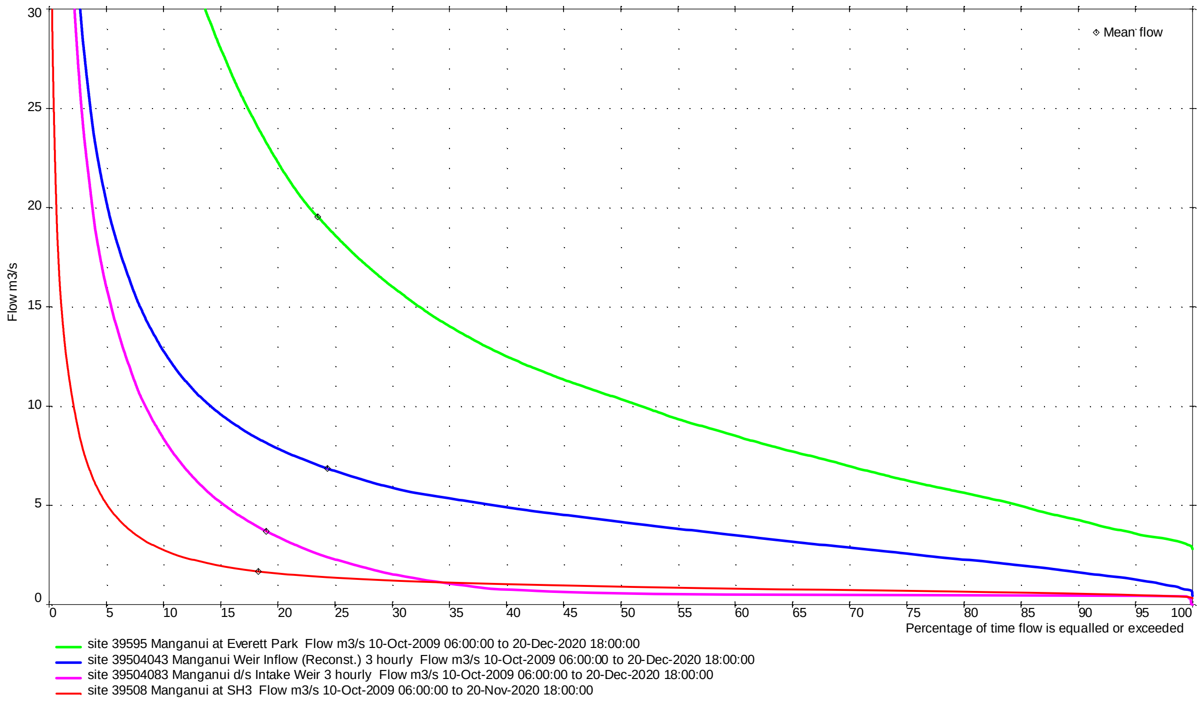

Figure 3.24 Manganui River flow duration curves October 2009 to December 2020. Green curve – Everett Park; blue curve – Manganui Weir inflow; magenta curve – Manganui below intake weir; and red curve – SH3. Mean flow on each curve is indicated by diamond marker

Table 3.9 Manganui Weir inflow versus Manganui below intake weir flow duration data (October 2009 to December 2020)

% time flow is exceeded	Manganui Weir inflow (m^3/s)					Manganui below intake weir (m^3/s)				
	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON
1	55.4	45.8	51.7	70.4	55.1	51.4	42.0	48.0	66.5	50.7
2	36.3	27.9	36.4	42.5	36.5	32.2	23.4	33.0	38.5	32.2
5	20.3	13.3	20.5	24.2	20.8	16.0	9.19	16.6	19.9	16.1
10	12.8	7.53	12.36	16.34	13.20	8.4	3.49	8.52	11.9	8.50
20	7.87	4.73	7.51	10.48	8.21	3.42	1.17	3.68	5.74	3.38
30	5.89	3.73	5.48	7.93	6.30	1.54	0.64	1.80	3.23	1.45
40	4.91	3.07	4.34	6.58	5.28	0.77	0.54	0.92	1.87	0.71
50	4.17	2.62	3.48	5.56	4.61	0.57	0.51	0.62	0.91	0.56
60	3.50	2.28	2.83	4.99	4.02	0.51	0.50	0.52	0.59	0.51
70	2.88	1.95	2.21	4.46	3.46	0.49	0.49	0.50	0.50	0.49
80	2.28	1.67	1.66	3.95	2.93	0.48	0.48	0.48	0.47	0.48
90	1.64	1.39	1.13	3.31	2.38	0.46	0.46	0.46	0.45	0.46
95	1.27	1.21	0.95	2.93	2.09	0.45	0.45	0.46	0.44	0.45
98	0.97	0.99	0.80	2.48	1.76	0.44	0.45	0.45	0.43	0.43
99	0.83	0.77	0.76	2.25	1.36	0.42	0.43	0.44	0.41	0.43

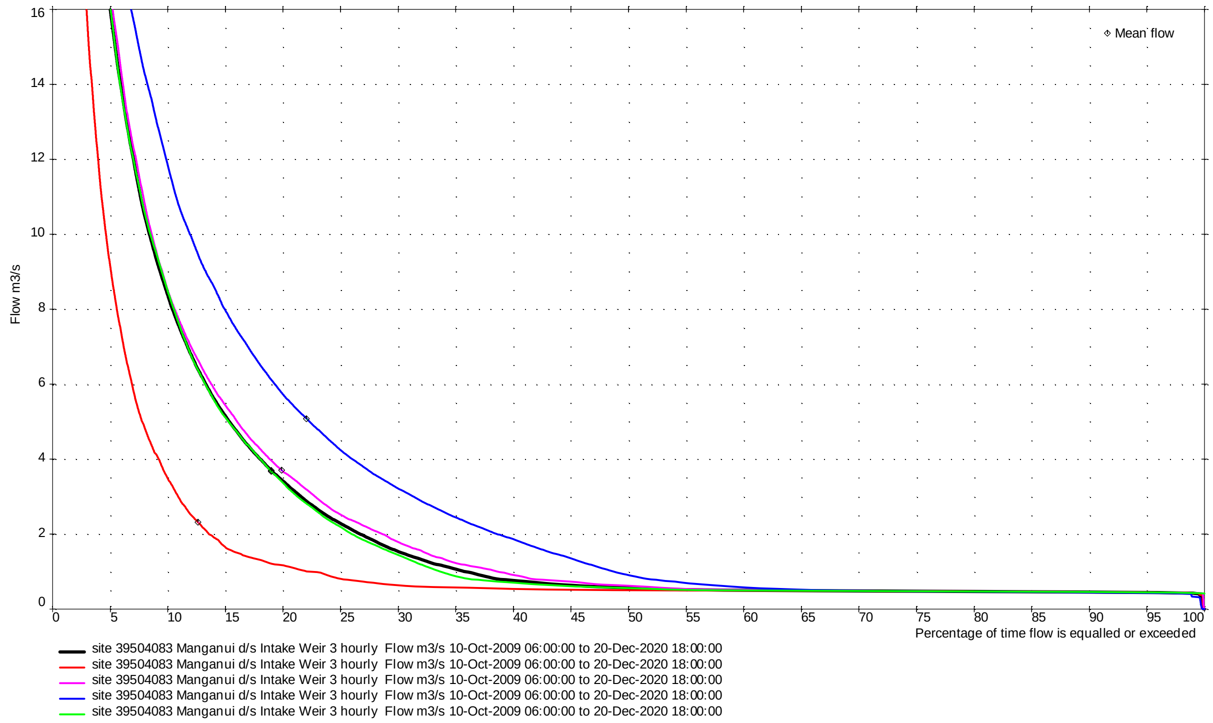

Figure 3.25 Manganui River downstream of Intake Weir: flow duration curves October 2009 to December 2020. Red – summer (D, J, F); magenta – autumn (M, A, M); blue – winter (J, J, A); green – spring (S, O, N); black – full year

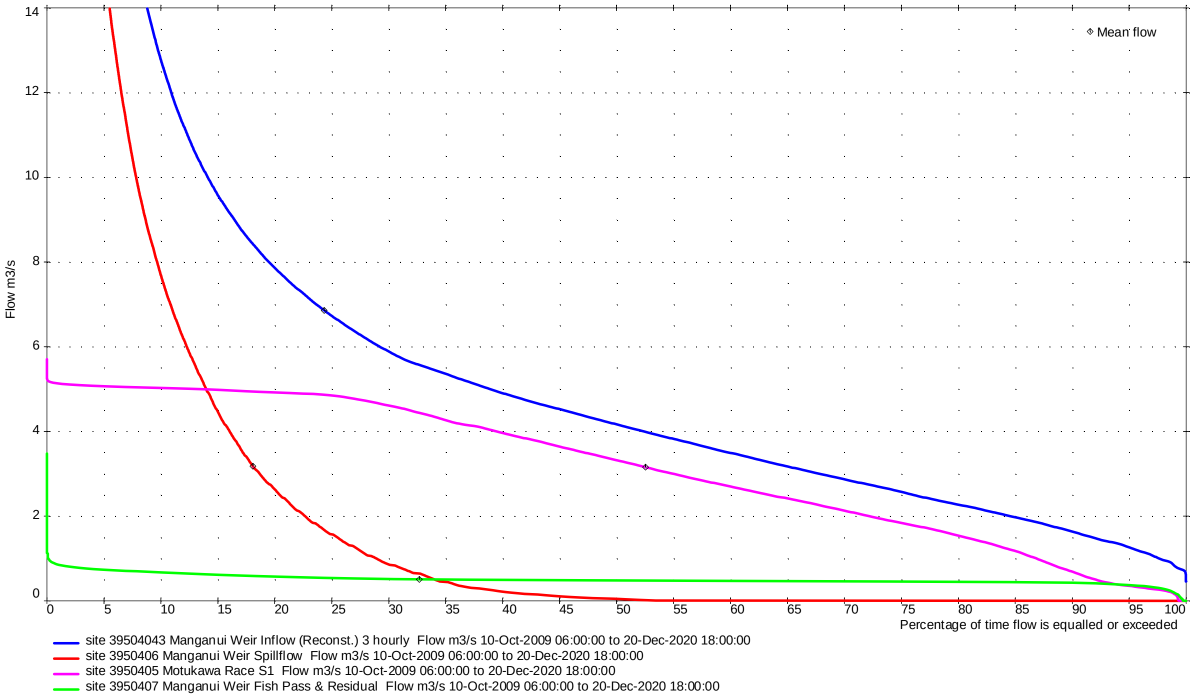

Figure 3.26 Flow duration curves at the Manganui intake weir, comprising Manganui Weir inflow (blue curve); diverted flow to Motukawa Race measured at S1 (magenta curve); spill flow at Manganui Weir (weir overflow, red curve); combined left bank and right bank (fish pass) residual flow (green curve), for period October 2009 to December 2020

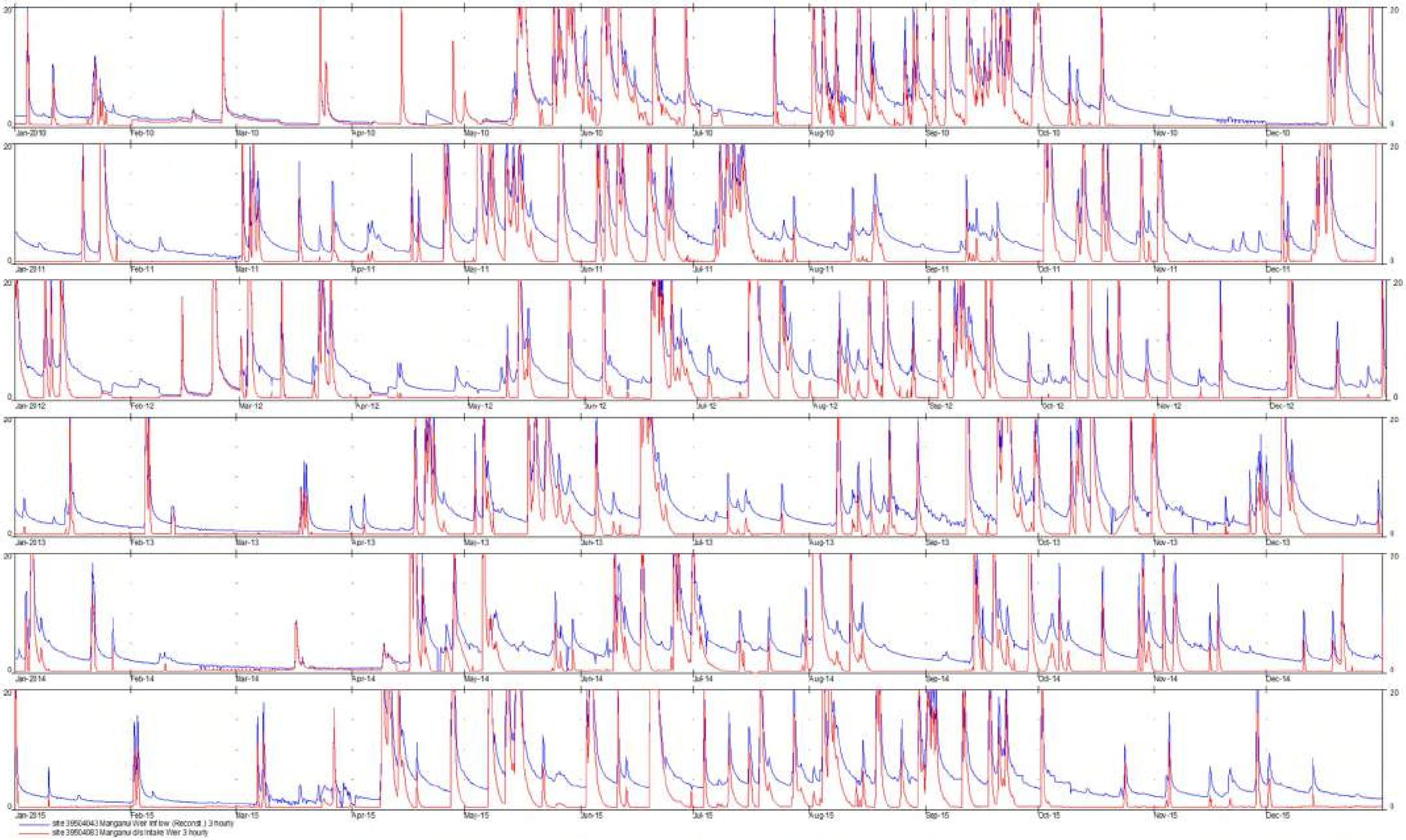

Figure 3.27 Manganui Weir inflow (blue trace) versus residual river flow downstream of weir (i.e. weir overflow plus fish pass flows on left and right banks) (red trace). Flow in m^3/s, from 2010 to 2015

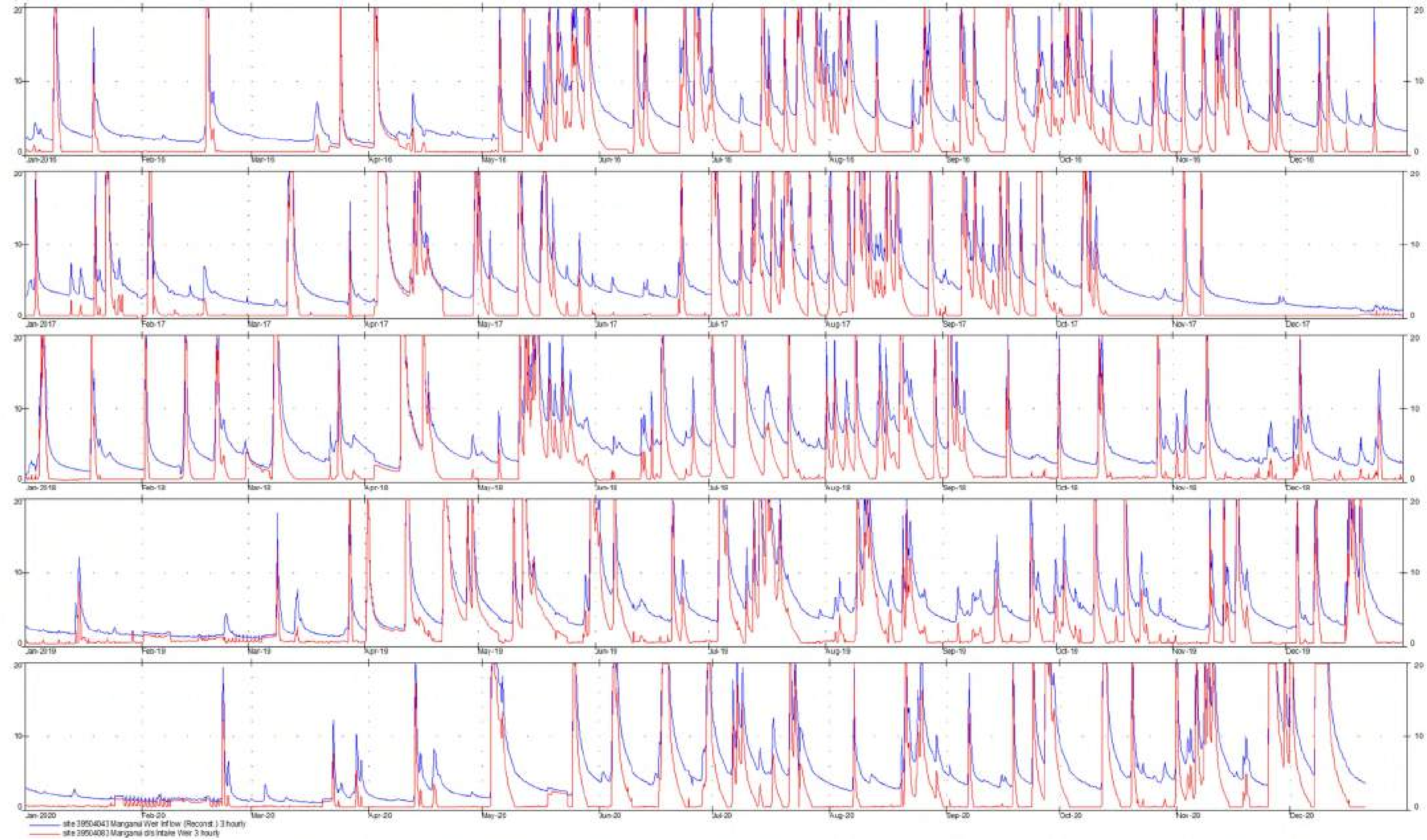

Figure 3.28 Manganui Weir inflow (blue trace) versus residual river flow downstream of weir (i.e. weir overflow plus fish pass flows on left and right banks) (red trace). Flow in m^3/s, from 2016 to 2020

3.7.3 Waitara River nodes

Table 3.10 provides a tabulation of the mean monthly flows for the period 2010 to 2020 for the three nodal locations on the Waitara River, i.e.

- Waitara above its confluence with Makara Stream (into which the Motukawa tailrace discharges) (Node *f.*)
- Waitara at Tarata (Node *h.*)
- Waitara at Bertrand Road (Node *i.*)

Table 3.10 Waitara River mean monthly flows at three locations

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Waitara River above Makara Stream (tailrace) confluence (Node f.): Mean monthly river flow (m^3/s)												Mean
2010	13.0	9.4	6.2	4.2	30.7	58.6	11.9	50.4	87.7	32.7	4.2	28.4	28.1
2011	34.0	5.7	18.0	21.2	51.7	61.2	53.0	18.9	15.9	45.5	32.6	43.5	33.6
2012	32.3	12.9	28.4	6.7	28.2	32.3	54.0	40.4	41.9	40.8	14.9	16.9	29.3
2013	9.9	8.1	3.7	21.3	31.9	44.9	17.1	22.1	57.9	65.1	24.4	17.3	27.0
2014	26.2	3.2	2.9	33.9	29.3	33.0	29.5	46.4	27.5	30.8	33.5	26.5	27.0
2015	4.3	5.4	5.1	45.0	59.8	91.2	34.4	66.5	36.7	22.2	24.3	8.2	33.6
2016	14.1	8.7	6.2	8.9	52.4	41.3	49.3	51.9	57.5	39.5	56.9	14.9	33.6
2017	29.0	40.2	13.5	72.9	41.2	13.7	60.8	75.6	64.8	18.0	13.2	4.3	37.2
2018	14.6	11.8	37.4	30.5	64.8	36.8	53.0	43.3	12.3	9.8	18.8	14.3	29.1
2019	4.6	3.6	9.5	26.6	20.5	29.5	60.0	47.8	22.1	31.9	19.6	32.9	25.9
2020	3.5	4.3	6.6	10.6	35.5	35.7	39.1	26.4	53.6	24.1	43.2	68.5	29.4
Minimum	3.5	3.2	2.9	4.2	20.5	13.7	11.9	18.9	12.3	9.8	4.2	4.3	25.9
Average	16.8	10.3	12.5	25.6	40.5	43.5	42.0	44.5	43.4	32.8	26.0	25.1	30.4
Maximum	34.0	40.2	37.4	72.9	64.8	91.2	60.8	75.6	87.7	65.1	56.9	68.5	37.2
Year	Waitara River at Tarata (Node h.): Mean monthly river flow (m^3/s)												Annual
2010	14.8	9.6	6.3	4.5	33.1	63.6	15.1	55.9	94.6	37.0	5.4	31.6	31.0
2011	37.7	7.4	21.6	24.9	58.2	68.0	59.1	23.1	19.6	51.4	36.6	48.4	38.2
2012	36.7	14.5	33.3	8.6	32.3	37.6	60.2	46.1	47.1	45.6	17.9	19.9	33.5
2013	12.6	9.7	5.0	24.9	38.4	51.7	21.5	27.4	64.7	72.0	28.6	21.4	31.5
2014	30.4	4.3	3.3	37.2	35.0	39.0	34.8	52.4	32.3	35.8	38.7	29.2	31.2
2015	5.8	6.6	6.9	50.7	66.8	98.2	39.8	73.8	43.3	25.4	27.4	10.3	38.0
2016	16.4	10.6	7.3	10.3	57.9	47.0	55.6	58.1	63.5	45.4	63.4	18.7	38.0
2017	33.3	44.6	16.5	77.6	47.8	17.7	67.9	83.4	71.9	22.2	15.6	5.1	41.9
2018	17.1	15.2	41.7	33.6	70.8	42.5	59.7	49.4	15.9	12.8	22.5	17.6	33.4
2019	5.9	4.1	11.2	28.9	23.5	34.3	65.5	53.3	26.3	36.9	22.8	36.9	29.3
2020	4.5	5.0	8.3	12.4	39.2	40.8	44.6	30.4	58.5	28.5	48.8	74.2	33.1
Minimum	4.5	4.1	3.3	4.5	23.5	17.7	15.1	23.1	15.9	12.8	5.4	5.1	29.3
Average	19.6	12.0	14.7	28.5	45.7	49.1	47.6	50.3	48.9	37.5	29.8	28.5	34.5
Maximum	37.7	44.6	41.7	77.6	70.8	98.2	67.9	83.4	94.6	72.0	63.4	74.2	41.9
Year	Waitara River at Bertrand Road (Node i.): Mean monthly river flow (m^3/s)												Annual
2010	19.9	16.7	12.2	10.0	60.9	102.4	22.8	88.1	155.7	58.3	8.7	56.5	51.1
2011	51.9	11.5	34.4	34.8	98.1	110.5	84.5	32.2	28.3	86.6	49.5	86.7	59.5
2012	58.1	30.4	59.1	14.4	50.5	57.1	103.2	76.0	73.5	69.6	30.3	31.1	54.7
2013	21.6	18.7	9.3	38.3	68.4	84.6	34.1	43.7	106.0	106.5	43.0	39.3	51.2
2014	50.8	8.7	7.2	57.9	52.9	70.1	54.6	86.9	50.5	51.2	55.0	41.6	49.1
2015	12.0	13.0	14.0	89.4	110.2	160.1	61.9	119.9	70.1	36.1	37.6	17.1	61.8
2016	24.6	20.2	13.3	19.5	86.1	70.0	86.6	86.2	91.7	69.9	99.5	33.2	58.5
2017	53.3	62.0	31.2	110.9	75.5	30.4	113.3	132.3	108.7	37.9	24.6	8.5	65.7
2018	26.8	28.1	58.4	56.5	103.3	62.7	92.9	71.9	28.2	23.1	33.5	25.8	51.2
2019	10.5	7.1	17.2	53.7	43.7	52.6	103.8	76.3	39.9	55.8	35.7	52.9	46.1
2020	8.6	8.6	11.8	17.5	60.1	69.7	66.8	47.3	81.7	50.4	89.0	113.1	52.2
Minimum	8.6	7.1	7.2	10.0	43.7	30.4	22.8	32.2	28.2	23.1	8.7	8.5	46.1
Average	30.7	20.5	24.4	45.7	73.6	79.1	75.0	78.3	75.8	58.7	46.0	46.0	54.7
Maximum	58.1	62.0	59.1	110.9	110.2	160.1	113.3	132.3	155.7	106.5	99.5	113.1	65.7

Figure 3.29 is a histogram plot of the monthly mean flows for each location, which shows the highly seasonal pattern in the flow behaviour. For example, at Tarata, the mean flow in the 6 months from May to October is about twice the mean flow for the other six months of the year. This is also the case at Bertrand Road which includes the contribution of the Manganui River.

Figure 3.30 presents the flow duration curves for the three nodal locations on the Waitara River and for the Motukawa station discharge on the same plot for the water balance period (this is similar to Figure 2.31 but with the addition of the Waitara above Makara Stream and the Power Station discharge). This comparison shows the relative contribution of the Power Station discharge to the flow recorded at Tarata and Bertrand Road.

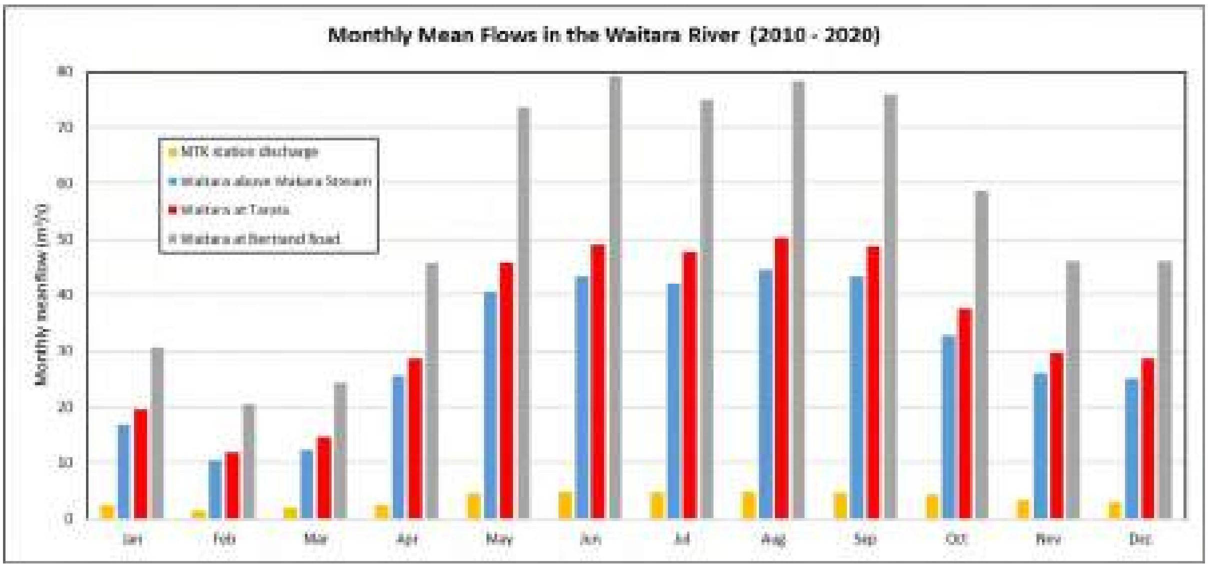

Figure 3.29 Waitara River: mean flow distribution by month-of-year for three nodal locations. Motukawa Power Station discharge also shown to indicate relative magnitude

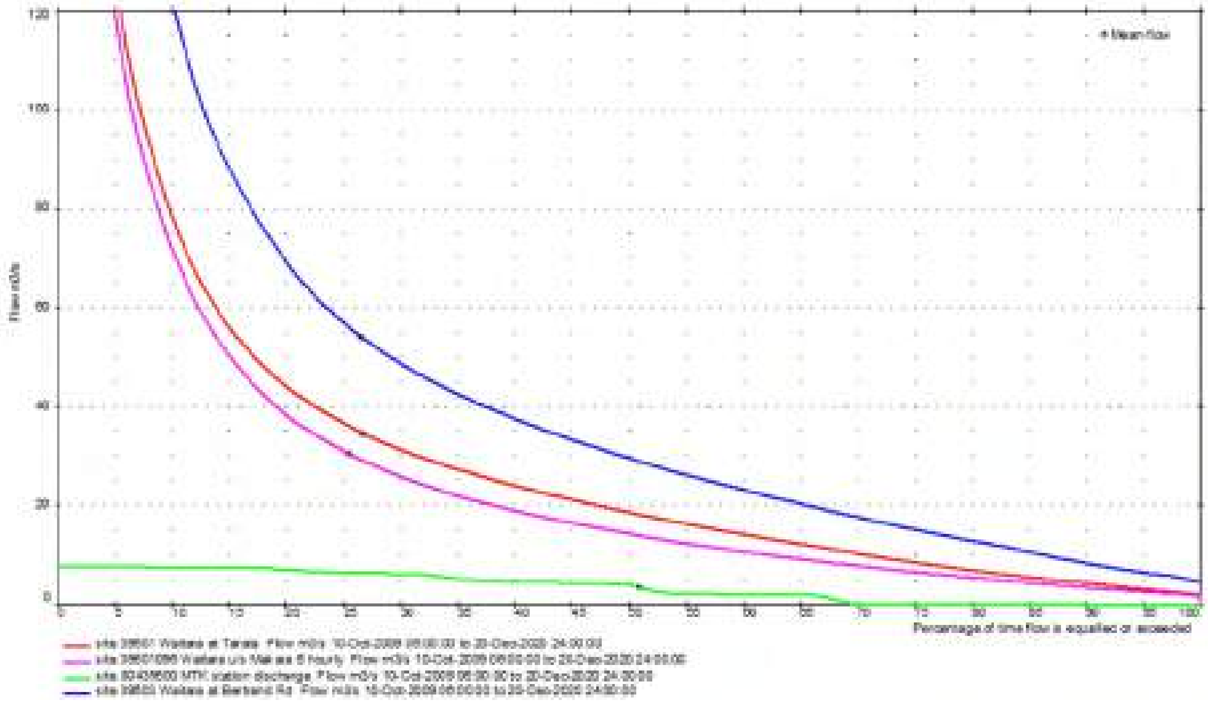

Figure 3.30 Waitara River flow duration curves October 2009 to December 2020. Blue curve – Bertrand Road; red curve – Tarata; magenta curve – Waitara upstream of Makara Stream; and green curve – Motukawa station discharge. Mean flow on each curve is indicated by diamond marker

3.8 Summary of flow statistics

Table 3.11 presents a selection of flow statistics for the nodal locations on the Manganui and Waitara rivers and the Motukawa HEPS. These statistics are influenced by the period of record used and are based on the water balance period October 2009 to December 2020.

Table 3.11 Summary flow statistics for key locations (nodes)

Node	Location	Catchment (km^2)	[1] Flow value for statistic (m^3/s)							
			Mean	[2] MAF	10% exc.	25% exc.	Median	75% exc.	90% exc.	7-d MALF
a.	Manganui at SH3	13.0	1.69	60	2.76	1.36	0.91	0.69	0.55	0.49
b.	Manganui above intake weir	80	6.86	201	12.8	6.73	4.17	2.58	1.64	1.18
c.	Manganui below intake weir	80	3.70	201	8.39	2.29	0.57	0.48	0.46	0.45
d.	Manganui at Everett Park	282	19.5	672	37.5	18.6	10.35	6.27	4.26	3.68
f.	Waitara above Makara Stream	685	30.5	~660	72.1	31.1	14.35	6.63	3.51	2.79
h.	Waitara at Tarata	701	34.6	678	78.7	36.7	18.65	8.52	4.41	3.44
i.	Waitara at Bertrand Road	1113	54.8	974	123	57.1	29.6	15.2	8.36	6.79
j.	[3] Lake Ratapiko	12.4	[6]197.98	[4] 198.78	198.51	198.39	198.23	197.82	197.23	[5] 196.43
k.	Motukawa Race at S1	-	3.16	[4] 5.20	5.03	4.85	3.33	1.85	0.69	0
l.	MTK station discharge	-	3.56	[4] 7.87	7.63	6.46	4.11	0	0	0

Notes:

[1] Values in table are flows in m^3/s except for Lake Ratapiko which are levels in RL m. Exceedance percentiles 10%, 25%, 50% (median), 75%, 90% are shown, as well as a very high and a typical low flow (level)

[2] MAF = mean annual flood, applicable to nodes *a.* to *i.* only. For nodes *j.*, *k.* and *l.* the 0.1% exceedance value shown

[3] Lake levels in RL m shown for Lake Ratapiko

[4] The 0.1% exceedance value shown in the MAF column for nodes *j.*, *k.* and *l.*

[5] The 95% exceedance lake level shown for Lake Ratapiko

[6] Mean lake level with dropouts removed

4 Proposed Motukawa HEPS Operating Regime

4.1 Proposed changes

Two changes that have hydrological implications are being proposed by Trustpower in relation to the currently consented operation of the Scheme:

- Abstraction from the Mangaotea Stream is proposed to be discontinued; and
- The maximum take from the Manganui River into the Motukawa Race is proposed to be increased to 7,500 l/s from the currently consented maximum of 5,200 l/s given the hydraulic capacity of the Motukawa Race and the ability to generate additional renewable electricity from the Scheme.

As described in earlier sections, the historical take from the Mangaotea Stream has been relatively minor, contributing less than 1% (29 l/s out of 3603 l/s, refer to Table 3.2) of the total inflow volume to Lake Ratapiko. The Mangaotea pump station has not operated since March 2018. Cessation of this take is not expected to make a material difference to the operation of the Scheme in the future and also means that there will no longer be a residual reach in the Mangaotea Stream.

No change to the currently consented maximum discharge from the Motukawa Power Station (7,787 l/s) is proposed.

4.2 Operational model of the Scheme

To assess the potential hydrological changes from an increased maximum take from the Manganui River, a hydrological model of the Scheme's operation was developed based largely on historical operational data and Trustpower advice on particular aspects (e.g. generation dispatch). The model uses historical river flows and Scheme inflows for the water balance period October 2009 to December 2020.

In essence the model simulates an "active management" regime that Trustpower could deploy to manage the Scheme inflows and generation (and thus also lake levels)

Part of the active management strategy could be to curtail diversion from the Manganui River (by throttling the Motukawa Race intake gates) when the level of Lake Ratapiko is high because of high coincident local catchment inflows. This already occurs to an extent via water level sensors along the race installed to comply with Special Condition 2 of Consent 3371-2.1, but additional factors and sensor inputs would likely be taken into account in the operational decision process.

4.3 Modelled operation for take of 7.5 m^3/s from Manganui River

4.3.1 Scenario modelling

Scenario modelling requires a range of simplifying assumptions to allow conceptualisation of the Scheme's operation (several are outlined in the preceding section). Many assumptions involve a level of judgement and therefore the simulated flow regime will have an inherent degree of uncertainty. Furthermore, for exactly the same historical take capacity, river inflow and market conditions, the Scheme could have been operated differently within the same constraints (i.e., operator behaviour and strategy/policy are also significant factors).

For this report, a potential future operational scenario has been modelled to illustrate the potential changes to the Scheme's operation associated with the proposed increase in maximum take from the Manganui River. Clearly, many other scenarios are possible depending on the assumptions made and the control parameters selected. It is anticipated that Trustpower will continue to make adjustments to the operation of the Scheme to improve outcomes from the increased take capacity, and to respond to the requirements of the electricity market.

It must also be noted that the actual operation of the Scheme in future and its effects on the downstream river flow regime will be subject to natural variability (and any trends) in the weather and climate and thus the flow patterns in the Manganui and Waitara catchments. However, for the current assessment, there is an implicit assumption that future hydro-climatic conditions are reasonably represented by historical observational data.

4.3.2 Modelled lake level regime

Figure 4.1 compares the historical and modelled lake level duration curves for the last five years 2016 to 2020. Duration curves for the full year and “summer” months November to March are shown. Historical levels can be considerably lower than modelled levels because the hydrological model does not explicitly replicate the historical instances when the lake was drawn down for maintenance purposes.

In the simulation, generation is managed such that lake levels are within 0.5 m of full during the weekends over the “summer” months. Indeed, the modelled levels are often higher on “summer” weekends than observed historically. Evidence of this can be seen in Figure 4.1, which shows that the magenta curve (modelled “summer” levels) plots above the red curve (historical “summer” levels) for almost 60% of the time.

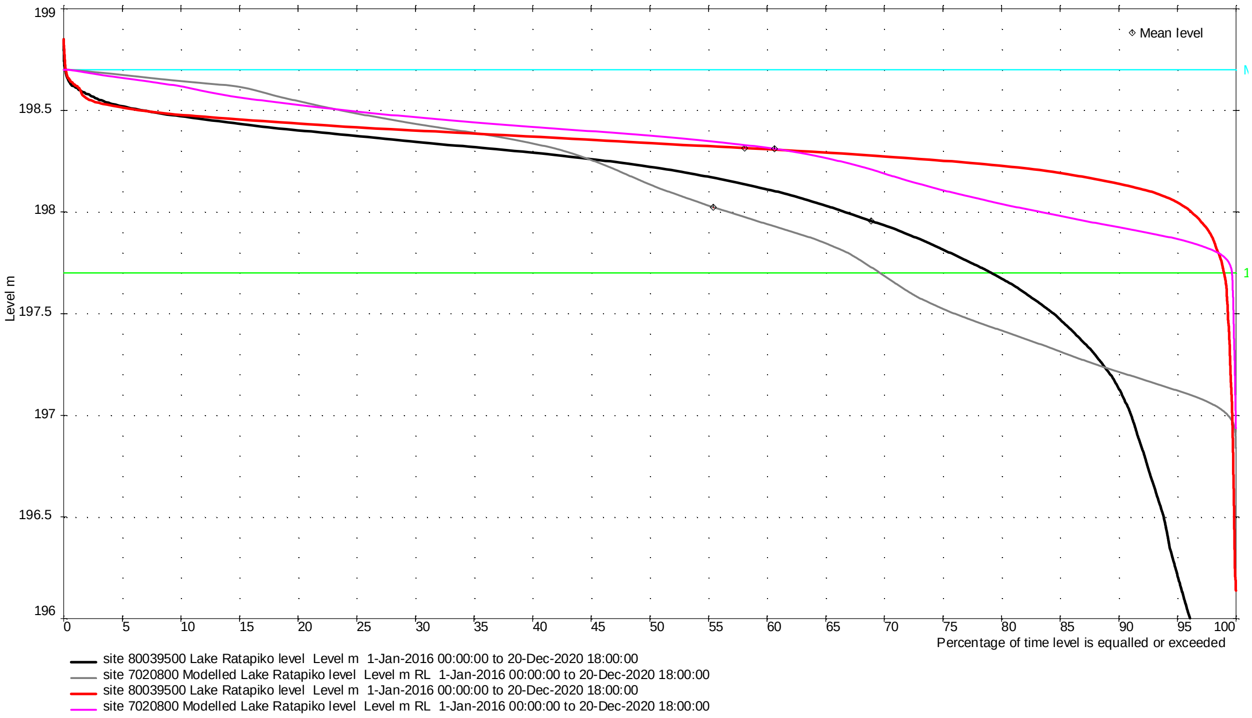

Figure 4.1 Comparison of historical and modelled Lake Ratapiko level duration curves. Black curve – historical full year; grey curve – modelled full year; red curve – historical “summer” months (Nov to Mar); and magenta curve – modelled “summer” months (Nov to Mar). The diamond marker indicates the mean level on each curve. Upper threshold (cyan) is the max. normal op. level (RL 198.7 m), and the lower threshold (green) marks the level within 1 m of full (RL 197.7 m)

4.3.3 Ratapiko Dam spill

A specific aim of the modelled lake operational strategy is to improve usage of the greater inflows available to the Scheme. This appears achievable; despite higher inflows the modelled mean spill is only 0.012 m^3/s compared with an estimated mean spill of 0.083 m^3/s historically between 2010 and

2020. However, as noted earlier (Section 3.4.5), the bulk of the historical spill occurred between February and May of 2010 when there were upgrade works at the Power Station. Discounting this period and February 2012 (when significant spill occurred that was not associated with high inflows), the historical mean spill reduces to 0.014 m^3/s (which is similar to the modelled mean spill based on a maximum take of 7.5 m^3/s from the Manganui River).

The stack of tables presented in Table 4.1 summarise the mean monthly spill flows at Ratapiko Dam assessed from the historical record, the modelled scenario, and the difference between historical and modelled.

Table 4.1 Modelled (7.5 m^3/s take capacity) and historical (5.2 m^3/s take capacity) mean monthly spill flows at Ratapiko Dam 2010 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
	Estimated historical spill at Ratapiko Dam: mean monthly flow (m^3/s)												
2010	0.000	3.569	2.377	0.748	0.402	0.040	0.000	0.080	0.138	0.067	0.000	0.000	0.600
2011	0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.000	0.000	0.070	0.000	0.000	0.011
2012	0.000	2.331	0.202	0.000	0.000	0.000	0.173	0.000	0.000	0.000	0.000	0.000	0.212
2013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.040	0.000	0.000	0.000	0.003	0.005
2015	0.000	0.000	0.002	0.000	0.000	0.629	0.000	0.000	0.000	0.000	0.000	0.000	0.052
2016	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.002
2017	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.001	0.000	0.000	0.000	0.000	0.002
2018	0.000	0.037	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.004
2019	0.000	0.000	0.000	0.067	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.000	0.007
2020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.246	0.018
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.000	0.540	0.235	0.074	0.037	0.069	0.021	0.011	0.013	0.012	0.005	0.023	0.083
Maximum	0.000	3.569	2.377	0.748	0.402	0.629	0.173	0.080	0.138	0.070	0.056	0.246	0.600
Year	Modelled spill at Ratapiko Dam: mean monthly flow (m^3/s)												Annual
2010	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.001	0.066	0.009	0.000	0.029	0.010
2011	0.063	0.000	0.005	0.000	0.014	0.036	0.005	0.000	0.000	0.000	0.005	0.020	0.012
2012	0.025	0.000	0.005	0.000	0.017	0.008	0.063	0.011	0.011	0.000	0.001	0.002	0.012
2013	0.000	0.005	0.004	0.001	0.006	0.011	0.000	0.000	0.072	0.084	0.012	0.001	0.016
2014	0.011	0.000	0.000	0.009	0.000	0.009	0.002	0.020	0.003	0.002	0.001	0.000	0.005
2015	0.004	0.000	0.000	0.019	0.051	0.154	0.002	0.022	0.003	0.000	0.003	0.000	0.021
2016	0.002	0.000	0.000	0.000	0.011	0.008	0.021	0.015	0.014	0.006	0.017	0.002	0.008
2017	0.004	0.010	0.004	0.038	0.015	0.000	0.032	0.026	0.025	0.000	0.001	0.000	0.013
2018	0.006	0.000	0.058	0.000	0.018	0.006	0.011	0.007	0.000	0.000	0.002	0.000	0.009
2019	0.000	0.000	0.017	0.002	0.000	0.013	0.051	0.014	0.000	0.000	0.004	0.018	0.010
2020	0.000	0.000	0.013	0.000	0.018	0.012	0.003	0.006	0.014	0.001	0.005	0.059	0.011
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
Average	0.010	0.001	0.010	0.006	0.014	0.024	0.017	0.011	0.019	0.009	0.005	0.012	0.012
Maximum	0.063	0.010	0.058	0.038	0.051	0.154	0.063	0.026	0.072	0.084	0.017	0.059	0.021
Year	Difference in spill at Ratapiko Dam (modelled minus historical): mean monthly flow (m^3/s)												Annual
2010	0.000	-3.569	-2.377	-0.748	-0.402	-0.029	0.000	-0.079	-0.072	-0.058	0.000	0.029	-0.591
2011	0.063	0.000	0.005	0.000	0.014	-0.021	0.005	0.000	0.000	-0.070	0.005	0.020	0.002
2012	0.025	-2.331	-0.197	0.000	0.017	0.008	-0.110	0.011	0.011	0.000	0.001	0.002	-0.200
2013	0.000	0.005	0.004	0.001	0.006	0.011	0.000	0.000	0.072	0.084	0.012	0.001	0.016
2014	0.011	0.000	0.000	0.009	0.000	-0.009	0.002	-0.020	0.003	0.002	0.001	-0.003	0.000
2015	0.004	0.000	-0.002	0.019	0.051	-0.475	0.002	0.022	0.003	0.000	0.003	0.000	-0.030
2016	0.002	0.000	0.000	0.000	0.011	0.008	0.002	0.015	0.014	0.006	0.017	0.002	0.006
2017	0.004	0.010	0.004	0.038	0.015	0.000	0.014	0.025	0.025	0.000	0.001	0.000	0.011
2018	0.006	-0.037	0.058	0.000	0.018	-0.010	0.011	0.007	0.000	0.000	0.002	0.000	0.005
2019	0.000	0.000	0.017	-0.065	0.000	0.013	0.033	0.014	0.000	0.000	0.004	0.018	0.003
2020	0.000	0.000	0.013	0.000	0.018	0.012	0.003	0.006	0.014	0.001	-0.051	-0.187	0.002
Minimum	0.000	-3.569	-2.377	-0.748	-0.402	-0.475	-0.110	-0.079	-0.072	-0.070	-0.051	-0.187	-0.591
Average	0.010	-0.538	-0.225	-0.068	-0.023	-0.045	-0.003	0.000	0.006	-0.003	0.000	-0.011	-0.071
Maximum	0.063	0.010	0.058	0.038	0.051	0.013	0.033	0.025	0.072	0.084	0.017	0.029	0.016

4.3.4 Diversion from Manganui Weir

Figure 4.2 presents flow duration curves that compare the modelled diversion to the Scheme from the Manganui River based on a maximum take of 7.5 m^3/s with the historical diversion (maximum take of 5.2 m^3/s). The difference between the two curves indicates the additional Scheme inflow afforded by higher maximum take. Figure 4.3 compares the corresponding modelled and historical residual river flows below the Manganui Weir (total fish pass flow, which remain unchanged, plus the weir overflow). In both plots the river inflow duration curve is also shown for reference. Figure 4.4 presents the modelled and historical residual river flow duration curves on a seasonal basis. It may be seen that the greatest difference (indicating the greatest increase in take) occurs in the winter months (Jun, Jul, Aug) and least difference in the summer months (Dec, Jan, Feb).

Over the full modelled period October 2009 to December 2020, the modelled increase in the mean diverted flow to the Motukawa Race is 0.51 m^3/s, which is an increase of 16% over historical. There is a corresponding reduction (of 0.51 m^3/s) in the Manganui Weir overflow, representing a 14% reduction in the residual river flow. Trustpower is not seeking any change to the residual flow requirements.

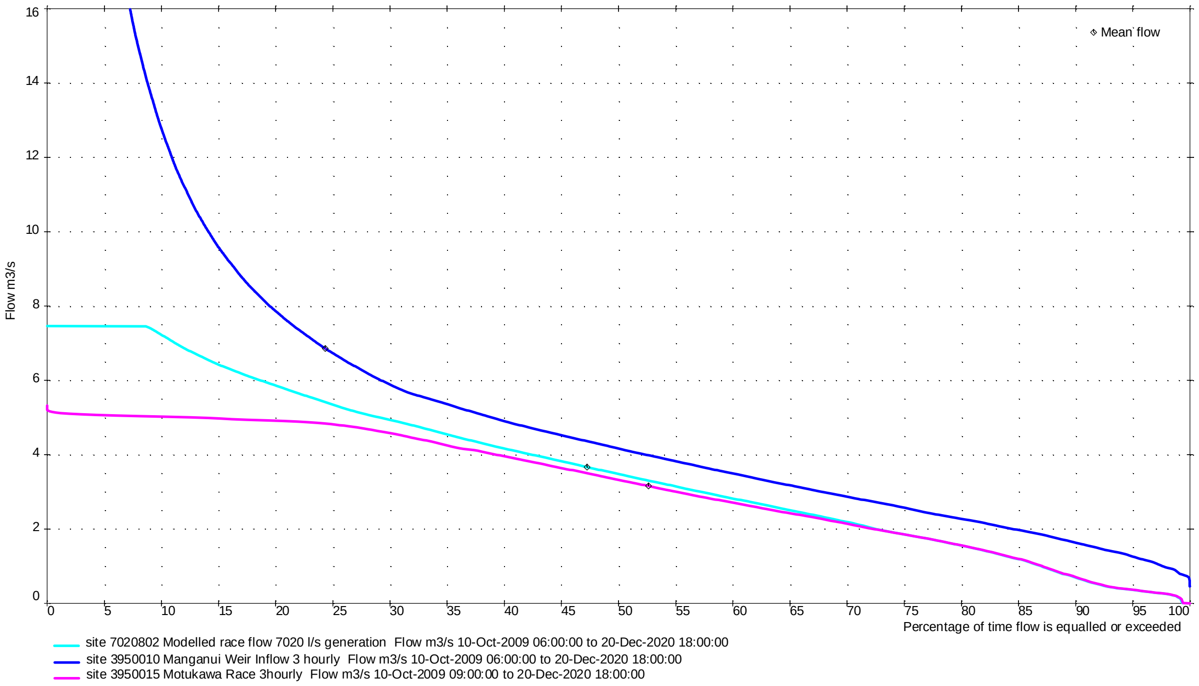

Figure 4.2 Comparison of flow duration curves: modelled diversion based on a 7.5 m^3/s maximum take capacity (cyan curve) versus the historical diversion (magenta curve). The inflow duration curve is also shown (blue curve). The diamond marker on each curve indicates the mean flow

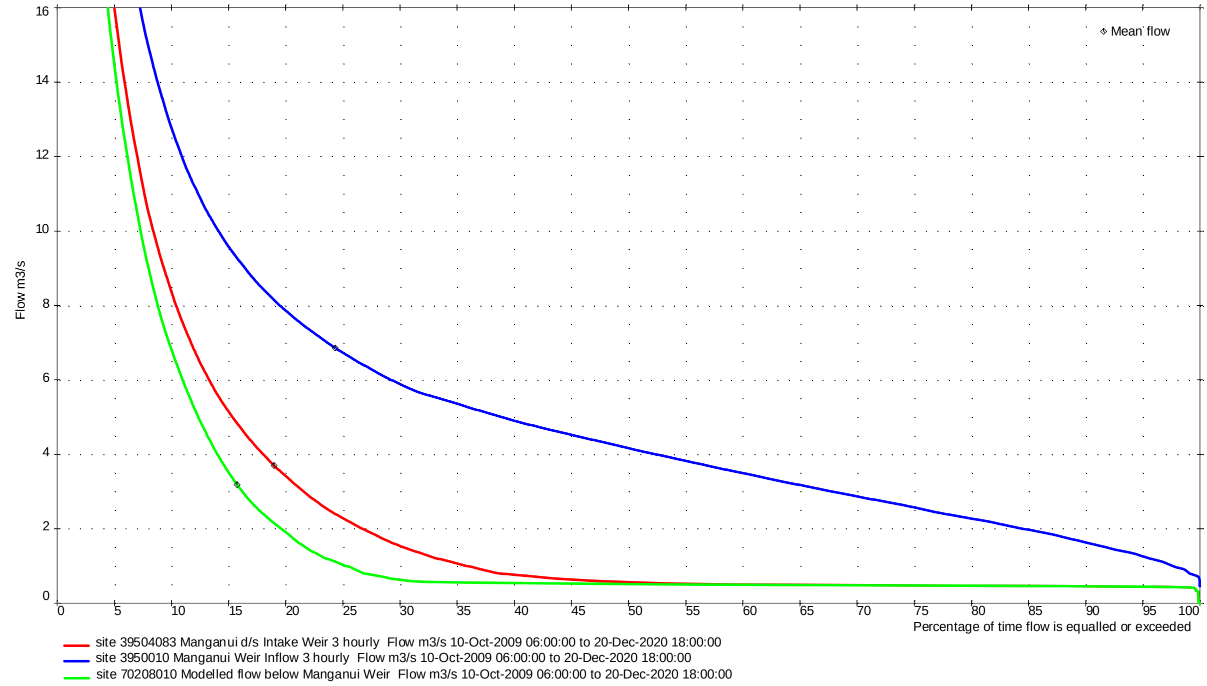

Figure 4.3 Comparison of flow duration curves: modelled residual river for 7.5 m^3/s race capacity (green curve) versus historical (red curve). The inflow duration (blue curve) is also shown. The diamond marker on each curve indicates the mean flow

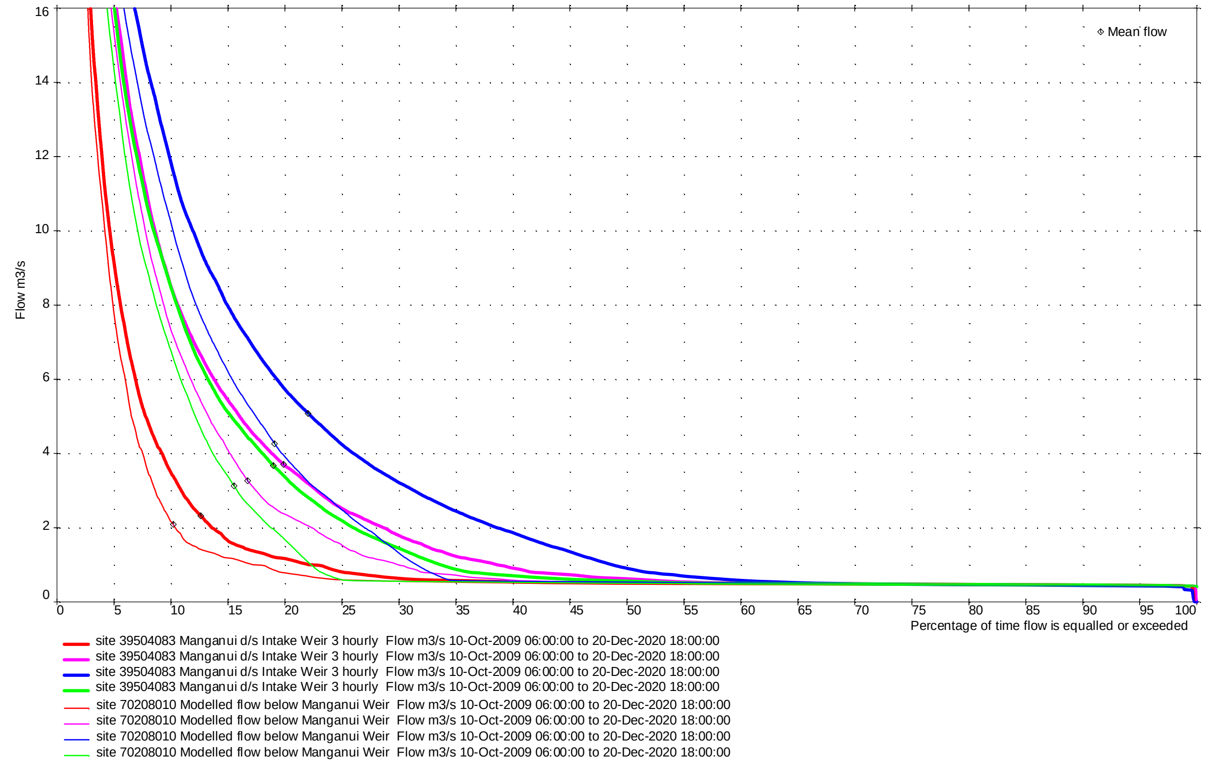

Figure 4.4 Comparison of seasonal flow duration curves of residual river flow below Manganui Weir. Red for summer (D, J, F); magenta for autumn (M, A, M); blue for winter (J, J, A); green for spring (S, O, N). Thick line for historical and thin line for modelled diversion for 7.5 m^3/s race capacity. The diamond marker on each curve indicates the mean flow

Table 4.2 presents the flow ordinates corresponding with the flow duration curves in Figure 4.4 (for the Manganui River below the intake weir).

Table 4.2 Comparison of flow duration data for the residual river below Manganui Weir – historical versus modelled, the latter for a maximum take of 7.5 m^3/s

% time flow is exceeded	Below Manganui Weir (m^3/s) - historical					Below Manganui Weir (m^3/s) - 7.5 m^3/s max take				
	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON	Annual	Summer DJF	Autumn MAM	Winter JJA	Spring SON
1	51.4	42.0	48.0	66.5	50.7	49.5	40.1	46.3	64.1	48.9
2	32.2	23.4	33.0	38.5	32.2	30.5	21.9	31.7	36.4	30.4
5	16.0	9.2	16.6	19.9	16.1	14.5	7.81	15.4	18.1	14.4
10	8.39	3.49	8.52	11.87	8.50	6.84	2.17	7.35	10.2	6.78
20	3.42	1.17	3.68	5.74	3.38	1.91	0.79	2.37	3.92	1.69
30	1.54	0.64	1.80	3.23	1.45	0.63	0.56	1.00	1.33	0.57
40	0.77	0.54	0.92	1.87	0.71	0.55	0.52	0.59	0.56	0.54
50	0.57	0.51	0.62	0.91	0.56	0.52	0.51	0.54	0.54	0.51
60	0.51	0.50	0.52	0.59	0.51	0.51	0.49	0.51	0.52	0.50
70	0.49	0.49	0.50	0.50	0.49	0.49	0.48	0.49	0.49	0.49
80	0.48	0.48	0.48	0.47	0.48	0.47	0.47	0.48	0.47	0.48
90	0.46	0.46	0.46	0.45	0.46	0.46	0.46	0.46	0.45	0.46
95	0.45	0.45	0.46	0.44	0.45	0.45	0.45	0.46	0.44	0.45
98	0.44	0.45	0.45	0.43	0.43	0.44	0.44	0.45	0.43	0.43
99	0.42	0.43	0.44	0.41	0.43	0.41	0.43	0.44	0.41	0.43

Table 4.3 shows the number of days for each month between 2010 and 2020 that the *additional* take from the Manganui River is greater than a nominal threshold (set at 0.1 m^3/s).

Table 4.4 provides tabulations of the modelled mean monthly diverted flow based on a maximum take capacity of 7.5 m^3/s and of the mean monthly flow difference relative to historical.

There is a strong seasonal bias in the distribution of the additional take, with 72% of the days registering an increase in take (greater than the threshold) occurring in the six months from May to October and 75% of the additional take volume occurring over these months.

Table 4.3 Number of days when increased take from Manganui River greater than 0.1 m^3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
2010	7	1	2	3	13	28	3	26	28	9	0	10	130
2011	4	0	11	10	21	21	13	7	7	17	2	10	123
2012	13	2	11	1	7	17	14	18	16	13	2	8	122
2013	4	2	3	10	19	14	6	13	12	16	8	8	115
2014	9	0	1	12	12	16	11	14	14	14	8	6	117
2015	2	3	5	12	14	18	21	24	20	4	5	3	131
2016	5	3	3	4	21	21	22	18	23	21	17	8	166
2017	10	6	6	10	18	4	21	22	23	10	3	0	133
2018	6	10	11	8	20	18	26	27	30	25	15	14	210
2019	3	1	9	19	26	28	24	29	28	24	11	11	213
2020	1	2	4	3	10	18	24	14	11	13	22	13	135
Averages	5.8	2.7	6.0	8.4	16.5	18.5	16.8	19.3	19.3	15.1	8.5	8.3	146.5

Table 4.4 Modelled mean monthly take from the Manganui River based on 7.5 m³/s take capacity and the increase in mean monthly take over historical, 2010 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Modelled take from Manganui River for 7.5 m^3/s maximum take: Mean monthly flow (m^3/s)												Mean
2010	1.95	0.42	0.26	0.32	2.30	5.00	2.24	5.32	5.50	3.84	1.07	2.69	2.59
2011	2.83	1.56	3.38	3.52	5.59	5.41	4.71	3.83	3.25	5.14	3.06	3.69	3.85
2012	4.00	0.78	4.23	1.84	3.66	4.81	4.79	5.09	4.91	4.24	2.72	2.92	3.69
2013	2.55	1.60	1.06	3.05	4.99	4.51	3.32	4.27	4.20	4.60	3.47	3.49	3.43
2014	3.40	1.19	0.31	2.97	3.99	5.14	4.17	4.61	4.21	4.52	4.31	2.33	3.44
2015	1.67	1.47	1.66	4.18	4.93	4.76	5.09	5.47	5.68	3.17	3.06	2.69	3.66
2016	2.93	2.44	1.51	1.94	5.04	5.41	5.63	5.25	5.94	5.61	5.49	4.26	4.29
2017	4.01	3.16	2.67	2.43	5.40	3.50	5.82	5.53	5.70	4.19	2.62	1.01	3.84
2018	2.75	3.90	3.60	2.47	4.96	5.02	5.85	6.26	4.32	3.50	3.90	3.72	4.19
2019	1.71	0.62	1.78	3.19	3.93	5.14	5.32	5.52	4.77	5.50	3.83	4.23	3.82
2020	1.27	0.93	1.45	2.20	3.55	5.34	5.83	4.56	4.41	4.72	5.40	4.75	3.72
Minimum	1.27	0.42	0.26	0.32	2.30	3.50	2.24	3.83	3.25	3.17	1.07	1.01	2.59
Average	2.64	1.64	1.99	2.56	4.39	4.91	4.80	5.07	4.81	4.46	3.54	3.25	3.68
Maximum	4.01	3.90	4.23	4.18	5.59	5.41	5.85	6.26	5.94	5.61	5.49	4.75	4.29
Year	Increase in take from the Manganui River: Mean monthly flow (m^3/s)												Annual
2010	0.24	0.00	0.00	0.00	0.77	2.07	0.10	1.68	1.57	0.33	0.00	0.38	0.60
2011	0.11	0.00	0.33	0.35	0.94	0.92	0.46	0.31	0.16	0.85	0.06	0.42	0.41
2012	0.51	0.00	0.42	0.02	0.34	0.70	0.63	0.80	0.79	0.49	0.11	0.30	0.43
2013	0.11	0.13	0.10	0.43	0.89	0.56	0.15	0.58	0.68	0.49	0.28	0.31	0.39
2014	0.23	0.00	0.00	0.72	0.40	0.91	0.30	0.61	0.66	0.54	0.31	0.11	0.40
2015	0.06	0.12	0.14	0.49	0.55	0.81	1.09	0.92	0.90	0.21	0.15	0.10	0.46
2016	0.22	0.13	0.05	0.05	0.82	0.80	0.87	0.57	1.06	0.83	0.58	0.26	0.52
2017	0.35	0.17	0.25	0.46	0.74	0.13	1.14	0.84	1.04	0.41	0.17	0.00	0.48
2018	0.28	0.58	0.28	0.29	0.76	0.58	1.03	1.33	0.73	0.46	0.34	0.47	0.59
2019	0.12	0.01	0.26	1.56	1.41	0.79	1.35	1.13	0.69	0.99	0.51	0.51	0.78
2020	0.01	0.09	0.10	0.18	0.48	1.00	1.13	0.76	0.45	0.59	1.17	0.53	0.54
Minimum	0.01	0.00	0.00	0.00	0.34	0.13	0.10	0.31	0.16	0.21	0.00	0.00	0.39
Average	0.20	0.11	0.18	0.41	0.74	0.84	0.75	0.86	0.79	0.56	0.33	0.31	0.51
Maximum	0.51	0.58	0.42	1.56	1.41	2.07	1.35	1.68	1.57	0.99	1.17	0.53	0.78

4.3.5 Mangorei Power Station

The modelled increase in the generation flow averaged over the water balance period (October 2009 to December 2020) is 0.55 m^3/s.

The modelling results indicated there were many periods when the simulated generation flow decreased relative to historical, but more commonly, the simulated generation was higher than historical. Differences between modelled and historical generation are attributed to:

- Increased race inflows afforded by a higher maximum take of 7.5 m^3/s from the Manganui River
- The different historical strategies used for managing Lake Ratapiko levels versus the simulated regime, including different electricity market conditions and daily generation profiles
- A modelled peak generation outflow (7.02 m^3/s) that matches recent operation, but which is lower than during some periods in the past (historically up to 7.87 m^3/s)
- Station outages, whether unplanned or scheduled and whether full or partial (e.g. for station upgrade works, routine/annual maintenance), that have occurred in the past and which are not adequately replicated in the simulated operation [4]

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[4] The hydrological model uses a simplistic proxy for replicating such periods; when the historical Motukawa Race flow falls below a nominal threshold (in this case 2.0 m^3/s), no increase in take from the Manganui River is permitted even though additional flow is available for abstraction. This approach also accommodates periods of high local inflows when the race intake gates are partially closed to reduce local flooding. Furthermore, flow bypass at the station (if any) is not simulated.

- Potential errors in the Motukawa Power Station discharge record, including unmarked periods of missing data and errors/uncertainties in the station load versus discharge rating curves.

Given the above, a direct comparison between the modelled and historical generation flows on a day-to-day or even month-to-month basis may not be particularly representative. However, all things being equal, it is anticipated that the increase in generation flow should have a pattern that matches the increase in race flow (while allowing for the reduction in spill flow at Ratapiko Dam and the cessation of the Mangaotea Stream abstraction) on a month-by-month basis.

By using the hydrological model to simulate operation of the Scheme with the current maximum take of 5.2 m^3/s (instead of 7.5 m^3/s) at the Manganui Weir, it was found that the “active management” strategy (described in Sections 4.2 earlier) was able to increase the take from the Manganui River by 0.14 m^3/s and increase generation flow by 0.20 m^3/s. Therefore, arguably only 64% (1 minus 0.20/0.55) of the generation flow increase is derived from the proposed 2.3 m^3/s increase in the maximum diversion from the Manganui River and the remainder from an enhanced operational strategy and other factors (e.g. avoided station outages, which may not be preventable).

4.3.6 Summary of modelled changes in the Scheme flows

Table 4.5 tabulates the predicted changes in the mean monthly flow resulting from an increase in the maximum Manganui River take to 7.5 m^3/s (from 5.2 m^3/s currently) for the following components of the Motukawa HEPS:

- Diverted flow from the Manganui River to the Motukawa Race
- Residual river flow below the Manganui Weir
- Spill at Ratapiko Dam
- Motukawa Power Station discharge

Table 4.5 MTK Scheme: predicted change in mean monthly flows for 7.5 m^3/s take capacity

Year	Increase in take from the Manganui River: Mean monthly flow (m^3/s)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2010	0.24	0.00	0.00	0.00	0.77	2.07	0.10	1.68	1.57	0.33	0.00	0.38	0.60
2011	0.11	0.00	0.33	0.35	0.94	0.92	0.46	0.31	0.16	0.85	0.06	0.42	0.41
2012	0.51	0.00	0.42	0.02	0.34	0.70	0.63	0.80	0.79	0.49	0.11	0.30	0.43
2013	0.11	0.13	0.10	0.43	0.89	0.56	0.15	0.58	0.68	0.49	0.28	0.31	0.39
2014	0.23	0.00	0.00	0.72	0.40	0.91	0.30	0.61	0.66	0.54	0.31	0.11	0.40
2015	0.06	0.12	0.14	0.49	0.55	0.81	1.09	0.92	0.90	0.21	0.15	0.10	0.46
2016	0.22	0.13	0.05	0.05	0.82	0.80	0.87	0.57	1.06	0.83	0.58	0.26	0.52
2017	0.35	0.17	0.25	0.46	0.74	0.13	1.14	0.84	1.04	0.41	0.17	0.00	0.48
2018	0.28	0.58	0.28	0.29	0.76	0.58	1.03	1.33	0.73	0.46	0.34	0.47	0.59
2019	0.12	0.01	0.26	1.56	1.41	0.79	1.35	1.13	0.69	0.99	0.51	0.51	0.78
2020	0.01	0.09	0.10	0.18	0.48	1.00	1.13	0.76	0.45	0.59	1.17	0.53	0.54
Minimum	0.01	0.00	0.00	0.00	0.34	0.13	0.10	0.31	0.16	0.21	0.00	0.00	0.39
Average	0.20	0.11	0.18	0.41	0.74	0.84	0.75	0.86	0.79	0.56	0.33	0.29	0.51
Maximum	0.51	0.58	0.42	1.56	1.41	2.07	1.35	1.68	1.57	0.99	0.58	0.51	0.78
Year	Reduction in Residual Flow below Manganui Weir: Mean monthly flow (m^3/s)												Annual
2010	0.24	0.00	0.00	0.00	0.77	2.07	0.10	1.68	1.57	0.33	0.00	0.38	0.60
2011	0.11	0.00	0.33	0.35	0.94	0.92	0.46	0.31	0.16	0.85	0.06	0.42	0.41
2012	0.51	0.00	0.42	0.02	0.34	0.70	0.63	0.80	0.79	0.49	0.11	0.30	0.43
2013	0.11	0.13	0.10	0.43	0.89	0.56	0.15	0.58	0.68	0.49	0.28	0.31	0.39
2014	0.23	0.00	0.00	0.72	0.40	0.91	0.30	0.61	0.66	0.54	0.31	0.11	0.40
2015	0.06	0.12	0.14	0.49	0.55	0.81	1.09	0.92	0.90	0.21	0.15	0.10	0.46
2016	0.22	0.13	0.05	0.05	0.82	0.80	0.87	0.57	1.06	0.83	0.58	0.26	0.52
2017	0.35	0.17	0.25	0.46	0.74	0.13	1.14	0.84	1.04	0.41	0.17	0.00	0.48
2018	0.28	0.58	0.28	0.29	0.76	0.58	1.03	1.33	0.73	0.46	0.34	0.47	0.59
2019	0.12	0.01	0.26	1.56	1.41	0.79	1.35	1.13	0.69	0.99	0.51	0.51	0.78
2020	0.01	0.09	0.10	0.18	0.48	1.00	1.13	0.76	0.45	0.59	1.17	0.53	0.54
Minimum	0.01	0.00	0.00	0.00	0.34	0.13	0.10	0.31	0.16	0.21	0.00	0.00	0.39
Average	0.20	0.11	0.18	0.41	0.74	0.84	0.75	0.86	0.79	0.56	0.33	0.31	0.51
Maximum	0.51	0.58	0.42	1.56	1.41	2.07	1.35	1.68	1.57	0.99	1.17	0.53	0.78
Year	Change in Ratapiko Spill Flow: Mean monthly flow (m^3/s)												Annual
2010	0.000	-3.569	-2.377	-0.748	-0.402	-0.029	0.000	-0.079	-0.072	-0.058	0.000	0.029	-0.591
2011	0.063	0.000	0.005	0.000	0.014	-0.021	0.005	0.000	0.000	-0.070	0.005	0.020	0.002
2012	0.025	-2.331	-0.197	0.000	0.017	0.008	-0.110	0.011	0.011	0.000	0.001	0.002	-0.200
2013	0.000	0.005	0.004	0.001	0.006	0.011	0.000	0.000	0.072	0.084	0.012	0.001	0.016
2014	0.011	0.000	0.000	0.009	0.000	-0.009	0.002	-0.020	0.003	0.002	0.001	-0.003	0.000
2015	0.004	0.000	-0.002	0.019	0.051	-0.475	0.002	0.022	0.003	0.000	0.003	0.000	-0.030
2016	0.002	0.000	0.000	0.000	0.011	0.008	0.002	0.015	0.014	0.006	0.017	0.002	0.006
2017	0.004	0.010	0.004	0.038	0.015	0.000	0.014	0.025	0.025	0.000	0.001	0.000	0.011
2018	0.006	-0.037	0.058	0.000	0.018	-0.010	0.011	0.007	0.000	0.000	0.002	0.000	0.005
2019	0.000	0.000	0.017	-0.065	0.000	0.013	0.033	0.014	0.000	0.000	0.004	0.018	0.003
2020	0.000	0.000	0.013	0.000	0.018	0.012	0.003	0.006	0.014	0.001	-0.051	-0.187	-0.014
Minimum	0.00	-3.57	-2.38	-0.75	-0.40	-0.48	-0.11	-0.08	-0.07	-0.07	-0.05	-0.19	-0.59
Average	0.01	-0.54	-0.23	-0.07	-0.02	-0.04	0.00	0.00	0.01	0.00	0.00	-0.01	-0.07
Maximum	0.06	0.01	0.06	0.04	0.05	0.01	0.03	0.03	0.07	0.08	0.02	0.03	0.02
Year	Increase in MTK generation flow: Mean monthly flow (m^3/s)												Annual
2010	0.23	3.57	2.37	0.75	1.12	2.05	-0.03	1.67	1.56	0.39	0.00	0.35	1.15
2011	0.05	0.00	0.33	0.35	0.93	0.94	0.46	0.31	0.16	0.92	0.05	0.40	0.41
2012	0.48	2.33	0.61	0.02	0.29	0.68	0.74	0.73	0.76	0.48	0.05	0.24	0.61
2013	0.05	0.12	0.05	0.42	0.83	0.46	0.06	0.45	0.52	0.37	0.25	0.29	0.32
2014	0.21	0.00	0.00	0.70	0.30	0.89	0.29	0.60	0.58	0.44	0.24	0.05	0.36
2015	0.02	0.11	0.15	0.42	0.39	1.21	1.04	0.78	0.81	0.15	0.07	0.09	0.44
2016	0.21	0.13	0.05	-0.08	0.72	0.73	0.80	0.46	0.91	0.76	0.55	0.25	0.46
2017	0.34	0.15	0.24	0.41	0.69	0.10	1.00	0.72	1.01	0.28	0.04	-0.04	0.41
2018	0.23	0.58	0.22	0.19	0.69	0.53	1.00	1.30	0.65	0.36	0.33	0.47	0.55
2019	0.12	-0.01	0.24	1.63	1.41	0.78	1.32	1.11	0.69	0.99	0.51	0.49	0.78
2020	0.01	0.09	0.08	0.18	0.46	0.99	1.12	0.75	0.44	0.58	1.22	0.72	0.55
Minimum	0.01	-0.01	0.00	-0.08	0.29	0.10	-0.03	0.31	0.16	0.15	0.00	-0.04	0.32
Average	0.18	0.64	0.39	0.45	0.71	0.85	0.71	0.81	0.73	0.52	0.30	0.30	0.55
Maximum	0.48	3.57	2.37	1.63	1.41	2.05	1.32	1.67	1.56	0.99	1.22	0.72	0.78

Note: The apparent reduction in spill flow for the months February, March and April are dominated by the “avoided” spill between February and May 2010 which are associated with historical station upgrade works at the time, and therefore not necessarily representative of future operation.

Figure 4.5 is a histogram plot of the monthly mean flow change for each scheme component. Table 4.6 summarises the predicted overall mean flow changes from increasing the race capacity to 7.5 m^3/s compared with historical operation.

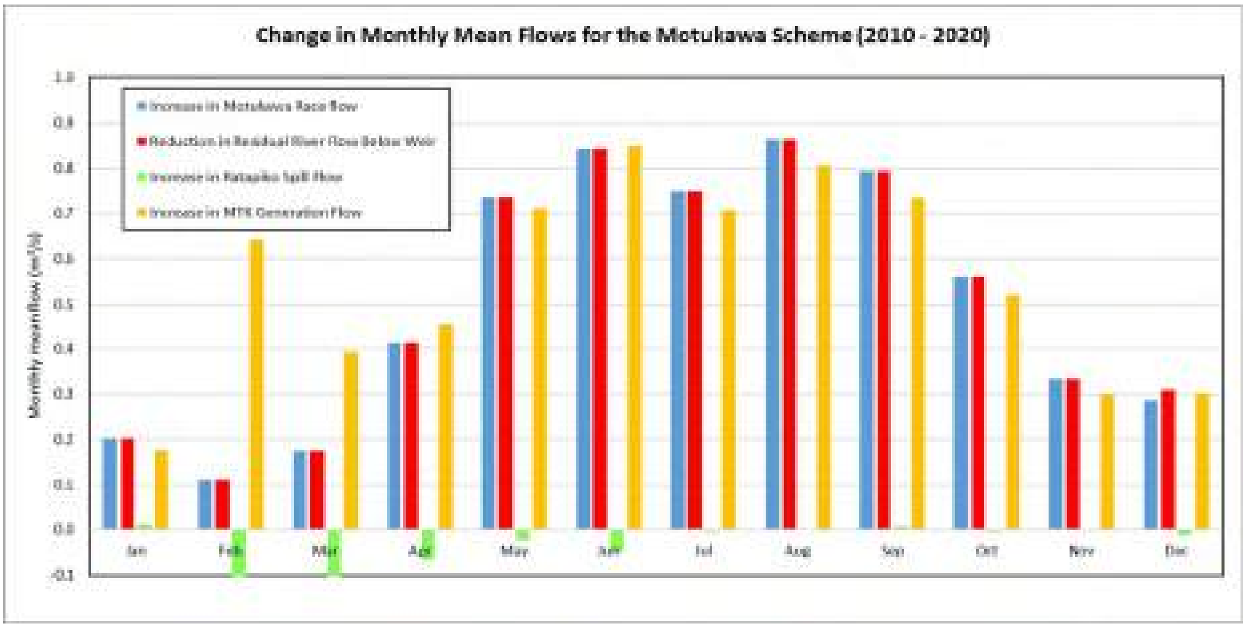

Figure 4.5 *Motukawa Scheme: predicted change in component mean flows by month-of-year based on the maximum take from the Manganui River increased to 7.5* m^3/s*. Note that the increase in generation for the months February and March are skewed by the apparent avoided spill in the same months which are largely associated with historical station upgrade works*

Table 4.6 Predicted scheme mean flows for 7.5 m^3/s take capacity from the Manganui River

Scenario	Mean flows (m^3/s) for period Oct 2009 to Dec 2020						
	Race flow at S1	Race flow increase*	Mangaotea take	Ratapiko spill	Ratapiko spill change*	MTK generation	Generation flow increase*
Historical operation (Oct 2009 to Dec 2020)	3.16	-	0.029	0.083	-	3.56	-
Modelled operation with 7.5 m^3/s maximum take, plus active management	3.67	0.51	0	0.012	- 0.71	4.12	0.55

* Relative to historical

5 Implications of Climate Change

5.1 Introduction

In this section, the predicted changes in the future climate for the Taranaki region are based on the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment as interpreted by the Ministry for the Environment (MfE 2018). The potential impacts on the water resources of the Manganui and Waitara Rivers and the operation of the Motukawa HEPS have been inferred from these predictions. However, it must be noted that many of the predictions are presented on small scale maps of New Zealand or as regional generalisations, from which it is difficult to draw catchment-specific inferences.

Climate projections for New Zealand have been prepared by MfE for three future periods: 2031 – 2050, 2081 – 2100 and 2101 – 2120, all expressed as changes relative to a baseline “present day” period of 1986 – 2005. These future 20-year periods are centred on 2040, 2090 and 2110, and so the climate projections are referred to as the 2040, 2090 and 2110 predictions. Given that the maximum term of the renewed consents will be 35 years (end of renewed period not extending beyond 2057), predictions for 2040 are arguably more relevant than for 2090 or 2110 (apart from the greater uncertainty of these more distant projections).

The IPCC 5th Assessment considered four emissions scenarios, known as representative concentration pathways (RCPs). These RCPs include one mitigation pathway (RCP2.6), two stabilisation pathways (RCP4.5 and RCP6.0) and one pathway with very high greenhouse gas concentrations (RCP8.5), i.e. essentially “business as usual”. While there is no likelihood assigned to each scenario (i.e. no statement is made whether any one scenario is more likely than another), a midrange scenario is commonly adopted for assessment of potential impacts. The midrange scenarios are RCP4.5 and RCP6.0.

5.2 Temperature and rainfall

Table 5.1 presents the predicted changes in the mean temperature and rainfall for 2040 and 2090 relative to the baseline period (1986 – 2005) for the Taranaki Region. These predictions are from the MfE (2018) publication and include the ensemble average as well as the range (5th percentile to 95th percentile) of predictions over all models within the ensemble used (viz. 37 models for RCP4.5 and 18 models for RCP6.0). While the mean temperature change is, in general, relatively uniform within a region, the mean change in rainfall is spatially more variable, and the tabulated rainfall values are for New Plymouth. Predictions for 2090 are shown in addition to those for 2040 to indicate the trend with time.

A notable feature of the tabulated values is the large spread in the possible future outcomes across the range of global circulation models (GCMs) used for predictions.

Table 5.1 Predicted changes in the seasonal and annual mean temperature and mean rainfall for the Taranaki region (extracted from MfE 2018)

Future time period and emissions scenario	Summer (DJF)	Autumn (MAM)	Winter (JJA)	Spring (SON)	Annual
[1] Change in mean temperature (in °C) for future period relative to baseline period (1986 – 2005)					
2040, RCP4.5	0.9 (0.4, 1.5)	0.9 (0.4, 1.4)	0.9 (0.6, 1.2)	0.8 (0.3, 1.1)	0.9 (0.5, 1.2)
2040, RCP6.0	0.9 (0.3, 1.6)	0.9 (0.3, 1.2)	0.8 (0.3, 1.2)	0.7 (0.2, 1.2)	0.8 (0.3, 1.2)
2090, RCP4.5	1.5 (0.7, 2.7)	1.5 (0.8, 2.2)	1.5 (0.9, 2.1)	1.3 (0.7, 1.9)	1.4 (0.9, 2.1)
2090, RCP6.0	1.9 (1.0, 3.9)	1.9 (1.0, 2.9)	1.9 (1.2, 2.8)	1.6 (1.0, 2.3)	1.8 (1.1, 2.9)
[1,2] Change in mean rainfall (in percent) for future period relative to baseline period (1986 – 2005)					
2040, RCP4.5	0 (-9, 8)	1 (-9, 12)	4 (-6, 15)	1 (-0,10)	2 (-5, 7)
2040, RCP6.0	-1 (-13, 8)	1 (-12, 12)	5 (-5, 15)	-1 (-9, 8)	1 (-5, 8)
2090, RCP4.5	2 (-10, 14)	2 (-8, 12)	5 (-9, 18)	0 (-8, 9)	2 (-5, 10)
2090, RCP6.0	2 (-23, 23)	4 (-17, 30)	9 (-8, 33)	2 (-14, 18)	4 (-13, 26)

Notes:

1 The values in each column represent the ensemble average, and in brackets the range (5th percentile to 95th percentile) over all models within that ensemble, which consists of 37 global climate models for RCP4.5 and 18 global climate models for RCP6.0.

2 MfE (2018) does not provide a prediction of the mean rainfall changes for entire regions as a whole or as an average, but provides predictions for one or two specific locations within a region. For the Taranaki region, the predicted changes are given only for New Plymouth.

By 2040, the mean temperature in Taranaki is projected to increase by around 0.9 °C for both RCP4.5 and RCP6.0. By interpolating between the 2040 and 2090 predictions, the projected mean temperature increase by 2057 (end of 35 year term from 2022) is approximately 1.1 °C. There is little variation across the seasons, with spring experiencing a slightly lower increase.

By 2040, the mean rainfall for New Plymouth (representing the Taranaki region – see note 2 in Table 5.1) is predicted to increase by about 5% in winter and remain relatively unchanged for the other seasons. By 2090, the mean rainfall is projected to increase by between 5% and 9% in winter and by around 2% to 4% for the other seasons.

MfE (2018) also provides the predicted increase in the number of “hot days” per year (maximum temperature ≥ 25 °C), by region, for two future periods viz. 2040 and 2090 under the four RCPs. These predictions are presented in Table 5.2 and indicate a doubling of the average number of hot days by 2040, and 3 to 4 times as many hot days compared with the present by 2090.

Table 5.2 Average number of “hot days” (maximum temperature ≥ 25 °C) per year for Taranaki (extracted from MfE 2018)

For Taranaki region	Present day (1986 – 2005)	Future period 2040		Future period 2090	
		RCP4.5	RCP6.0	RCP4.5	RCP6.0
Average number of “hot days” per year	6.5	13.5	13.4	19.7	26.6

The average number of “cold nights” (minimum temperature ≤ 0 °C) per year is also given in MfE (2018). For Taranaki, the average number of cold nights are projected to decrease from 6.3 to around 2.7 by 2040 (average of RCP4.5 and RCP6.0) and to about 1.2 by 2090 (average of RCP4.5 and RCP6.0).

Projected changes in extreme (storm) rainfall depths, expressed as a function of the predicted mean temperature increase, are described in Carey-Smith et al (2018). A range of storm durations (from 1 hour to 5 days) and different average recurrence intervals (ARIs) from 2 years to 100 years were considered. Figure 5.1 shows, for example, the estimated percentage change in storm depth per °C of warming for the 50-year ARI event for all of New Zealand. It may be seen that for the Waitara catchment, the increase in storm depth is around 10% for a short duration event (1 hour) and progressively reduces for longer duration events, i.e. to around 5% for the 5-day rainfall. As noted earlier, the predicted mean temperature increase for Taranaki by 2040 is about 0.9 °C (and 1.1 °C by 2056). Given the direct linkage between storm rainfall depth and flood size, a similar increase in the peak flood flows (i.e. 5% to 10%) may be expected by 2040.

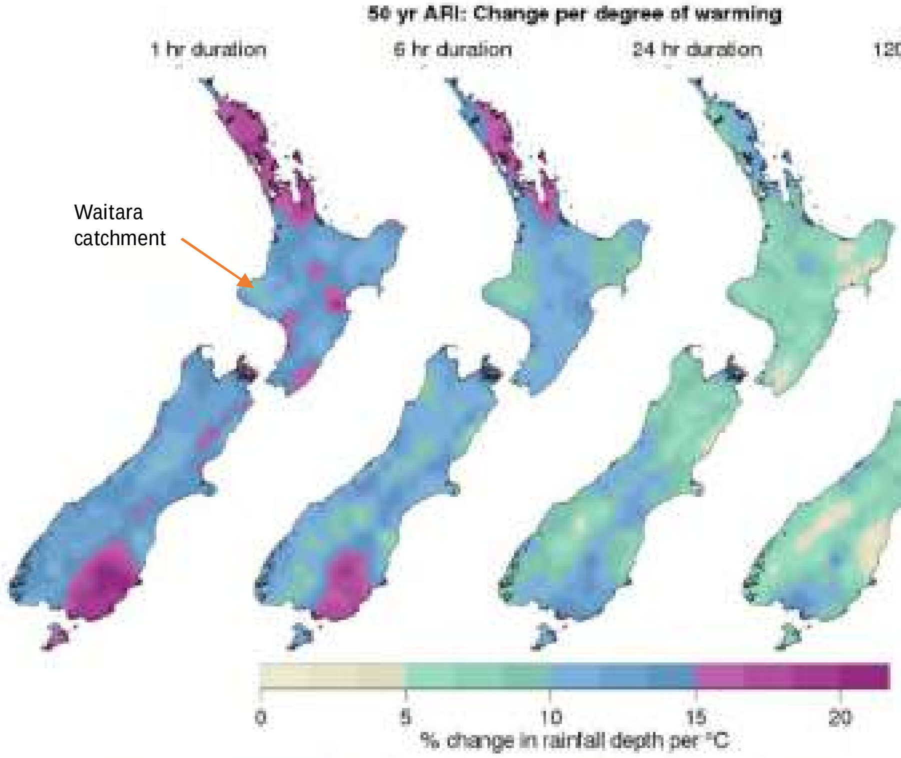

Figure 5.1 *Change in the 50-year rainfall event magnitude for four different event durations. Taken from Carey-Smith et al (2018)*

At the other end of the scale, the average number of "dry days" (rainfall less 1 mm/day) is also predicted to change under a future climate. Figure 5.2 shows the frequency of dry days increases with RCP and time for much of the North Island including the Taranaki region. Associated with the increase in dry days will be increased occurrence of drought, as shown by the maps of the change in potential evapotranspiration deficit (PED) presented in MfE (2018). These maps (not shown here) indicate an increase of PED of roughly around 50 mm by 2040 for the Waitara catchment.

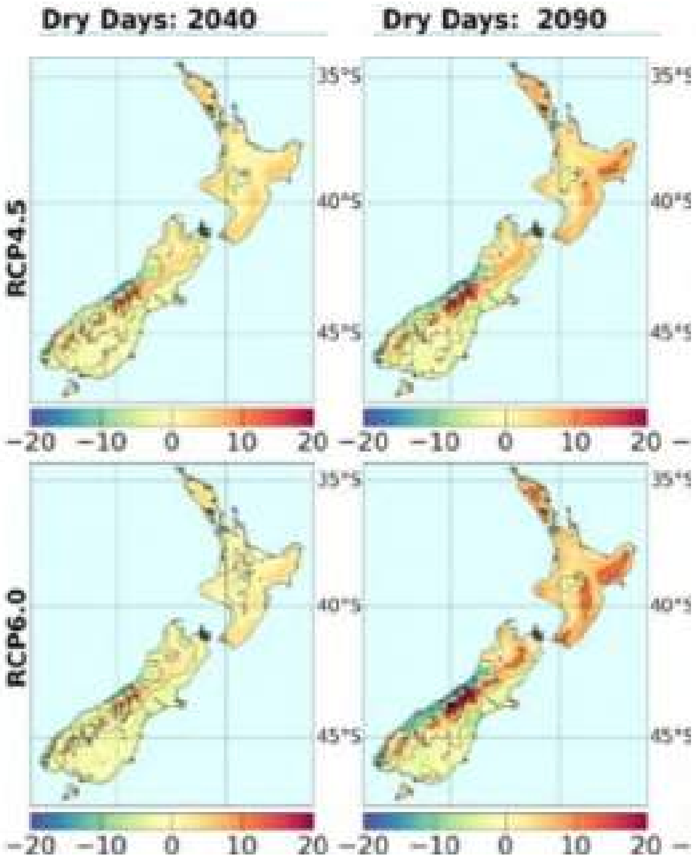

Figure 5.2 *Projected changes in the annual number (in days) of "dry days" (rainfall less than 1 mm/day) compared with the baseline period (1986 – 2005) for RCP4.5 and RCP6.0 for two future time periods 2040 and 2090. Taken from MfE (2018)*

5.3 Implications for Motukawa HEPS

By 2040, based on the two midrange climate change scenarios (RCP4.5 and RCP6.0), the mean temperature in the Waitara catchment is expected to be about 0.9 °C warmer relative to present day (1986 – 2005 baseline). This warming would be accompanied by a modest increase in the evapo-transpiration rates in the catchment, which has the potential to reduce catchment runoff and thus the river flow, particularly over the summer and autumn seasons. In addition, the projected increases in the number of "hot days" and "dry days" are likely to further reduce and prolong summer low flows. However, averaged over the year, this flow reduction could be offset to a large extent by the projected increase in mean rainfall in the winter months (of about 5% by 2040, per Table 5.1).

Therefore, in terms of the flow in the Waitara River (and the Manganui River), the anticipated net result based on the above changes is that:

a) for the winter months, there is a likelihood of increased mean flow
b) there is also a likelihood of a reduction in the summer mean flow
c) furthermore, both the frequency and duration of low flow events are likely to increase (and droughts likely to become more severe)
d) peak flood discharges may also increase with the predicted increase in storm rainfall depths.

Some of these changes, particularly incidence of prolonged and reduced low flows in the Manganui River through summer and early autumn, would be reflected in the pattern of diverted flows into Lake Ratapiko. Flow derived from the local lake catchment would also be subject to the anticipated changes described above. However, these changes are not expected to be large enough to significantly affect the current (or proposed) operating regime of the Motukawa HEPS including the lake level management.

5.4 Manganui River flows

Sections 2.6.2, 2.6.4 and 2.6.5 earlier provided simple trend analyses of, respectively, the seasonal mean flows, low flows and flood flows in the Manganui River.

There is evidence of increasing winter mean flows in the Manganui River, both in the upper reaches (as represented by the SH3 record – see Figure 2.7) and the lower reach of the river (as demonstrated by the Everett Park record – see Figure 2.10), which is consistent with climate change prediction (a) provided above. However, contrary to prediction (b), there does not appear to be a decreasing trend (yet) in the summer mean flows. In fact, the SH3 record, which commenced recording in May 1972, seems to suggest an increasing trend in summer mean flows.

Likewise, there is no apparent trend yet of increasing frequency and duration of low flows (cf. prediction (c)) in either the SH3 or Everett Park records (see Figures 2.18 and 2.19). Though, it is notable that the first four months of 2020 were the driest such period on record for Everett Park and the second driest in the longer SH3 record.

The annual flood series for both the SH3 and Everett Park do not (yet) exhibit an increasing trend (cf. prediction (d)). However, trends in such extremes typically require a longer record than is available to reliably detect.

5.5 Waitara River flows

The longest flow record in the Waitara catchment is at the Tarata gauge (commenced recording in December 1968). Sections 2.7.1, 2.7.3 and 2.7.4 earlier provided simple trend analyses of, respectively, the seasonal mean flows, low flows and flood flows for the Waitara River at both the Tarata and Bertrand Road gauges.

Similar to the Manganui River, there appears to be a weak increasing trend in the winter mean flows recorded at Tarata (see Figure 2.28), which agrees with prediction (a). However, a decline in mean summer flows was not detected (cf. prediction (b), see Figure 2.27).

The Bertrand Road record is less useful for trend analysis as it is shorter (commenced in February 1980) and does not include the generally drier period pre-1980. Therefore, flow trends projected from the Bertrand Road record could be misleading, whether it is the seasonal mean flow or low flow frequency. A case in point is the apparent decline in the 7-day low flows recorded at Bertrand Road (see Figure 2.38) which is not reflected in the longer Tarata record (cf. prediction (c)). As a further example, the first four months of 2020 was the driest 4-month period in the Bertrand Road record. However, prior to 1980, the longer Tarata record shows that the summer of 1972/1973 and the first four months of both 1974 and 1978 were all drier.

It is noted that the multi-decadal variability of summer mean flows observed in the Waitara River at Tarata could indicate a potential link to the phases of the Interdecadal Pacific Oscillation[3] (see Section 2.7.1), where there is a tendency for higher summer flows to occur during the "warm" phases. Therefore, any apparent trends in the flow records (and associated projections therefrom) require to be interpreted taking into account both potential climate change and IPO signals.

The annual flood series for both Tarata and Bertrand Road do not (yet) exhibit an increasing trend (cf. prediction (d)). A considerably longer record is needed to confirm if there is a trend.

6 Hydrological Alterations from Motukawa HEPS

The preceding Sections 2 and 3 of this report present a large amount of hydrological information on, respectively, the Manganui/Waitara catchments and their water resources, and the hydrological operation of the Motukawa HEPS. The latter effectively quantifies the “hydrological footprint” of the Scheme. Section 4 presents the proposed operating regime of the Scheme premised on a 2.3 m^3/s increase in the maximum take (new maximum 7.5 m^3/s) from the Manganui River. The main objective of these hydrological summaries and analyses is to inform studies by other experts on a range of environmental and socio-economic aspects potentially affected by the existing scheme.

As a preface, it is noted that there are few direct hydrological effects. Rather there is greater scope for hydrological changes or alterations, which can manifest as consequential effects on a range of environmental and socio-economic values (e.g. ecology, recreation and cultural). This section summarises the hydrological alterations resulting from the operation of the Scheme. Note that descriptions below use effect and alteration interchangeably even though there is a difference[5].

The Motukawa HEPS, commissioned in 1927, is well-bedded in the environment. Clearly, the historical alterations associated with its construction are more significant than ongoing (or current) effects that persist in the current built environment. Hydrological alterations resulting from the presence and operation of the Scheme are summarised in Table 6.1.

Table 6.1 Summary of hydrological alterations caused by the Motukawa Scheme

Aspect	Hydrological Alteration (Flow statistics based on data and operational history 2010 to 2020)
Diversion of Manganui River	
· Creation of residual river	Diversion from the Manganui River has created a length of residual river 25 km long between the Manganui Weir (race intake) and the confluence of the Manganui and Waitara rivers. Over this reach many significant tributaries enter the Manganui River that proportionately lessen the flow reduction. The diverted water is not permanently lost but is returned to the Waitara River via the Power Station tailrace which discharges to the Makara Stream, a minor tributary of the Waitara River.
· Changed flow regime in the residual river (ongoing)	Mean flow in the residual river is reduced by 3.16 m^3/s (46%) compared with no diversion occurring (6.86 m^3/s), and the block of flow removed comprises baseflows up to moderately high flows, resulting in reduced and prolonged low flows in the residual river. In the lower reaches of the Manganui River, the flow reduction represents 14% of the natural mean flow in volumetric terms. (Note that for a maximum take of 7.5 m^3/s at the Manganui Weir, the flow reduction would be about 3.67 m^3/s, representing 16% of the natural mean flow in the lower reaches of the river.)
· Increased flow in Makara Stream and the Waitara River downstream of Tarata (ongoing)	Diverted flow from the Manganui River enters Lake Ratapiko where it is drawn for hydro-electric power generation and is discharged to the Waitara River via the Makara Stream. As a result, the mean flow in the Waitara River at Tarata is increased by 10.5% (and by an order of magnitude in the Makara Stream).

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[5] A change doesn’t necessary represent an adverse effect (but it can). However, there are hydrological effects that can arise from particular changes to the flow regime, e.g. flooding hazard, erosion).

Aspect	Hydrological Alteration (Flow statistics based on data and operational history 2010 to 2020)
Presence of Motukawa Race	
- Modified local drainage	Along its alignment, the Motukawa Race intercepts the flow from a small local catchment (area about 4 km^2 and mean flow around 0.13 m^3/s). The race serves as the main drainage channel for this catchment, discharging to Lake Ratapiko.
Creation of Lake Ratapiko and presence of Ratapiko Dam	
- Damming and diversion of Mako Stream and unnamed tributaries	The dam effectively diverts flow from the upper Mako Stream and other minor tributaries (total catchment 8.5 km^2) into the man-made lake for hydro-electric generation. There is no residual flow apart from occasional spill flow and dam seepage. A major tributary (another Makara Stream, catchment area of 24 km^2) joins the Mako Stream about 7 km downstream from the dam.
- Lake level fluctuations (ongoing)	Daily ramping of generation results in a complementary fluctuation in lake levels that has a daily amplitude of, typically, between 0.25 m and 0.4 m. Outside of the summer months, there is sometimes also a weekly ramping cycle with an amplitude of 1.5 m or greater.
Power station operation	
- Modified flow regime in lower river (ongoing)	Under normal (non-flood) flow conditions, operation of the Motukawa HEPS is typified by large swings in the station outflow on a daily basis, as generation is ramped up and down to complement the energy demand profile. These diurnal outflow patterns propagate downstream to the Waitara River and are progressively dampened (reduced in amplitude) with distance from the Power Station.
- Hydraulic effects from daily flow ramping (ongoing)	With the diurnal fluctuation in the river flow, there is a complementary fluctuation in the river level: - As measured in the Waitara River at Tarata, typically up to 0.15 m during higher baseflows (e.g. in the winter months) and up to around 0.25 m under low flow conditions - As measured in the Waitara River at Bertrand Road, generally around 0.08 m to 0.12 m.

It is noted that flow diversion from the Manganui River is not expected to have a material effect on the morphology of the residual river channel. This is because the maximum flow that can be diverted of 7.5 m^3/s represents only a small percentage of the flood flows generally considered to be responsible for morphological change, i.e. floods around the mean annual flood size, which is estimated to be 201 m^3/s at the Manganui Weir (see Table 2.13). That is, a reduction of up to 7.5 m^3/s in a flood is not expected to have an effect on the dominant morphological processes.

There is sufficient capacity in the existing Motukawa Race to convey the increased take to Lake Ratapiko. Furthermore, Trustpower would adjust its operation of the Scheme to optimise usage of the increased take capacity. The predicted incremental hydrological changes from this proposal relative to current operation are summarised in Table 6.2 for the key locations (nodes) in the Manganui and Waitara catchments. These changes have been assessed from provisional hydrological modelling (refer to Sections 4.2 and 4.3). Nodes *a., b., e.* and *f.* are upstream of and not affected by this proposed take increase.

Table 6.2 Predicted hydrological changes from an increased maximum take of 7.5 m^3/s from Manganui River

Location	Catchment area	Predicted hydrological changes relative to current operation
Manganui River below diversion weir (node *c.*)	80 km^2	Mean flow in the residual river reduced by 0.51 m^3/s (about 7.5% of the mean inflow), with the greatest reduction over the wetter months May to September. More sustained periods at or close to the minimum flow (typically around 0.45 m^3/s) can be expected.
Manganui River at Everett Park (node *d.*)	282 km^2	The changes above will propagate to the confluence with the Waitara River. However, the relative change in the lower reaches of the Manganui, such as at this flow recording site, is expected to be minor. For example, the greatest monthly mean flow reduction of 0.86 m^3/s (for the month of August) represents 3.5% of the current mean flow at Everett Park.
Motukawa Race (S1) (node *k.*)	N/A	Mean diverted flow from the Manganui River increased by 0.51 m^3/s, with the greatest increase occurring over the wetter months May to September.
Lake Ratapiko (node *j.*)	12.4 km^2	Trustpower will re-optimise its operation of the Scheme to use the higher river intake capacity to increase generation throughflow and minimise spill at Ratapiko Dam. Modelling shows that it is possible to keep spill at current low levels. However, lake levels may need to be held at lower levels than historically (but still some 3 m above the consented minimum) from April/May to September/ October.
Motukawa Power Station discharge (node *l.*)	N/A	Mean generation flow will increase by 0.55 m^3/s, with the period May to September experiencing larger increases. It is likely that the station will generate at or close to capacity for more sustained periods (i.e., potentially reduced diurnal cycling) over the wetter months.
Makino Stream above Waitara confluence (node *g.*)	126 km^2	As noted for Lake Ratapiko above, spill flow is not expected to increase with the increased diversion capacity. Spill at Ratapiko Dam, which is relatively minor, enters the Mako Stream which becomes the Makino Stream. The Makino Stream joins the Waitara River upstream of the outflow from the Power Station.
Waitara River at Tarata (node *h.*)	701 km^2	The changes in the Power Station discharge are comparatively minor on the main stem of the Waitara River. For example, the maximum generation increase of 0.85 m^3/s for the month of June represents less than 2% of the river mean flow at this recording site.
Waitara River at Bertrand Road (node *i.*)	1,113 km^2	At this flow recording site in the lower Waitara River, changes from the increased take capacity are further “diluted”. The increase in generation flow will be offset to a degree by the reduction in the Manganui River flow. These perturbations are very minor compared with the magnitude of the river flow (mean flow of 55 m^3/s).

7 Summary and Conclusions

The current consents for the operation of the Motukawa HEPS expire on 1 June 2022. Trustpower has commenced a process to obtain replacement consents to permit operation of the Scheme for a further term. An assessment of the effects of the Scheme on the environment is required to support the consent application. This report, which is one of a series of technical assessment reports, addresses the hydrological aspects of the Scheme.

In hydrological terms, the Motukawa HEPS effectively transfers water from the eastern, wetter flank of the greater Waitara catchment (specifically, from the Manganui River) to the main stem of the Waitara River above Tarata, which derives its flows from the larger but relatively drier western flank of the catchment.

This report has sought to:

- Describe the general hydrological setting of the Motukawa HEPS, including an assessment of the flow regime of the Waitara River as well as its major tributary, the Manganui River
- Describe the historical operation of the Motukawa HEPS, including diversion from the Manganui River, Lake Ratapiko levels, and daily flow fluctuations at the Power Station
- Describe the proposed operational regime of the Motukawa HEPS, including the proposed increase in the maximum take from the Manganui River
- Summarise the anticipated effects of projected climate change on the river flow regime and Scheme operation
- Describe the hydrological alterations resulting from the Scheme and its operation, including the incremental changes from the proposed operation

The main points and conclusions from this assessment are as follows:

Hydrology and water resources of the Manganui River

(i) A continuous record of the flow at Manganui Weir is available only from 1962 to 1973. An inflow record for a more contemporary period October 2009 to 2020 was derived from Trustpower's monitoring data at the river intake and verified against other flow records.

(ii) Including the above, flow records at three locations are available to characterise the hydrology of the Manganui River. The longest record, at SH3 (catchment area 13.0 km^2), has 49 years of data from 1972 and is representative of the headwaters, while the record at Everett Park (282 km^2) has 30 years of data starting in 1991 and is representative of the lower river. At Manganui Weir (80 km^2), the inflow to and residual river below the weir were able to be characterised and contrasted.

(iii) There is strong reducing gradient in the unit area runoff (mean flow, low flow and flood) from the headwaters to the lower elevations of the Manganui catchment. This combined with the shape of the drainage network from the slopes of Mount Taranaki result in flows at the Manganui Weir being similar to that at Everett Park on a per unit area basis (e.g. mean annual runoff of about 2.7 m versus 2.55 m once diverted flows added back to Everett Park record) but both are considerably less than recorded at SH3.

(iv) Above the Manganui diversion, the mean flow is 6.86 m^3/s, the median flow 4.17 m^3/s, the mean annual flood 201 m^3/s, and the 7-day MALF estimate is 1.18 m^3/s. A simple trend analysis did not indicate any apparent trend (yet) in the low flows or the flood flows in the Manganui catchment. However, there appears to be a trend of increasing winter mean flows, which is consistent with climate change predictions.

(v) It is notable that the first four months of 2020 were the driest on record for Everett Park and the second driest at SH3.

Hydrology and water resources of the Waitara River

(vi) Flow records at two locations are available to characterise the hydrology of the Waitara River. The Tarata gauge (catchment area 701 km^2) has a 52-year long record from 1969 and is located a short distance (4.3 km) downstream of the confluence with Makara Stream (into which the Motukawa Power Station discharges). The Bertrand Road gauge (1113 km^2) has 41 years of data from 1980 and is located further downstream i.e. 9.5 km below the confluence with the Manganui River. The recorded flows at both gauges reflect the diurnal generation pattern of the Scheme.

(vii) Per unit catchment area, the low flows (and, to a lesser extent, the mean flow) are higher at Bertrand Road compared with Tarata because of the contribution from the Manganui River. The mean annual runoff at Tarata, excluding diverted flow from the Manganui, is 1.4 m (31.3 m^3/s) while it is 1.55 m at Bertrand Road (55 m^3/s); both are significantly lower than recorded for the Manganui catchment (2.5 m to 4.1 m of runoff). As for the Manganui River, there is a strong seasonal behaviour in the Waitara River flow (stronger than in the Manganui River). At both Tarata and Bertrand Road, the mean flow in the six months from May to October is about twice the mean flow for the other six months of the year.

(viii) There is no apparent trend (yet) in the annual or summer mean flows, but suggestion of a very weak increasing trend in winter mean flows in the Tarata record. However, the summer mean flows pre-1980 and post-2007 appear markedly lower (by about a third) compared with the period in between (1981 to 2006), indicating a potential link to the phases of the Interdecadal Pacific Oscillation (viz. higher summer flows during the “warm” phase). Any apparent trend in the shorter Bertrand Road record will be skewed by phases of the IPO.

(ix) At Bertrand Road, the first four months of 2020 were the driest on record while the summer of 2019/2020 was the second driest. However, the longer Tarata record shows that, prior to the start of the Bertrand Road, the summer of 1972/1973 and the first four months of both 1974 and 1978 were even drier.

Hydrological operation of the Motukawa Scheme

(x) Time-series data recorded by Trustpower allow the hydrological operation of the Motukawa HEPS to be characterised, and of these, the Manganui Weir overflow record (full range measurement commencing in October 20009) is the shortest, which limits the assessment of the Scheme’s water balance to the past 11 years (October 2009 to December 2020).

(xi) Flow from the Manganui River is diverted into the 4.6 km long Motukawa Race, which intercepts some local drainage (catchment area 3.9 km^2) en route to Lake Ratapiko. The maximum take from the Manganui is limited by consent to 5.2 m^3/s and this may be supplemented by a pumped abstraction of up to 0.45 m^3/s from the Mangaotea Stream, which the race crosses in an aqueduct. The intake gates are partially closed to restrict take from the Manganui when race water levels approach consented thresholds, which typically occurs when the Mangaotea Stream is in flood and/or when Lake Ratapiko level is high.

(xii) Over the water balance period (Oct 2009 to Dec 2020), the mean flow of the Manganui River was 6.86 m^3/s, and an estimated 46% of this flow (3.16 m^3/s) was diverted into Lake Ratapiko. Pumping from the Mangaotea Stream, which occurred intermittently between November 2008 and March 2018, contributed on average 0.029 m^3/s or less than 1% of the total lake inflow (3.60 m^3/s), with the remainder (~11%) derived from the local lake catchment (12.4 km^2). Outflow from the lake is dominated by the draw-off to the Power

Station (97.6%) with the remainder spilled at Ratapiko Dam (2.3%) or occurring as seepage and other losses.

(xiii) A residual flow past the Manganui Weir of at least 400 l/s is provided in two fish passes; an older fish pass on the left abutment and a more recently built stepped channel on the right bank. Contributing to the residual river flow are overtopping flows at the weir which averaged 3.18 m^3/s over the water balance period. Together with the recorded average fish pass flow of 513 l/s (sum of left and right), the mean residual river flow amounted to 54% of the mean inflow.

(xiv) At Lake Ratapiko, the consented minimum and maximum (full) normal operating levels are RL 194.0 m and RL 198.7 m respectively, thus affording a 4.7 m operating range. Over the five years from 2016 to 2020, the lake was operated over a significantly tighter band; excluding periods the lake was drawn down for maintenance (in April of most years), the level was within 2 m of full for 97% of the time and within 1 m of full for 84% of the time. Generation ramping results in a corresponding fluctuation in lake levels that has a daily amplitude of typically 0.25 m to 0.4 m. At times (usually outside of the summer months) there is also a weekly ramping cycle with an amplitude of 1.5 m or greater.

(xv) Trustpower endeavours to maintain the lake level within 0.5 m of full during weekends over the summer for recreational users subject to operational requirements. Between 2016 and 2020, the lake level was held within 0.5 m of full for 85% of the time between November and March, and for 97% of the time when weekdays were excluded.

(xvi) The consented maximum flood discharge from the lake to the Mako Stream is 55 m^3/s. However, flood assessments indicate that the peak spill flow at Ratapiko Dam is 101 m^3/s in the 1000-year ARI flood, and larger floods are possible (but extremely rare). Over the water balance period, the mean spill flow was 0.083 m^3/s, however, the bulk of this spill was associated with prolonged station outages (e.g. upgrade works in the first half of 2010), and discounting these periods, the mean spill was only 0.014 m^3/s, and the average number of spill days per year was 3 days.

(xvii) Operation of the Motukawa Power Station is characterised by large diurnal variations in the station outflow as generation is ramped up and down to complement the energy demand profile. These diurnal flow patterns propagate from the tailrace to the Makara Stream and in the Waitara River up to Bertrand Road and beyond. There is some attenuation (smoothing and flattening) of the generation pulse as it travels downstream.

(xviii) Fluctuations in the river level from generation activity as measured in the Waitara River at Tarata are typically up to 0.15 m during higher baseflows (e.g. in the winter months) and up to around 0.25 m under low flow conditions. At Bertrand Road, these fluctuations are generally around 0.08 m to 0.12 m.

Proposed operating regime of the Motukawa Scheme

(xix) Pumping from the Mangaotea Stream into the Motukawa Race, which ceased in March 2018, is proposed to be permanently discontinued. Cessation of this take, which contributed, on average, less than 1% of the total lake inflow, is not expected to make a material difference to the operation of the Scheme.

(xx) The maximum take from the Manganui River into the Motukawa Race is proposed to be increased to 7.5 m^3/s from the currently consented maximum of 5.2 m^3/s. The proposed increase recognises the spare hydraulic capacity of the race (to accommodate the higher flow); the high river flows available for harvesting at the weir; the better match between lake inflow and outflow capacity and the additional renewable generation that would result.

(xxi) To assess the potential changes from an increased maximum take, a hydrological model of the Scheme's operation was developed. This model simulates an "active management" regime. While various future operational scenarios are possible (and natural variability in the climate and river flows adds to overall uncertainty) the modelled scenario is considered to provide a fair representation of the potential changes to the Scheme's operation from the proposed increased take.

(xxii) Over the full modelled period October 2009 to December 2020, the modelled increase in the mean diverted flow to the Motukawa Race is 0.51 m^3/s, which is 16% greater than historical. There is a corresponding reduction in the Manganui Weir overflow, representing a 14% decrease in the residual river mean flow. A strong seasonal bias is observed in the distribution of the additional take, with 75% of the additional take volume occurring in the six months from May to October.

(xxiii) A mean generation flow that is 0.55 m^3/s higher is modelled, representing an increase of 15% over historical. However, it is noted that a small proportion (13% to 15%) of the increase is a result of avoiding spill from historical station outages (that are not replicated in the model). Despite the increased take the modelled mean spill from Lake Ratapiko is 0.012 m^3/s compared with 0.083 m^3/s historically.

<u>Implications of climate change</u>

(xxiv) In the Taranaki region, the future climate is predicted to be warmer (e.g. by around 0.9 C by 2040) with higher rainfall in winter (e.g. about 5% more). Coupled with a predicted increase in the number of both "hot days" and "dry days", this is expected to result in reduced summer mean flow and increased frequency and duration of low flow events. However, the reduction in the summer mean flow may be offset by an increase in the winter mean flow. Flood discharges may also increase with the predicted larger storm rainfall depths.

(xxv) Reference to the apparent trends observed in the long term flow records for the Manganui and Waitara rivers (as described earlier) indicate that, apart from a weak trend of increasing winter mean flows, the other anticipated changes from predicted climate change (viz. reduction in summer mean flows, increase in low flow frequency, larger floods) have not yet manifested. That noted, trends in extremes typically require a longer record than is available to reliably detect.

(xxvi) In any case, predicted hydrological changes from climate change to 2040 or the end of the term of renewed consents are not expected to be great enough to significantly affect the current operating regime of the Motukawa HEPS including Lake Ratapiko.

<u>Hydrological alterations from the Motukawa Scheme</u>

(xxvii) Diversion from the Manganui River has created a residual river reach 25 km long between the Manganui Weir (race intake) and the confluence of the Manganui and Waitara rivers. Over this reach many significant tributaries enter the Manganui River that proportionately lessen the flow reduction.

(xxviii) Mean flow in the residual river is reduced by 3.16 m^3/s (46%) compared with no diversion occurring (6.86 m^3/s), and the block of flow removed comprises baseflows up to moderately high flows, resulting in reduced and prolonged low flows in the residual river. In the lower reaches of the Manganui River, the flow reduction represents 14% of the natural mean flow.

(xxix) Diverted flow from Manganui River enters Lake Ratapiko where it is drawn for hydro-electric power generation and is discharged to Waitara River via the Makara Stream. As a result, the mean flow in the Waitara River at Tarata is increased by 10.5% (and by an order of magnitude in the Makara Stream).

(xxx) The most notable hydrological alteration in the Waitara River from operation of the Scheme is the diurnal fluctuations caused by daily flow ramping at the Motukawa Power Station.

<u>Predicted further alterations if maximum take from Manganui River increased to 7.5 m^3/s</u>

(xxxi) Mean flow below the Manganui Weir is predicted to reduce by a further 0.51 m^3/s, with the greatest reduction over the wetter months May to September. The mean flow in the residual river would then be 46% of the mean inflow (and the diverted flow 54% of the river inflow). More sustained periods at or close to the minimum flow (typically around 0.45 m^3/s) can be expected.

(xxxii) All other alterations are minor as the incremental change is small (e.g. 2.6% reduction in the mean flow at Everett Park, 1.6% increase in the mean flow of the Waitara River at Tarata).

8 Applicability

This report has been prepared for the exclusive use of our client Trustpower Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our Trustpower Ltd will submit this report as part of an application for resource consent and that Taranaki Regional Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Report prepared by:

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David Leong

Technical Director Hydrology and Hydraulics

DCL
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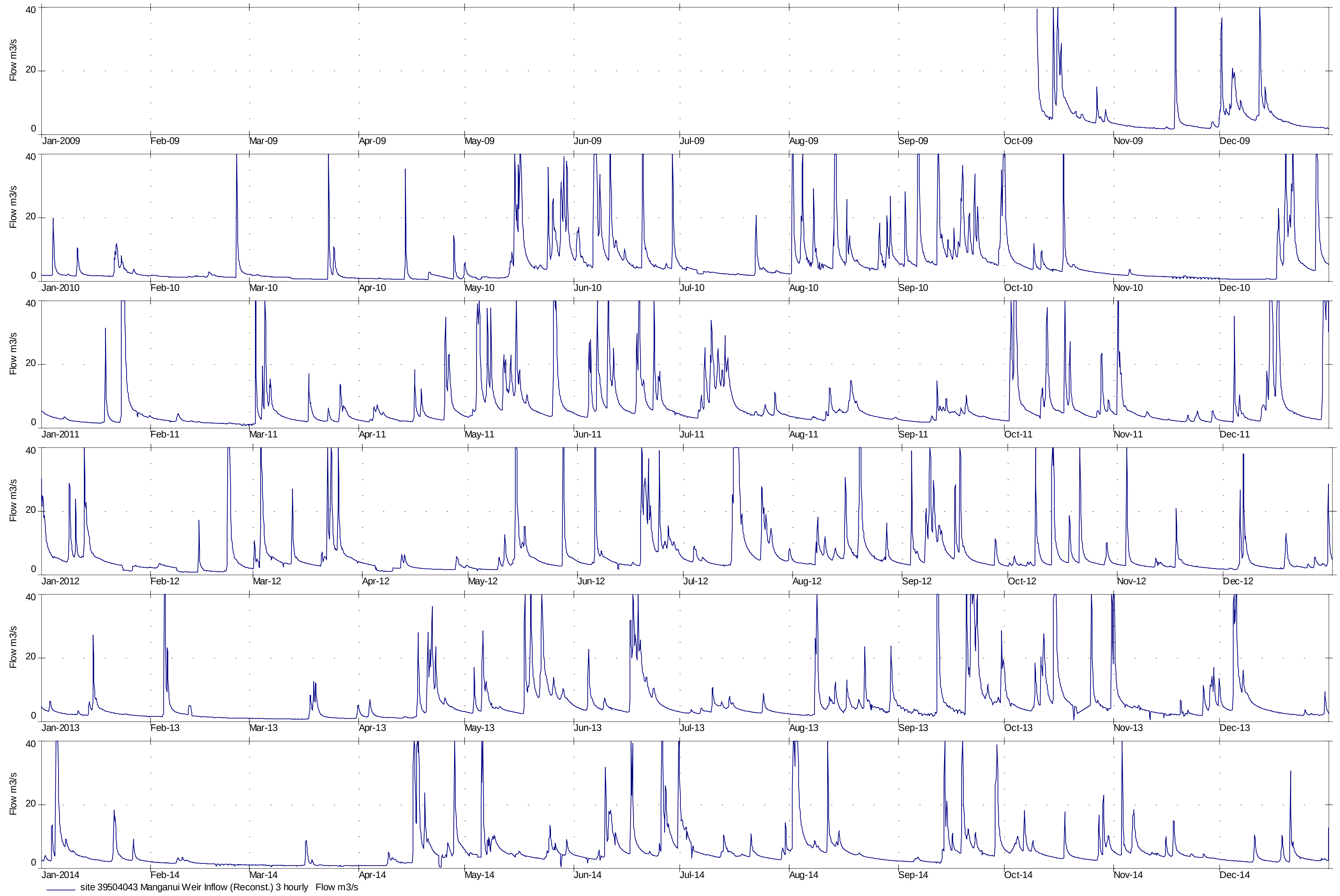
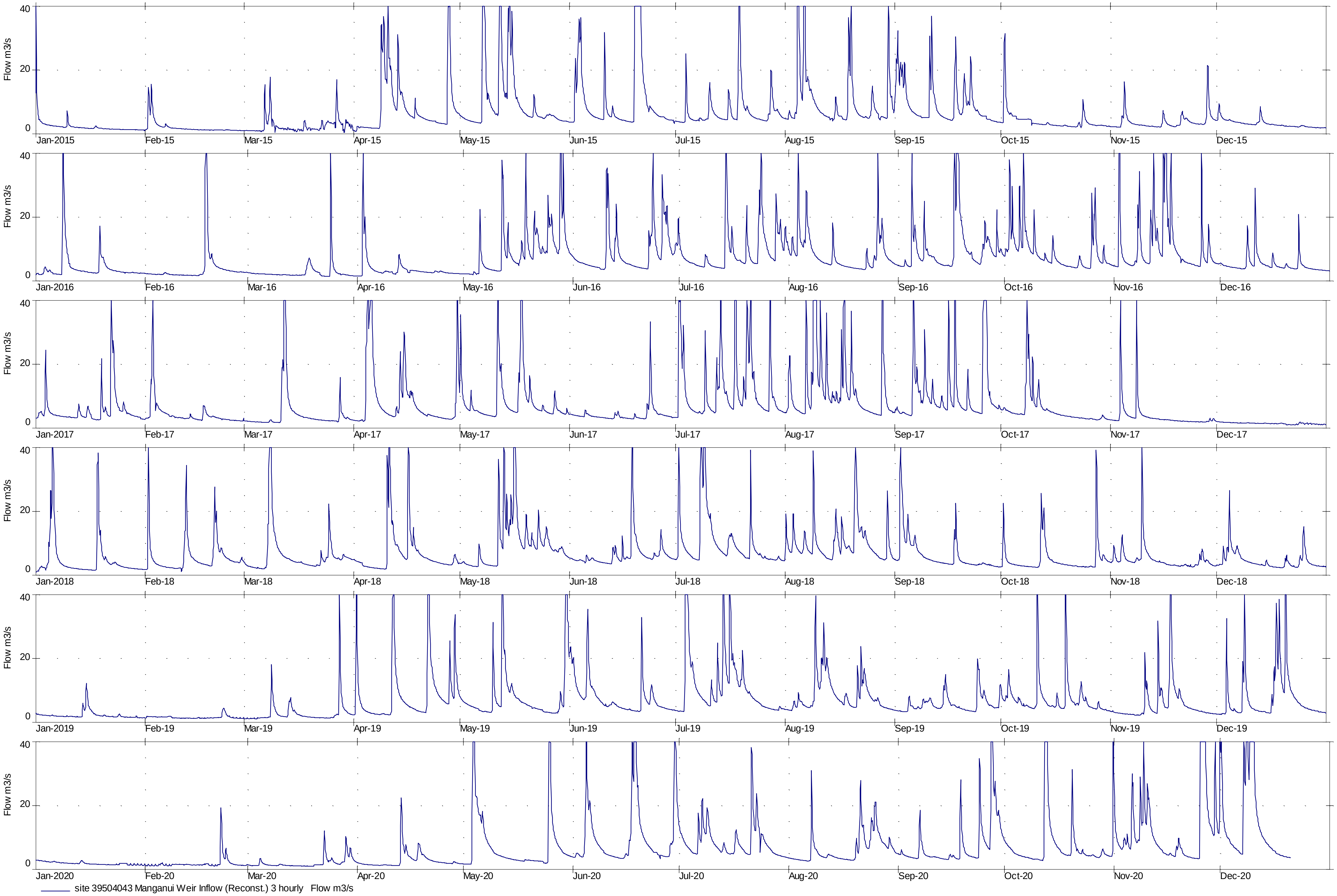
Appendix A: Manganui Weir inflow hydrographs

A1 Manganui Weir inflow time series, reconstituted record, October 2009 to December 2020

Appendix A1 Manganui Weir inflow reconstituted record




Flow m3/s
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20
0
Jan-2015
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
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Oct-15
Nov-15
Dec-15
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 39504043 Manganui Weir Inflow (Reconst.) 3 hourly Flow m3/s

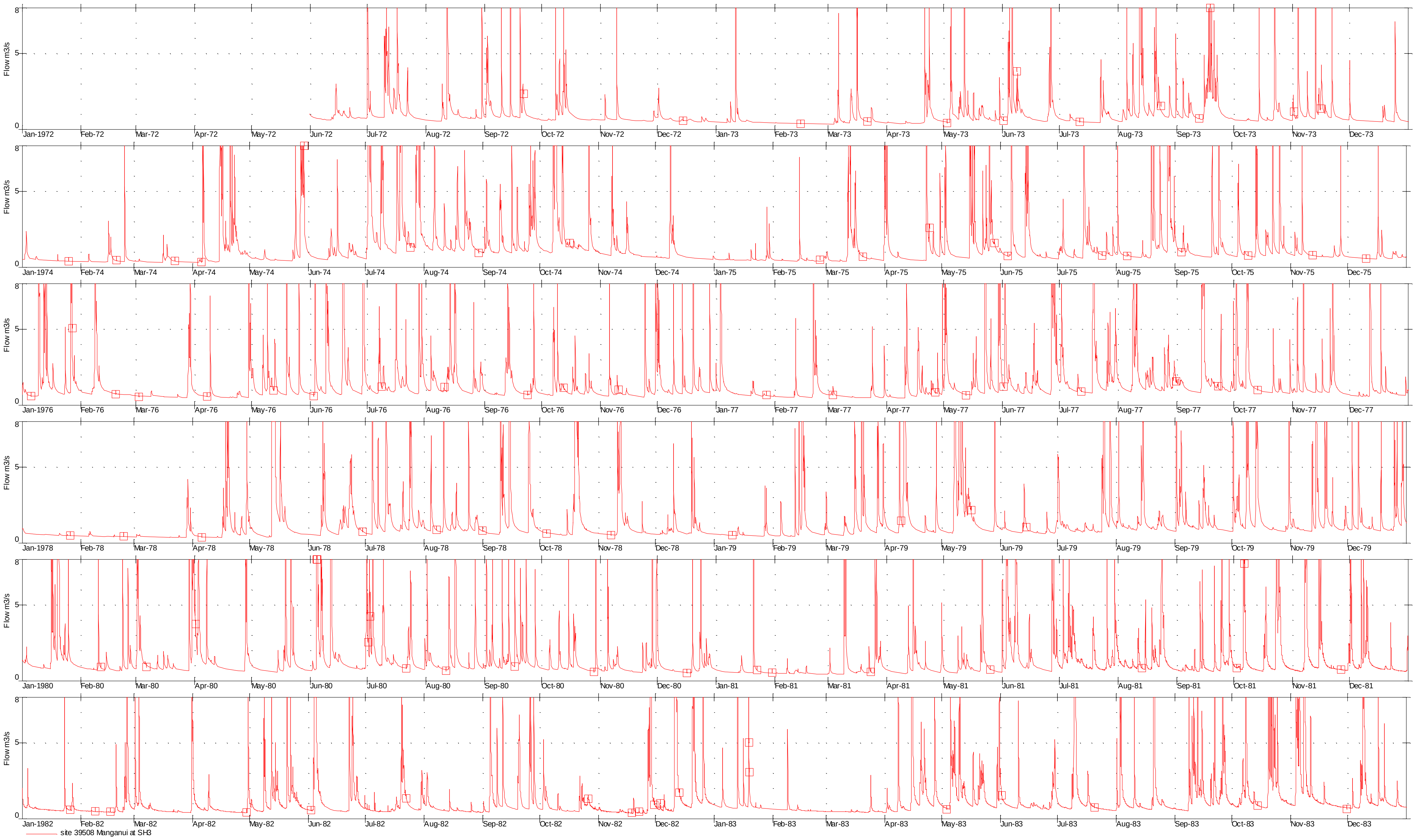
Appendix B: Manganui River flow hydrographs

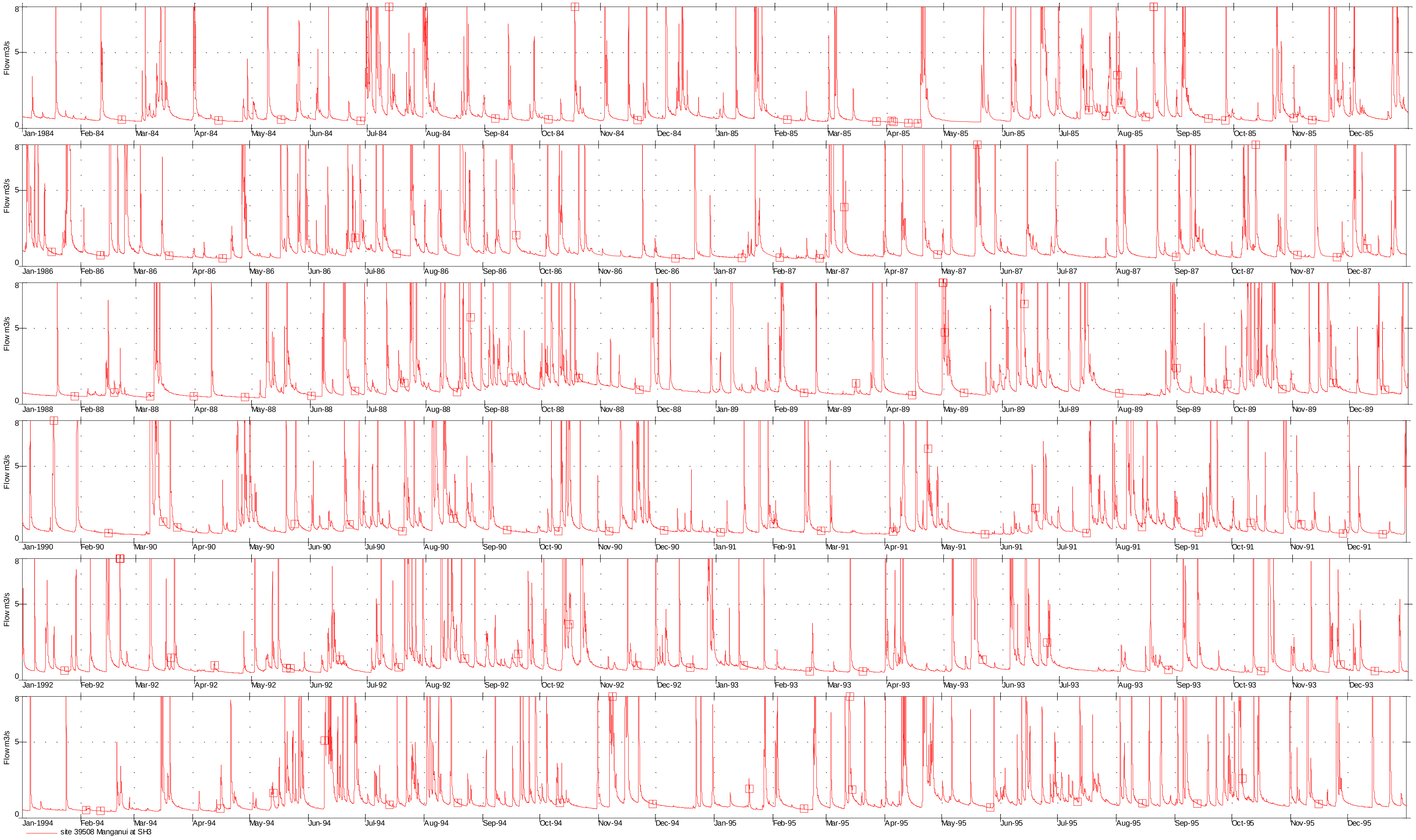
B1 Manganui River at SH3 flow time series, 1972 to 2019

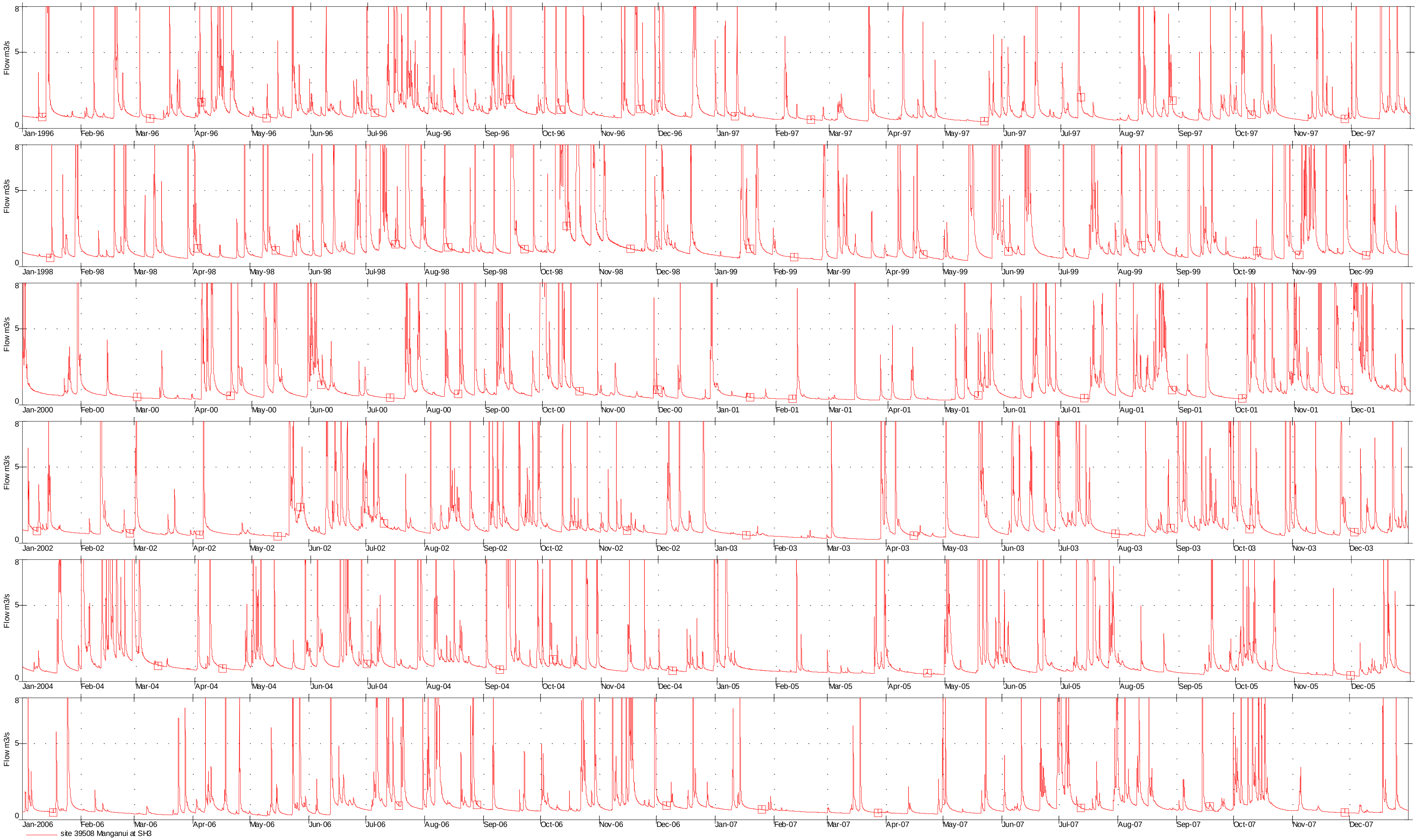
B2 Manganui River at Tariki Road flow time series, 1962 to 1973

B3 Manganui River at Everett Park flow time series, 1991 to 2020

Appendix B1 Manganui River at SH3




Flow m3/s
8
5
0
Jan-1984 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85 Feb-85 Mar-85 Apr-85 May-85 Jun-85 Jul-85 Aug-85 Sep-85 Oct-85 Nov-85 Dec-85
Jan-1986 Feb-86 Mar-86 Apr-86 May-86 Jun-86 Jul-86 Aug-86 Sep-86 Oct-86 Nov-86 Dec-86 Jan-87 Feb-87 Mar-87 Apr-87 May-87 Jun-87 Jul-87 Aug-87 Sep-87 Oct-87 Nov-87 Dec-87
Jan-1988 Feb-88 Mar-88 Apr-88 May-88 Jun-88 Jul-88 Aug-88 Sep-88 Oct-88 Nov-88 Dec-88 Jan-89 Feb-89 Mar-89 Apr-89 May-89 Jun-89 Jul-89 Aug-89 Sep-89 Oct-89 Nov-89 Dec-89
Jan-1990 Feb-90 Mar-90 Apr-90 May-90 Jun-90 Jul-90 Aug-90 Sep-90 Oct-90 Nov-90 Dec-90 Jan-91 Feb-91 Mar-91 Apr-91 May-91 Jun-91 Jul-91 Aug-91 Sep-91 Oct-91 Nov-91 Dec-91
Jan-1992 Feb-92 Mar-92 Apr-92 May-92 Jun-92 Jul-92 Aug-92 Sep-92 Oct-92 Nov-92 Dec-92 Jan-93 Feb-93 Mar-93 Apr-93 May-93 Jun-93 Jul-93 Aug-93 Sep-93 Oct-93 Nov-93 Dec-93
Jan-1994 Feb-94 Mar-94 Apr-94 May-94 Jun-94 Jul-94 Aug-94 Sep-94 Oct-94 Nov-94 Dec-94 Jan-95 Feb-95 Mar-95 Apr-95 May-95 Jun-95 Jul-95 Aug-95 Sep-95 Oct-95 Nov-95 Dec-95
site 39508 Manganui at SH3


Flow m3/s
8
5
0
Jan-1996
Feb-96
Mar-96
Apr-96
May-96
Jun-96
Jul-96
Aug-96
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Oct-96
Nov-96
Dec-96
Jan-97
Feb-97
Mar-97
Apr-97
May-97
Jun-97
Jul-97
Aug-97
Sep-97
Oct-97
Nov-97
Dec-97
Flow m3/s
8
5
0
Jan-1998
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Flow m3/s
8
5
0
Jan-2000
Feb-00
Mar-00
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Flow m3/s
8
5
0
Jan-2002
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Flow m3/s
8
5
0
Jan-2004
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Flow m3/s
8
5
0
Jan-2006
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
Jan-07
Feb-07
Mar-07
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Jul-07
Aug-07
Sep-07
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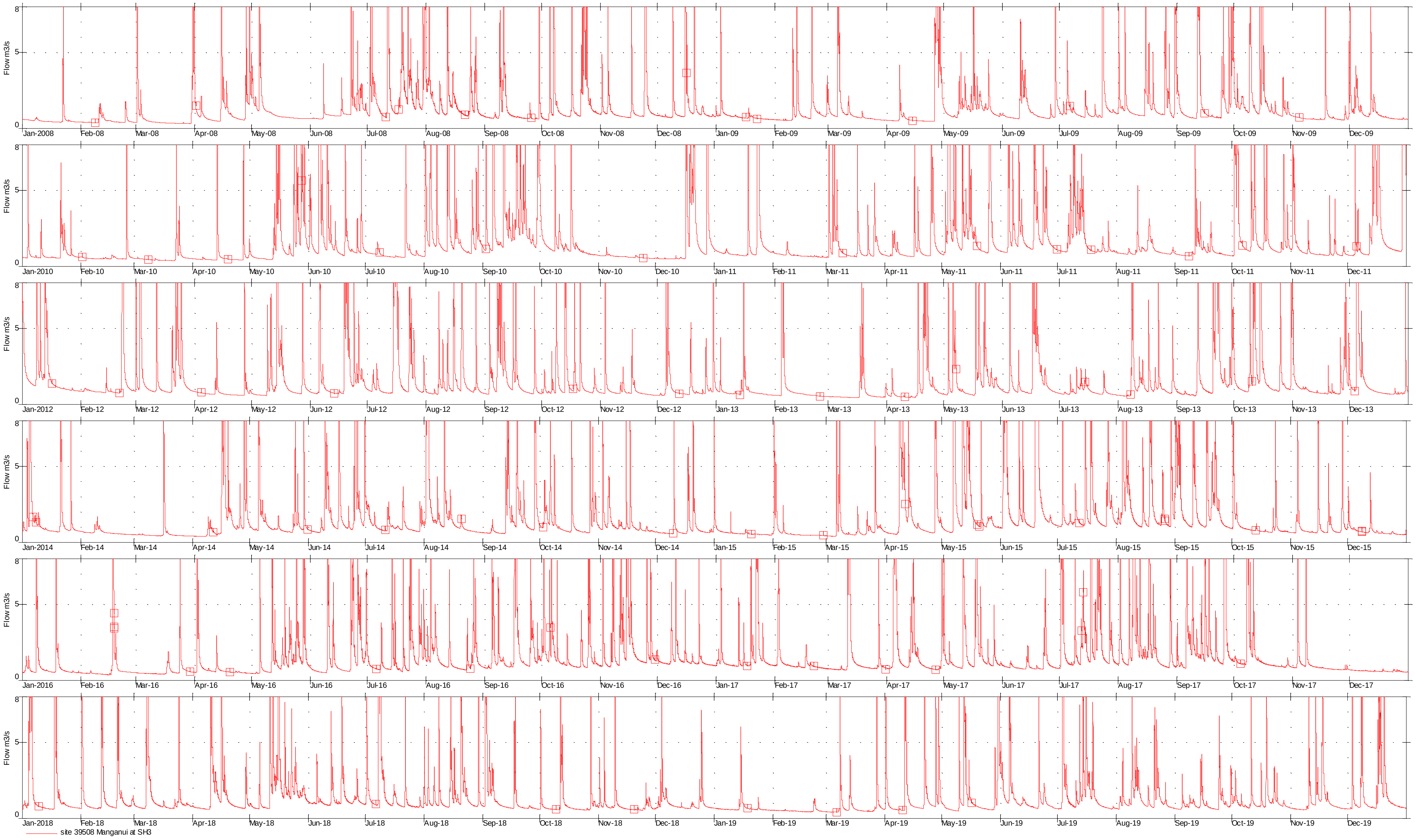
Nov-07
Dec-07
site 39508 Manganui at SH3


Flow m3/s
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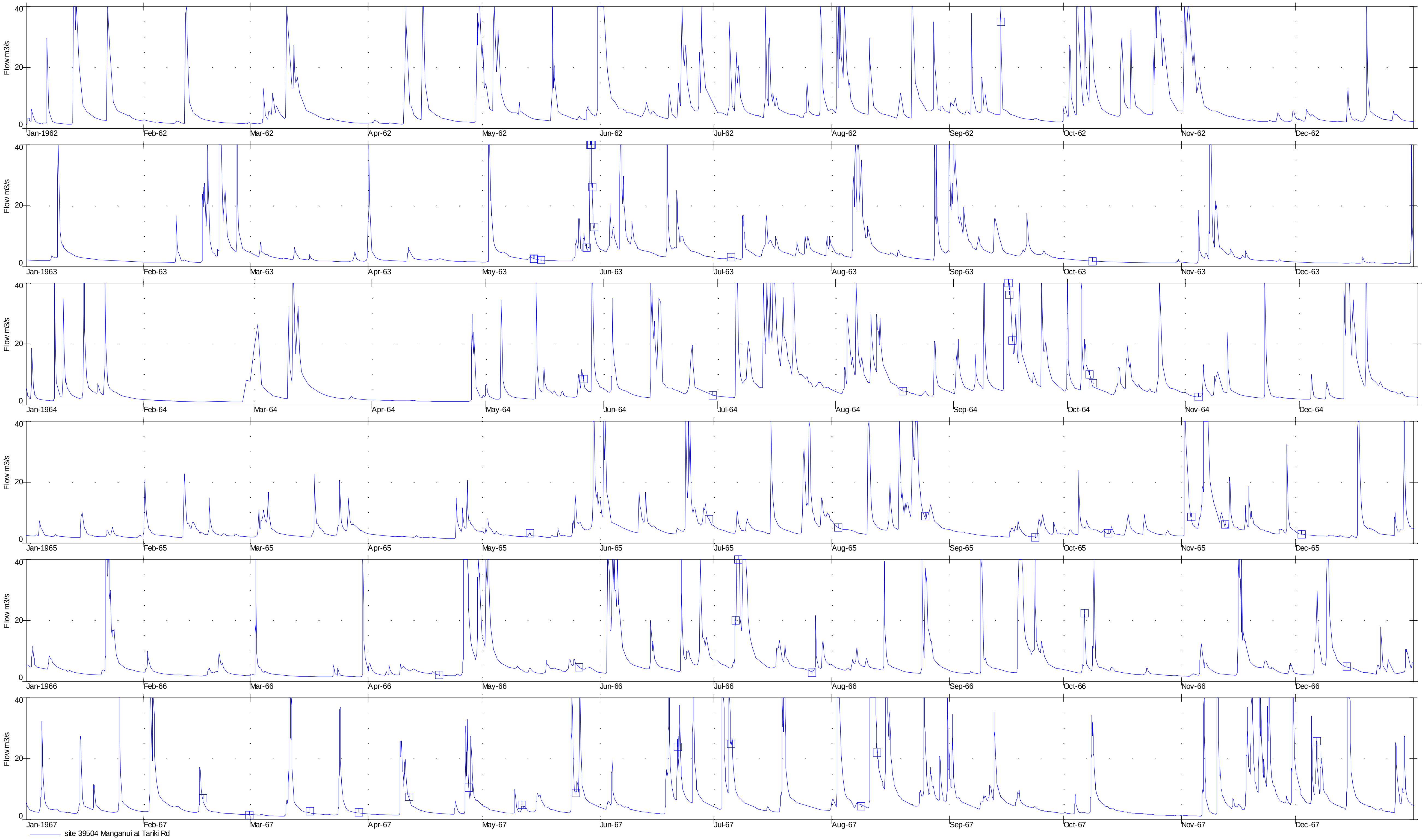
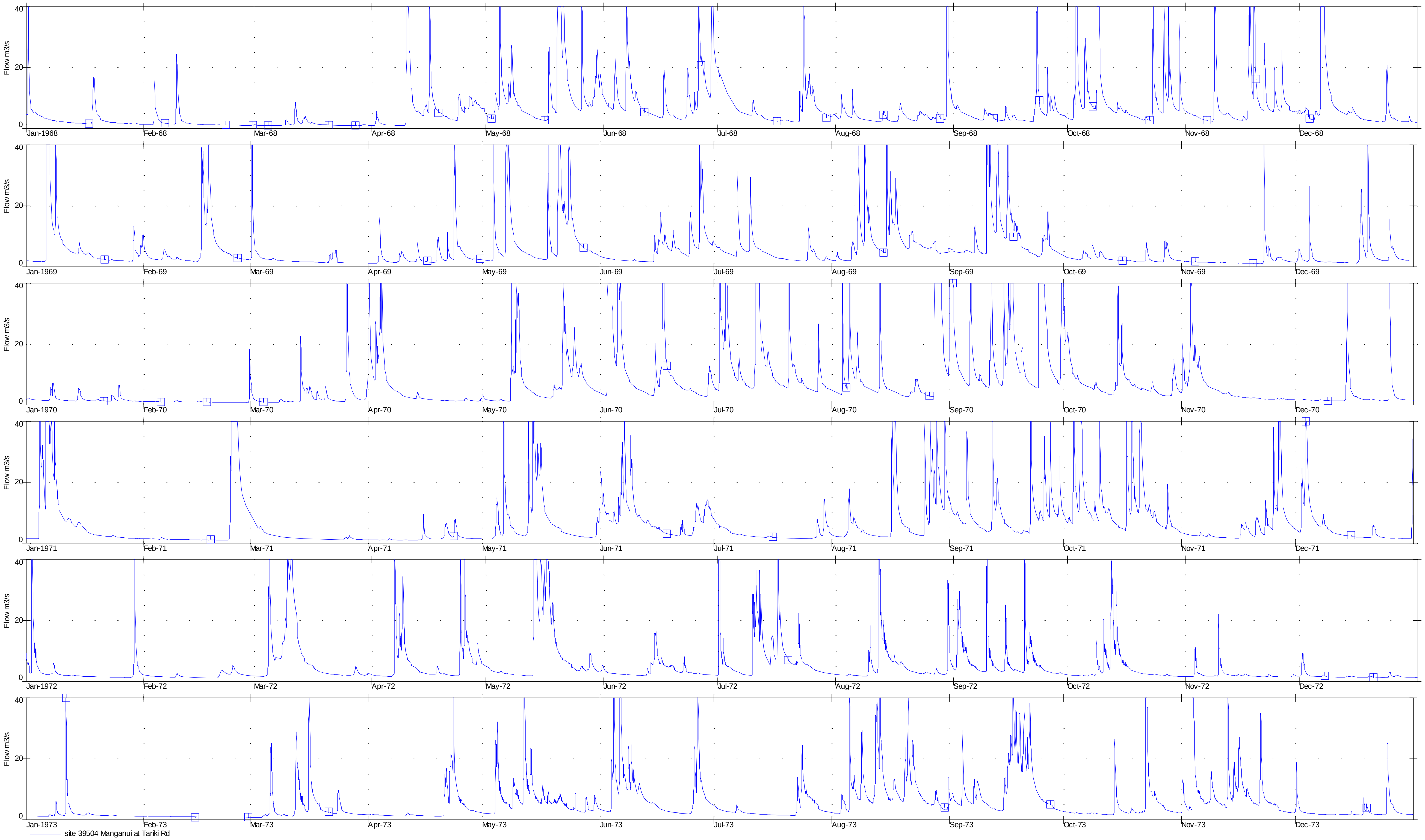
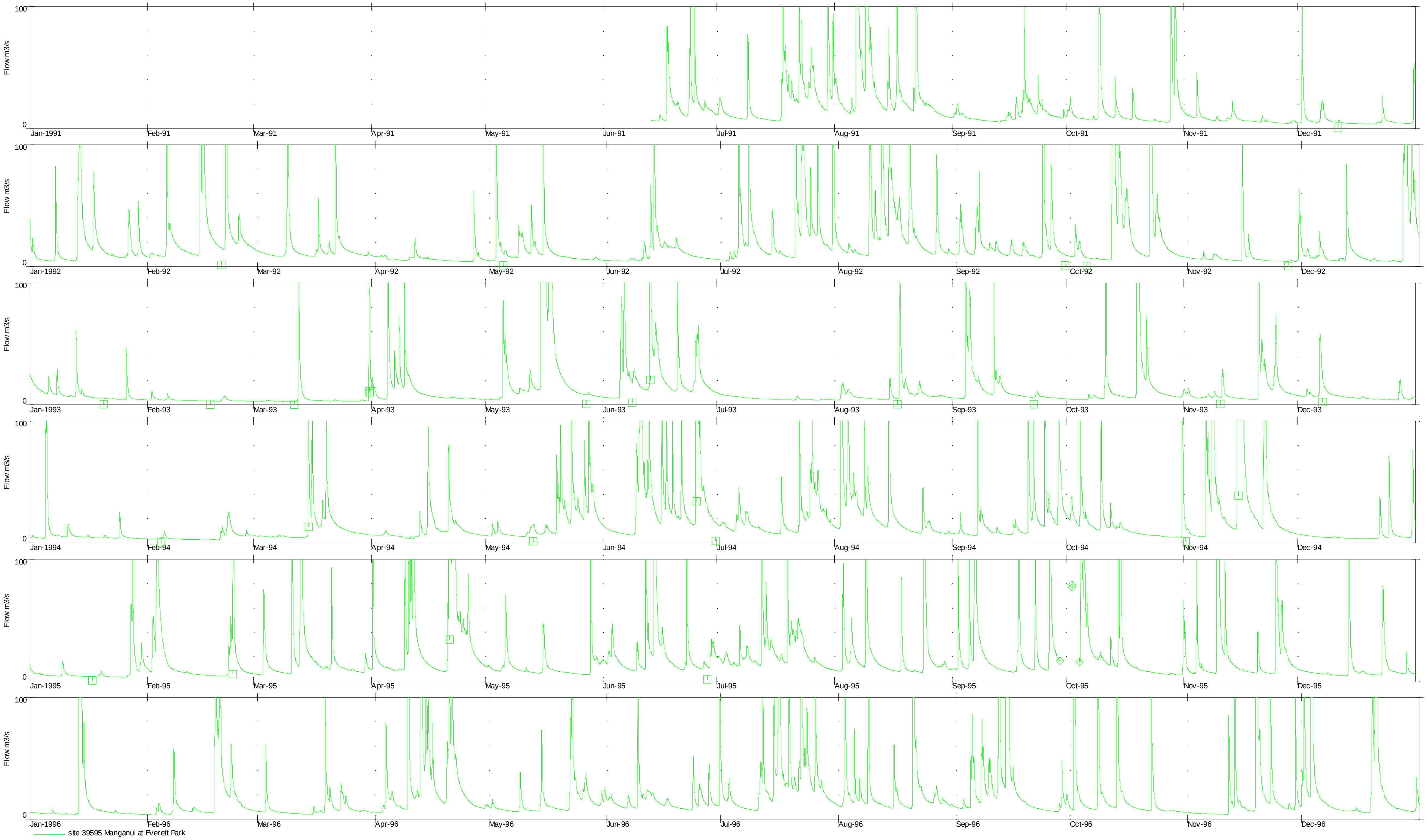
5
0
Jan-2008
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Flow m3/s
8
5
0
Jan-2010
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Flow m3/s
8
5
0
Jan-2012
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Flow m3/s
8
5
0
Jan-2014
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Flow m3/s
8
5
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Flow m3/s
8
5
0
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
site 39508 Manganui at SH3

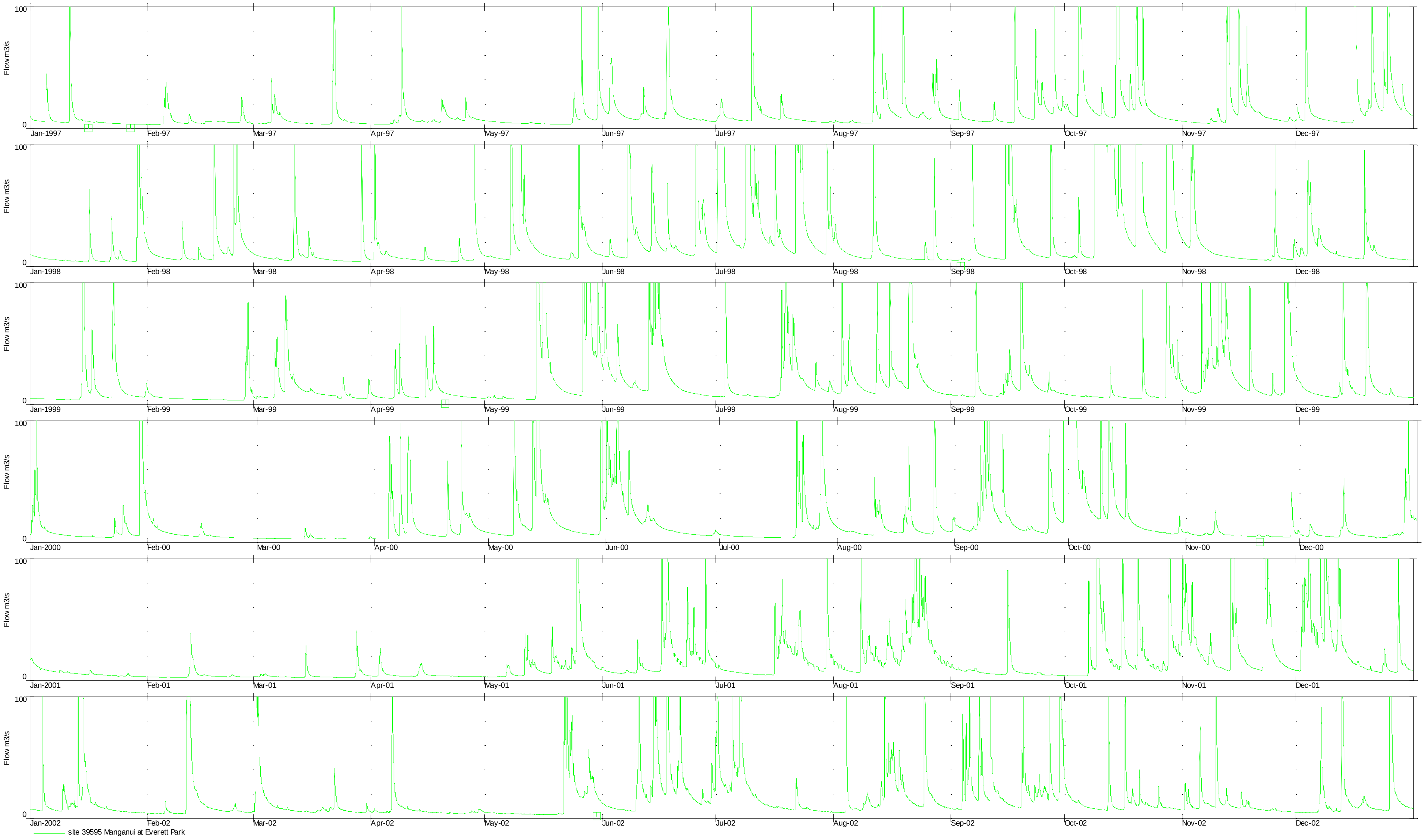
Appendix B2 Manganui River at Tariki Road

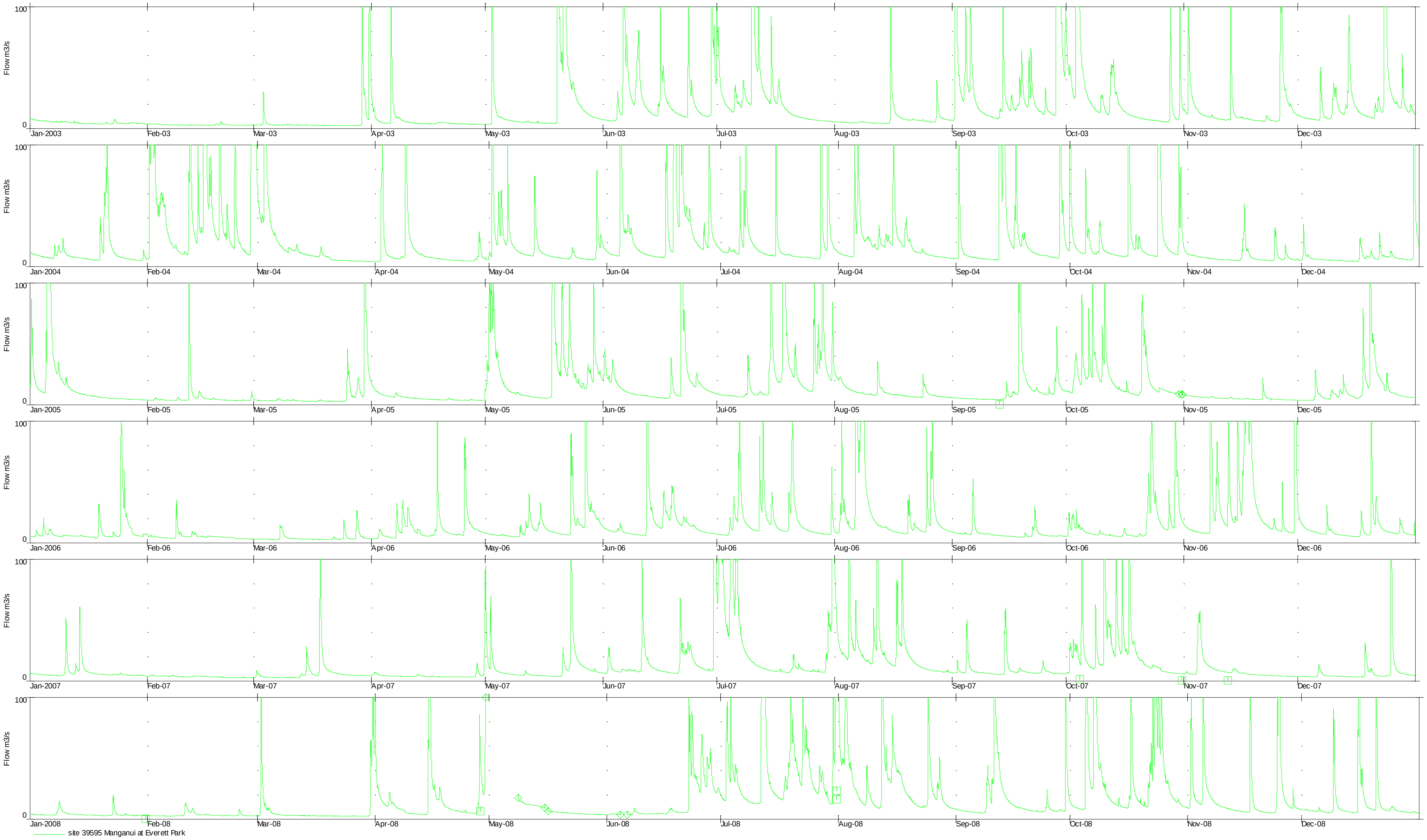


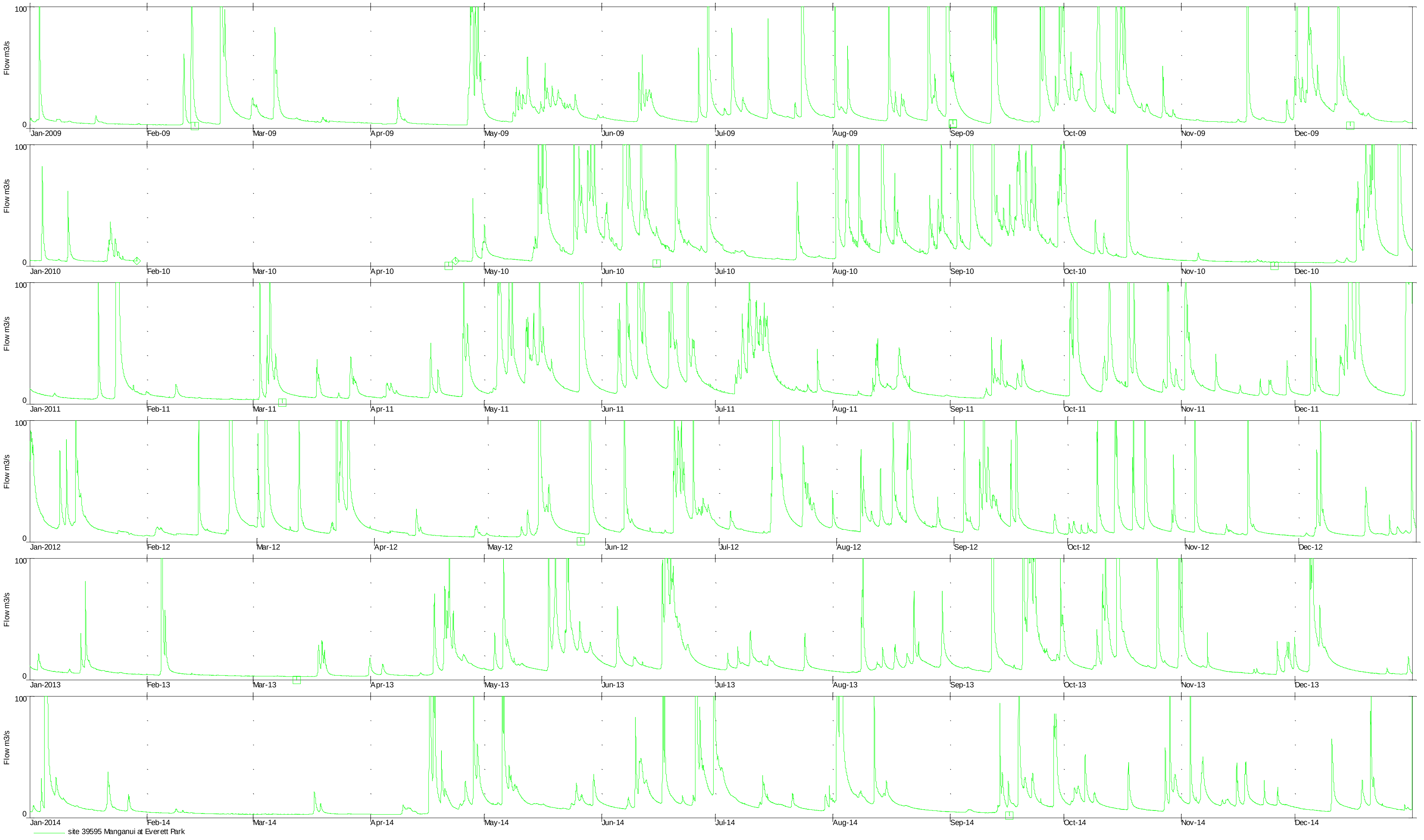

Flow m3/s
40
20
0
Jan-1968
Feb-68
Mar-68
Apr-68
May-68
Jun-68
Jul-68
Aug-68
Sep-68
Oct-68
Nov-68
Dec-68
Flow m3/s
40
20
0
Jan-1969
Feb-69
Mar-69
Apr-69
May-69
Jun-69
Jul-69
Aug-69
Sep-69
Oct-69
Nov-69
Dec-69
Flow m3/s
40
20
0
Jan-1970
Feb-70
Mar-70
Apr-70
May-70
Jun-70
Jul-70
Aug-70
Sep-70
Oct-70
Nov-70
Dec-70
Flow m3/s
40
20
0
Jan-1971
Feb-71
Mar-71
Apr-71
May-71
Jun-71
Jul-71
Aug-71
Sep-71
Oct-71
Nov-71
Dec-71
Flow m3/s
40
20
0
Jan-1972
Feb-72
Mar-72
Apr-72
May-72
Jun-72
Jul-72
Aug-72
Sep-72
Oct-72
Nov-72
Dec-72
Flow m3/s
40
20
0
Jan-1973
Feb-73
Mar-73
Apr-73
May-73
Jun-73
Jul-73
Aug-73
Sep-73
Oct-73
Nov-73
Dec-73
site 39504 Manganui at Tariki Rd

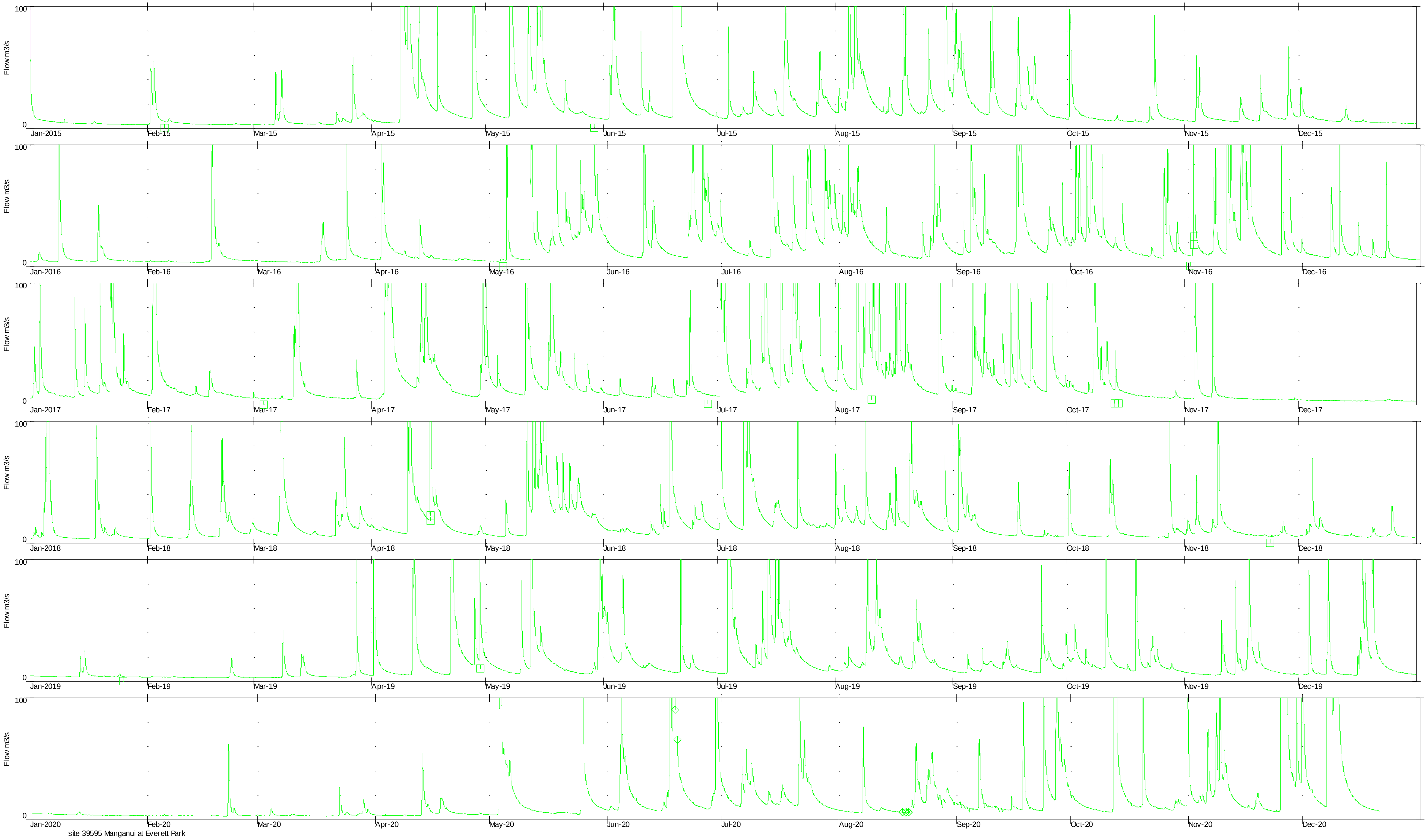
Appendix B3 Manganui River at Everett Park




Flow m3/s
100
0
Jan-1997
Feb-97
Mar-97
Apr-97
May-97
Jun-97
Jul-97
Aug-97
Sep-97
Oct-97
Nov-97
Dec-97
Flow m3/s
100
0
Jan-1998
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Flow m3/s
100
0
Jan-1999
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Flow m3/s
100
0
Jan-2000
Feb-00
Mar-00
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Flow m3/s
100
0
Jan-2001
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Flow m3/s
100
0
Jan-2002
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
site 39595 Manganui at Everett Park


Flow m3/s
100
0
Jan-2003
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Flow m3/s
100
0
Jan-2004
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Flow m3/s
100
0
Jan-2005
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Flow m3/s
100
0
Jan-2006
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
Flow m3/s
100
0
Jan-2007
Feb-07
Mar-07
Apr-07
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07
Nov-07
Dec-07
Flow m3/s
100
0
Jan-2008
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
site 39595 Manganui at Everett Park


100
0
Flow m3/s
Jan-2009
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Jan-2010
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
Jan-2011
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-2012
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-2013
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-2014
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
site 39595 Manganui at Everett Park

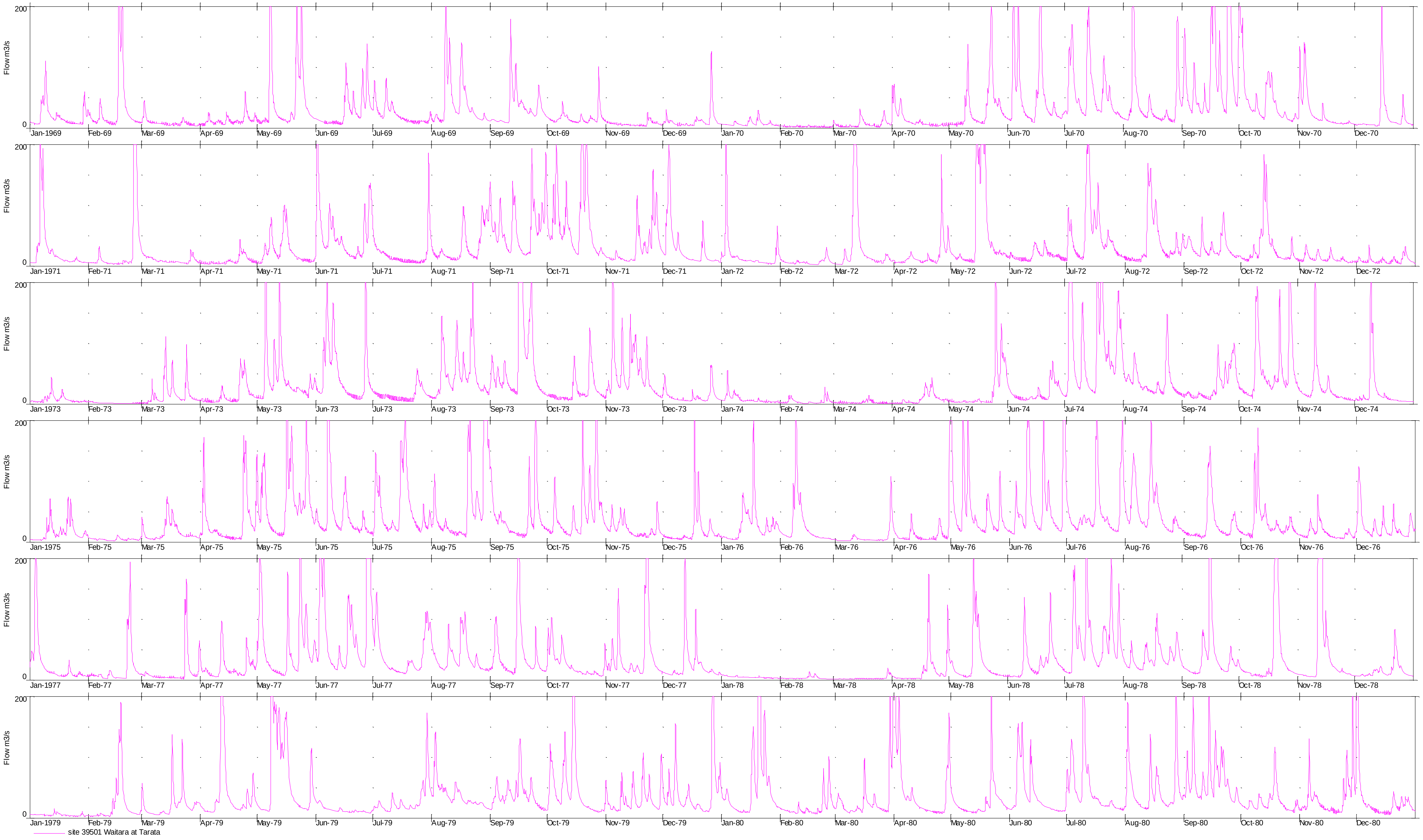

Flow m3/s
100
0
Jan-2015
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 39595 Manganui at Everett Park

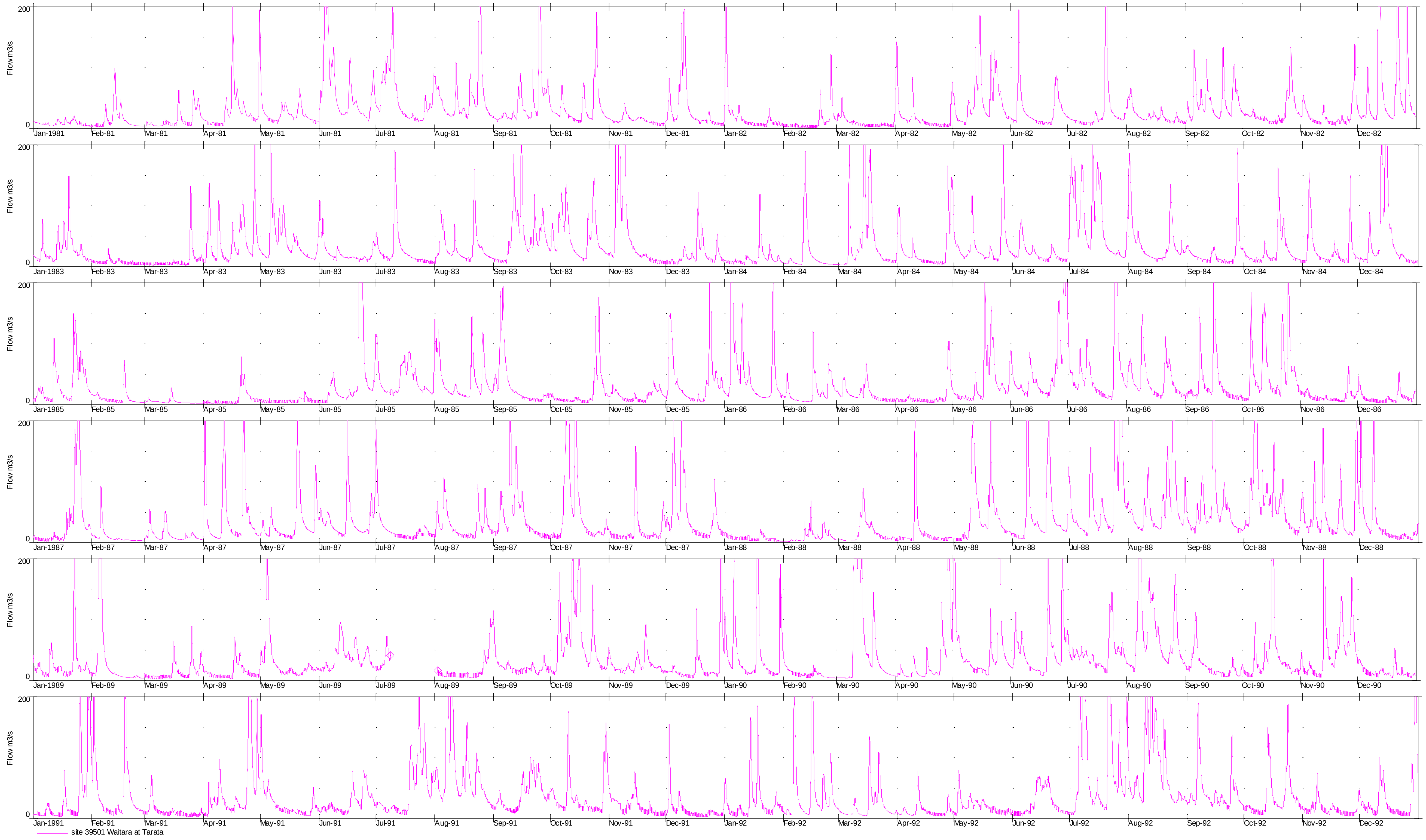
Appendix C: Waitara River flow hydrographs

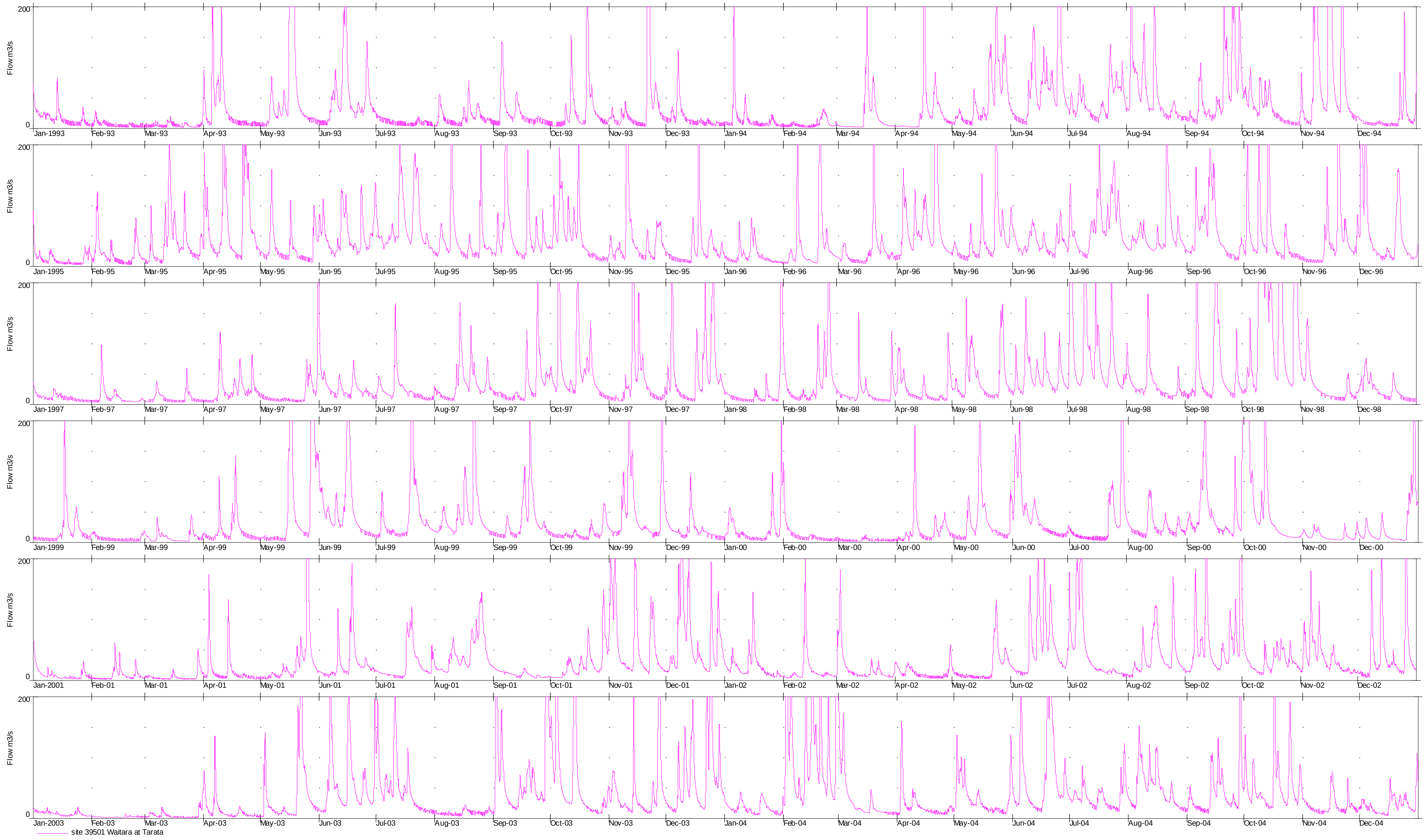
C1 Waitara River at Tarata flow time series 1968 to 2020

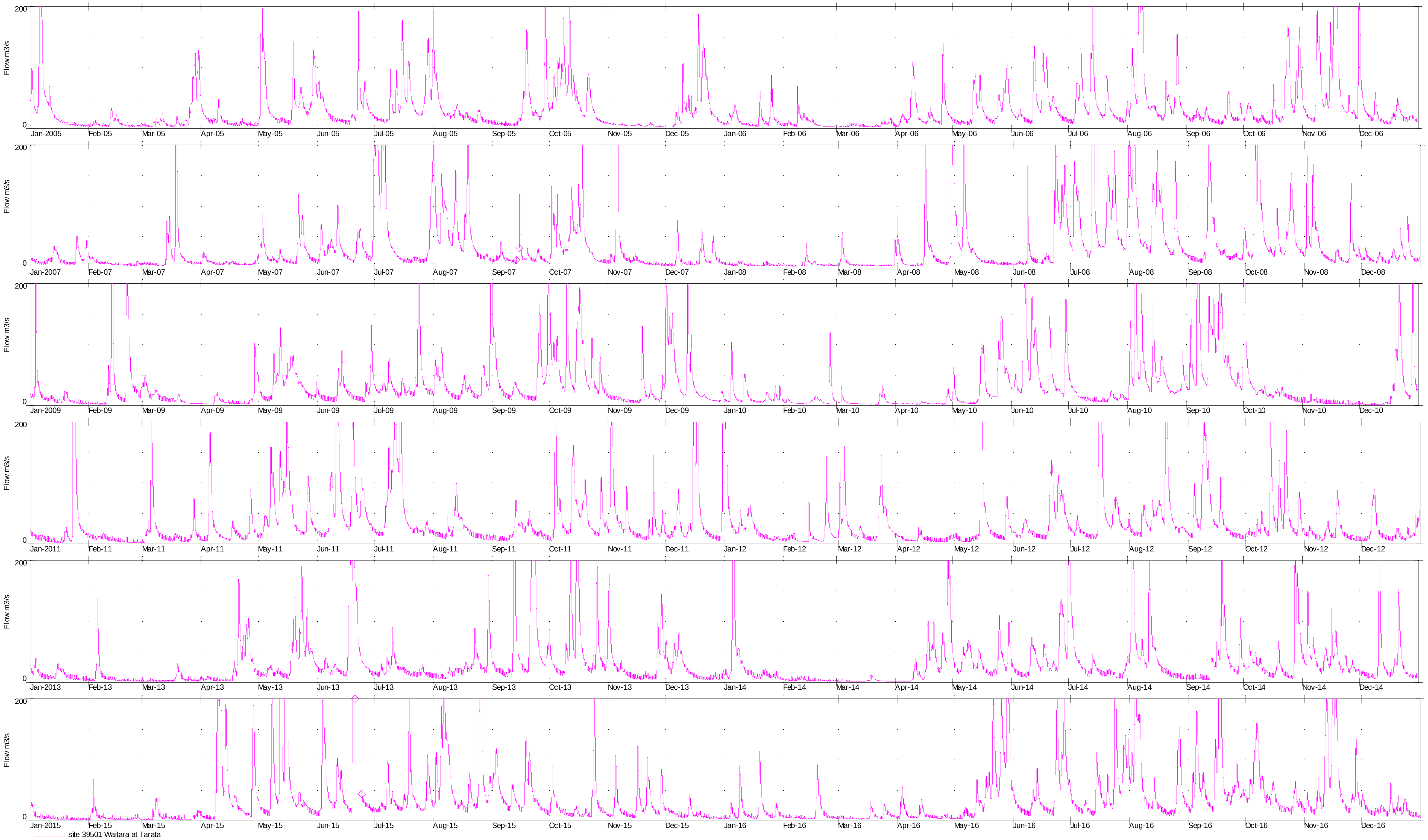
C2 Waitara River at Bertrand Road time series 1980 to 2020

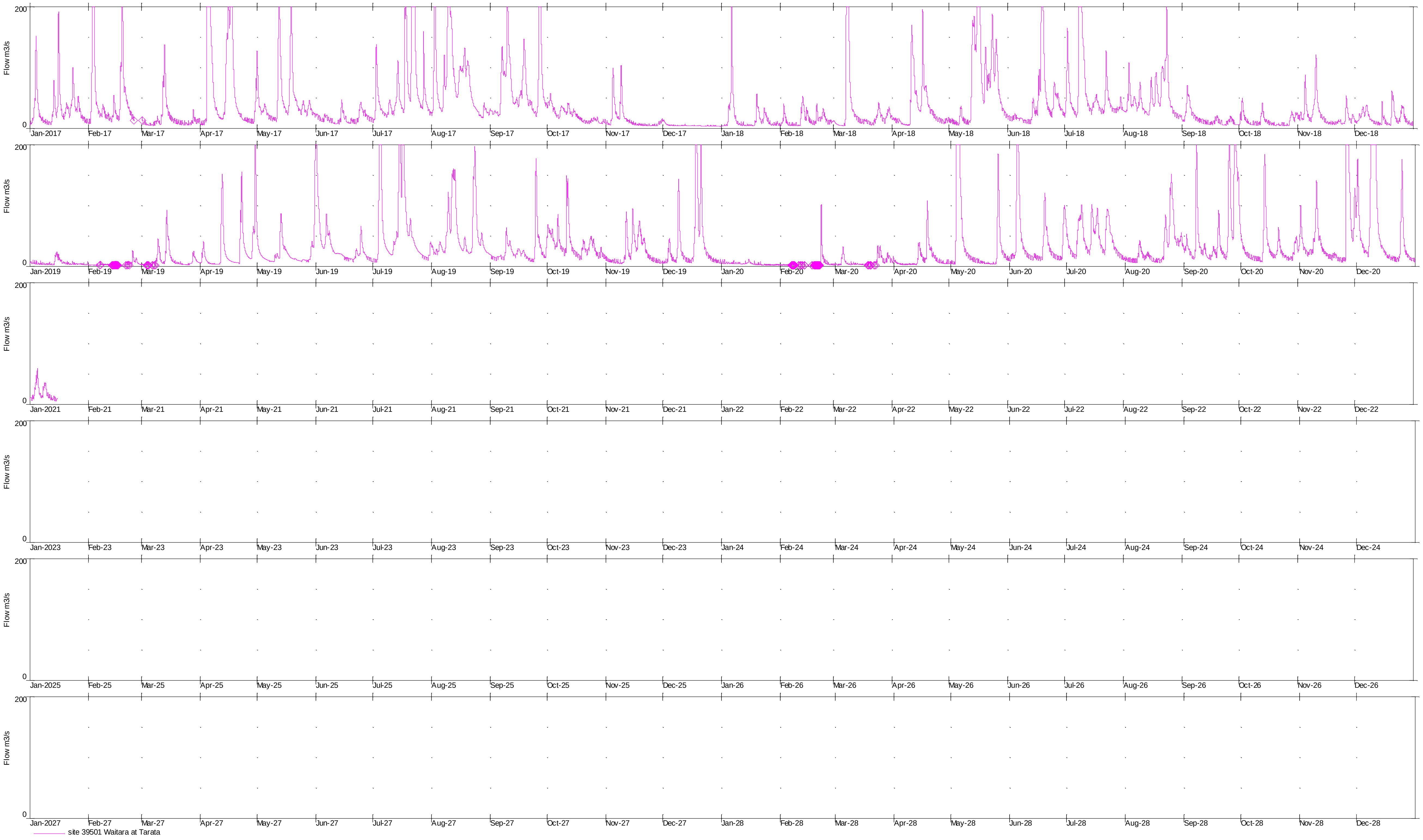
Appendix C1 Waitara River at Tarata (m^3/s)



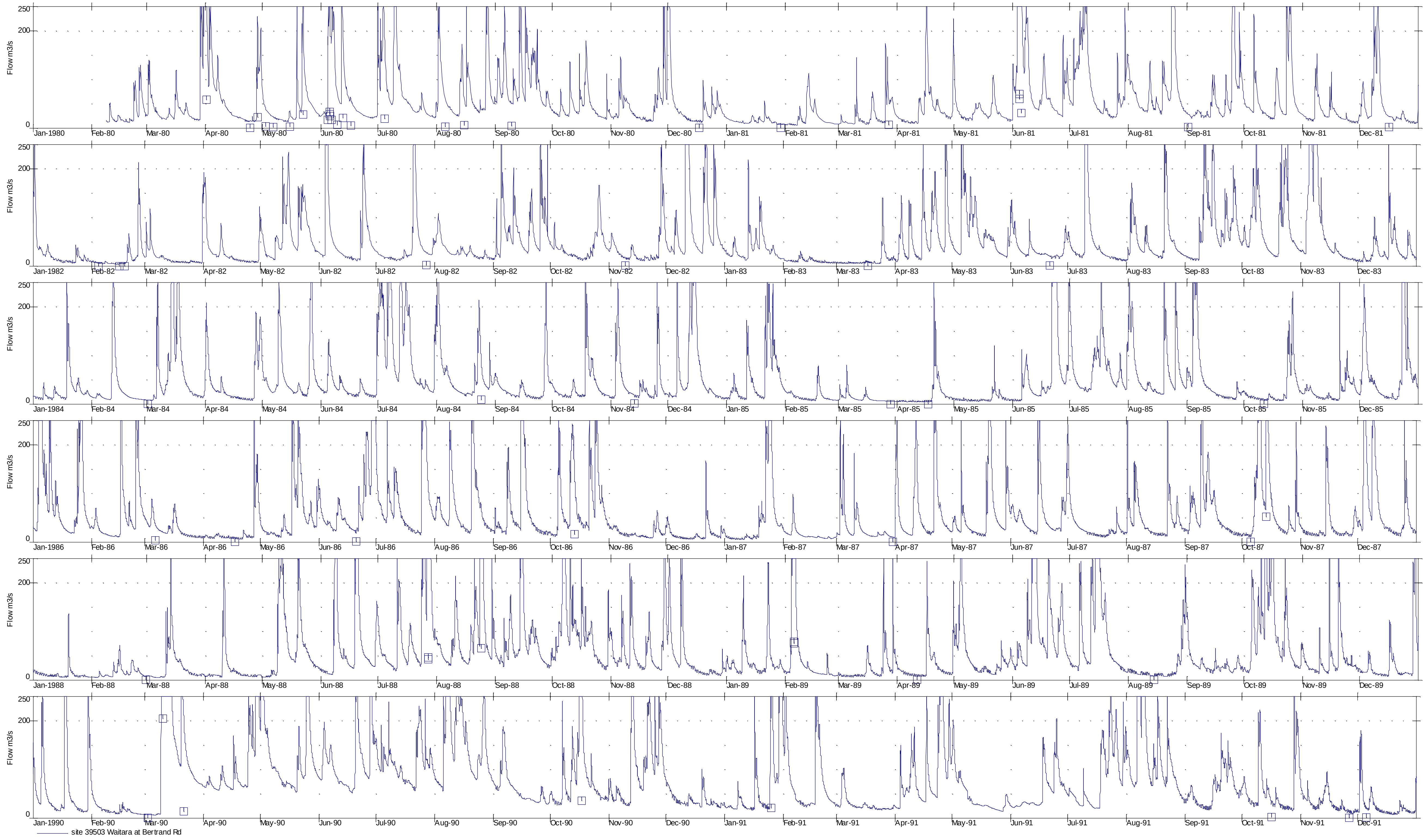

Flow m3/s
200
0
Jan-1981 Feb-81 Mar-81 Apr-81 May-81 Jun-81 Jul-81 Aug-81 Sep-81 Oct-81 Nov-81 Dec-81 Jan-82 Feb-82 Mar-82 Apr-82 May-82 Jun-82 Jul-82 Aug-82 Sep-82 Oct-82 Nov-82 Dec-82
Jan-1983 Feb-83 Mar-83 Apr-83 May-83 Jun-83 Jul-83 Aug-83 Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84
Jan-1985 Feb-85 Mar-85 Apr-85 May-85 Jun-85 Jul-85 Aug-85 Sep-85 Oct-85 Nov-85 Dec-85 Jan-86 Feb-86 Mar-86 Apr-86 May-86 Jun-86 Jul-86 Aug-86 Sep-86 Oct-86 Nov-86 Dec-86
Jan-1987 Feb-87 Mar-87 Apr-87 May-87 Jun-87 Jul-87 Aug-87 Sep-87 Oct-87 Nov-87 Dec-87 Jan-88 Feb-88 Mar-88 Apr-88 May-88 Jun-88 Jul-88 Aug-88 Sep-88 Oct-88 Nov-88 Dec-88
Jan-1989 Feb-89 Mar-89 Apr-89 May-89 Jun-89 Jul-89 Aug-89 Sep-89 Oct-89 Nov-89 Dec-89 Jan-90 Feb-90 Mar-90 Apr-90 May-90 Jun-90 Jul-90 Aug-90 Sep-90 Oct-90 Nov-90 Dec-90
Jan-1991 Feb-91 Mar-91 Apr-91 May-91 Jun-91 Jul-91 Aug-91 Sep-91 Oct-91 Nov-91 Dec-91 Jan-92 Feb-92 Mar-92 Apr-92 May-92 Jun-92 Jul-92 Aug-92 Sep-92 Oct-92 Nov-92 Dec-92
site 39501 Waitara at Tarata

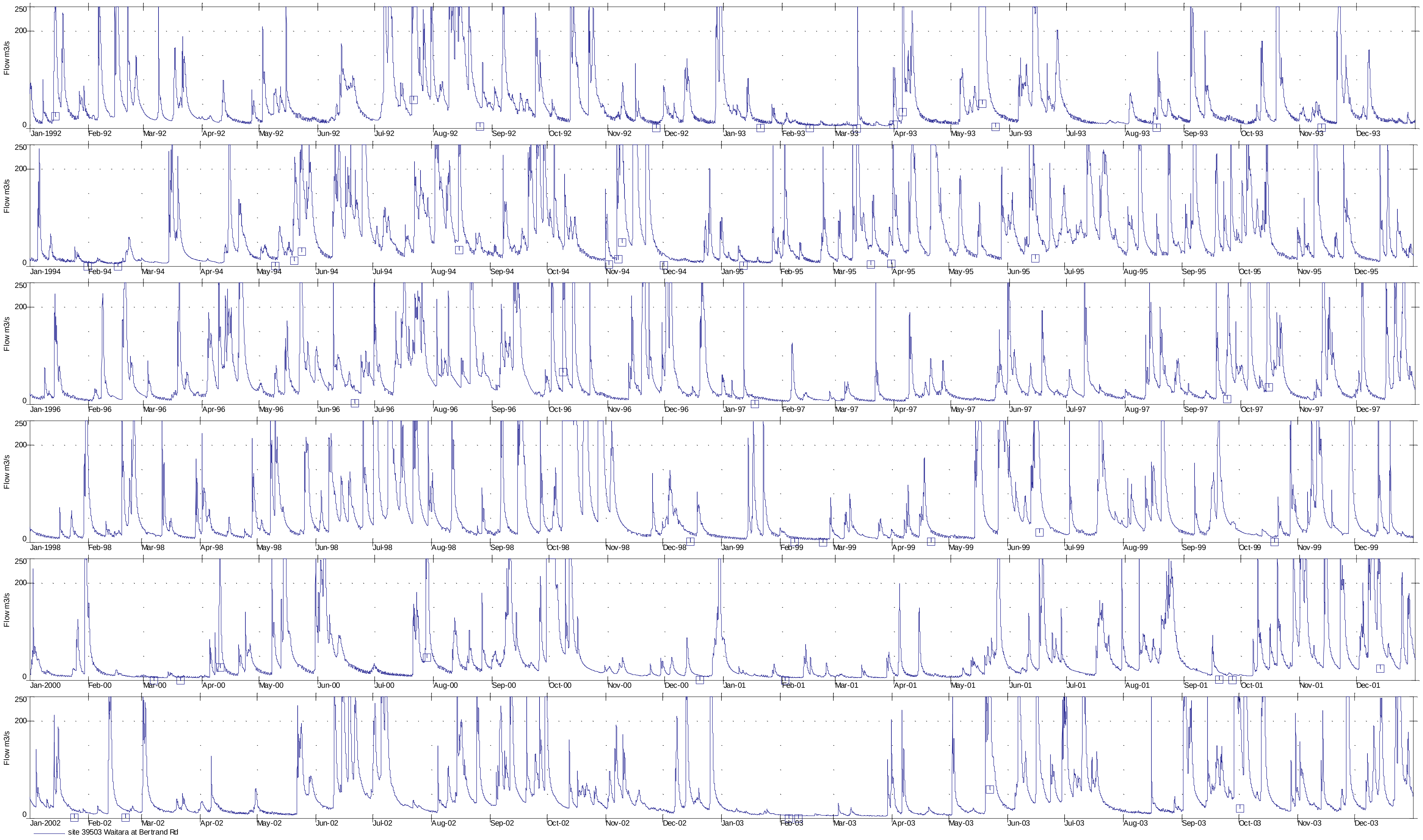

Flow m3/s
200
0
Jan-1993
Feb-93
Mar-93
Apr-93
May-93
Jun-93
Jul-93
Aug-93
Sep-93
Oct-93
Nov-93
Dec-93
Jan-94
Feb-94
Mar-94
Apr-94
May-94
Jun-94
Jul-94
Aug-94
Sep-94
Oct-94
Nov-94
Dec-94
Jan-1995
Feb-95
Mar-95
Apr-95
May-95
Jun-95
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-96
Feb-96
Mar-96
Apr-96
May-96
Jun-96
Jul-96
Aug-96
Sep-96
Oct-96
Nov-96
Dec-96
Jan-1997
Feb-97
Mar-97
Apr-97
May-97
Jun-97
Jul-97
Aug-97
Sep-97
Oct-97
Nov-97
Dec-97
Jan-98
Feb-98
Mar-98
Apr-98
May-98
Jun-98
Jul-98
Aug-98
Sep-98
Oct-98
Nov-98
Dec-98
Jan-1999
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-2001
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-2003
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
site 39501 Waitara at Tarata


Flow m3/s
200
0
Jan-2005 Feb-05 Mar-05 Apr-05 May-05 Jun-05 Jul-05 Aug-05 Sep-05 Oct-05 Nov-05 Dec-05 Jan-06 Feb-06 Mar-06 Apr-06 May-06 Jun-06 Jul-06 Aug-06 Sep-06 Oct-06 Nov-06 Dec-06
Flow m3/s
200
0
Jan-2007 Feb-07 Mar-07 Apr-07 May-07 Jun-07 Jul-07 Aug-07 Sep-07 Oct-07 Nov-07 Dec-07 Jan-08 Feb-08 Mar-08 Apr-08 May-08 Jun-08 Jul-08 Aug-08 Sep-08 Oct-08 Nov-08 Dec-08
Flow m3/s
200
0
Jan-2009 Feb-09 Mar-09 Apr-09 May-09 Jun-09 Jul-09 Aug-09 Sep-09 Oct-09 Nov-09 Dec-09 Jan-10 Feb-10 Mar-10 Apr-10 May-10 Jun-10 Jul-10 Aug-10 Sep-10 Oct-10 Nov-10 Dec-10
Flow m3/s
200
0
Jan-2011 Feb-11 Mar-11 Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11 Dec-11 Jan-12 Feb-12 Mar-12 Apr-12 May-12 Jun-12 Jul-12 Aug-12 Sep-12 Oct-12 Nov-12 Dec-12
Flow m3/s
200
0
Jan-2013 Feb-13 Mar-13 Apr-13 May-13 Jun-13 Jul-13 Aug-13 Sep-13 Oct-13 Nov-13 Dec-13 Jan-14 Feb-14 Mar-14 Apr-14 May-14 Jun-14 Jul-14 Aug-14 Sep-14 Oct-14 Nov-14 Dec-14
Flow m3/s
200
0
Jan-2015 Feb-15 Mar-15 Apr-15 May-15 Jun-15 Jul-15 Aug-15 Sep-15 Oct-15 Nov-15 Dec-15 Jan-16 Feb-16 Mar-16 Apr-16 May-16 Jun-16 Jul-16 Aug-16 Sep-16 Oct-16 Nov-16 Dec-16
site 39501 Waitara at Tarata


Flow m3/s
200
0
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Flow m3/s
200
0
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Flow m3/s
200
0
Jan-2021
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Sep-22
Oct-22
Nov-22
Dec-22
Flow m3/s
200
0
Jan-2023
Feb-23
Mar-23
Apr-23
May-23
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
Dec-23
Jan-24
Feb-24
Mar-24
Apr-24
May-24
Jun-24
Jul-24
Aug-24
Sep-24
Oct-24
Nov-24
Dec-24
Flow m3/s
200
0
Jan-2025
Feb-25
Mar-25
Apr-25
May-25
Jun-25
Jul-25
Aug-25
Sep-25
Oct-25
Nov-25
Dec-25
Jan-26
Feb-26
Mar-26
Apr-26
May-26
Jun-26
Jul-26
Aug-26
Sep-26
Oct-26
Nov-26
Dec-26
Flow m3/s
200
0
Jan-2027
Feb-27
Mar-27
Apr-27
May-27
Jun-27
Jul-27
Aug-27
Sep-27
Oct-27
Nov-27
Dec-27
Jan-28
Feb-28
Mar-28
Apr-28
May-28
Jun-28
Jul-28
Aug-28
Sep-28
Oct-28
Nov-28
Dec-28
site 39501 Waitara at Tarata

Appendix C2 Waitara River at Bertrand Road




Flow m3/s
250
200
0
Jan-1992
Feb-92
Mar-92
Apr-92
May-92
Jun-92
Jul-92
Aug-92
Sep-92
Oct-92
Nov-92
Dec-92
Jan-93
Feb-93
Mar-93
Apr-93
May-93
Jun-93
Jul-93
Aug-93
Sep-93
Oct-93
Nov-93
Dec-93
Jan-1994
Feb-94
Mar-94
Apr-94
May-94
Jun-94
Jul-94
Aug-94
Sep-94
Oct-94
Nov-94
Dec-94
Jan-95
Feb-95
Mar-95
Apr-95
May-95
Jun-95
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-1996
Feb-96
Mar-96
Apr-96
May-96
Jun-96
Jul-96
Aug-96
Sep-96
Oct-96
Nov-96
Dec-96
Jan-97
Feb-97
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Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
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May-01
Jun-01
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Aug-01
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Jan-2002
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Mar-02
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Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
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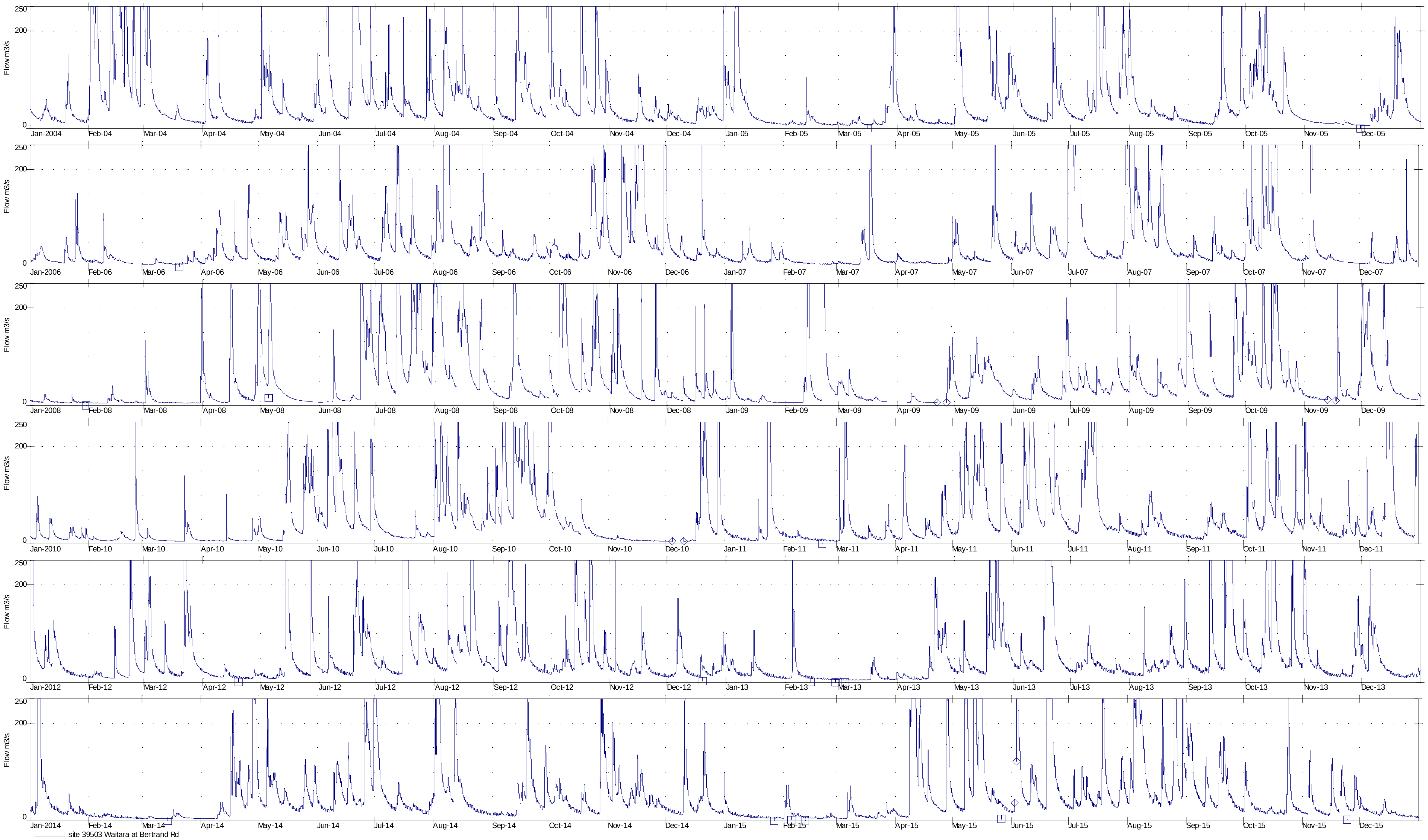
Sep-03
Oct-03
Nov-03
Dec-03
site 39503 Waitara at Bertrand Rd


Flow m3/s
250
200
0
Jan-2004
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
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Jan-2006
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Apr-06
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Jun-06
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May-07
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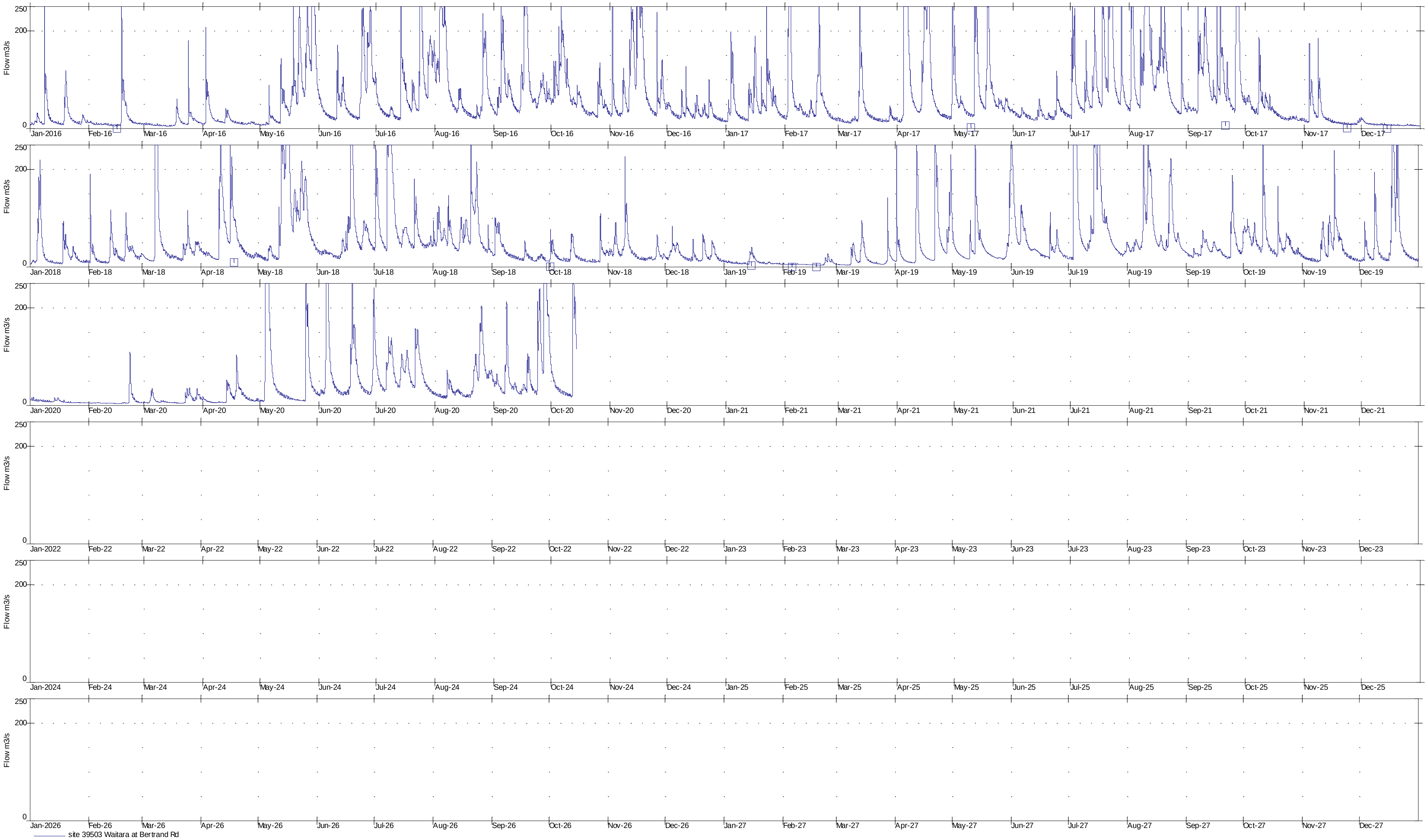
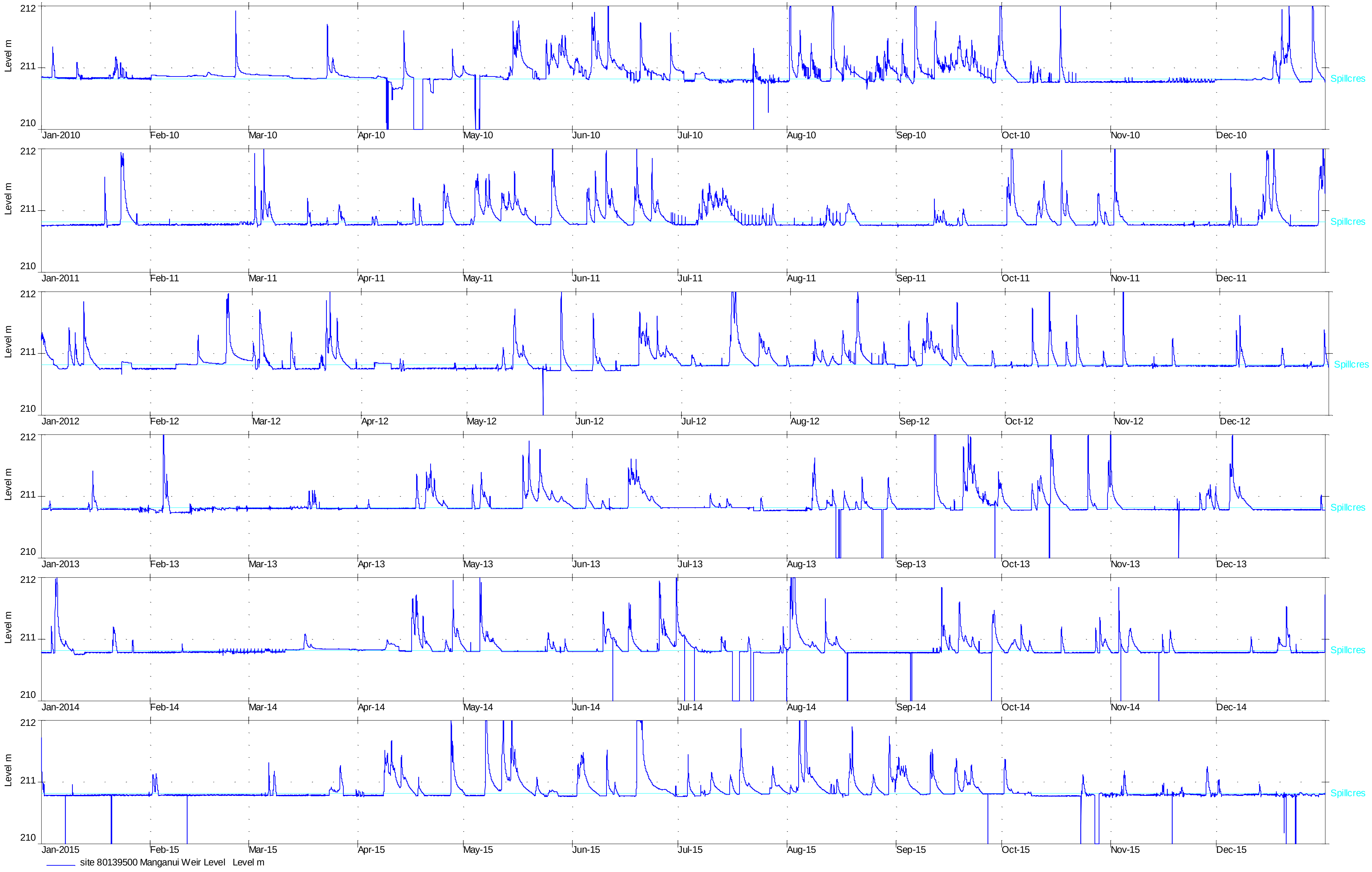
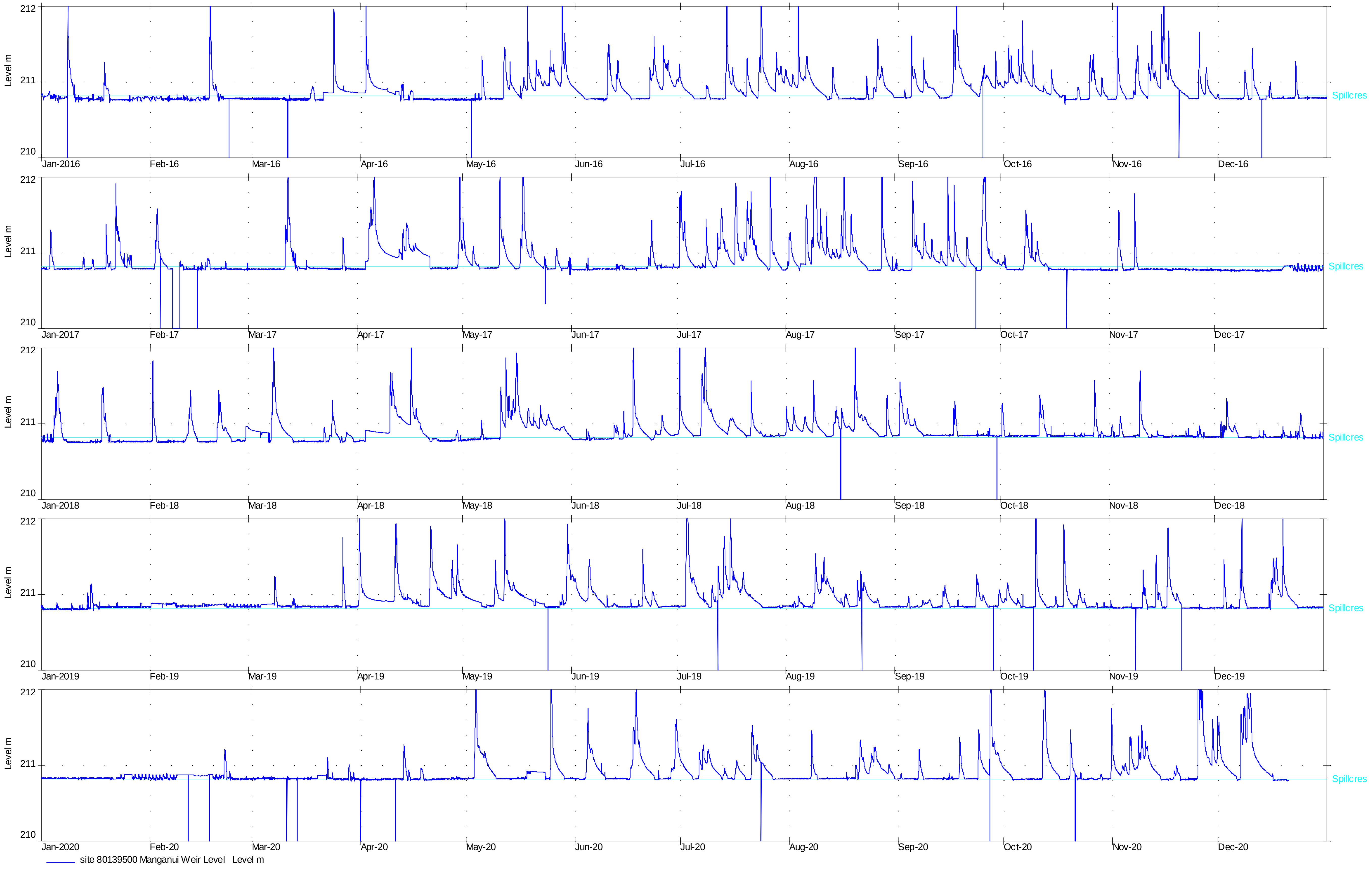
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Jan-2010
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-2012
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-2014
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
site 39503 Waitara at Bertrand Rd


Flow m3/s
250
200
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Jan-2022
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Sep-22
Oct-22
Nov-22
Dec-22
Jan-23
Feb-23
Mar-23
Apr-23
May-23
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
Dec-23
Jan-2024
Feb-24
Mar-24
Apr-24
May-24
Jun-24
Jul-24
Aug-24
Sep-24
Oct-24
Nov-24
Dec-24
Jan-25
Feb-25
Mar-25
Apr-25
May-25
Jun-25
Jul-25
Aug-25
Sep-25
Oct-25
Nov-25
Dec-25
Jan-2026
Feb-26
Mar-26
Apr-26
May-26
Jun-26
Jul-26
Aug-26
Sep-26
Oct-26
Nov-26
Dec-26
Jan-27
Feb-27
Mar-27
Apr-27
May-27
Jun-27
Jul-27
Aug-27
Sep-27
Oct-27
Nov-27
Dec-27
site 39503 Waitara at Bertrand Rd

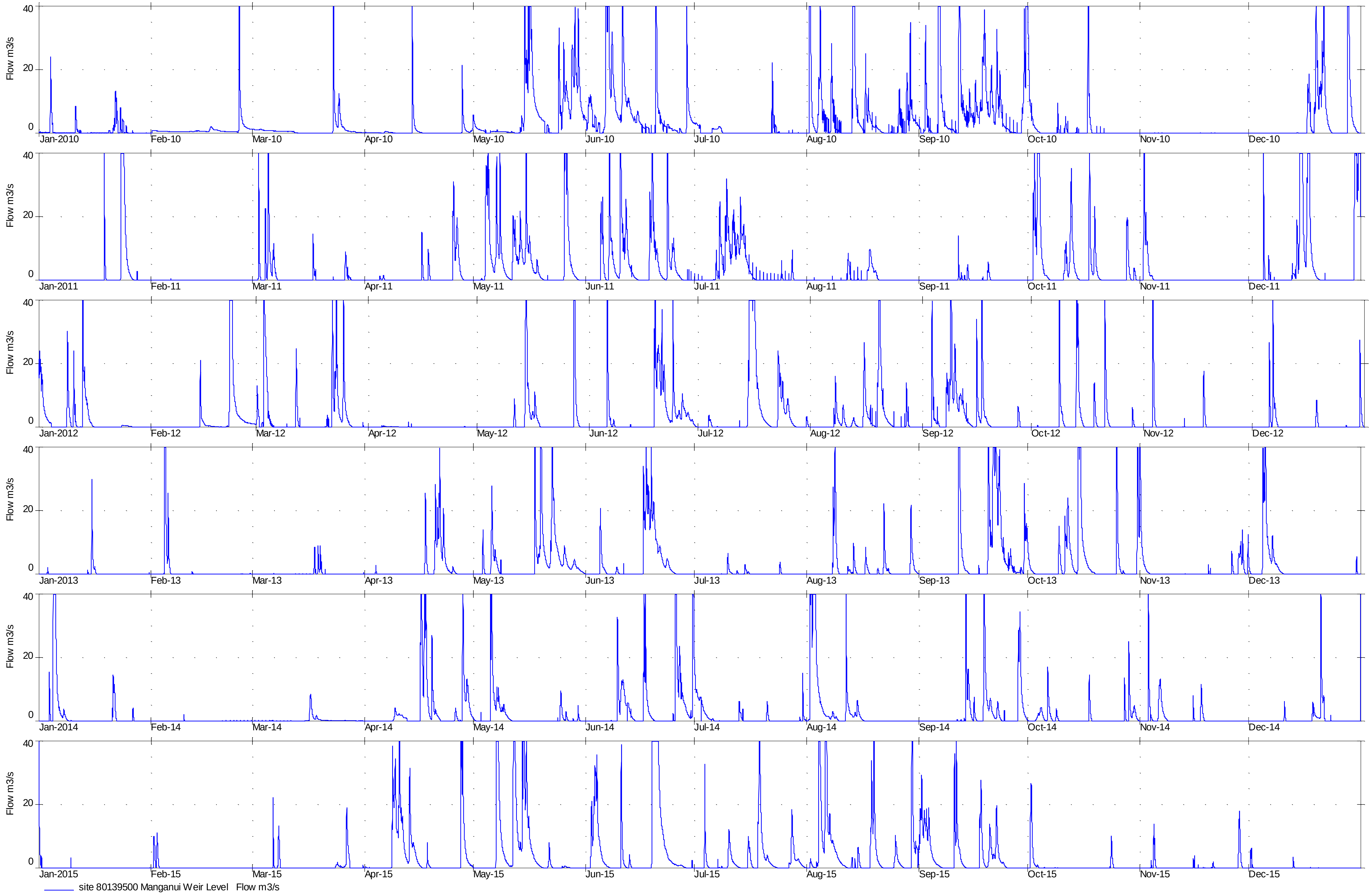
Appendix D: Motukawa Scheme time series data

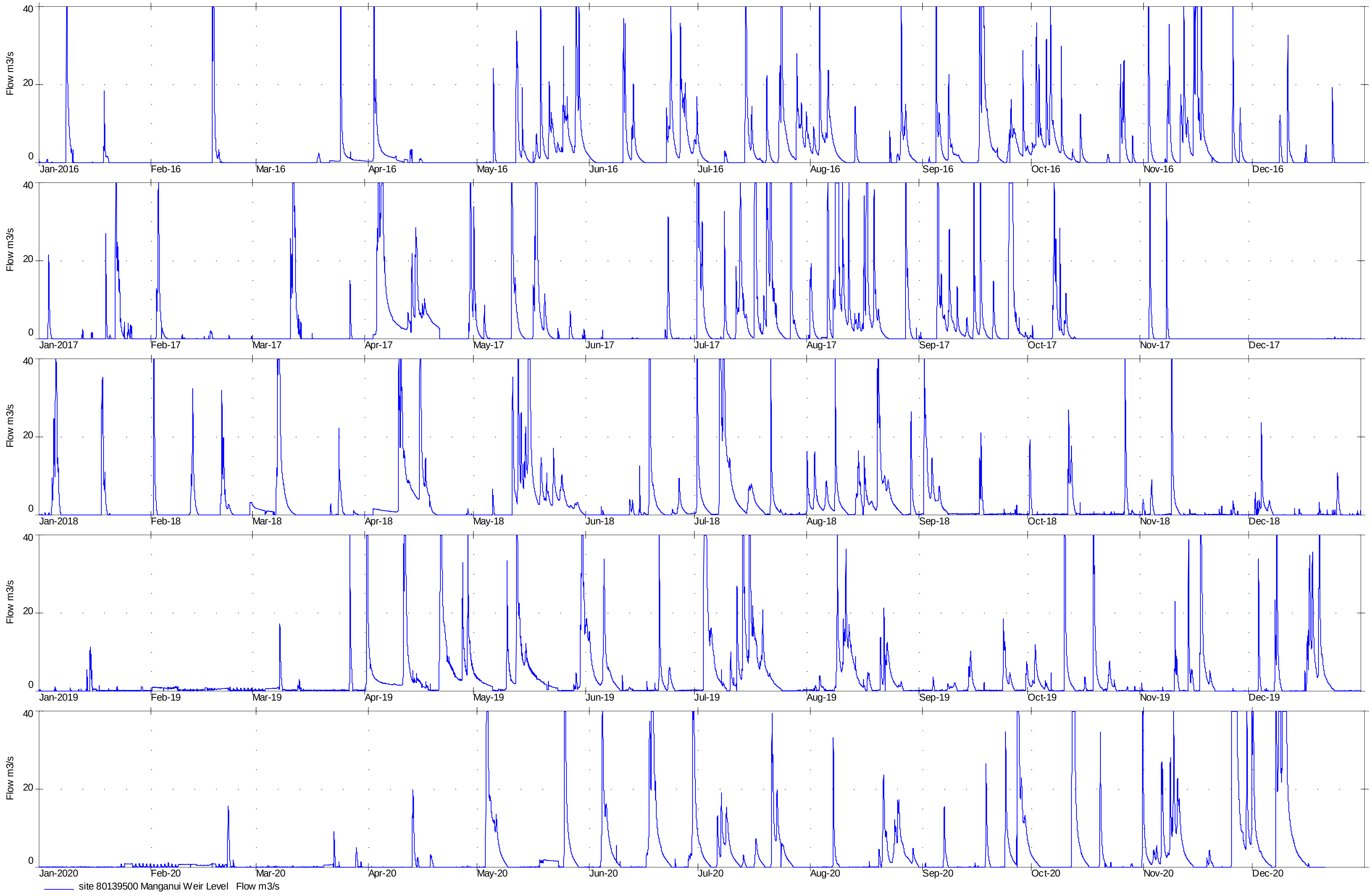
Appendix D1 Manganui Weir water level (RL m). Threshold line (cyan) is the weir crest level (RL 210.82 m)



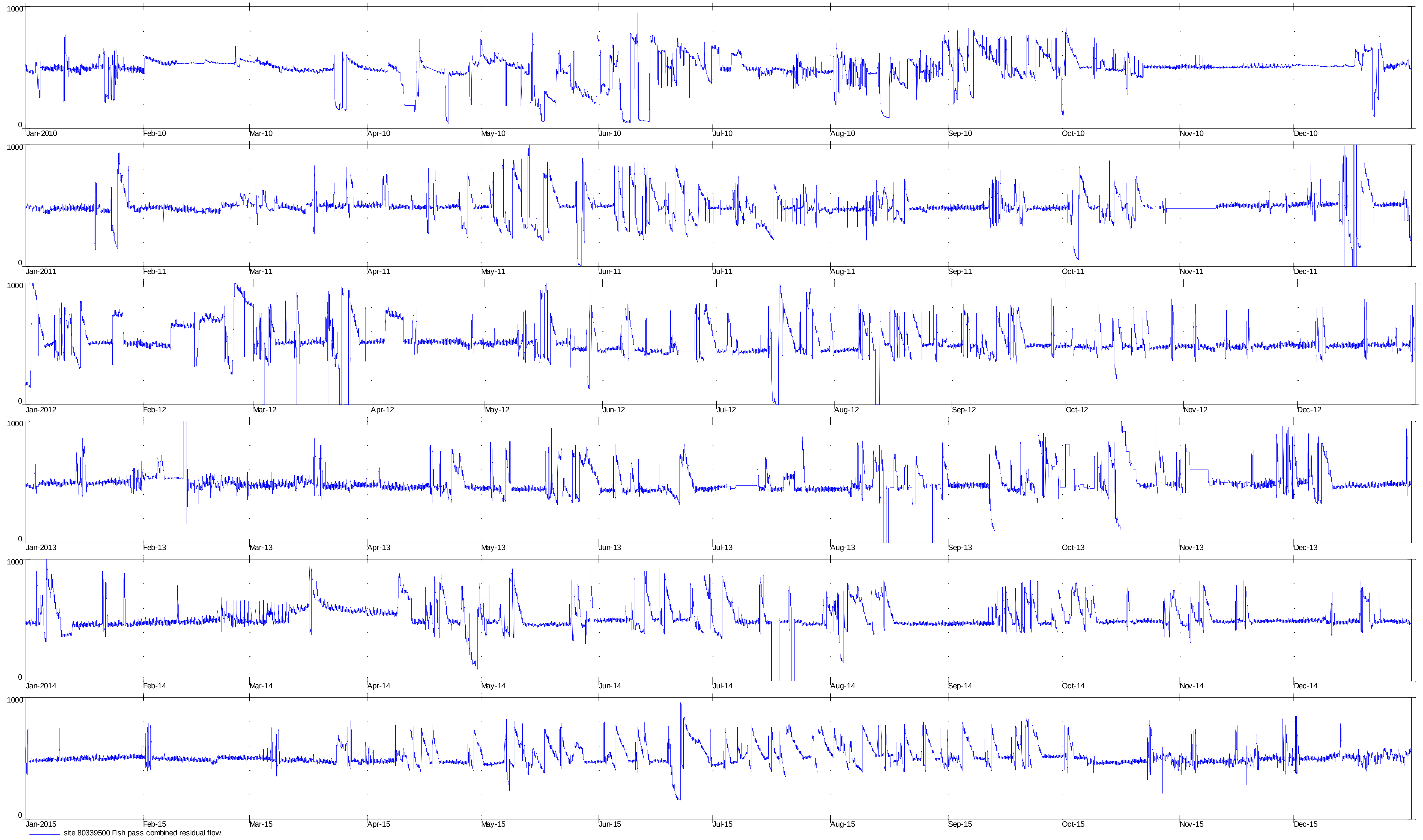

Level m
212
211
210
Spillcres
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80139500 Manganui Weir Level   Level m

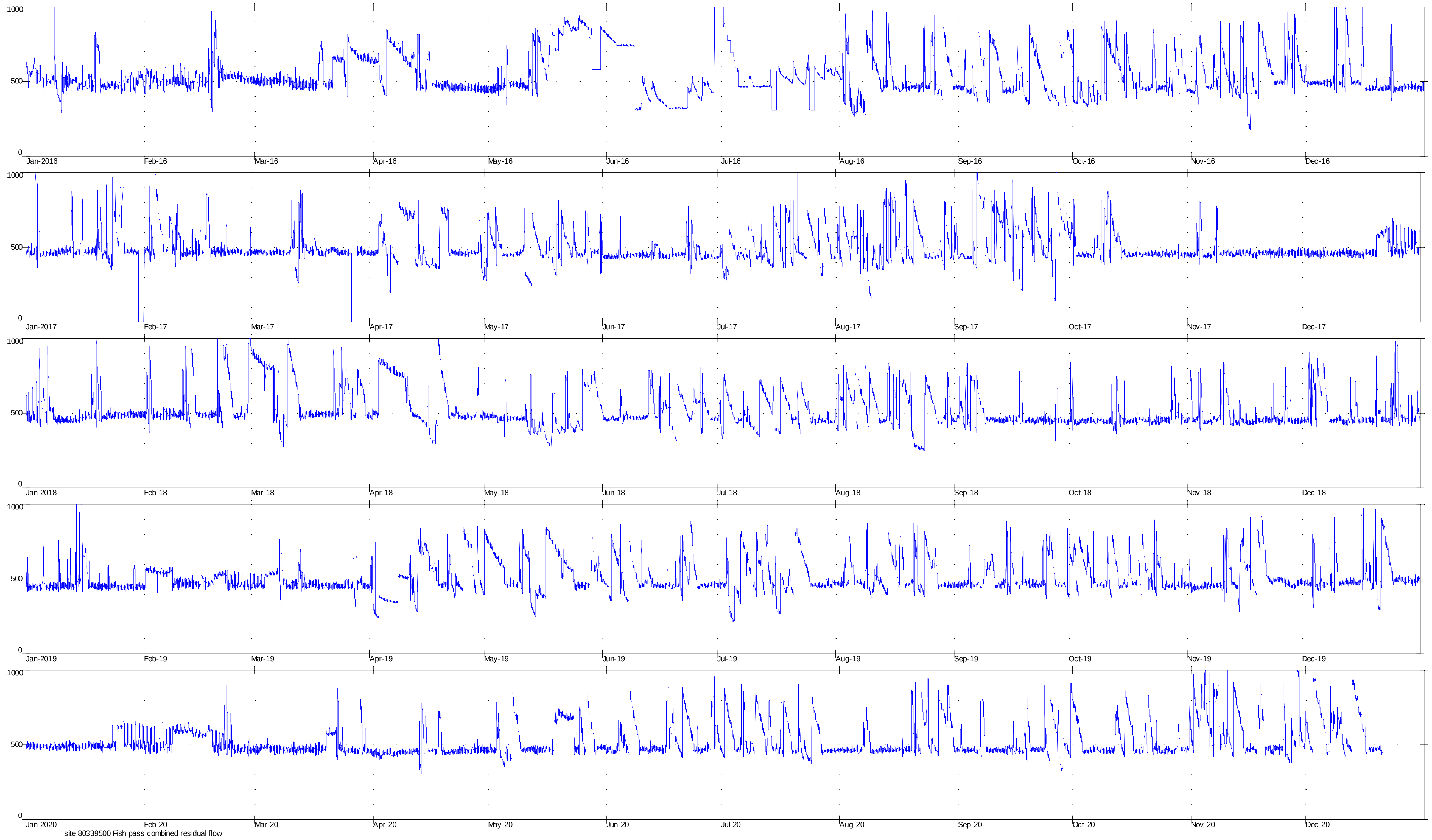
Appendix D2 Manganui Weir spill flow (m^3/s)



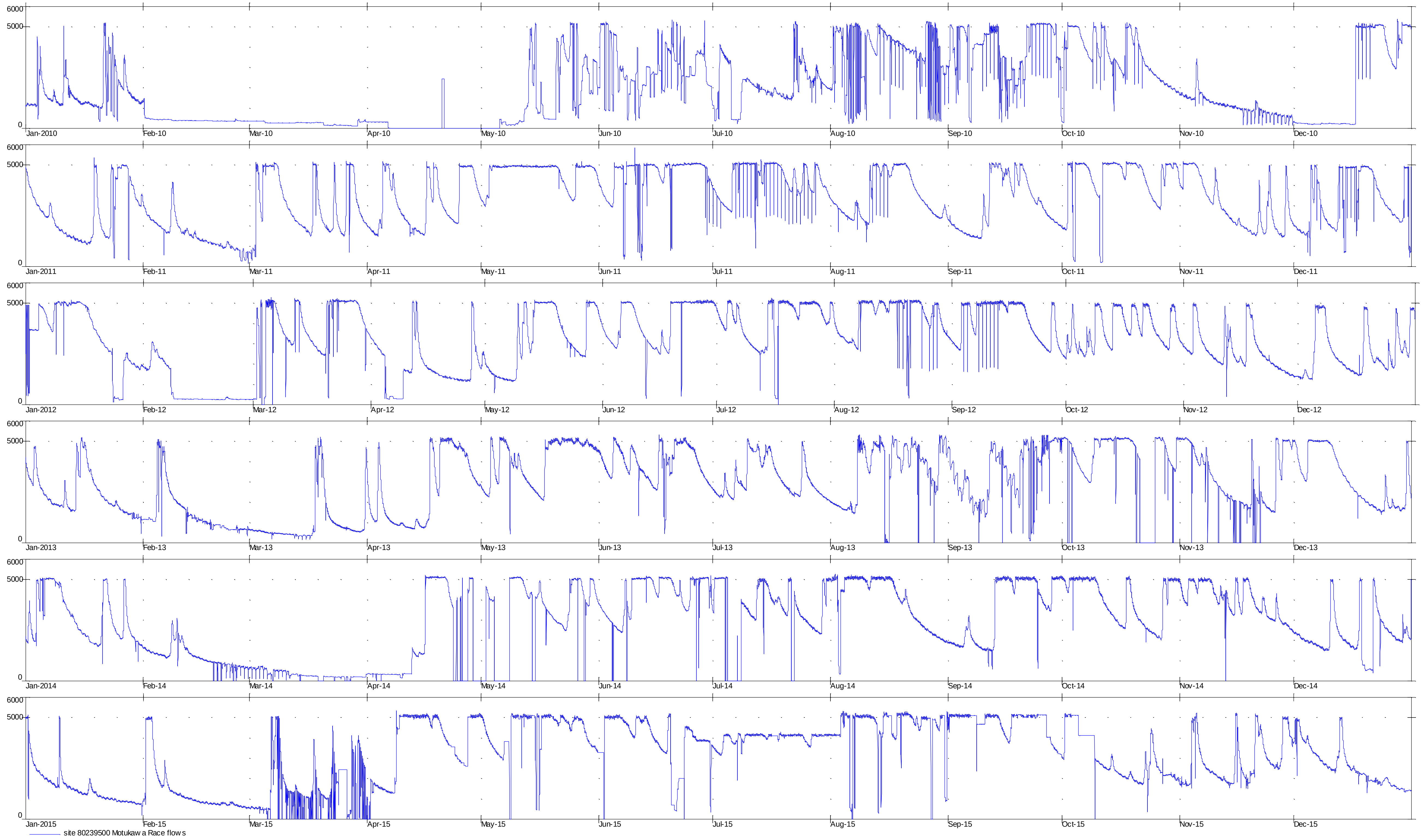

Flow m3/s
40
20
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80139500 Manganui Weir Level Flow m3/s

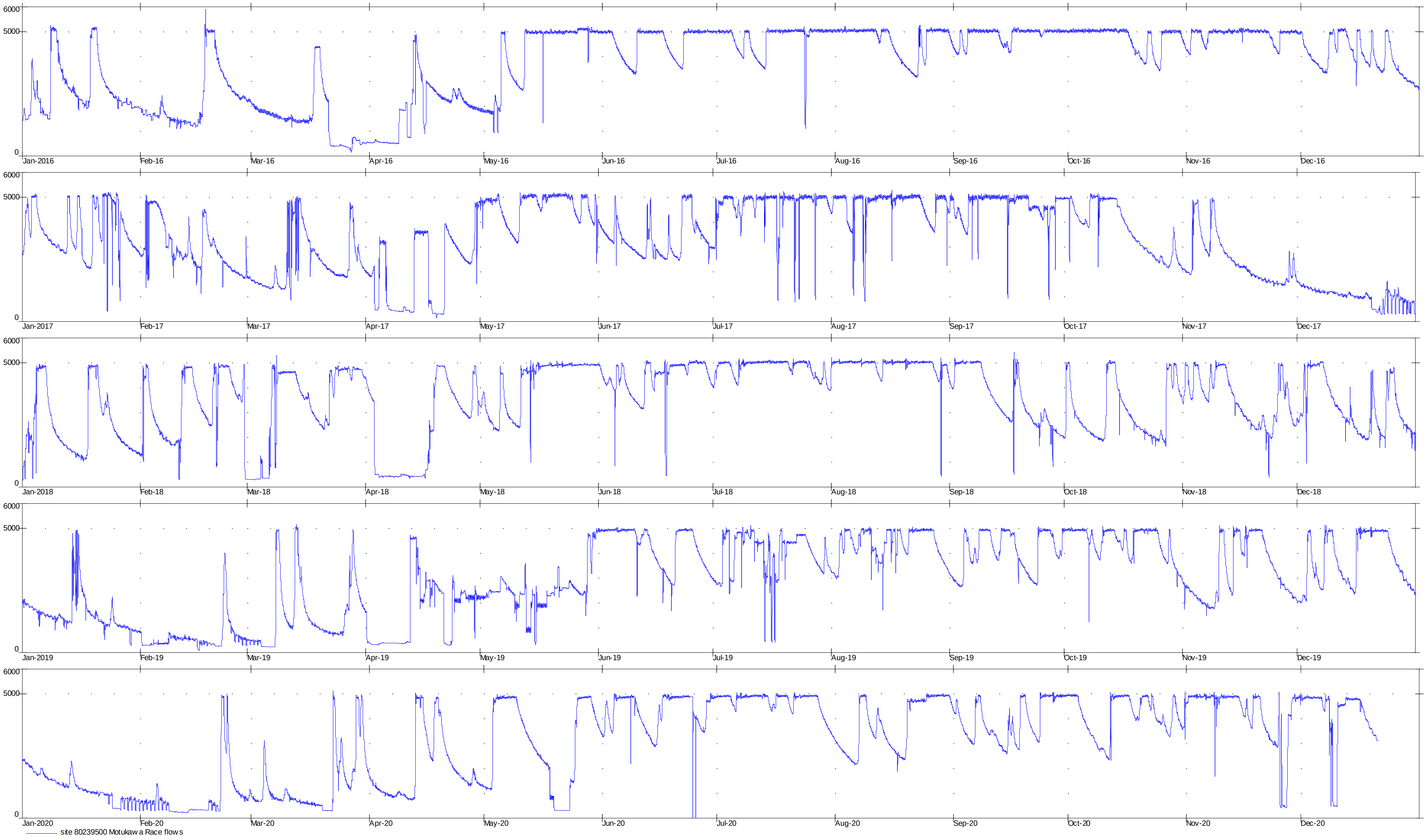
Appendix D3 Combined fish pass flow at Manganui Weir (left bank plus right bank) (l/s)



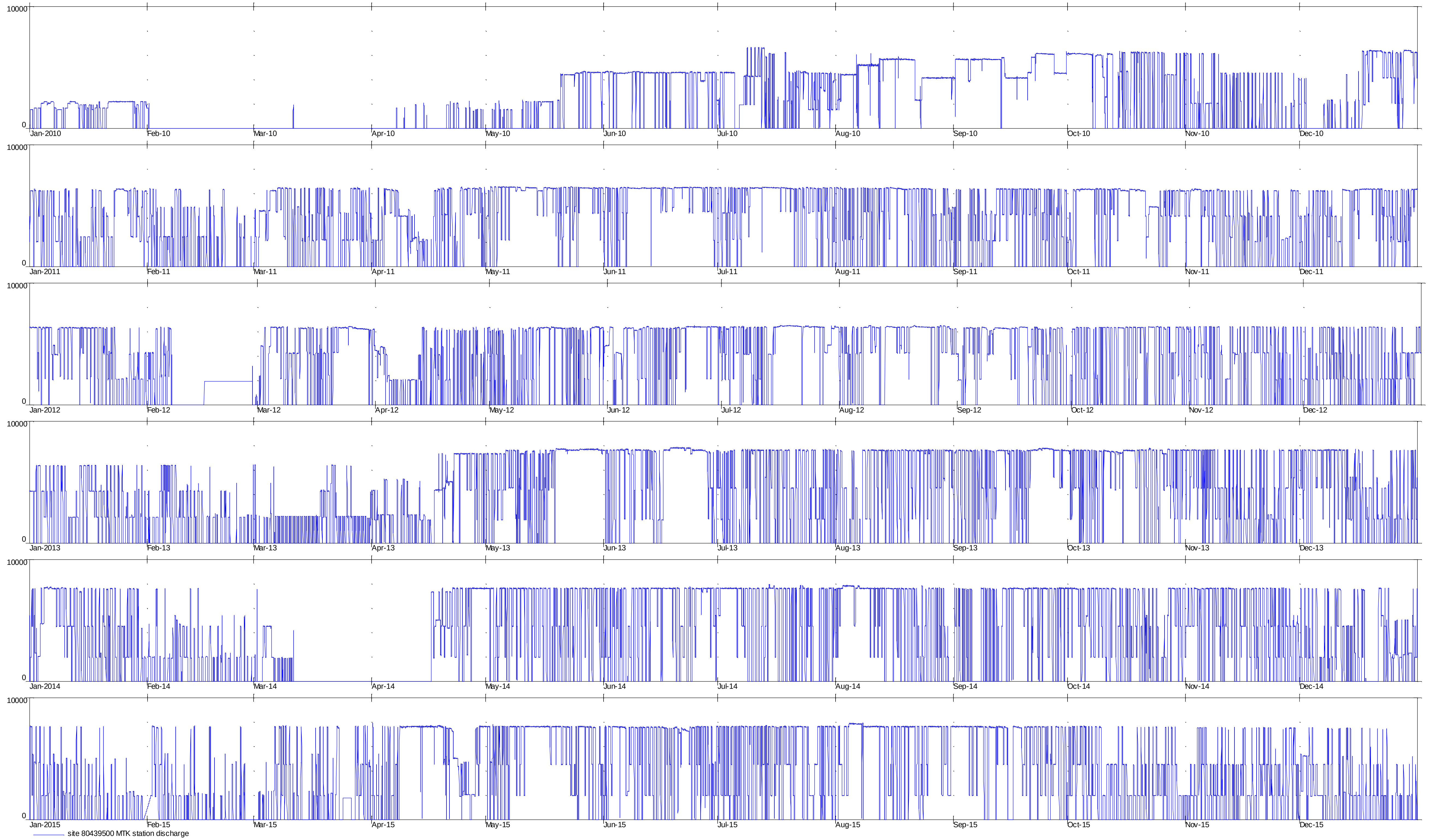

1000
500
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
1000
500
0
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
1000
500
0
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
1000
500
0
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
1000
500
0
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80339500 Fish pass combined residual flow

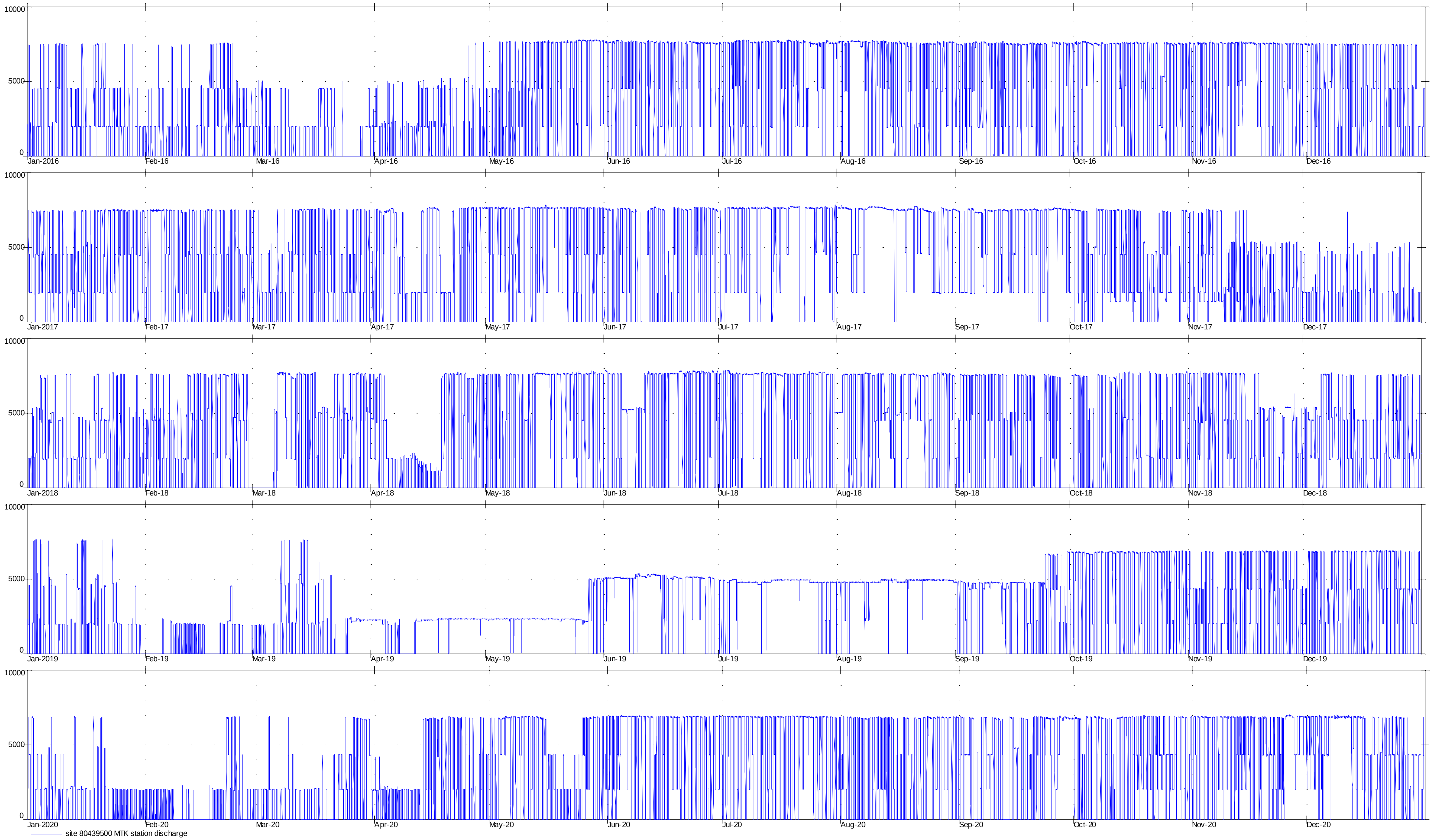
Appendix D4 Motukawa Race flow (at S1 recorder) (l/s)




6000
5000
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
6000
5000
0
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
6000
5000
0
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
6000
5000
0
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
6000
5000
0
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80239500 Motukawa Race flows

Appendix D5 Motukawa Power Station discharge (l/s)

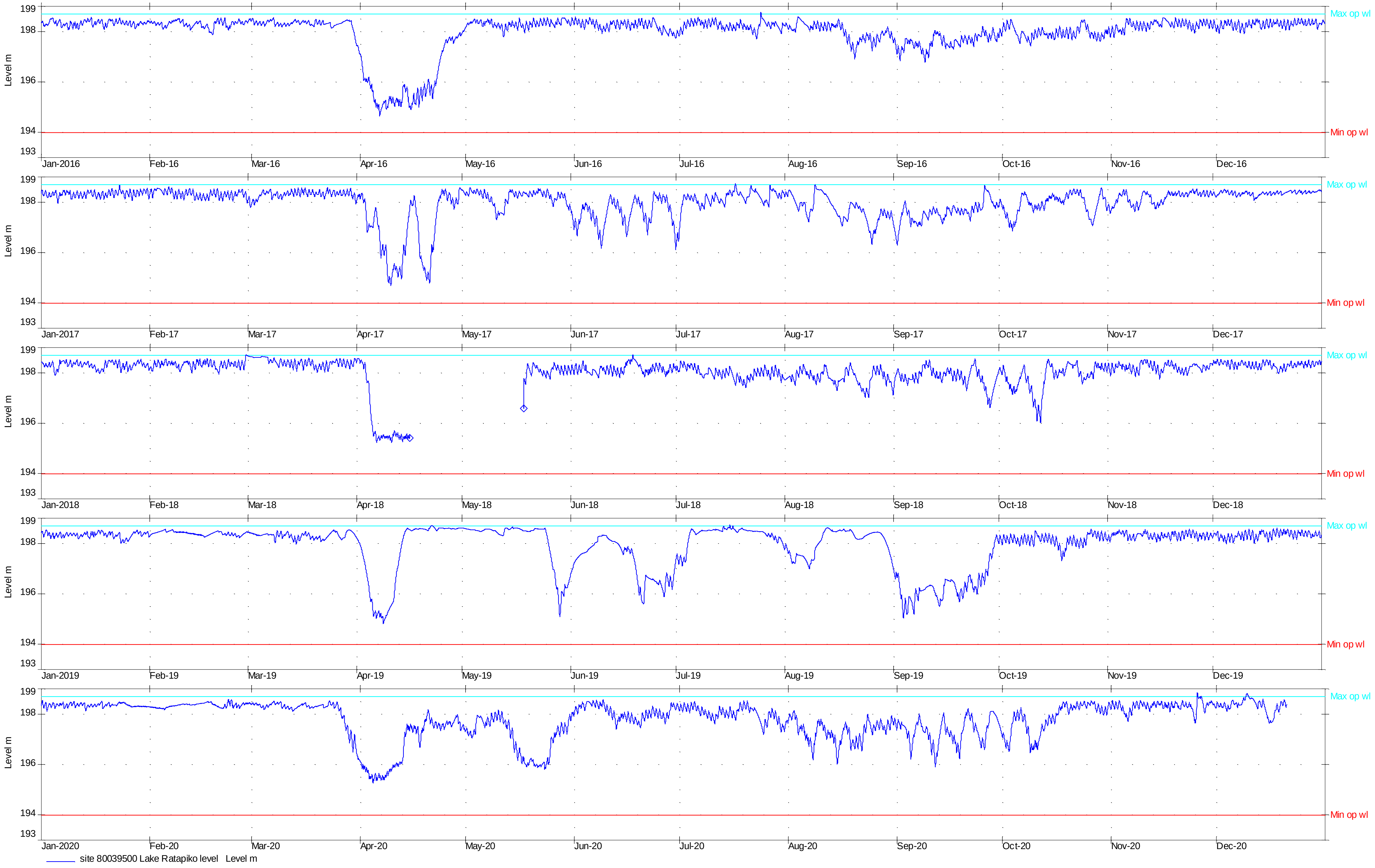



10000
5000
0
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
10000
5000
0
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
10000
5000
0
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
10000
5000
0
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
10000
5000
0
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80439500 MTK station discharge

Appendix D6 Lake Ratapiko water level (RL m). Threshold lines are the minimum (RL 194.0 m, red) and maximum (RL 198.7 m, cyan) normal operating levels


Level m
199
198
196
194
193
Max op wl
Min op wl
Jan-2006
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
Jan-2007
Feb-07
Mar-07
Apr-07
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07
Nov-07
Dec-07
Jan-2008
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-2009
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Jan-2010
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
site 80039500 Lake Ratapiko level Level m


Level m
199
198
196
194
193
Max op wl
Min op wl
Jan-2011
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Jan-2012
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
Dec-12
Jan-2013
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-2014
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Jan-2015
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
site 80039500 Lake Ratapiko level Level m


Level m
199
198
196
194
193
Max op wl
Min op wl
Jan-2016
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-2017
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-2018
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-2019
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-2020
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
site 80039500 Lake Ratapiko level Level m

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