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Hydrological Modelling Dataset

Report 2: Flow Series Description and Methodology

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PREFACE

A large proportion of New Zealand's electricity needs are met by generation from hydro power. Information about the distribution of inflows and the capability of the various hydro systems is necessary to ensure a reliable, competitive, and efficient market and electricity system.

The hydrological modelling dataset (HMD) is a dataset of hydrological information made available by the Electricity Authority. The dataset was known as the SPECTRA update until 2010. In 2015 the dataset was revised to become the HMD, a comprehensive dataset that can be relied upon by modellers and analysts to test scenarios, provide commentary and inform decisions.

The HMD is comprised of data provided by hydro generators and supplemented with data from other sources. These parties are acknowledged for their contribution and for making this data available.

The HMD consists of three main components:

1. **Infrastructure and hydrological constraint attributes:**
    - This dataset records standing information about the capability of the main hydro schemes.
2. **Flows:**
    - This time series dataset records data for inflows for reservoirs and flows at various existing or potential hydro generating sites.
3. **Storage and spill:**
    - This time series dataset records storage for the main hydro schemes.

This report describes the second component of the HMD, the flow datasets.

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1 INTRODUCTION

This Hydrological Modelling Dataset (HMD) full update was requested by the Electricity Authority and includes data to 31 December 2025.

An interim update simply adds one year of data to the end of the previous full HMD update, whereas the full update from 2024 recalculated all data back to July 1931. This interim update includes data from 1 July 1931 to 31 December 2025.

The HMD consists of six datasets:

- Infrastructure attributes:

  Lists the changes over time to the 'plant factors' or 'average efficiency factors' for each of the power stations associated with the 10 largest reservoirs.

- Hydrological constraints:

  Lists the constraints put on hydrological parts of schemes usually via consent conditions. This was completed for the power stations associated with the 10 largest reservoirs in New Zealand.

- Actual flows:

  a) 'Actual' inflows or outflows to or from several reservoirs in New Zealand. The inflows are modelled data, the outflows are generally measured data;
  b) Tributary flows or local inflows into various reservoirs;
  c) Hypothetical 'actual' flows, i.e., flows which could occur under certain regimes; and
  d) Actual river flows at gauging stations which could be possible hydro-power schemes in the future; and
  e) Average daily outflows from daily derived flow records.

  Many of these are also part of the natural flow dataset.

- Natural flows:

  a) 'Natural' uncontrolled inflows to several reservoirs in New Zealand;
  b) Modelled natural inflows or tributary inflows to reservoirs, as though they are uncontrolled; and
  c) River flows at gauging stations which could be possible hydro-power schemes in the future.

  Many of these are also part of the actual flow dataset.

- Lake storage:

  Daily active storage volumes from 1980 to 2025 for the 10 largest hydro lakes in NZ.

- Spill volume:

  Average daily spill flow data for 25 sites in New Zealand including the 10 largest hydro-lakes and each of the structures downstream. Daily spill data is from 24:00 to 24:00 filed at the end of the day, identical to the daily actual and natural flow datasets.

The lake storage, spill volumes, infrastructure attributes, and hydrological attributes datasets were produced for the first time in 2015. Daily spill volumes were produced for the first time in 2020.

The average outflows of the reservoirs that are a part of the Waikato and Waitaki schemes were produced for the first time in 2017.

Flow routines for actual and natural flows are re-run for each update and new datasets created. These datasets are then compared with previous data to ensure continuity. Explanations of any differences between successive full update datasets are provided in a separate report – “Hydrological Modelling Dataset: HMD Flow Series Comparison” and are completed during a full update.

The following Power Companies have provided data for this update:

- Contact Energy Ltd
- Genesis Energy Ltd
- King Country Energy
- Meridian Energy Ltd
- Mercury Energy Ltd
- Pioneer Energy Ltd
- Manawa Energy Ltd

The HMD also relies heavily on data sourced from the Water Resources Archive, provided by the National Institute of Water and Atmospheric Research (NIWA), and funded by the Public Good Science Fund (PGSF). Flow series from several rivers form a fundamental component of the datasets discussed. Their inclusion aligns with the purpose of the Government funding that supports their collection.

Additional river flow series were provided by Hawkes Bay Regional Council and Environment Canterbury Regional Council. Their assistance with this project is gratefully acknowledged.

All input data records have been checked for gaps and, where necessary, these have been filled to provide continuous time series.

All data are recorded at daily intervals from 00:00-23:59 and filed at the 23:59 time step. This value represents the mean for the day.

1.1 CLIMATE CHANGE

The HMD is based on recorded flows, and the interaction of these flows with both hydro-electric power infrastructure and the consenting framework. No specific consideration is given to the future potential effects of climate change on the flow regimes of the various rivers.

The raw data, however, contains all the inherent climatic effects on the recorded flow regimes of the various rivers. Consequently, the data includes seasonality, persistence, and any climatic trends or cycles which have affected the flow regimes.

Where data have been synthesised, to fill gaps in the records, this has been based on correlation with the most appropriate ‘donor’ site, over the longest period of concurrent data. Consequently, the synthetic records include any effects of climatic variability inherent in the ‘donor’ record. Since the flow regimes for the two records have similar characteristics, hence their correlation, the transference of any climate signature is appropriate. However, since the longest period of concurrent record is used to derive the synthetic series, the correlation will include the average effect of any climatic variability of change over that time. Shorter-term climatic effects will not be apparent in the synthetic data. Such an approach is the best possible to synthesise periods of missing record, and results in the least error while still including any longer-term climate signature.

It should be noted that the use of daily average flows in the HMD provides significant smoothing of any minor effects of climate variability and change, especially the potential impact of short duration – high intensity flood events.

The HMD therefore contains all those actual longer-term climatic signatures which have affected the various rainfall-runoff relationships. Any shorter or more subtle trends are smoothed over periods of synthetic flow data. HMD does not provide any quantitative consideration of the potential effects of climate change in the future.

1.2 THE POWER ARCHIVE

A significant amount of input data for the HMD datasets is from the Power Archive. In the mid-late 1970s the Power Division of the Ministry of Works and Development commenced development of the Power Archive, a repository for all hydrometric data relating to the various hydro systems, reservoirs and dams throughout New Zealand. Over time the Power Archive evolved to include not only the hydrometric data but also various additional outputs such as machine flows, generation, spills, inflows, gate openings, and natural inflows and lake levels.

Management of the Power Archive has also moved over time from the Ministry of Works and Development to the Works and Development Services Corporation NZ, to Works Consultancy Services, Opus International Consultants Ltd, and currently, WSP.

With the break-up of the Electricity Corporation of New Zealand into several separate companies the Power Archive was also partitioned. While the majority of the original Power Archive is still maintained by WSP, several of the power companies have taken these services in-house, e.g., Manawa Energy and Genesis Energy. Ongoing maintenance of the Power Archive by WSP has ensured continuity and consistency of independently quality assured data for use in analysis and modelling.

Despite this partitioning of the Power Archive the various hydrometric and generation sets are still generally collectively referred to as the Power Archive.

1.3 QUALITY CODES

The National Environmental Monitoring Standards steering group (NEMS) has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEO) and the Ministry for the Environment (MFE) (NEMS, 2013).

These standards describe how to collect, process, retain and archive environmental data, using best practice methodologies. The NEMS incorporates a common National Quality Code Schema (NQCS) across all measured environmental parameters, which assigns a final Quality Code to the data. This code describes how the data meets the various requirements under each environmental standard; the degree of rigour in which the standard is applied affects the final quality of the data.

It was recommended that these standards be adopted throughout New Zealand and all data be collected, processed and quality coded appropriately.

The National Quality Code Schema is divided into six Zones of Quality within a numeric index which describes how the collected and processed environmental data meets the relevant standard. These six zones have a parent code summarising the overarching quality of the data; 100 represents Missing Record; 200 is Unverified or Cautionary Data; 300 is Synthetic; 400 is Poor Quality; 500 is Fair Quality; and 600 is Good Quality. To achieve Good Quality data requires each component of the standard to be practised; from the data collection stage to archiving.

The NQCS can be introduced in its basic parent form, or it can be expanded upon to provide more data quality detail by agencies where a greater level of detail is required; detail relating to data quality and operational requirements and standards. This expansion to the NQCS is called child coding. These child codes are currently allocated in-house and have therefore been developed to differentiate between data quality in the HMD.

Table 1-1 shows the quality codes used for the HMD. If no measured data was recorded, and replacement data could not be reasonably calculated, a missing record is filed with a quality code of 100 assigned to the null time period. The direct measurement of flow and the spill flow volumes were both coded as 200, because the quality of this data is non-verified. This number is a parent code and has been outlined by the NQCS. All of the rest of the quality codes used for the HMD are child codes that were created under the parent code of synthetic data (300). A 301 code denotes that the data was created via simple arithmetic, for example, Site 1 + Site 2. The 310 code is used when data is made via a correlation with another dataset, for example, when there is no

available data for a site, so a relationship is established with an adjacent station to correlate the data. The codes 320 and 325 represent data that has been manufactured, usually with calculations or models. The 330 code denotes that the data has been entered as the median flow, for example, for gap filling where other methods were not deemed appropriate. The 335 code describes data used to fill small gaps using a combination of correlation, visual interpolation and site-specific information from the recording authority to provide the most likely flow. The 340 code is used when the data has been replicated for larger periods of data. This may occur when whole or parts of years were replicated and entered to fill a piece of missing record, using a combination of correlation, calculation and modelling. This occurred often between 1931 and 1934 when there were a limited number of sites operating at this time. The last code is 350 indicates where the data is synthetic but is of an unknown origin, with no new suitable data or reliable methodology to derive that period of data that would be more representative.

Table 1-1: Description of the quality codes used for the HMD.

Code	Description
100	Missing Record
200	Unknown or non-verified quality
301	Simple arithmetic
310	Correlation
320	Manufactured via calculations or models (WSP)
325	Manufactured by the recording authority
330	Median flow
335	Small gap filling via correlation, calculation and interpolation
340	Replicated data
350	Unknown origin

1.4 DATASET CONSTRUCTION SUMMARY

The HMD data record for any of the flow series is often a composite record derived using different methods for different periods, as illustrated in Table 1-2 (North Island) and Table 1-3 (South Island).

Table 1-3 (South Island) lists the source of the record for each flow site and period. The quality code for each piece of the composite record is listed along with the definition of the quality code (Table 1-1). Small gaps and their associated quality code are not listed in the table; it provides the overarching quality for most of the data within each dataset. Manufactured (W) denotes the record is manufactured by WSP and Manufactured (RA) denotes the record has been manufactured by the recording authority.

Where records are not available or a scheme component was not commissioned for the early part of the period, such as the Ahuriri River at Benmore prior to 1949, synthetic flows are often used based on correlation with another flow record. This procedure can ensure that statistics, including the mean and standard deviation, of the simulated flows are as accurate as possible. However, the record has the unavoidable feature that the high and low flows in the simulated flow follow those of the flow site to which they are correlated. This can result in more extreme events in the overall generation system than would have occurred. Alternatively, it may result in a slightly compressed record with fewer extremes. As most of the simulated flows are relatively small, this is unlikely to have a major effect except when there is a focus on a specific flow event.

Table 1-2: Quality of HMD flow datasets for North Island flow sites.

Flow Site	Period	Quality Code	Code Definition
Arapuni tributaries	01/07/31 - 31/12/25	301	Synthetic – Simple Arithmetic
Karapiro tributaries	01/07/31 - 06/07/47	320	Synthetic – Manufactured (W)
	07/07/47 – 31/12/25	301	Synthetic – Simple Arithmetic
Tokaanu Linear	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Tokaanu TPD	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Taupō Linear	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Taupō TPD	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Taupō Natural	01/07/31 – 31/12/25	320	Synthetic – Manufactured (W)
Taupō Infrastructure	01/07/31 – 31/12/25	320	Synthetic – Manufactured (W)
Taupō Operational	01/07/31 – 31/12/92	310	Synthetic - Correlation
	01/01/93 – 31/12/25	320	Synthetic – Manufactured (W)
Rangipō Linear	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Rangipō TPD	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Waikaremoana	01/07/31 - 31/12/25	325	Synthetic – Manufactured (RA)
Matahina	01/07/31 – 31/12/66	350	Synthetic - Unknown
	01/01/67 – 31/12/25	325	Synthetic – Manufactured (RA)
Wheao	01/07/31 - 01/01/99	310	Synthetic - Correlation
	02/01/99 - 31/12/25	325	Synthetic – Manufactured (RA)
Mangahao	01/07/31 – 06/10/97	350	Synthetic - Unknown
	07/10/97 – 31/12/25	325	Synthetic – Manufactured (RA)
Pātea	01/07/31 - 01/01/99	310	Synthetic - Correlation
	02/01/99 - 31/12/25	325	Synthetic – Manufactured (RA)
Kaimai	01/07/31 - 10/07/93	310	Synthetic - Correlation
	11/07/93 - 31/12/25	325	Synthetic – Manufactured (RA)
Ngaruroro at Whanawhana	01/07/31 - 31/08/60	310	Synthetic - Correlation
	01/09/60 - 31/12/25	200	Actual
Ngaruroro at Kuripapango	01/07/31 - 19/09/63	310	Synthetic - Correlation
	20/09/63 - 31/12/25	200	Actual
Ngaruroro at Chesterhope	01/07/31 - 25/11/76	310	Synthetic - Correlation
	26/11/76 - 31/12/25	200	Actual
Mohaka at Raupunga	01/07/31 - 28/02/57	310	Synthetic - Correlation
	01/03/57 - 31/12/25	200	Actual

Table 1-3: Quality of HMD datasets for South Island flow sites.

Flow Site	Period	Quality Code	Code Definition
Waitaki tributaries	01/07/31 - 31/12/25	301	Synthetic – Simple Arithmetic
Benmore	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Benmore t_p	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
OhauRes	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Ohau	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Pūkaki	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Natural Pūkaki	01/07/31 - 31/12/25	301	Synthetic – Simple Arithmetic
Tekapo	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Natural Tekapo	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Manapōuri	01/07/31 – 07/09/69	320	Synthetic – Manufactured (W)
(with Mararoa)	08/09/69 - 31/12/25	301	Synthetic – Simple Arithmetic
Manapōuri	01/07/31 – 01/05/32	320	Synthetic – Manufactured (W)
(without Mararoa)	02/05/62 – 31/12/25	301	Synthetic – Simple Arithmetic
Manapōuri (water right reduction)	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Te Anau	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Monowai Inflow	01/07/31 – 30/04/77	310	Synthetic - Correlation
	01/05/77 - 31/12/25	320	Synthetic – Manufactured (W)
Roxburgh tributaries	01/07/31 - 31/12/25	301	Synthetic – Simple Arithmetic
Wānaka	01/07/31 - 31/12/25	200	Actual
Hāwea	01/07/31 - 31/12/25	320	Synthetic – Manufactured (W)
Cobb	01/07/31 – 21/11/45	310	Synthetic - Correlation
	24/11/45 – 31/12/25	325	Synthetic – Manufactured (RA)
Coleridge	01/07/31 – 31/12/50	320	Synthetic – Manufactured (W)
	01/01/51 – 31/12/25	325	Synthetic – Manufactured (RA)
Highbank	01/07/31 - 30/04/51	350	Synthetic - Unknown
	01/05/51 - 30/04/98	325	Synthetic – Manufactured (RA)
	01/05/98 - 31/05/02	350	Synthetic - Unknown
	01/06/02 - 31/12/25	325	Synthetic – Manufactured (RA)
Waipori	01/07/31 – 31/12/87	350	Synthetic - Unknown
	01/01/88 – 16/09/97	310	Synthetic - Correlation
	17/09/97 – 30/06/10	200	Actual
	01/07/10 – 18/05/12	310	Synthetic - Correlation
	19/05/12 – 31/12/25	200	Actual
Grey + Taramakau (No Taipo) (CLOSED)	01/07/31 – 31/12/15	320	Synthetic – Manufactured (W)

Grey + Taramakau (No Taipo)	01/07/31 – 31/12/25	320	Synthetic – Manufactured (W)
Clarence at Jollies	01/07/31 - 27/03/34	340	Synthetic – Replicated Data
	28/03/34 - 31/12/59	310	Synthetic - Correlation
	01/01/60 - 31/12/25	200	Actual
Waiau at Glenhope	01/07/31 – 31/01/74	310	Synthetic - Correlation
	01/02/74 – 05/07/99	200	Actual
	06/07/99 – 26/09/03	310	Synthetic - Correlation
	27/09/03 – 17/07/08	200	Actual
	18/07/08 - 31/12/25	310	Synthetic - Correlation
Waiau at Marble Point	01/07/31 - 06/10/67	310	Synthetic - Correlation
	07/10/67 - 31/12/25	200	Actual
Wairau at Dip Flat	01/07/31 - 29/03/34	340	Synthetic – Replicated Data
	30/03/34 - 31/05/51	310	Synthetic - Correlation
	01/06/51 - 31/12/25	200	Actual
Hurunui at Mandamus	01/07/31 - 29/03/34	340	Synthetic – Replicated Data
	30/03/34 - 25/10/56	310	Synthetic - Correlation
	26/10/56 - 31/12/25	200	Actual
Hurunui at SH1 Bridge	01/07/31 - 13/12/74	310	Synthetic - Correlation
	14/12/74 - 18/06/99	200	Actual
	19/06/99 - 17/08/00	310	Synthetic - Correlation
	18/08/00 – 31/12/25	200	Actual
Lake Onslow	01/07/31 – 31/12/25	310	Synthetic – Correlation

1.5 UPDATE TO HILLTOP SOFTWARE

As of 2017, all scripts used as part of the HMD update, whether for a full update or an interim update, have been converted from Tideda scripts into Hilltop Manager using the vimsim scripting language (commonly referred to as creating virtual measurements). This means none of the calculations are derived in Tideda software, with all data analysis, scripting and graphing carried out in Hilltop and packages associated with this software.

This software has increased accuracy as it stores the entire number, rather than rounding to a whole number. This will result in differences due to rounding when comparing HMD outputs pre 2022 and this has been addressed in subsequent full update comparison analysis and reports.

1.6 SUMMARY AND DESCRIPTION OF FLOW SITES

A summary of each of the HMD flow sites is listed in Table 1-4 for the North Island and Table 1-5 for the South Island.

Table 1-4: North Island flow dataset names and mean values derived for this HMD update (2025).

Flow	Model flow name	Flow site number*	Description	Mean flow (m^3/s)	Type
Arapuni Tribs	Arapuni	92724 (1)	Waikato tributary flow between Taupō and Arapuni PS	82.04	A
Karapiro Tribs	Karapiro	92714 (1)	Waikato tributary flow between Taupō and Karapiro PS	90.82	A
Tokaanu	TokaanuTPD	92790 (3)	Non-linear correlations of Taupō natural inflows used to create Tokaanu inflow	52.53	A
	Toka_Linear	22790 (3)	Linear correlations of Taupō natural inflows used to create Tokaanu inflow	53.10	A
Taupō	TaupoTPD	92790 (1)	Sub catchment inflows non-linear functions of Taupō inflows to create Taupō inflows including TPD diversions using 1995-2004 consent conditions	155.94	A
	Taupo_Linear	22790 (1)	Linear correlations of Taupō natural inflows used to create Taupō inflows including TPD diversions	154.05	A
	Taupo_Actual	42790 (1)	Rating distribution correlates TPD flow and Taupō inflow, based on the 1993 to 2005 operating regime to create Taupō inflows including TPD diversions. Reflects the current operating regime.	140.44	A
	Taupo_ Infra	72790(1)	Non-linear correlations of Taupō natural inflows used to create Taupō Inflows including TPD Diversions using consent conditions as active from 2004 to present	149.22	A
Natural Taupō	Nat_Taupo	62790(1)	Natural Taupō Inflow	125.99	N
Rangipō	RangipoTPD	92790 (2)	Sub-catchment inflows are based on non-linear function of Taupō inflows to create Rangipō inflows. Incorporates latest water right discharges.	34.67	A
	Rangi_linear	22790 (2)	Linear correlations of Taupō natural inflows used	28.76	A
Waikaremoana	Waikaremoana	3650 (1)	Waikaremoana Inflows	17.78	N+A
Matahina	Matahina	93254 (1)	Matahina Inflows	64.53	A
Wheao	Wheao	15462(1)	Wheao/Flaxy Power Station outflow	12.55	A
Mangahao	Mangahao	97502(1)	Local inflows	8.99	A
Pātea	Patea	34300(1)	Pātea Power Station outflow	20.02	A

Flow	Model flow name	Flow site number*	Description	Mean flow (m^3/s)	Type
Kaimai	Wairoa	14130(1)	Kaimai outflows at Ruahihi	11.91	A
Ngaruroro	Whanawhana	123103 (1)	Ngaruroro River flow at Ngaruroro at Whanawhana recorder	34.86	N+A
	Kuripapango	123104 (1)	Ngaruroro River flow at Ngaruroro at Kuripapango recorder	17.74	N+A
	Chesterhope	123150 (1)	Ngaruroro River flow at Ngaruroro at Chesterhope recorder	43.77	N+A
Mohaka	Raupunga	121801 (1)	Mohaka River flow at Mohaka at Raupunga	79.04	N+A

"N" denotes a natural flow, uncontrolled flow
"A" denotes an actual flow
"N+A" denotes a flow that is both actual and natural
(*) Denotes item number of historic Tideda file, data is now stored in Hilltop Manager and uses the primary number

Table 1-5: South Island flow dataset names and mean values derived for this HMD update (2025).

Flow	Model flow name	Flow site number*	Description	Mean flow (m^3/s)	Type
Waitaki P.S. Tribs	Waitaki	98714 (2)	Waitaki tributary flows between Lakes Pūkaki & Tekapo and Waitaki Lake relative to Waitaki Power Station	152.12	A
Benmore	Benmore	98614 (4)	Waitaki tributary flow between Lakes Pūkaki & Tekapo and Benmore (Separate Tekapo simulation) and includes Tekapo spill	132.96	A
	Ben_tp	98615 (2)	Waitaki tributary flow between Lakes Pūkaki & Tekapo and Benmore (Combined lakes Tekapo - Pūkaki simulation) which is Ōhau inflow plus the scaled Ahuriri River flow	123.46	A
Ōhau (separate Tekapo model)	OhauRes	98614 (6)	Ōhau A only, residual flows of $12m^3/s$ May to Oct and $8m^3/s$ Nov to Apr	70.22	A
	Ohau	98614 (3)	Ōhau B and C only. Assumes all Ōhau inflow flows into Ōhau B and C	80.20	N+A
Pūkaki	Pukaki	98614 (2)	Pūkaki inflows including Tekapo outflows, removing the Tekapo B station discharges from 1977 to avoid duplication	196.17	A
Natural Pūkaki	Nat_Puk	98770 (1)	Natural Lake Pūkaki inflow	127.02	N
Tekapo	Tekapo	98614 (1)	Separate Tekapo simulation	69.29	A
Natural Tekapo	Nat_Tek	98770 (2)	Natural Lake Tekapo Inflow	83.95	N+A
Manapōuri	Manawmara	99551 (1)	Manapōuri local inflows allowing for Mararoa dirty water spill	136.78	A

Flow	Model flow name	Flow site number*	Description	Mean flow (m^3/s)	Type
	Manapouri	99550 (1)	Manapōuri local inflows with no Mararoa input	122.69	N
	Manareduced	99552 (1)	Manapōuri local inflows allowing for Mararoa dirty water spill, 12, 14 and 16m^3/s min flow from MLC, flushing and recreational releases from MCL	125.10	A
Te Anau	Teanau	9570 (1)	Te Anau Inflows	285.21	N+A
Monowai	Mono_Inflow	199540 (1)	Monowai Power Station inflows based on the measured downstream flow sites of the Monowai River	12.91	N+A
Roxburgh	Roxburgh	99110 (1)	Roxburgh tributary flows – but excluding Hāwea outflows	447.77	A
Wānaka	Wanaka	9154 (1)	Wānaka outflows	198.83	N+A
Hāwea	Hawea	9170 (1)	Hāwea inflows	64.70	N+A
Cobb	Cobb	97904 (2)	Cobb inflows	5.34	N+A
Coleridge	Coleridge	97904 (1)	Coleridge inflows	24.65	A
Highbank	Highbank	7968(1)	Highbank Power Station outflow	13.38	A
Waipori	Waipori	174395(1)	Waipori Power Station outflow	7.37	A
Grey+ Taramakau-Taipo	Grey_tara_closed	77106(1)	Grey River at Dobson including Taramakau but not Taipo. This site is now closed because the Taramakau dataset is unavailable, requiring a new methodology for calculation	437.36	A
Grey+ Taramakau-Taipo	Grey_tara	77106(2)	Grey River at Dobson including Taramakau but not Taipo. Calculated by correlating the available Taramakau with the (now available) Taipo record to get an extended record for Taramakau, to then derive the Grey River+Taramakau-Taipo dataset	433.23	A
Waiau	Clarence	162105 (1)	Waiau River flow at Clarence at Jollies recorder	14.40	N+A
	Glenhope	164604 (1)	Waiau River flow at Waiau at Glenhope recorder	33.72	N+A
	Marble Point	164602 (1)	Waiau River flow at Waiau at Marble Point recorder	94.01	N+A
Wairau	Dip Flat	160114 (1)	Wairau River flow at Wairau at Dip Flat recorder	26.68	N+A
Hurunui	Mandamus	165104 (1)	Hurunui River flow at Hurunui at Mandamus recorder	51.27	N+A
	SH 1 Bridge	165101 (1)	Hurunui River flow at SH1 Bridge	66.43	N+A

Flow	Model flow name	Flow site number*	Description	Mean flow (m^3/s)	Type
Lake Onslow	Onslow	175237 (1)	Lake Onslow Inflows simulated from a correlation based on catchment area from Waipori	2.93	N+A

"N" denotes a natural flow, uncontrolled flow
"A" denotes an actual flow
"N+A" denotes a flow that is both actual and natural
(*) Denotes item number of historic Tideda file, data is now stored in Hilltop Manager and uses the primary number

2 ACTUAL FLOWS

2.1 NORTH ISLAND

2.1.1 WAIKATO (ARAPUNI AND KARAPIRO)

For the HMD flow series, tributary flow is calculated at Arapuni and Karapiro. Flow records at Karapiro do not begin until 1947 and the earlier record has been simulated from the Arapuni record.

Tributary flows at Arapuni are calculated simply by subtracting the Taupō outflows from the outflows at Arapuni. Karapiro tributary flows are calculated similarly for the period of actual record (7 July 1947 – present) and are simulated from Arapuni tributary flows, scaled up by 20%, for the period before 1947 (Halliburton, December 1993).

2.1.2 TOKAANU, TAUPŌ AND RANGIPŌ

The Tongariro Power Development (TPD) simulation has undergone revision over time, to incorporate changing hydrological infrastructure, constraints and optimisation of flow regimes. This has resulted in the creation of three individual modelling datasets that represent the Taupō Inflows, along with two datasets of inflows at Rangipō and Tokaanu.

In the 2018 full update, two additional Taupō Inflow series were further created, to model the Natural Taupō Inflows and the Taupō Inflow regime incorporating only the consents active from 2004.

Each of these datasets are described in detail below that are created as part of the HMD update.

2.1.2.1 SITE 22790

Site 22790 was the original Taupō, Tokaanu and Rangipō inflow simulation at each of these locations in the TPD scheme. It uses four input sites: Taupō Inflows (2790), Waihohonu at Desert Road, Wairehu Canal at Gauging Bridge and Lake Moawhango Inflows. Using linear calculations and correlations, the inflow series are derived, with the original minimum flow conditions and infrastructure as at 1993 included. The original Tideda script used was TAUPŌ.SIM. The datasets are back calculated to July 1931.

This site was superseded in 1996 by site 92790, following the conclusions from the 1992 Waikato River consent hearing. These datasets are still included in the HMD update for historical reference.

In 2020, the historic Tideda script was updated into Hilltop Manager software. This has resulted in differences due to rounding for the 2020 update. Using Hilltop is now the standard practise moving forward for the HMD update.

2.1.2.2 SITE 92790

Following an extensive revision of the TPD simulation (Henderson, 1996) to incorporate minimum flow rules at Te Maire on the Whanganui River, Tūrangi and Poutū Intake on the Tongariro River, and different rules about spill at Rangipō Intake and flows at Waikato Falls, site 92790 was created for Taupō, Tokaanu and Rangipō Inflows. Several logical errors in the previous simulation (pre-1996) were also corrected. Consequences of the changes introduced were:

- 2.5m³/s increase in Taupō inflows;
- 6.2m³/s increase in Rangipō flows;
- 2.1m³/s decrease in Tokaanu flows; and
- 1.2m³/s increase in Western Diversion flows.

Using the derived Taupō Natural Inflow series from the Total Inflow series, this dataset simulates the flow series at various rivers, canals and reservoirs within the TPD scheme using non-linear correlations, incorporating the change in infrastructure constraints to model the inflows back to 1931. It used two scripts that have now been converted into Hilltop as of 2022; TAUPŌFUN.SIM and TAUPŌTPD.SIM which detail the inputs and various rules of the simulation. This simulation therefore supersedes site 22790 as it optimises the flow regime and uses the consents following the 1992 Waikato consent hearing.

From 1 December 2004 further consent conditions were introduced, which required increased releases to the Whanganui River from the Western Diversions, and therefore a reduction in flows diverted to Lake Taupō. Following a detailed review (Opus, 2016), a new simulation and site was created using the operational Taupō Inflow series. This dataset, site 72790, more accurately incorporates the observed changes of Tongariro Power Development Foreign Inflows (TPD Inflows) into Lake Taupō than site 92790. Therefore, site 92790 is superseded by site 72790 to represent the present-day infrastructure back calculated to 1932.

Site 92790 for Tokaanu, and Rangipō Inflows, were not reviewed at this time, and therefore remain as the primary inflow series for these sites, superseding site 22790 for their respective inflows.

2.1.2.3 SITE 42790

In 2015 a new dataset was created to represent the ‘actual’ Taupō Inflows, as used by Mercury. This dataset is part of the Power Archive and is derived from the relationship between measured Lake Level and measured Total Outflow from Lake Taupō. It is derived from Taupō Total Inflow, site 2790, and is used as part of site 22790.

This operational inflow dataset more accurately represents the true TPD operating regime, as it captures the changing infrastructure through time; from July 1931 to September 1969 the flows mirror the Taupō natural inflows, before the addition of TPD Foreign inflows into the lake. After 1969 the flow regime changes as new infrastructure is built. Step-changes are also observable in the dataset where changes to consent operations impact the actual inflows into Lake Taupō. This dataset therefore reflects the changes to minimum flow regimes in the wider catchment through time and should be used to represent the actual inflows into Lake Taupō.

This dataset is provided from the Power Archive for each update, therefore any changes between updates reflects data corrections, rating changes, or other forms of modifications following review and auditing of the dataset.

2.1.2.4 SITE 62790

In 2018 a new dataset was requested by the Electricity Authority to show the naturalised inflow series into Lake Taupō. This dataset had been used as an input site for 92790 and 42790 historically but had not been included as part of the HMD update as an individual site.

This dataset is derived from a correlation of the recorded Lake Level and Net Outflow from Lake Taupō, which requires the Tongariro Power Development (TPD) Foreign Inflows dataset from Genesis. Any changes to the TPD dataset will impact the naturalised series, and therefore sites 92790, 42790 and 72790.

This dataset is the simulated natural inflow into Lake Taupō if there was no TPD scheme and therefore has less flow than the actual total inflow for Lake Taupō.

2.1.2.5 SITE 72790

Following a detailed review of the Taupō Inflow simulation regime of site 92790 and site 42790 (Opus, 2016) a new Taupō Inflow dataset was created, with the purpose of being included in future HMD updates. Site 72790, the Taupō Inflow Infrastructure dataset, was created to represent the current operating regime back calculated to 1931.

The site is derived by correlating the TPD Inflows with the actual total inflow series (i.e., site 42790) from 2004-2025, to back calculate the TPD Inflows to 1931. This means the most recent consent conditions are used. This extended TPD inflow series is then added to the naturalised Taupō inflow series, i.e., site 62790 from 1931 to 2004, with the actual Taupō Inflows used from 2004 to the present. The result is a Taupō Inflow series which represents the theoretical inflow into Lake Taupō, if the 2004 consents were active from 1931.

This site supersedes site 92790 for Taupō Inflows in representing the current infrastructure back to 1931, as it uses the most up to date information.

2.1.2.6 PROCESS TO CALCULATE TPD FLOW SITES

A detailed summary of how each of the sites used to create the above sites is described below.

Net Taupō outflows

Subtract recorded diversion flows (Wairehu Canal and Moawhango Tunnel) from Taupō outflows to give net Taupō outflows. Genesis provides a dataset called 'TPD Foreign Inflows' which includes all flows that have been diverted into Lake Taupō.

Taupō total inflows (site 2790)

Uses total inflows data from the Power Archive. This is calculated on a monthly basis as part of the Mercury Energy monthly Power Archive update. It is used to create site 42790, which is identical where actual measurements are, with data prior to TPD Foreign Inflows simulated with the natural inflow record back to 1931.

Taupō natural inflows (site 62790)

Uses the net Taupō outflows and Lake Level data from Lake Taupō, along with TPD Foreign Inflows dataset provided by Genesis.

Outline of TAUPŌFUN.SIM, now in Hilltop

Uses full record of Taupō Natural Inflows (62790) as input to TAUPOFUN.SIM which has been converted into Hilltop vimsim language.

Apply non-linear transformations to Taupō natural inflows, to simulate flows at the following locations in the scheme:

- Western Diversion with no minimum flow rules
- Tongariro at Tūrangi natural flows
- Natural inflow to Lake Rotoaira
- Natural inflows to the lower Tongariro above Tūrangi and downstream of Poutū Dam and Poutū Intake.
- Natural inflows to the middle Tongariro between Rangipō Dam and Poutū Intake
- Natural flows in the Tongariro River at Rangipō Dam
- Natural flows in the Waihohonu Stream at Waihohonu Tunnel
- Natural inflows to Lake Moawhango
- Flows in the Wahianoa Aqueduct at Mangaio Tunnel
- Natural flows in the Whanganui River at Te Maire

Outputs were then used in the TAUPOTPD.SIM, which was converted into Hilltop vimsim language and stored in virtual measurements in 2022.

Merge modelled natural flows

Overwrite modelled flows from the TAUPOTPD.SIM script at all locations listed above (except Wahianoa Aqueduct) with simulated natural flows based on recorded data.

Outline of TAUPOTPD.SIM, now in Hilltop

- Model effect of Te Maire minimum flows to reduce Western Diversion flows
- Add Waihohonu tunnel flows to Rangipō and subtract from mid Tongariro
- Add Wahianoa flow to Moawhango inflow
- Model Lake Moawhango operation and Moawhango Tunnel flows
- Determine Poutū spill required
- Determine Rangipō spill required
- Determine if Rangipō (and Moawhango) should be shut down because flows too high
- Calculate total available flow at Rangipō
- Calculate total available flow at Tokaanu
- Calculate Taupō inflow including diversion flows for full record

More detail is given for the various components below:

Net Taupō outflows – Because the next step uses an algorithm based on the idea of natural river flow recessions, the net outflows are needed rather than the total outflows as recorded. Taupō net outflows are those that would have occurred if no additional water was diverted into the catchment, i.e., the TPD Foreign Inflows subtracted from the Total Outflow of Lake Taupō.

Taupō natural inflows – A lake inflow algorithm that takes lake levels and net outflows and calculates inflows that have realistic recession shapes, so that the resulting inflow time series is useable for simulation of natural flows at other locations. Previous inflows have had erratic behaviour especially at low flows, caused by fluctuations in recorded levels because of atmospheric effects on the lake, and fluctuations in outflows caused by generation requirements. Taupō natural inflows are those, which would have flowed into Lake Taupō anyway; so, no adjustment is necessary here. It is the Taupō Natural inflow record, which is used to extend shorter low flow records, and to simulate the flows that would have occurred at various flow sites, had they been as they are today back in 1932.

Flow transformations – Data recorded in the rivers and diversions of the scheme have been used to model natural flows at various locations since 1960 when data recording began. The result of this work, done mostly as part of resource consent studies and for the Whanganui Minimum Flows Appeal, has been used to derive a set of non-linear transformations. These quasi-quadratic functions allow the transformation of Taupō natural inflows into time series that preserve the flow distribution of the modelled series. This means that not only the mean but also higher order moments of the modelled series are preserved. Linear regressions would only preserve the mean if the relationship modelled is in fact linear. These considerations are particularly important when using the modelled series to simulate rules that involve minimum flows and flood flows.

Merge modelled natural flows – Application of the flow transformations is for the full length of record (1931 to present). A better estimate of natural flow at each location since approximately 1960 can be gained by using the model data that was used to derive the transformations. This has the advantage that during extreme events flows at all flow sites will be independently measured, rather than a scaled version of Taupō inflows. The true magnitude of extremes will thus be better estimated.

Western Diversion – The flow in the Western Diversion, as if it were run with no releases down the Whakapapa River, is modelled by transforming Taupō natural inflows. The result is a natural looking hydrograph with a maximum value of 41.6m³/s. Flow in the Whanganui River at Te Maire is also modelled by transforming Taupō natural inflows. The Western Diversion flow is subtracted from the modelled Te Maire flow, and the result tested against the new minimum flow rule (29m³/s from 1 December to 31 May each year, no rule at other times). If

the rule is violated, water is released from the Western Diversion to meet it. This means, at times, there is no diversion of water.

Eastern Diversion and Tongariro – Inflows to various parts of the Tongariro River are determined. Flows above Rangipō are derived by subtracting these modelled flows from modelled flows at Tūrangi. Waihohonu River diversion flows and Moawhango inflows (including Wahianoa Aqueduct flows) are calculated and the "total flows at Rangipō (RangipoTPD)" are then determined by adding these to the Tongariro flow at Rangipō.

The contribution to flow at Tokaanu from the Tongariro River is calculated by adding Rangipō inflows to the Tongariro inflows between Rangipō and Poutū and subtracting Poutū spill (Moawhango Tunnel contribution is included at each step so that the tunnel capacities are properly dealt with).

Rotoaira local inflows are calculated and the minimum release (0.6m³/s) into Poutū Stream is subtracted. Finally, the Western Diversion flows and Poutū Tunnel flows are added to the Rotoaira local inflows and water diverted from the Tongariro River to establish the "total flow available at Tokaanu Power Station (TokaanuTPD)".

Taupō Inflow – The "total inflow to Lake Taupō (TaupoTPD)", incorporating diverted water from the TPD scheme. This is achieved by a lake inflow algorithm that uses Lake Level and Total Outflow from Lake Taupō, and is part of the Power Archive, calculated on a monthly basis for Mercury.

2.1.3 WAIKAREMOANA

Inflow records for Lake Waikaremoana go back to 1929. Inflows to individual scheme components were not originally available and so inflows were based on flows at Tuai Power Station. These include leakage but do not include water spilled at the Kaitawa gates which is not recaptured at the Whakamarino canal intake. Waikaremoana inflow data has been revised and improved in the past and the methods that were used to recalculate the inflows can be found in Works Consultancy Services Ltd "Hydrological Data Reference Manual; Lake Waikaremoana Inflow Data 1929 to 1995" (Greer *et* al., 1996).

However, from June 2001 onwards, Genesis Energy has calculated Waikaremoana inflows directly. Data supplied for HMD updates suffer from negative inflows because of leakage associated with Lake Waikaremoana. At the request of the Electricity Authority, negative inflows supplied were set to zero for the purposes of water balance modelling, though the data from Genesis Energy still contains the negative values. Genesis Energy are working on ways to solve this negative inflow issue.

2.1.4 MATAHINA

Flows are available for the Matahina Power Station since its commissioning in 1967. From 1948 to 1967 flows are simulated from the Rangitaiki River at Te Teko and prior to 1948 from Lake Taupō outflow.

Feedback highlighted that the synthetic data prior to 1948 appears to be inconsistent with the later record, i.e., the standard deviation for this period is 50% lower. This difference is most likely caused by the inability of the simulation process to accurately model flood events. The resulting apparent reduction in the magnitude of floods has a significant influence on the standard deviation. Since the energy generation potential of the river is most strongly related to the average flow conditions, this inconsistency for a period of the data record is not regarded as significant.

This flow site is not recalculated back to 1931 as part of a full HMD update; it is only calculated as far back as the data provided. The data are supplied by the parent company and is simply appended to the previous dataset. Matahina outflows – 93254 (1) is one of these flow sites where it is treated the same as in an interim update as a full HMD update.

2.1.5 WHEAO/FLAXY

Historically, data for the Wheao Power Station outflows was supplied by Trustpower (now Manawa Energy) from 1999 to 2016. It was therefore necessary to extend this record back from 1999 to 1931. Data was available from Rangitaiki at Murupara from 1948 to 2008.

To create a synthetic record for Rangitaiki at Murupara from 1948 back to 1931, a flow distribution rating (obtained via analysis of Taupō Natural Outflows and Rangitaiki at Murupara) was applied to Taupō Natural Outflow.

To reduce the Rangitaiki at Murupara flow range to resemble Wheao Power Station flows, another flow distribution rating was derived using Rangitaiki at Murupara and Wheao Power Station. This flow distribution was then applied to actual and synthetic Rangitaiki at Murupara data to derive synthetic Wheao flow data.

This flow site is not recalculated back to 1931 as part of a full HMD update; it is only calculated as far back as the data provided. The data is supplied by Manawa Energy and simply appended to the previous dataset unless additional historic data is provided i.e. it is treated the same as in an interim update as a full HMD update.

Care was taken to maintain the water balance of the power station output. Table 2-1 details the mean flows for the synthetic and actual data.

Table 2-1: The mean actual and synthetic outflow data for the Wheao power station.

Record	Record Length	Mean Flow (m^3/s)
Actual Wheao Power Station	1999-2007	12.5
Synthetic Wheao Power Station*	1999-2007	12.3
Actual and Synthetic Wheao Power Station	1931-2025	12.6

*Prior to superimposing the actual Wheao record over the HMD series

2.1.6 MANGAHAO

Because of the limited data available for the Mangahao Power Scheme a simulated No.2 reservoir inflow record has been produced (Freestone & Maslin, October 1991). The No.2 inflow record represents 97% of the total scheme inflow; the remaining 3% comes from the Arapeti (No.3) catchment. The synthetic record is based on a series of different methods each considered appropriate for a period of the schemes history. A trend is apparent when the cumulative deviation from the mean is examined for the synthetic record. However, this has been compared with the Manawatū River record and is considered to be real.

Machine flows were calculated using a modified cumecs to megawatt ratio based on analysis of individual machine loads (G1, G2 and G3) and accusonic data over the 1996 year. Revised cumecs/MW ratios of 0.431 (G1 Francis) and 0.503 (G2 and G3 Peltons) were also calculated. As of 2022, G1 used a ratio of 0.435 and G2 and G3 a ratio of 0.51. The MH generator data has also been provided, with a ratio of $6m^3/s$ per megawatt.

Mangahao data from 8 October 1997 to 31 December 2025 are actual data. Inflow data are based on spill from the No. 2 dam and machine generation, i.e., outflows. King Country Energy have noted however, that the communications cable downstream of No2 Dam has had issues in the past, with spill data from 28-April-2013 until 2017 deemed unreliable and has been replaced with spill data from No. 1 Dam. This should be quite accurate as the tipgate position is used to calculate spill flows. It does not include spill flows less than $1m^3/s$. For HMD updates after 2018, No. 2 dam spill and machine generation data was provided and combined to represent the inflows.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by KCE/Manawa Energy and is simply appended to the previous dataset unless additional new data is provided i.e. it is treated the same as in an interim update as a full HMD update.

2.1.7 PĀTEA

The synthetic outflow data for Pātea Power Station was created in 2007. Data for this power station was historically supplied by Trustpower (now Manawa Energy) from 1999 to 2007. It was therefore necessary to extend this record back from 1999 to 1931. To do this, data from Pātea River at Mangamingi and McColls were used.

The Pātea at Mangamingi record begins in April 1975 and ends in April 1984. The Pātea at McColls record runs from November 1986 to July 1995. Data from these two flow sites were combined to give a non-continuous record from 1975 to 1995.

To create a synthetic record for Pātea from 1975 back to 1931, a flow distribution rating (obtained via analysis of Taupō Natural inflow and combined Pātea) was applied to Taupō Natural inflow.

To reduce the combined Pātea flow range to resemble Pātea Power Station flows another flow distribution rating was derived using combined Pātea and Pātea Power Station. This flow distribution was then applied to actual and synthetic Pātea data to derive synthetic Pātea flow data.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa Energy and is simply appended to the previous dataset unless additional new data is supplied i.e. it is treated the same as in an interim update as a full HMD update.

Care was taken to maintain the water balance in the Pātea River. Table 2-2 details the mean flows during the record for the synthetic and actual data.

Table 2-2: The mean outflow for Pātea Power Station and Pātea River.

Record	Record Length	Mean Flow (m^3/s)
Pātea at Mangamingi	1975-1984	24.2
Pātea at McColls	1986-1995	28.1
Pātea Power Station	1999-2007	18.5
Synthetic Pātea Power Station Data*	1999-2007	16.9
Actual and synthetic Pātea Power Station	1931-2025	20.0

*Prior to superimposing the actual Pātea record over the HMD series

2.1.8 KAIMAI

The SPECTRA dataset for the Kaimai scheme was created in 2007 using flow site 14132 Wairoa at Power Station. The flow site begins July 1993 and finishes in February 2007. The Wairoa at Power Station record was extended back from 1993 to 1931. Synthetic data was created by analysing simulated natural Taupō inflow and Wairoa at Power station and applying the distribution rating to the simulated natural inflow record at Lake Taupō. Actual data is now recorded at the generation outflow from Ruahihi powerhouse representing the Kaimai outflow.

Actual data and synthetic data were combined to provide a flow record for Wairoa at Power Station from 1931 to 2025.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa Energy and is simply appended to the previous dataset unless additional new data is provided i.e. it is treated the same as in an interim update as a full HMD update.

Table 2-3 shows the mean flow for each record for synthetic and actual data. Comparisons were made to ensure a similar water balance was maintained for Kaimai outflows at Ruahihi when creating synthetic data.

Table 2-3: The mean outflow for Kaimai at Ruahihi.

Record	Record Length	Mean Flow (m^3/s)
Wairoa at Power Station	1993-2007	12.0
Synthetic Wairoa at Power Station*	1993-2007	12.1
Actual and synthetic Kaimai at Ruahihi	1931-2025	11.9

*Prior to superimposing the actual Wairoa record over the HMD series

2.1.9 NGARURORO RIVER, HAWKES BAY

In a previous Opus report, "Additional SPECTRA Investigations" (Payne, 2005), five possible hydro-power schemes were identified along the Ngaruroro River. The HMD series have been developed at three of the flow recording sites to represent flows at these schemes; Ngaruroro at Whanawhana, Ngaruroro at Kuripapango and Ngaruroro at Chesterhope Bridge.

2.1.9.1 NGARURORO AT WHANAWHANA

The longest flow record in the vicinity of the Ngaruroro River is the Ngaruroro at Fernhill data. This record extends back to 1953. Unfortunately, no gaugings were available at this flow site between 1974 and 2005 resulting in unrealistic flows. Consequently, data from this period could not be used. The Ngaruroro at Whanawhana record, which extends back to 1960, is used instead. The Ngaruroro at Whanawhana recorder was correlated with the longer Lake Waikaremoana inflow record to extend the HMD series back to 1931.

The best correlation was obtained through a distribution rating of the Lake Waikaremoana record (1960-2001). The distribution of flow in the resulting dataset is similar to the actual distribution of flow, therefore the Ngaruroro at Whanawhana record is used from 1960 to present.

Inflow to Lake Waikaremoana is calculated from lake level and outflow data. The resulting Ngaruroro at Whanawhana rated record between 1931 and 1960 has some lake level characteristics, including a greater number of flood events. Care was taken to maintain the water balance in the river.

Table 2.4: Ngaruroro at Whanawhana mean flow

Record	Record Length	Mean Flow (m^3/s)
Ngaruroro at Whanawhana	1960-2001	35.2
Rated Ngaruroro at Whanawhana*	1960-2001	34.9
Rated Ngaruroro at Whanawhana	1931-2025	34.9

*Prior to superimposing the actual Whanawhana record over the HMD series

2.1.9.2 NGARURORO AT KURIPAPANGO

The Ngaruroro at Kuripapango record begins in 1963. This record was extended back to 1931 through a distribution correlation with the extended Ngaruroro at Whanawhana record. The distribution rating compared flow data over the period 1963 to 2006. Actual data from the Ngaruroro at Kuripapango record is appended to the rated data. Care was taken to maintain the water balance in the river. Table 2.5 details the mean flows during the record correlation phases.

Table 2.5: Ngaruroro at Kuripapango mean flow

Record	Record Length	Mean Flow (m^3/s)
Ngaruroro at Kuripapango	1963-2005	17.2
Rated Ngaruroro at Kuripapango*	1963-2005	17.1
Rated Ngaruroro at Kuripapango	1931-2025	17.7

*Prior to superimposing the actual Ngaruroro at Kuripapango record over the HMD series

2.1.9.3 NGARURORO AT CHESTERHOPE BRIDGE

The Ngaruroro at Chesterhope Bridge record begins in 1976. This record was extended back to 1932 through a distribution correlation with the extended Ngaruroro at Whanawhana record. The distribution rating compared flow data over the period 1976 to 2006. Actual data from the Ngaruroro at Chesterhope Bridge record is applied to the rated data. Gaps in the Chesterhope Bridge record are filled from the synthetic data.

The data showed very low summer flows in 1948 and 1954. The rest of the synthetic data is reasonable. Care was taken to maintain the water balance in the river. Table 2.6 details the mean flows during the record correlation periods.

Table 2.6: Ngaruroro at Chesterhope Bridge mean flow

Record	Record Length	Mean Flow (m3/s)
Ngaruroro at Chesterhope Bridge	1976-2005	41.8
Rated Ngaruroro at Chesterhope Bridge*	1976-2005	41.3
Rated Ngaruroro at Chesterhope Bridge	1931-2025	43.8

*Prior to superimposing the actual Ngaruroro at Chesterhope Bridge record over the HMD series

2.1.10 MOHAKA RIVER, HAWKES BAY

The longest flow record on the Mohaka River is the Mohaka at Raupunga recorder. This record extends back to 1957. The Mohaka at Raupunga record was correlated with the Lake Waikaremoana inflow record to extend the HMD series back to 1931.

On 6 January 1985 a large landslide occurred upstream of the Raupunga gauge. This suppressed flow at the gauge significantly for approximately 10 hours and impacted on flows for approximately three days. The low stage value resulting from the landslide was removed from the data for the distribution analysis to provide a normal distribution of data.

The best correlation was obtained through a distribution rating of the Lake Waikaremoana inflow record comparing flow data over the period 1957-2001. The distribution of flow in the resulting dataset is like actual flow at the high end of the spectrum. Flows at the low end of the spectrum are slightly lower than the actual record.

Inflow to Lake Waikaremoana is calculated from lake level and outflow data. The resulting Mohaka at Raupunga rated record between 1931 and 1957 has some lake level characteristics, including a greater number of oscillations. Rated low flows are slightly lower and more common than in the actual record as the lake inflow regularly drops to zero.

The Mohaka at Raupunga record (including the suppressed flow values in 1985) is used from 1957 to present. Gaps in the record were filled from correlation with the Ngaruroro at Whanawhana record.

Care was taken to maintain the water balance in the river. Table 2-7 details the mean flows during the record correlation periods.

Table 2-7: The mean flow for Mohaka at Raupunga.

Record	Record Length	Mean Flow (m^3/s)
Mohaka at Raupunga*	1957-2001	79.5
Rated Mohaka at Raupunga**	1957-2001	78.7
Rated Mohaka at Raupunga	1931-2025	79.0

*Without low flows triggered by the landslide.

**Prior to superimposing the actual Mohaka at Raupunga record over the HMD series.

2.2 SOUTH ISLAND

2.2.1 WAITAKI

For the HMD modelling, the flows in the Waitaki River are considered in two components, inflow to Lakes Pūkaki and Tekapo; and tributary inflows below the lakes at Benmore and Waitaki Power Stations.

2.2.1.1 PŪKAKI AND TEKAPO INFLOWS

Two options are modelled:

- Pūkaki Inflows are the calculated inflows from a lake level and outflow algorithm combined with the Tekapo Outflows from the Tekapo Canal and therefore could be used for power generation downstream. The natural Pūkaki inflows are simulated from subtracting the actual Tekapo discharge into Lake Pūkaki to simulate the inflows prior to the current infrastructure.
- Tekapo Inflows are the calculated inflows from Lake Tekapo into the Tekapo Canal; they are therefore constrained by the maximum capacity of the canal (130m³/s) and the minimum release flows that Genesis must comply with as part of the agreement with Meridian. These flows therefore look more like outflows but represent the inflows that are available for power generation at Tekapo A and Tekapo B power stations.

2.2.1.2 ŌHAU INFLOWS

Ōhau A is affected by residual flows in the Upper Ōhau River. Therefore, two simulations are run to represent available inflows from Ōhau for generation:

- Ōhau – Ōhau B & C only, no loss of water. This is the total inflow into Lake Ōhau that is available; and
- Ōhau Res – Residual flows diverted to the Upper Ōhau River of 12m³/s (Nov to Apr) and 8m³/s (May to Oct). This results in less available inflows available for use.

2.2.1.3 BENMORE TRIBUTARY

This includes Ahuriri, Ōhau, and tributaries between Tekapo, Pūkaki, and Ōhau outfalls. Prior to 1949 the Ahuriri River was not measured, so it is simulated from Ōhau inflows. After 1964 the flow gauging site was inundated by Lake Benmore, so a flow site further up the river at South Diadem is used, with a scaling factor to account for additional inflows. Small tributary flows in the areas between the major lakes and Benmore are accounted for by adding 33% to the Ahuriri flow.

There are two flows sets for Benmore tributaries:

- Benmore is based on the separate Tekapo simulation and includes Tekapo spill.
- Benmore_tp is based on the combined lakes Tekapo-Pūkaki simulation and is simply Ōhau inflow plus Ahuriri scaled up by 33%.

2.2.1.4 WAITAKI TRIBUTARY

A separate tributary flow has also been produced for Waitaki power station (Halliburton, December 1993). Previously, Waitaki and Aviemore tributaries were scaled from Benmore. Waitaki tributary equals total Waitaki flow minus the outflow from Lakes Tekapo and Pūkaki. Prior to 22 August 1977 this was calculated from the total discharge from each lake, whereas after that date it is calculated from total Pūkaki discharge minus Tekapo spill only.

There are several gaps in the early Pūkaki outflow record. A simulation has been incorporated into the updating routines, which fills these gaps with synthetic data based on Tekapo outflows.

Feedback from the draft SPECTRA 2007 report highlighted poor Waitaki flow data when compared to Benmore. Measurement inaccuracies produce negative flows when compared to Benmore power station tributaries. However, the effect tributaries have on lake levels is complicated and require assumptions that do not necessarily work well for long term records. Meridian suggests that work on these inaccuracies should be addressed on a project-by-project basis for shorter data sets.

2.2.2 MANAPŌURI

The HMD Manapōuri data is intended to be used as local inflows, whereas Lake Te Anau has a controllable outflow. Inflows and outflows for Lake Te Anau are available from 1926 and for Lake Manapōuri from May 1932. The local catchment, or tributary, contribution to Manapōuri inflow is determined by subtracting the Te Anau outflows from the total Manapōuri inflows. For the period before 30 April 1932 when the record at Manapōuri began, the local inflows are simulated from Te Anau outflow.

For the purposes of the HMD modelling, a record of Manapōuri local inflows is required upon which future predictions of inflows can be based. To achieve this, records are synthesised which either include or exclude the Mararoa River for the entire record. The Mararoa has been included in the Power Archive inflows since the commissioning of the Manapōuri Power Station in August 1969. Outflow was first measured downstream of the Mararoa confluence (with power station flows added) (Duffy et al., 1993).

Prior to the availability of actual Mararoa River records, and for filling gaps, synthetic flows are simulated from Te Anau outflows. The equations used were derived by Robertson et al. (1989) and later confirmed by Maslin et al. (1993).

Several options are available for the Manapōuri flows:

- With Mararoa diversion (*site 99551*). Note that when Mararoa flows are above 40m³/s, the Mararoa is spilled. This only approximates the actual operation of the Mararoa control structure. Also, when Mararoa water is being spilled, it is not possible to avoid some clean water spill from Lake Manapōuri. This is hypothetical actual flow.
- Without Mararoa (*site 99550*), which represents the view of a possible extreme outcome of water rights application. This is a hypothetical natural flow, not an actual flow series.
- With the minimum flow regime implemented, Mararoa diversion and the Mararoa dirty water spill (*site 99552*). This is hypothetical actual flow.

The minimum flow regime was introduced to the model. Previously, the minimum flow was assumed to be a constant 15m³/s throughout the year, although to date, there has not been a regular minimum flow except for a nominal minor flow through the fish pass. The 15m³/s figure was hypothetical only.

2.2.3 MONOWAI

Inflows previously existed from 1960 to 1999; however this methodology has since been updated as described below.

From July 1931 to April 1977 the data for Monowai Inflow was derived from correlating nearby river data. A linear regression with Te Anau and Manapōuri did not provide a suitable correlation. Therefore, a flow distribution rating was applied to extend the previous Monowai record. A rating was derived from the Monowai Riddell – Opus and Lake Te Anau inflow data and then applied to the Te Anau inflow data. This resulted in some differences for peak flow events in terms of timing, however, the two systems tracked each other well and flows were similar.

From the 2015 update onwards, this dataset is calculated using the Opus inflow regime and was recalculated back to May 1977. This is because of changes in NIWA ratings for input flow sites. This caused some differences in data which are further explained in Report 2a. Table 2-8 details the mean flows for the records. The same approach is continued by WSP.

Table 2-8: The mean flow for Monowai.

Record	Record Length	Mean Flow (m^3/s)
Riddell Inflow 1986 Report	1960 – 1985	12.3
Riddell – Opus Inflow	1960 – 1999	12.9
Monowai Rated Inflow	1960 – 1999	13.1
Monowai Rated Inflow & Riddell – Opus Inflows	1927 - 2006	13.0
Monowai Rated Inflow & Riddell – WSP Inflows	1931 - 2025	12.9

2.2.4 CLUTHA

2.2.4.1 HMD FLOW RECORDS

The following datasets are directly used for the Clutha schemes provided by Contact Energy.

- **Hāwea** – Inflows to Lake Hāwea are read directly from the Power Archive and daily averaged.
- **Wānaka** – Outflows from Lake Wānaka are read directly from the Power Archive and daily averaged.
- **Roxburgh** – Roxburgh inflows are read directly from the Power Archive and Hāwea outflows are subtracted to provide a local inflow dataset. This is daily averaged.

2.2.5 COBB

Prior to 1945, inflow to the Cobb reservoir was not recorded. Initially, inflows were simulated back to 1931 using a correlation with Lake Coleridge inflows. The 1993 SPECTRA Update used an improved method, utilising a correlation with Lake Rotoroa outflows since 1934 (Palmer, 1992 and Maslin et al., 1993). The first few years of inflows, however, are still based on Coleridge inflows.

This correlation was reassessed for the 1996 SPECTRA Update and an unsatisfactory r^2 value was obtained. After discussion with Lennie Palmer, ECNZ Generation (1996), it was decided to continue with the value (0.224) in the existing PSIM. This is based on the correlation of mean inflows at Coleridge and Cobb. From March 1934 to November 1945 the inflows are based on a correlation with Gowan at Rotoroa. From November 1945 to present, the inflows are calculated by Manawa Energy from actual outflow records with an allowance for change in lake storage.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa Energy and is simply appended to the previous dataset unless any new additional data is provided i.e. it is treated the same as in an interim update as a full HMD update.

2.2.6 COLERIDGE

The inflows into Lake Coleridge are from the local catchment together with diversions from the Wilberforce, Harper, and Acheron Rivers. Diversions from the Harper and Wilberforce rivers cease during floods when the diversion bunds are washed away. During the floods the only inflows are therefore from the local catchment and the Acheron Diversion. There are also turbidity constraints imposed on lake inflows.

The inflows are calculated using the equation:

$$Inflow = Outflow \pm Change\ in\ storage$$

where outflows include machine discharge, spill flow and the Oakden diversion outflow. The change in storage volume is calculated from measured lake levels (at the Power Station intake) and a lake level-volume relationship.

Lake Coleridge inflows prior to 1951 were initially synthesised from the Harper River flows but these were generally of poor quality. In late 1993, some historic weekly power station reports from 1928 to 1951 were

located in the station archives. From these several data items were loaded to computer which enabled the calculation of actual lake inflows. The resulting inflow record was a substantial improvement over the previously synthesised flows. This record replaced the synthetic record in the 1994 SPECTRA update.

When the Coleridge "Hydrological Data Reference Manual" (Greer, 1994) was compiled, the inflows were again scrutinised. A further period of record, recalculated with the pre-1951 data, was replaced on the archive. This involved only a relatively minor change to the way in which the inflows were calculated from April 1951 to September 1963. It did not significantly affect the mean flow. Note that the efficiency of the diversion works varies and this may affect flow trends. Data from 26 January 1998 to 31 December 2002 is synthetic record.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa Energy and is simply appended to the previous dataset unless any additional new data is provided i.e. it is treated the same as in an interim update as a full HMD update.

2.2.7 HIGHBANK

The ECNZ Highbank Power Station record begins in May 1951 and ends in May 1998. In June 2002, Trustpower (now Manawa Energy) began recording flow which continues.

In a 1990 Works Consultancy Services report, "Extended Flow Study – Mohaka, Mangahao, Grey, Arnold and Highbank", a synthetic Highbank dataset was created from 1931 to 1951. Some gaps exist in the dataset so as part of this report synthetic data were created to fill these gaps. The same PSIM that was used in the 1990 report was used in this study.

The PSIM uses variations in Lake Coleridge inflows to produce synthetic data. Actual Highbank data (ECNZ and Trustpower [now Manawa Energy]) and synthetic data were combined to provide an HMD flow record for Highbank Power Station.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa Energy and is simply appended to the previous dataset unless any new data is provided i.e. it is treated the same as in an interim update as a full HMD update.

Table 2-9 shows the mean flow for each record for the synthetic and actual data. Comparisons were made to ensure a similar water balance was maintained for the Highbank Power Station when creating synthetic data. The differences in mean flow may be partly caused by different companies running the power station in different ways.

Table 2-9: The mean outflows for Highbank Power Station.

Record	Record Length	Mean Flow (m^3/s)
Highbank actual (ECNZ)	1951-1988	13.7
Highbank actual (Trustpower [now Manawa Energy])	2002-2008	11.8
Synthetic Highbank	1931-2007	14.2
Actual and synthetic Highbank	1931-2025	13.4

2.2.8 WAIPORI

The HMD series for Waipori scheme was created in 2007. Waipori at Berwick and Waipori at Below No 4 Power Station data were correlated and compared with long term flow stations in the vicinity of the Waipori catchment. The long-term flow stations used in the comparisons were Lake Wānaka, Lake Te Anau, Lake Manapōuri, Lake Wakatipu, and Lake Roxburgh inflow, Clutha at Alexandra Bridge, and Clutha at Balclutha.

None of the seven lakes/flow sites had a comparable flow relationship with Waipori at Below No 4 Power Station (74395) or Waipori at Berwick (74321). The Waipori catchment contains a large lake, Lake Mahinerangi, and four power stations along the Waipori River. Lake Mahinerangi has a large storage capacity and therefore can

absorb any flood events. Any flow released from the lake passes through four power stations. This means that the flows in this catchment are controlled and behave differently from the natural flow occurrences in adjoining catchments. Figure 2-1 shows a flow hydrograph for Waipori at Below No 4 power station.

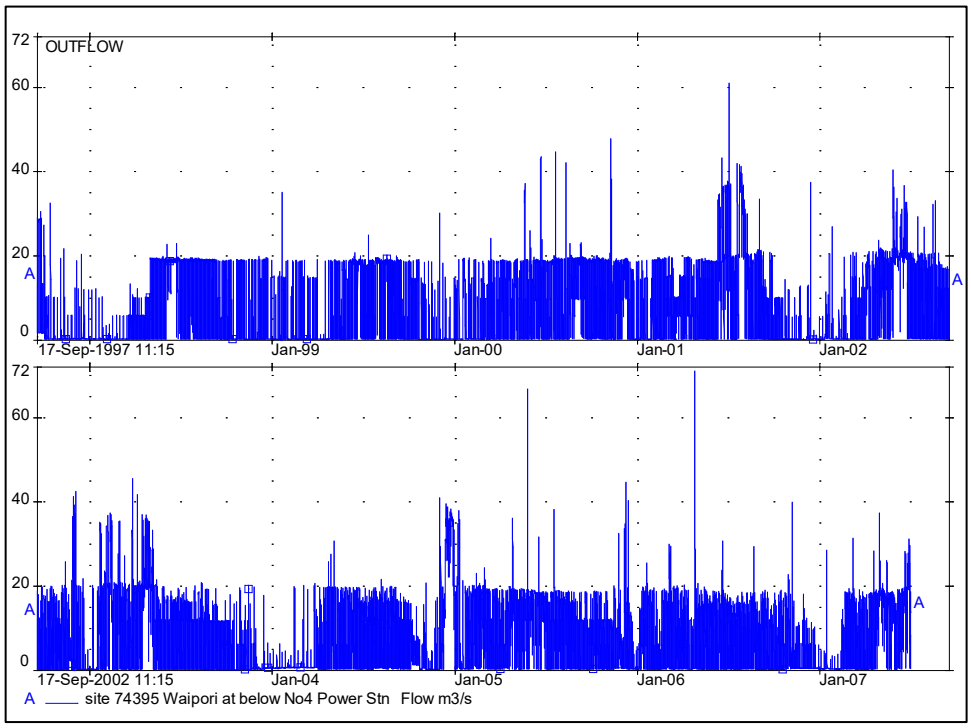


Figure 2-1: The flow at Waipori for Below No 4 Power Station.

Figure 2-2 highlights how the Waipori catchment does not reflect the behaviour of the surrounding catchments, showing Waipori at Below No 4 power station versus Lake Wānaka outflow. Waipori mainly has the profile associated with turbine discharge and occasional spill discharges. The spill discharges do not coincide with high flow events at Wakatipu. This comparison was found to be consistent across all flow sites when compared with Waipori.

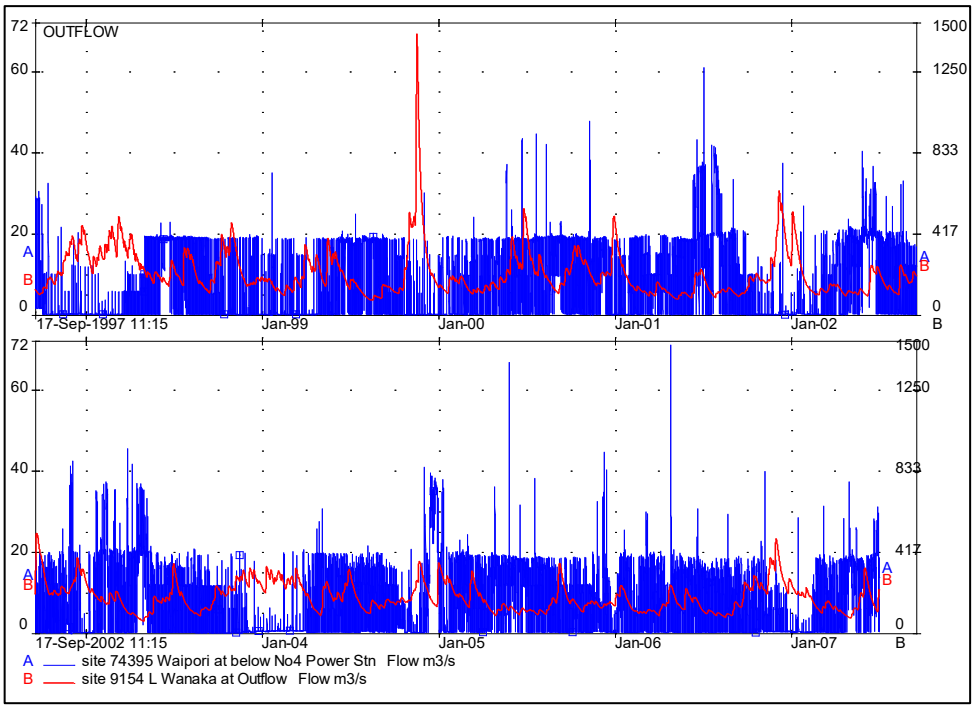


Figure 2-2: The flow at Waipori Below No 4 Power Station compared with Lake Wānaka outflow.

To create a synthetic flow dataset for this catchment an analysis was conducted for Waipori at Berwick and Waipori at Below No 4. The resultant flow distribution rating was then applied to Waipori at Berwick to reduce flows to that of Waipori at Below No 4.

Synthetic Waipori at Below No 4 data was combined with actual Waipori at Below No 4 Power Station to give a record from 1988 to 2007. The ratios from the "Trends in Flow Data report (1993)" were used and annual data series that had means that reflected the historic means were used to infill the dataset from 1931 to 1988.

Actual data and synthetic data were combined to provide a flow record for Waipori at Below No 4 Power Station from 1931 to 2007.

Waipori at Below No 4 Power Station data was not available for the period 1-Jul-2010 to 19-May-2012 from Trustpower (now Manawa Energy). A correlation with Waipori at Berwick was undertaken and inserted into the missing period.

This flow site is not recalculated back to 1931 as part of a full HMD update. The data is supplied by Manawa and is simply appended to the previous dataset unless any new additional data is provided i.e. it is treated the same as in an interim update as a full HMD update.

Table 2-10 shows the mean flow for each record for synthetic and actual data. Comparisons were made to ensure a similar water balance was maintained for Waipori at Below No 4 Power Station when creating synthetic data.

Table 2-10: The mean flows for Waipori at Below No 4 Power Station.

Record	Record Length	Mean Flow (m^3/s)
Waipori at Below No 4 Power Station	1997-2007	7.6
Waipori at Berwick	1988-2007	10.9
Synthetic Waipori at Below No 4 PS*	1998-2007	7.1
Actual and synthetic Waipori at Below No 4 Power Station	1931-2025	7.4

*Prior to superimposing the actual Waipori record over the HMD series

2.2.9 LAKE ONSLOW

From 2020, the EA requested a dataset of inflows to Lake Onslow to be included in the HMD update. At the time, there was considerable interest in this site for future pumped storage generation. Several investigations were commenced. However, the project was cancelled in 2023.

Inflows to Lake Onslow have not been recorded; therefore it was decided to use the outflows from the lake as a surrogate. There is an active flow station downstream of Lake Onslow: Teviot at Bridge Huts Road. However, as this contains a baseflow it was deemed to be overrepresenting the likely inflows into Lake Onslow. Therefore, the simulated inflows into the nearby Waipori power scheme was deemed more appropriate. This was scaled by catchment area to synthesize the inflows into Lake Onslow.

The catchment area at the Lake Onslow dam has a catchment area of 126km² compared to a catchment area of 317km² for the Waipori Station, resulting in a scaling factor of 0.397.

2.2.10 GREY RIVER

A flow record for the Grey River/Māwheranui at Dobson is available from July 1968 until present. An earlier record is synthesised from the Buller River at Berlins from 1952 to 1968, and from Lake Te Anau inflow prior to 1952. Lake Te Anau gave the best results of the few records available for the early period from 1930 (Freestone & Mills, June 1990).

The dataset used in the HMD is the flow in the Grey River at Dobson, including water diverted from the Taramakau River. This is derived from another dataset that also includes water diverted from the Taipo River. This is because the Taramakau at Greenstone Bridge recorder includes Taipo River flow, as it is downstream of the Taipo confluence. The calculation of the combined Grey+Taramakau-Taipo data is outlined below.

To determine the flows available for diversion into the Grey some assumptions must be made, as there are currently no firm scheme details. These are summarised as follows:

- Residual flows are required in the Taramakau and Taipo Rivers of 15m³/s and 5m³/s, respectively;
- Maximum canal flow is 230m³/s (twice the mean);
- Shut down of diversion structure intake during floods is not considered; and
- Utilisation of the water available for diversion is assumed to be 70%.

Based on these assumptions the diverted water is calculated. This is then added to the Grey at Dobson record. For the period before February 1979, when the Taramakau at Greenstone record begins, the total flow set is synthesised from the extended Grey record, based on the correlation between the two, from 1979 to the end of the Taramakau at Greenstone record in 2015.

The dataset including Taramakau only is then derived from the Grey+Taramakau-Taipo record by scaling down by 0.93, i.e., assuming that 7% of the total water is diverted from the Taipo River.

NIWA closed the Taramakau at Greenstone Bridge site at the end of 2015. The data for Taipo at SH1 Bridge was not originally available for use after 2016, however from 2024 the full record of data has been provided for use within the HMD update. Additionally, a new Grey River dataset has been created from 2017, with the original dataset maintained and included in the HMD update (i.e. site 77106 (1) Grey_Closed and site 77106 (2) Grey). The latter is calculated to the present day.

The approach to calculating the 77106 (2) Grey River dataset in previous updates (prior to 2023), without access to the full Taipo at SH1 Bridge record, has been to correlate the flow distribution data from the Grey River at Dobson flow site with the flow distribution data for the combined Grey+Taramakau-Taipo record for the period where the records overlap; 1979 to 2015. This resulted in a very strong correlation (r^2=0.99). A synthesised total flow series was derived by applying a non-linear rating to the Grey River at Dobson dataset. This synthetic flow set had the same assumptions regarding diversion and base flows as the previously derived dataset. However,

it had been noted that this approach resulted in very high flows (>8,000 m^3/s) for the earlier part of the record, prior to 1968, that were considered unlikely to occur.

With access to the full record for Taipo at SH1 Bridge (i.e. since 1978), a record for Taramakau at Greenstone Bridge from 2016 was able to be synthesised by correlation with the Taipo at SH1 bridge record. This resulted in a very strong correlation (r^2=0.9997), which is to be expected, as the Taipo site is upstream of the Taramakau site. The record for 77106 (2) Grey River from 2016 was then calculated using the same method described above for the 77106 (1) Grey River record and then added to the data from the 77106 (1) record (from 1931 to 2016) to create a full dataset from 1931 to current.

Table 2-11 details the mean flows of the actual Grey River at Dobson record compared to the period of correlation and the final synthesised Grey+Taramakau-Taipo datasets.

Table 2-11: Mean flows for the Grey River.

Record	Record Length	Mean Flow (m^3/s)
Grey River at Dobson	1979-2025	357.4
Grey+Taramakau-Taipo	1979-2016	449.0
Synthesised Grey+Taramakau-Taipo (original site)	1931-2016	436.8
Synthesised Grey+Taramakau-Taipo from Grey River (correlated site)	1931-2025	433.23

2.2.11 WAIAU RIVER, CANTERBURY

Four possible hydro-power scheme locations have been identified along the Waiau River. These are the Clarence to Waiau Diversion, Upper Waiau, Mid Waiau and Lower Waiau. The HMD records have been developed at three locations within the catchment; these are Clarence at Jollies (Clarence diversion), Waiau at Glenhope (Upper Waiau), and Waiau at Marble Point (Mid Waiau).

2.2.11.1 CLARENCE AT JOLLIES

The longest flow record in the vicinity of the Waiau River is the Clarence at Jollies recorder. Data extends back to 1960. The Clarence at Jollies recorder was correlated with the longer Gowan at Lake Rotoroa flow record to extend the HMD dataset back to April 1934.

The best correlation was obtained through a flow distribution rating of the Gowan record (1934-1991). The distribution of flow in the resulting dataset is similar to the actual distribution of flow. However, the Gowan record is based on lake inflows so many flood peaks have been reduced. Actual data from the Clarence at Jollies record (1960-present) replaces the rated data.

The first three years of record (1931-1934) were selected from average flows. The Works Consultancy Services Ltd produced a report in 1993 titled “Trends in Flow Data for Manapōuri Local Inflows, Mangahao, Cobb, Coleridge Inflows and Waikato Tributary Flows”. Appendix III of the report specified ratios from flow sites throughout New Zealand of the mean annual inflow to the mean total record, since 1931. Ratios less than one indicated inflows to the site were less than average and hence a drier year; ratios greater than one indicated inflows to the site were greater than average and hence a wetter year. The mean annual ratios at Lake Coleridge, which is the nearest flow site to the Waiau River, were 0.77, 0.65, and 1.05 during 1932, 1933, and 1934, respectively. 1932 and 1933 were therefore drier years than average.

The ratios were then applied to the total mean flow of the rated Clarence at Jollies record. Mean annual flows were determined for the three years and compared to annual flows from the entire record. Flows from years that had similar mean annual flows were replicated in the earlier record. Flows from 1956 are repeated in 1931, flows from 1969 are repeated in 1933, and flows in the first three months of 1953 are repeated in 1934.

Care was taken to maintain the water balance in the river. Table 2-12 details the mean flows during the record correlation phases. This flow has remained constant.

Although the mean flows compare well there is less flood peak amplitude in the correlated record 1931 to 1960.

Table 2-12: The mean flow at Clarence at Jollies.

Record	Record Length	Mean Flow (m^3/s)
Clarence at Jollies	1960-2025	14.42
Overall Clarence at Jollies	1931-2025	14.4

2.2.11.2 WAIAU AT GLENHOPE

The Waiau at Glenhope record begins in 1974. This record was extended back to 1931 through a distribution correlation with the extended Clarence at Jollies record. The distribution rating compared flow data over the period 1974 to 1999.

The Waiau at Glenhope flow site was not rated between 1999 and 2003 and is currently no longer rated (July 2008). The location is too dangerous to gauge at low flows in the jet-boat and too difficult to wade. To produce a flow series, a synthetic rating is produced using a distribution correlation with Marble Point.

There is less flood activity in the synthetic record (pre-1974) and, when combined with the low flow period in the 1930s, may produce an overall slightly lower long-term mean flow (1.8 m^3/s (5%) lower).

Care was taken to maintain the water balance in the river. Table 2-13 details the mean flows during the record correlation phases. This flow has remained constant.

Table 2-13: The mean flow for Waiau at Glenhope.

Record	Record Length	Mean Flow (m^3/s)
Waiau at Glenhope	1974-1999	35.8
Rated Waiau at Glenhope*	1974-1999	35.9
Rated Waiau at Glenhope	1931-2025	33.7

*Prior to superimposing the actual Waiau at Glenhope record over the HMD series

2.2.11.3 WAIAU AT MARBLE POINT

The Waiau at Marble Point record begins in 1967. This record was extended back to 1931 through a distribution correlation with the extended Clarence at Jollies record. The distribution rating compared flow data over the period 1967 to 2002. Data from February 2003 at the Marble Point flow site is provisional and was therefore not used in the distribution rating. Actual data from the Waiau at Marble Point record (1967 – 2006) is applied to the rated data.

Care was taken to maintain the water balance in the river. Table 2-14 details the mean flows during the record correlation phases. This flow has remained constant. The slightly lower mean flow for the longer record (1931 to 2025) is because of a dry period in the 1930s, and the reduced flood activity in the synthetic record.

Table 2-14: The mean flow for Waiau at Marble Point.

Record	Record Length	Mean Flow (m^3/s)
Waiau at Marble Point	1967-2002	98.7
Rated Waiau at Marble Point*	1967-2002	98.8
Rated Waiau at Marble Point	1931-2025	94.0

*Prior to superimposing the actual Waiau at Marble Point record over the HMD series

2.2.12 WAIRAU RIVER, MARLBOROUGH

There are currently two small power stations located on the Branch River near the Wairau River. The proposed scheme is to extend this existing hydro-electric scheme. The Wairau at Dip Flat record is important for the extension of this scheme.

2.2.12.1 WAIRAU AT DIP FLAT

The longest flow record in the vicinity of the Wairau River is from the Wairau at Dip Flat recorder. This record extends back to 1951. The Wairau at Dip Flat recorder was correlated with the Gowan at Lake Rotoroa flow record to extend the HMD series back to April 1934.

The best correlation was obtained through a distribution rating of the Gowan record comparing flow data over the period 1934-1991. The distribution of flow in the resulting dataset is similar to the actual distribution of flow. Actual data from the Wairau at Dip Flat record (1951-2006) is used.

As with the Waiau extension, the first three years of record were selected from average flows from the Works Consultancy Services Ltd report titled “Trends in Flow Data for Manapōuri Local Inflows, Mangahao, Cobb, Coleridge Inflows and Waikato Tributary Flows (1993)”. The mean annual inflow ratios (averaging ratios from Mangahao and Coleridge) were 0.805, 0.795, and 0.995 in 1932 (and 1931), 1933, and 1934 respectively. This period was drier than average.

The ratios were applied to the total mean flow of the correlated Gowan record (1934-2006, including actual data from the Wairau at Dip Flat record from 1951). Mean annual flows were determined for the three years and compared to annual flows from the entire record. Flows from years that had similar mean annual flows were replicated in the earlier record. Flows from 1941 are replicated in 1931 and 1933 and flows in 1954 are replicated in the initial three months of 1934.

Gaps in the record were filled from correlation with the Wairau at Hells Gate record (1965-1975) and the Wairau at Tuamarina flow site (1989-1999) which was replaced with the Barnetts Bank recorder 390m upstream (1999-2006). Care was taken to maintain the water balance in the river. Table 2-15 details the mean flows during the record correlation phases.

Table 2-15: The mean flow for Wairau at Dip Flat.

Record	Record Length	Mean Flow (m^3/s)
Wairau at Dip Flat	1951-1991	26.7
Rated Wairau at Dip Flat*	1951-1991	27.0
Rated Wairau at Dip Flat	1931-2025	26.7

*Prior to superimposing the actual Wairau at Dip Flat record over the HMD series

2.2.13 HURUNUI RIVER, CANTERBURY

There are two options for a proposed hydro-power scheme along the Hurunui River. The first is upstream of State Highway 1 Bridge near the mouth of the river; the second possible location is upstream of the Hurunui at Mandamus flow site.

2.2.13.1 HURUNUI AT MANDAMUS

The longest flow record on the Hurunui River is the Hurunui at Mandamus recorder. This record extends back to 1956. The Hurunui at Mandamus record was correlated with the longer Gowan at Lake Rotoroa flow record to extend the HMD series back to 1934.

The best correlation was obtained through a distribution rating of the Gowan record comparing flow data over the period 1934 to 1991. The distribution of flow in the resulting dataset is similar to the actual distribution of flow. However, the Gowan record is based on lake inflows so flood peaks are often smoothed. The Hurunui at

Mandamus record is used from 1956 to present.

As with the Waiau extension, the first three years of record were selected from average flows from the Works Consultancy Services Ltd report titled “Trends in Flow Data for Manapōuri Local Inflows, Mangahao, Cobb, Coleridge Inflows and Waikato Tributary Flows (1993)”. The mean annual inflow ratios at Coleridge were 0.77 in 1931 and 1932, 0.65 in 1933, and 1.05 in 1934.

The ratios are applied to the total mean flow of the correlated Gowan at Lake Rotoroa record (1934-2006, including actual Hurunui at Mandamus data from 1956). Mean annual flows were determined for the three years and compared to annual flows from the entire record. Flows from years that had similar mean annual flows were replicated in the earlier record. Flows from 1989 are replicated in 1931, flows from 1960 are replicated in 1933, and flows from 2003 are replicated in the initial three months of 1934. Care was taken to maintain the water balance in the river. Table 2-16 details the mean flows during the record correlation phases.

Table 2-16: The mean flow for Hurunui at Mandamus Bridge.

Record	Record Length	Mean Flow (m^3/s)
Hurunui at Mandamus	1956-1991	51.2
Rated Hurunui at Mandamus*	1956-1991	52.1
Rated Hurunui at Mandamus	1931-2025	51.3

*Prior to superimposing the actual Hurunui at Mandamus Bridge record over the HMD series

2.2.13.2 HURUNUI AT SH1 BRIDGE

The most downstream flow site in the Hurunui catchment is the Hurunui at SH1 Bridge flow site. Flow data at this site exists from 1974 to 1999. Between June 1999 and July 2000 this site is used for flood warning only. It has now been reinstated as a fully rated flow site. The lower Hurunui River is potentially the most useful for hydro-power development because of the greater catchment area and Pahau tributary.

The Hurunui at SH1 Bridge was extended back to 1931 through a distribution correlation with the extended Hurunui at Mandamus record. The distribution rating compared flow data over the period 1974 to 1999. Actual data from the Hurunui at SH1 Bridge record is applied to the rated data. Care was taken to maintain the water balance in the river. Table 2-17 details the mean flows during the record correlation phases. Note the difference in mean flow is caused by a lack of extreme events during the correlation period.

The Hurunui at Mandamus extended record is preferred as the main Hurunui flow dataset.

Table 2-17: The mean flow for Hurunui at SH1 Bridge.

Record	Record Length	Mean Flow (m^3/s)
Hurunui at SH1 Bridge	1974-1999	72.8
Rated Hurunui at SH1 Bridge*	1974-1999	72.9
Rated Hurunui at SH1 Bridge	1931-2025	66.4

*Prior to superimposing the actual Hurunui at SH1 Bridge record over the HMD series

3 NATURAL FLOWS

Natural flows are flows which are uncontrolled, i.e., there is no power station or other control structure upstream of the site. This dataset contains:

- ‘Natural’ uncontrolled inflows to several reservoirs in New Zealand;
- Modelled natural inflows or tributary inflows to reservoirs, as though they are uncontrolled;

— Flows at gauging stations which could be possible hydro-power schemes in the future.

Many of the natural flows are also actual flows. The methodologies used to create these flow sites have been discussed in Section 2, they will not be repeated in this section. A list of these flow sites and the corresponding section is included in Sections 3.1 and 3.2 for the North and South Islands respectively.

Three flow series have been created that simulate what inflows would be without the control structure in place. These are not actual flows; they are hypothetical natural flows and are discussed in Sections 3.2.

3.1 NORTH ISLAND/TE IKA-A-MĀUI

Each of the North Island natural flow sites and their corresponding methodology section are listed in Table 3-1.

Table 3-1: A list of North Island "natural" flow sites and the corresponding methodology section.

Flow	Model flow name	Flow site number	Section
Taupō	Natural Inflow	62790 (1)	2.1.2
Waikaremoana	Waikaremoana	3650 (1)	2.1.3
Ngaruroro	Whanawhana	123103 (1)	2.1.9
	Kuripapango	123104 (1)	2.1.9
	Chesterhope	123150 (1)	2.1.9
Mohaka	Raupunga	121801 (1)	2.1.10

3.2 SOUTH ISLAND/TE WAIPOUNAMU

Each of the South Island natural flow sites and their corresponding methodology section are listed in Table 3-2.

Table 3-2: A list of South Island "natural" flow sites and the corresponding methodology section.

Flow	Model flow name	Flow site number	Section
Pūkaki	Nat_Puk	98770 (1)	2.2.1
Waitaki P.S. Tribs	Waitaki	98714 (2)	2.2.1
Benmore	Ben_tp	98615 (2)	2.2.1
Manapōuri	Manapouri	99550 (1)	2.2.2
Te Anau	Teanau	9570 (1)	2.2.2
Monowai	Mono_Inflow	199540 (1)	2.2.3
Hāwea	Hawea	9170 (1)	2.2.4
Wānaka	Wanaka	9154 (1)	2.2.4
Cobb	Cobb	97904 (2)	2.2.5
Lake Onslow	Onslow	175237 (1)	2.2.9
Waiau	Clarence	162105 (1)	2.2.11
	Glenhope	164604 (1)	2.2.11
	Marble Point	164602 (1)	2.2.11
Wairau	Dip Flat	160114 (1)	2.2.12
Hurunui	Mandamus	165104 (1)	2.2.13
	SH 1 Bridge	165101 (1)	2.2.13

4 AVERAGE OUTFLOWS

Average outflows are the calculated mean total outflows derived from daily average flows. These are calculated for both the Waikato Power Scheme and the Waitaki Power Scheme. These mean total outflows can be used to calculate the tributary factors for use in modelling.

4.1 WAIKATO POWER SCHEME

Each of the lakes and their corresponding mean total outflows are listed in Table 4-1.

Table 4-1: A list of the mean total outflow for lakes within the Waikato Power Scheme.

Lake/location	Period Start	Period end	Mean total outflow (m^3/s)
Aratiatia	1-Jan-1980	31-Dec-2025	154.88
Ohakuri	1-Jan-1980	31-Dec-2025	185.10
Atiamuri	1-Jan-1980	31-Dec-2025	191.54
Whakamaru	1-Jan-1980	31-Dec-2025	195.11
Maraetai	1-Jan-1980	31-Dec-2025	217.46
Waipapa	1-Jan-1980	31-Dec-2025	216.37
Arapuni	1-Jan-1980	31-Dec-2025	235.14
Karapiro	1-Jan-1980	31-Dec-2025	239.14

4.2 WAITAKI POWER SCHEME

Each of the lakes and their corresponding mean total outflows are listed in Table 4-2.

Table 4-2: A list of the mean total outflow for lakes within the Waitaki Power Scheme.

Lake/location	Period Start	Period end	Mean total outflow (m^3/s)
Tekapo	1-Jan-1980	31-Dec-2025	85.28
Pūkaki	1-Jan-1980	31-Dec-2025	203.69
Ōhau	1-Jan-1980	31-Dec-2025	79.04
Benmore	1-Jan-1980	31-Dec-2025	351.52
Aviemore	1-Jan-1980	31-Dec-2025	356.90
Waitaki	1-Jan-1980	31-Dec-2025	371.34

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