Kaniere Forks and McKays Creek Power Schemes Re-consenting: Hydrological Study

Report prepared by: L Palmer, TrustPower Ltd

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Contents

1 Executive Summary

- The application to re-consent the McKays Creeks and Kaniere Forks power scheme is to be lodged in 2010.

- This report provides an assessment of the existing hydrology associated with these two schemes, and simulates likely hydrological outcomes should each or both of these schemes be upgraded. A new power station which discharges Lake Kaniere water back to the Kaniere River in the vicinity of Wards Road has also been included in the modelling.

- The available historic hydrological and generation records for the McKays Creek and Kaniere Forks power scheme have been analysed. Due to the limited quality checks on much of this hydrological data and with the gaugings and hence ratings been retrospectively applied, the quality of some of this record is suspected of being poor. The data record is of various lengths and hydrological summaries have been provided. The assessment of the existing hydrology is provided in Section 5.

- This historical data has been used to create a Lake Kaniere inflow record, and tributary flow records for the Kaniere River. Time-series record for areas of interest on the Kaniere River have been created, to compare the existing hydrology to that associated with possible upgrades of the power schemes.

- The 2002 to 2008 mean inflow to Lake Kaniere calculated from Lake Kaniere level and outflow records is about 7 m^3/s. A long term mean flow based on catchment area with Lake Brunner indicates a mean flow of 7.2 m^3/s (1968 to 2008). The Lake Brunner catchment is higher and probably wetter than Lake Kaniere. A cross check of the Lake Kaniere mean inflow based on McKays weir, McKays Creek station and tributary flow data indicates that the Lake Kaniere outflow to Kaniere River flow may be high and that the Lake Kaniere mean inflow may be around 6.6 m^3/s (2002 to 2008). However due to the quality of the records involved, and the limited checks on this data, no correction has been made to the Lake Kaniere inflow record.

- Over the 8 year period of record (2002-2009 inclusive) Lake Kaniere level has fluctuated between a level of -0.13m and 1.71m, with a median level over this period of 0.94 m. The lake commences to spill at just over 1.0m, with spill recorded for about 40% of the time, with an average spill over the 8 years of about 1.7 m^3/s.

- Kaniere Forks power station runs near its maximum consented flows of 1 m^3/s for around 80% of the time with a mean flow output of 0.88 m^3/s over the period 1 April 1999 to end of 2008. McKays Creek station has a mean flow output of 4.0 m^3/s, and with a design maximum of 5 m^3/s has a capacity factor of 80%. About 0.2 m^3/s of the McKays Creek mean flow comes from the Greens Creek diversion.

- The 2002 to 2009 mean (and median flow) to the Kaniere River at;
  - Lake Kaniere is 6.2 m^3/s (median is 5.6 m^3/s),
  - upstream of McKays weir around 6.6 m^3/s (5.6 m^3/s), 3.8 m^3/s of this to the McKays race.
  - downstream of McKays weir about 2.8 m^3/s (1.3 m^3/s).
  - downstream of Kaniere Forks station discharge increases to 4.8 m^3/s (2.7 m^3/s),
  - and to 10.4 m^3/s (7.5 m^3/s) downstream of McKays Creek station discharge.

- To enable the Kaniere Forks and McKays Creek power scheme operation to be modelled, an inflow series for Lake Kaniere was generated, along with local Kaniere tributary flow records. Sufficient historic data was available to generate an inflow series from Lake Kaniere level and outflow data from 2002, and this was extended back utilising Arnold River and Lake Brunner data. A Kaniere River tributary flow series has been generated using McKays weir and Butchers Creek flow data.

- A model was developed to replicate the current management and changes to the two schemes. These scenarios are described in Section 6, and include a "*Wards8_Mky8*" scenario which included the McKays Creek station upgraded to a maximum flow capacity of 9 m^3/s (maximum of 8 m^3/s from the Kaniere River), and a new station which would take flow from Lake Kaniere, and discharge water back to the Kaniere River somewhere in the vicinity of Wards Road. Kaniere Forks station is "decommissioned for this scenario. Proposed new minimum flow conditions are also included in this upgrade scenario with a 0.3 m^3/s minimum to the Kaniere River from the Lake, and downstream of McKays weir. Additional flow requirements are also proposed and modelled and include a 0.40 m^3/s minimum in the Kaniere River at Wards Road, and a 0.50 m^3/s minimum in the Kaniere River at McKays Ford (a location just upstream of McKays Creek, and which is the access ford to the McKays Creek power station).

- The model was calibrated to the existing scheme configuration and consented flows (Basecase scenario), and compared against the historic measured data. This comparison and that to the *Wards8_Mky8* upgrade scenario are presented in Section 6.

- Hydrological analysis was undertaken on this simulated record over the period 2002 to 2008 at several locations that included Lake Kaniere, and the Kaniere River at lake outflow, Wards Road, McKays weir, downstream Kaniere Forks station discharge, and downstream McKays Creek station discharge. These River locations were chosen for simulation and analysis as they were points of hydrological change and probably of interest for the re-consenting process.

- An operating strategy adopted for Lake Kaniere including running Kaniere Forks station at full output for all lake levels above -0.1m, but running McKays Creek or Wards station at about half their maximum output for Lake levels between -0.1 to 0.2m, and full or near full output above 0.2m.

- A comparison of the 2002 to 2008 actual time-series record against the Basecase indicated that the model reduced spill downstream of McKays weir and consequently generated more power through the McKays power station. In part this is due to the model not incorporating station outages (planned or otherwise), and had better management of the flows out off Lake Kaniere and downstream of McKays weir. The Basecase is better represented by more recent operation of the scheme and planned instrument upgrades will permit more efficient scheme operation. The Basecase was thought to adequately simulate the operation of the two schemes, especially to that which is possible within the current consents and operating regime.

- The Wards8_Mky8 upgrade scenario with a Wards station at 8 m^3/s and the McKays station upgraded to 9 m^3/s produced lower levels in Lake Kaniere with a mean level over the 2002 to 2008 period of 0.46m, which is 0.43m lower than the historic data (Table 6.2.1). The median level was also lowered by over 0.50m. Spill also reduced from the lake from over 40% of the time to 8% for the Wards8_McKays 8 m^3/s scenario.

- With a Wards station, flows below 0.5 m^3/s from Lake Kaniere to the Kaniere River occurred for 92% of the time. Historically such flows occur less than 1% of the time.

- Flows were restored to the Kaniere River with the discharge from the Wards Road station to the Kaniere River. Flows in the Kaniere River at this Wards location were for the upgrade scenario above 4 m^3/s for over 98% of the time.

- The McKays weir and gates are used to manage the Kaniere River flow into the McKays race and subsequently through the power station. Under the Basecase the average flow in the Kaniere River downstream of the McKays (either as residual or fresh flow) averaged 2.4 m^3/s over the 2002 to 2008 period. This flow is augmented by about 1.4 m^3/s from local pickup down to Kaniere Forks discharge, and then by another 1.8 m^3/s on its way to McKays Creek discharge.

- The existing minimum flow at the McKays weir is 0.20 m^3/s, with flows near this observed to occur less than 5% of the time. Under the Basecase calibration model such flows occurred about 50% of the time, which reflected the model putting more water through the McKays Creek station (4.8 m^3/s on average, against about 4.0 m^3/s recorded) and consequently less downstream of the weir.

- Uprating McKays Creek station to take up to 8 m^3/s from the Kaniere River reduced the flow downstream of the McKays weir. Flows below 0.50 m^3/s were modelled to increase by up to 50% of the time over the historic operation of the scheme. In part this is due to the model ‘limiting’ flow downstream of the weir to the minimum flow, but also due to the operating strategy for Lake Kaniere limiting release to the Wards and McKays Creek station to half output for over 20% of the time. This provided a 4 m^3/s McKays race capacity at the weir to capture local Kaniere tributary flow.

- The Wards8_Mky8 scenario did not include a Kaniere Forks station and results in these lower flows continuing until augmented by the McKays Creek station discharge. Otherwise the flow at this location is augmented by 1 m^3/s from the Kaniere Forks station for most of the time.

- The Wards8_Mky8 scenario the mean flow was 6.5 m^3/s through the Wards station and 7.2 m^3/s through the McKays Creek station. Under this upgrade scenario additional water was available to the McKays Creek station, as the Kaniere Forks station was not modelled.

- Green Creek which receives water diverted from Blue Bottle Creek adds on average about another 0.2 m^3/s to the McKay Creek station generation, and 0.3 m^3/s under the upgrade scenarios.

- The Kaniere River mean flow downstream of the McKay Creek discharge for the Basecase and upgrade scenario was 11.4 m^3/s, historic (and simulated) data indicates a mean flow of 10.8 m^3/s. Differences due to gaps in the historic record, and inconsistency in the Lake Kaniere and McKays weir historic data.

2 Scope:

This report provides a hydrological assessment of the historic data at several locations associated with the Kaniere Forks and McKays Creek hydro-electric power schemes. This assessment is extended to include upgrade options for Kaniere Forks and McKays Creek power stations, and includes a new station which utilises Lake Kaniere water and discharges back to the Kaniere River in the vicinity of Wards Road. Time series plots, flow distributions, monthly and average statistics are provided. Flood frequency analysis has not been undertaken, as generally the scheme has little influence on such events. For the purposes of re-consenting the following locations are expected to be of interest and are therefore reported on;

- Lake Kaniere level.
- Lake Kaniere inflow.
- Lake Kaniere total outflow.
- Kaniere River downstream of Lake Kaniere.
- Kaniere River downstream of Wards Road.
- Kaniere River upstream of McKays weir.
- Kaniere River downstream of McKays weir.
- Kaniere River downstream of Kaniere Forks station discharge.
- Kaniere River downstream of McKays Creek station discharge.
- Kaniere Forks station and McKays Creek station flows.
- Green Creeks diversion and Blue Bottle Creek residual flow.

3 Scheme Description

The main source of water for both Kaniere Forks and McKays Creek power schemes is Lake Kaniere, with flows being augmented from local tributary pick-up, and for McKays Creek station, from flow diverted from Blue Bottle Creek. Flow out of Lake Kaniere is controlled by a gate to the Kaniere Forks race, and by another two gates that manage the water released to the Kaniere River and that is later available to McKays Creek power station. At high lake levels, water spills from Lake Kaniere via the outlet weir.

The Kaniere race is approximately 9 km long, and the race and associated power station in 2009 marked a centenary of operation. The race has a consented take of 1.0 m^3/s, and the power station generates a maximum of 0.43 MW, and on average produces nearly 4 GWh annually. The discharge from the station - approximately 7 km from Lake Kaniere - is below the intake for the McKays Creek power scheme. The Kaniere race has several overflow features to limit race flows to the consented 1 m^3/s.

The McKays weir spans the Kaniere River approximately 6 km downstream from Lake Kaniere, and diverts water via two control gates into the McKays race. The consented take for the race at the intake is 5.0 m^3/s and further along this increases to 6.0 m^3/s and includes the maximum take of 1.0 m^3/s from the McKays race tributaries. The Greens intake and weir diverts Blue Bottle Creek water into Greens Creek which enters the McKays race approximately 2 km downstream from the McKays weir intake. The McKays power station has a maximum output of 1.1 MW and generates annually around 8 GWhs, and discharges the water back to the Kaniere River approximately 9 km from Lake Kaniere. The McKays race has several overflow features to limit race flows to the consented maximum flow.

Photos at various scheme locations are attached as Appendix 3.

A schematic of the Kaniere Forks and McKays Creek power schemes with their associated consents is attached as Appendix 4.

4 Hydrological Records

The following table lists the data series used in this study. From these records new time-series have been simulated. With the exception of the generation data, there are various periods of missing records. The Butchers Creek data has been supplied by the West Coast Regional Council, Brunner and Arnold data from NIWA, and the remaining information is archived on the TrustPower hydrometric database. A seven year gap exists in the Butchers Creek record. The station records are 30 minute average values, with the remaining data recorded at 15 minute intervals.

Table 4.1 – Hydrological record

Site – Longer term record	Type	Period of Record
Butchers Creek flow	15 minute spot	1971 to present (1)
Kaniere Forks power station MW	30 minute average	April 1999 to present
Kaniere River at Lake Kaniere outflow	15 minute spot	January 2002 to present
Lake Brunner level (and outflow)	15 minute spot	1968 to present (1)
Lake Kaniere level	15 minute spot	January 2002 to present (1)
Lower Arnold River (below dam)	15 minute spot	1998 to present (2)
McKays Creek power station MW	30 minute average	April 1999 to present
McKays weir level	15 minute spot	January 2002 to present (1)

Site – Short term record	Type	Period of Record
Blue Bottle Creek at McKays Siphon	15 minute spot	May 2009 to present
Greens Creek (race) at McKays race	15 minute spot	March 2009 to present
Kaniere River at McKays station ford	15 minute spot	May 2010 to present
McKays race at farm bridge	15 minute spot	April 2007 to present
McKays race (levels only) -upstream & downstream siphon -upstream & downstream tunnel	15 minute spot	From May 2009 to April 2010

Note 1 – Large gaps in record. Note 2 – composite flow record.

5 Hydrological Analysis – historical data

The analysis of actual records has been undertaken up to the end of 2009. Gaps, some large, exist in most the hydrological records, and this can influence the statistical comparison between records.

5.1 Lake Kaniere

5.1.1 Lake Kaniere level

Fifteen minute Lake Kaniere level records are available from January 2002 although there are several periods of missing data (Figure 5.1.1). Outflow from the lake is managed by three control gates, and from spill from the lake outlet weir. The outlet weir comprises a concrete section 26.5m long with a spill crest at 1.05m, and a 11.0m section with stop logs with a crest at around 1.01m. The distribution of the levels (Figure 5.1.2) indicates a median lake level of 0.93 m over the 8 years of record to the end of 2009, a mean level of 0.87m, and that the lake spills around 40% of the time.

The lake is normally lower over the winter months, which coincides with the lower inflows and the higher managed flow release for generation for this period. The maximum level recorded is 1.71m in January 2002, the second highest of 1.66m in 25 November 2008 (Figure 5.1.1). The lowest level of -0.13m was measured on 30 April to 1 May 2003.

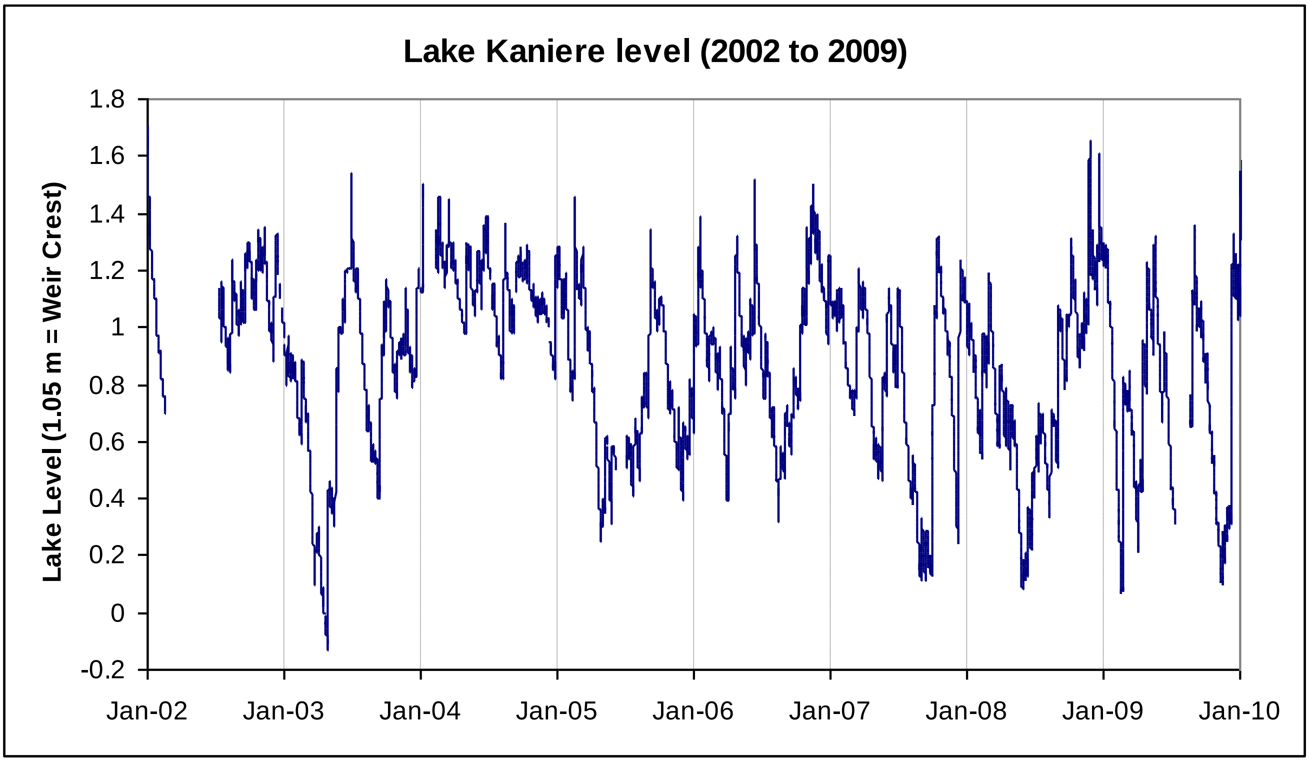

Figure 5.1.1. Lake Kaniere level (3 hourly averaged data).

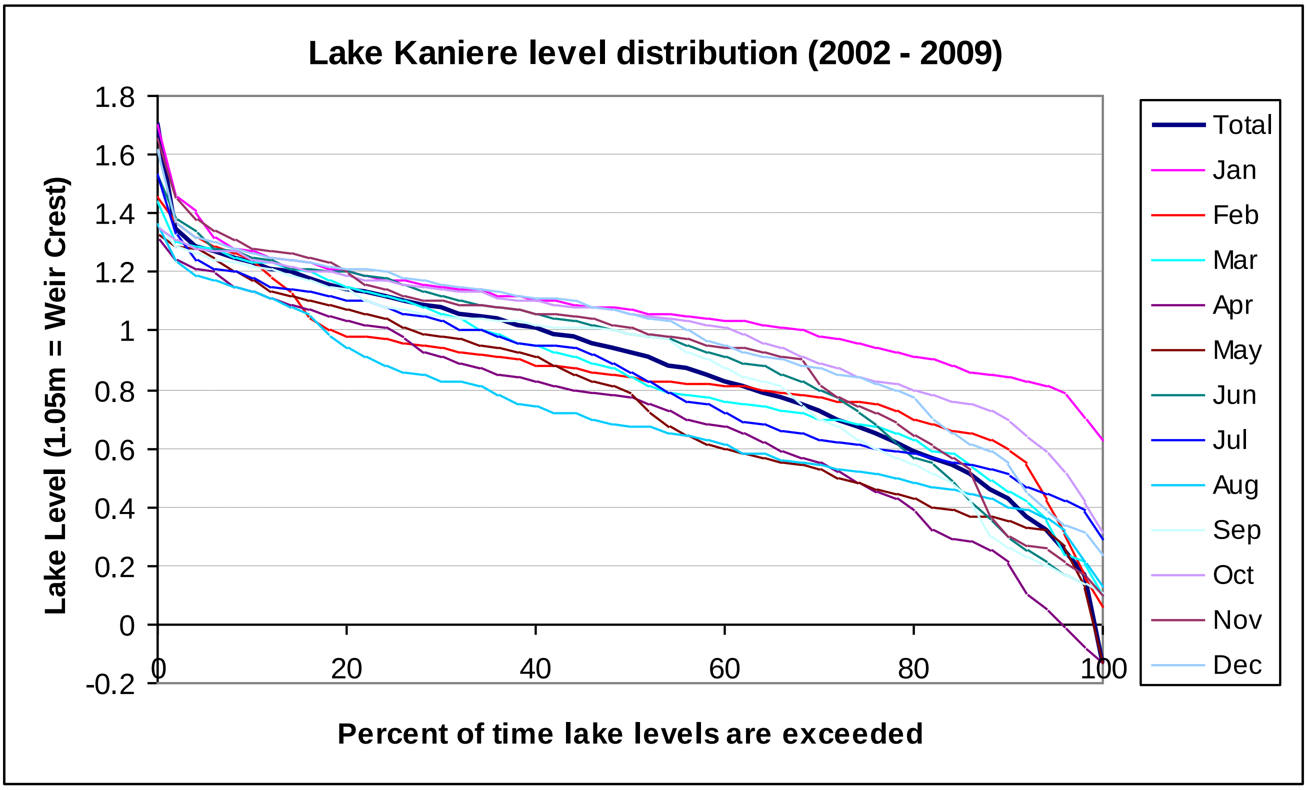

Figure 5.1.2. Lake Kaniere level distribution by month for the period 2002 to 2009.

5.2 Lake Kaniere Outflow

Flow out of Lake Kaniere is comprised of:

- flow down the Kaniere Forks race (managed via one lake control gate – see Appendix 1 photo 1)
- flow down the Kaniere River (managed via two lake control gate – photo 1)
- uncontrolled spill over the Lake Kaniere control weir (photo 3)

5.2.1 Kaniere Forks race flow

Flow into the Kaniere race is controlled by a single gate at the Lake Kaniere outlet. The race flow is augmented by local runoff on its 9 km journey to the power station, although several small creeks are avoided by the use of flumes. Race overflow features (Photo 4) are positioned at various locations along the race to limit the flows to the consented 1 m^3/s.

The flow down the Kaniere race has been determined from the Kaniere Forks generation information. A conversion of 2.38 m^3/s per MW has been used to convert the MW record to flow. This conversion is based on a gauging on 19 March 2008 at the Kaniere Forks race just upstream of the penstock intake, where a flow of 1.0 m^3/s was measured for a station output of 0.42 MW (Table A1.1). At times for various reasons (i.e. debris in the units, maintenance of the units) the station's efficiency will vary to this. The plot of the 1 April 1999 to 2009 generation flow data is illustrated in Figure A1.1 (Appendix 1 Figure 1) and the distribution of the data in Figure A1.2. The station is generating at near maximum output for 80% of the time, and has a capacity factor around 90%. Using the average conversion factor above, the mean flow through the station over this time is 0.88 m^3/s, with a maximum flow of 1.03 m^3/s derived. This 1.03 m^3/s flow is above the consented flow, but it's calculation is based on our use of the average conversion factor, which may not have been correct for the period of the higher calculated flow. We can therefore expect that around 1.0 m^3/s is entering the race via the Lake Kaniere control gate for over 80% of the time. This analysis includes periods of planned and unplanned outages.

5.2.2 Lake Kaniere weir flow

The Lake Kaniere (spill) weir (photo 3) has a rounded concrete crest 26.5m in length, and an 11m section comprised of stop logs. The distribution of the lake levels (Figure 5.1.2) indicates that the lake spills around 40% of the time, but more so in the months October through to January. The maximum recorded spill in the 2002 to 2009 period was in January 2002 with a lake level of 1.71m producing a spill of 38 m^3/s (flows calculate from weir formula). In November 2008 the lake level of 1.66m produced a 33 m^3/s spill. Mean spill over the record is 1.7 m^3/s. The spill flow distribution and weir rating are illustrated in Figure A1.3 and A1.4.

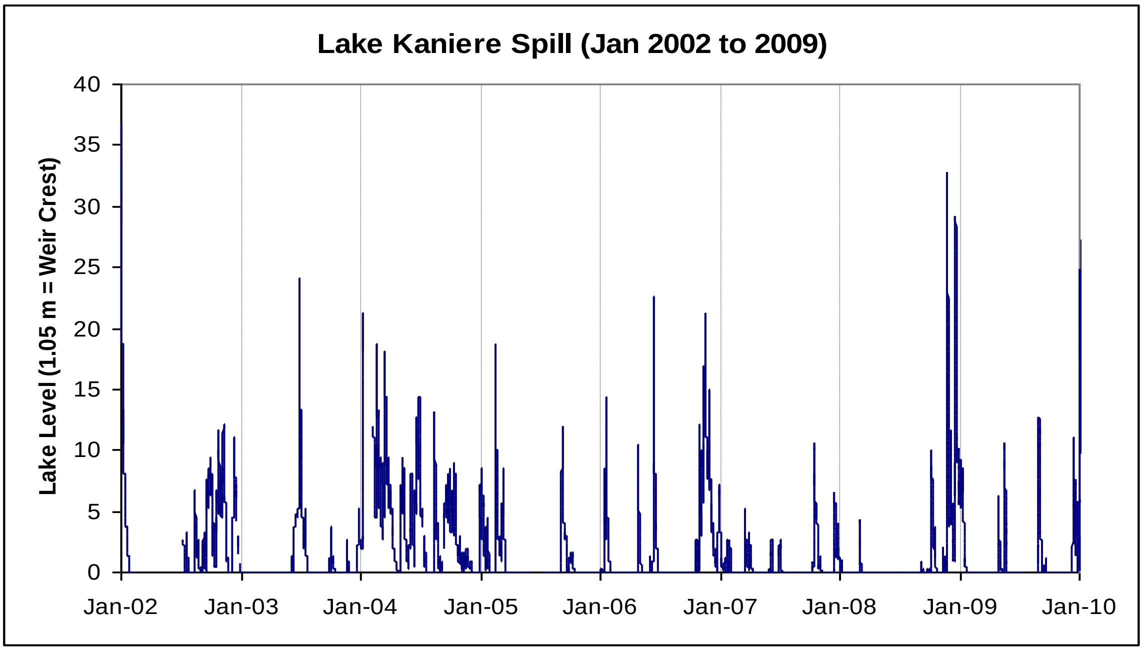

Figure 5.2.1. Lake Kaniere weir flow (3 hourly averaged data).

5.2.3 Kaniere River flow at Lake Kaniere

Both the flow to the Kaniere River and spill from the Lake Kaniere are recorded at a site positioned under the Lake Kaniere Road bridge (Photo 5). Several gaugings have been undertaken here, and back calculated flows based on McKays weir and station flow and local tributary pick up flow (based on the Butchers Creek records) have been used to construct a level to flow rating (Figure A1.5). There is observed to be some scatter of the gaugings undertaken by NIWA and by TrustPower to this outflow rating. A staff gauge installed at the time of the TrustPower gaugings indicated a good relationship (rating) between this level to flow, but the observed level changes were not as well represented by the TrustPower's Citec (operational) record. This may be in part due to the Citec transducer being slow to respond to changes in River level at this location, or possibly issues with the instruments calibration. As there is limited means to retrospectively check these levels, a composite rating was constructed, based on these gaugings to the longer-term Citec record, with cross checks made from McKays weir and derived weir tributary flows.

No long-term staff gauge is located with the recorder and few levels checks have been made. The available flow record up to end of 2009 is presented as Figure 5.2.2, and includes several periods of missing records.

Due to the controlled nature of the Lake Kaniere outflows, the flow distribution has a very flat shape with 75% of the flows between 4 to 8 m^3/s (Figure 5.2.3). The consented minimum flow is 0.20 m^3/s, with the minimum recorded flow of 0.92 m^3/s. The 2002 to 2009 median flow is 5.6 m^3/s, the mean flow 6.2 m^3/s and flows below 2 m^3/s occur for less than 4% of the time.

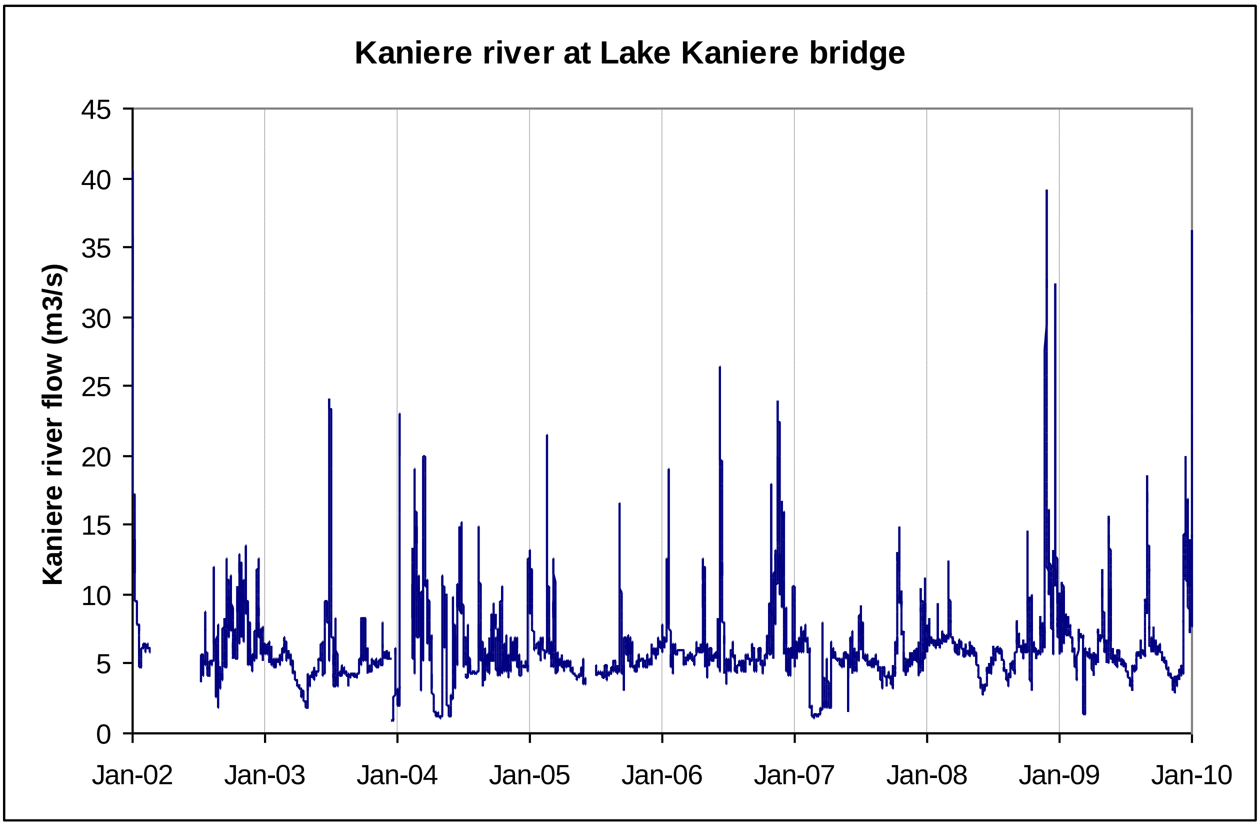

Figure 5.2.2. Kaniere River at lake outflow (site located at the Lake Kaniere Road bridge approximately 40m downstream of Lake Kaniere). Three hourly average data.

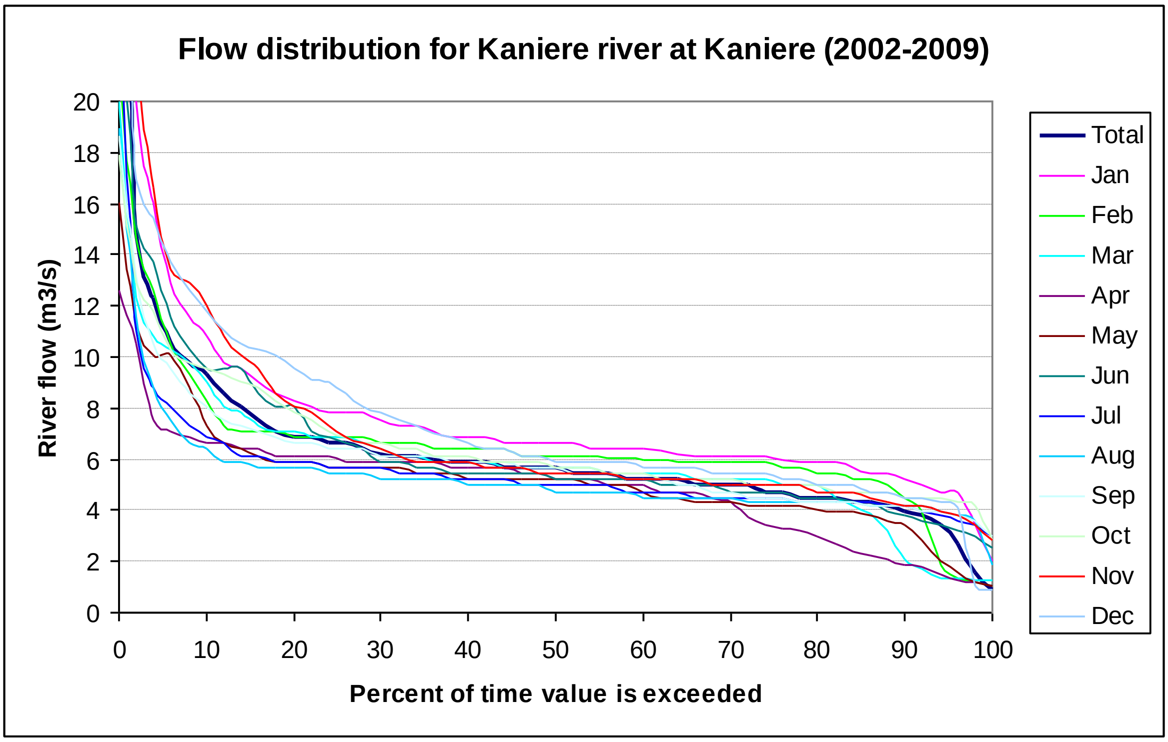

Figure 5.2.3. Kaniere River at Lake Kaniere flow distributions by month for the period 2002 to 2009.

5.2.4 Lake Kaniere Total Outflow

A Lake Kaniere total outflow series has been derived based on Kaniere race flows, and Kaniere River flows as measured immediately downstream of Lake Kaniere (the series as described above). The 2002 to 2009 average total outflow for Lake Kaniere is 7.04 m^3/s and the median 3-hourly flow is 6.44 m^3/s. Gaps in the respective records have been carried over into the total outflow record. Figure 5.2.4 presents the flow distribution for these three series, and Figure 5.2.5 the mean monthly flow over the 2002 to 2009 period.

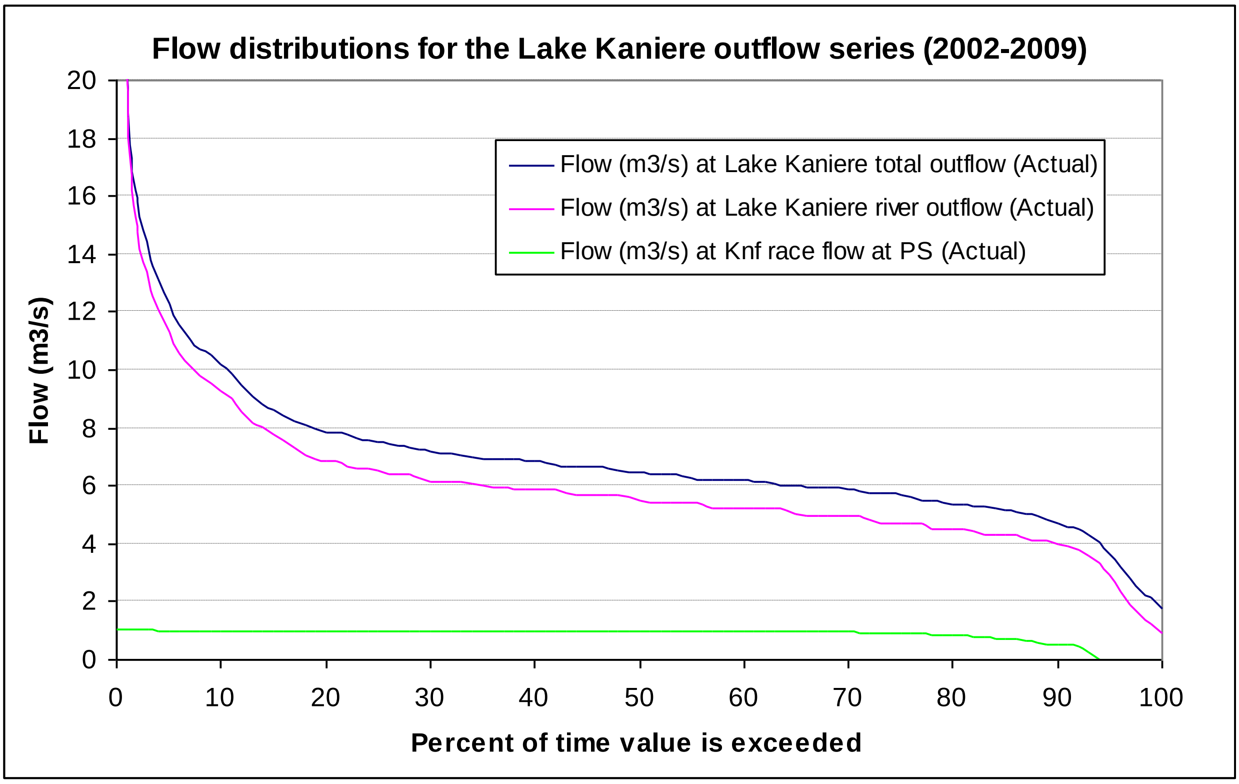

Figure 5.2.4. Lake Kaniere outflow series flow distributions for the period 2002 to 2009.

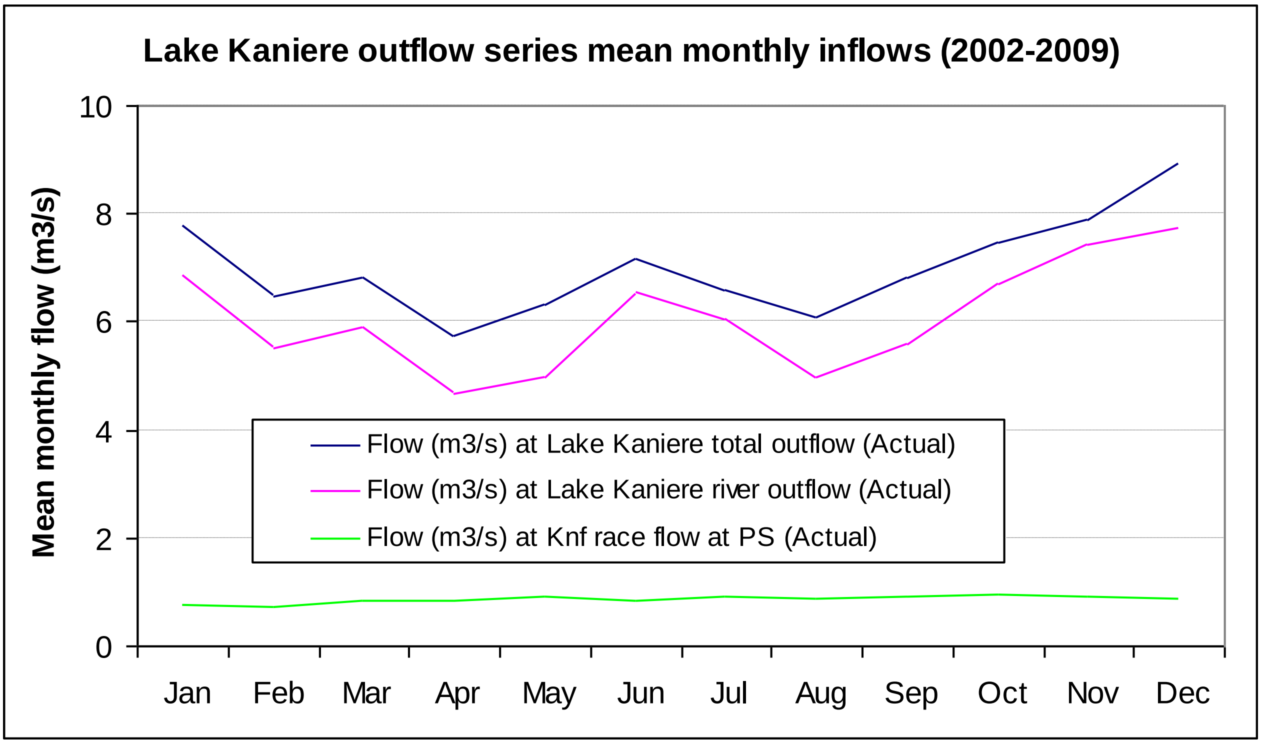

Figure 5.2.5. Lake Kaniere outflow series mean monthly flow for the period 2002 to 2009.

5.2.5 Lake Kaniere Inflow

In order for the scheme operation to be modelled, an inflow series for Lake Kaniere was generated. Sufficient historic data was available to generate an inflow series from Lake Kaniere level and outflow data from 2002, and this was extended back (and gaps in the data filled) utilising Arnold River and Lake Brunner data. Butchers Creek record was also analysed but due to the smaller catchment size this produced greater inflow fluctuation than the other locations. Also this record has a large gap from 1994 to 2000.

A 10 year period of record from 1999 produces a mean flow of 7.25 m^3/s for Lake Kaniere Inflows, and a median flow of 5.4 m^3/s. The monthly mean flow graph and daily inflow distribution are illustrated in Figure 5.2.6 and 5.2.7, and illustrate higher inflow periods for June, and September to January periods. Lower flows occur in the months of February to April, and July and August (Figure 5.2.6).

Back analysis of the 2002 to 2009 McKays weir total flow and the Kaniere River at lake outflow record indicate a discrepancy between the two, with the concurrent sets of records producing about similar period means (about 6.2 m^3/s at the lake outlet to 6.6 m^3/s at McKays weir). Analysis of the local Kaniere River tributary flow to the McKays weir indicates that the McKays weir flow should be around 1.0 m^3/s higher than the lake outflow. As there was insufficient information to confirm which or whether both records where in error, that no adjustment has been made to the derived Lake Kaniere inflow record.

An analysis of the longer term Lake Brunner record would indicate a Lake Kaniere mean flow of 7.2 m^3/s, based solely on catchment areas. Although larger, the Lake Brunner catchment is suspected to be wetter than Lake Kaniere.

In Section 6 this inflow series is used to simulate the hydrological affect of modifying Kaniere Forks and McKays Creek power schemes. The Butchers Creek record is used to simulate local Kaniere River tributary flow, but the record has a large gap to 2000. As generally the TrustPower derived records are available from 2002, the simulations are run over the period 2002 to 2008 inclusive. Analysis of the Kaniere inflow annual series indicates that 2002 and 2006 are above average inflows years, 2003, 2005 and 2007 below average, and 2004 and 2008 about average for the 1999 to 2008 period (Figure 5.2.8) Analysis of the 1972 to 2009 Butchers Creek record indicates similar conditions (Appendix A2.1). The Lake Kaniere mean inflow for the period 2002 to 2008 is 7.0 m^3/s.

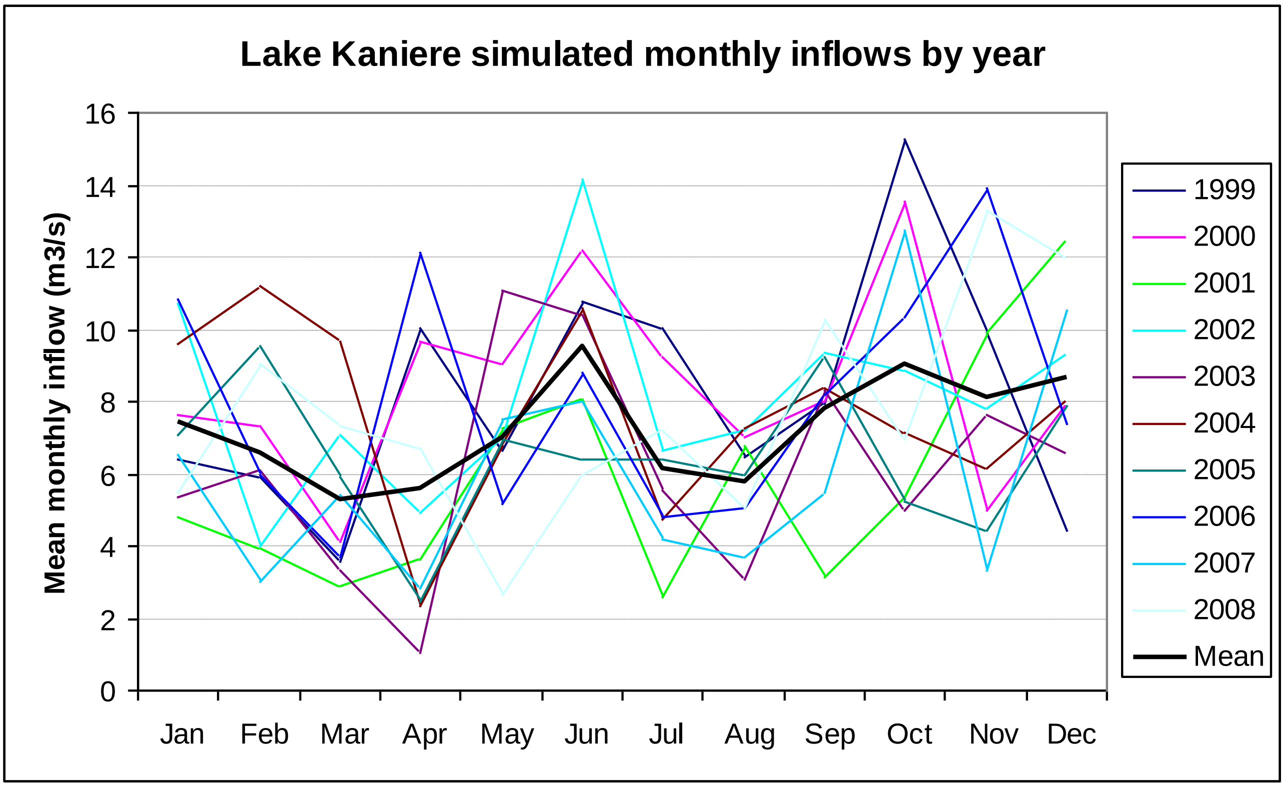

Figure 5.2.6. Lake Kaniere simulated monthly inflows by year.

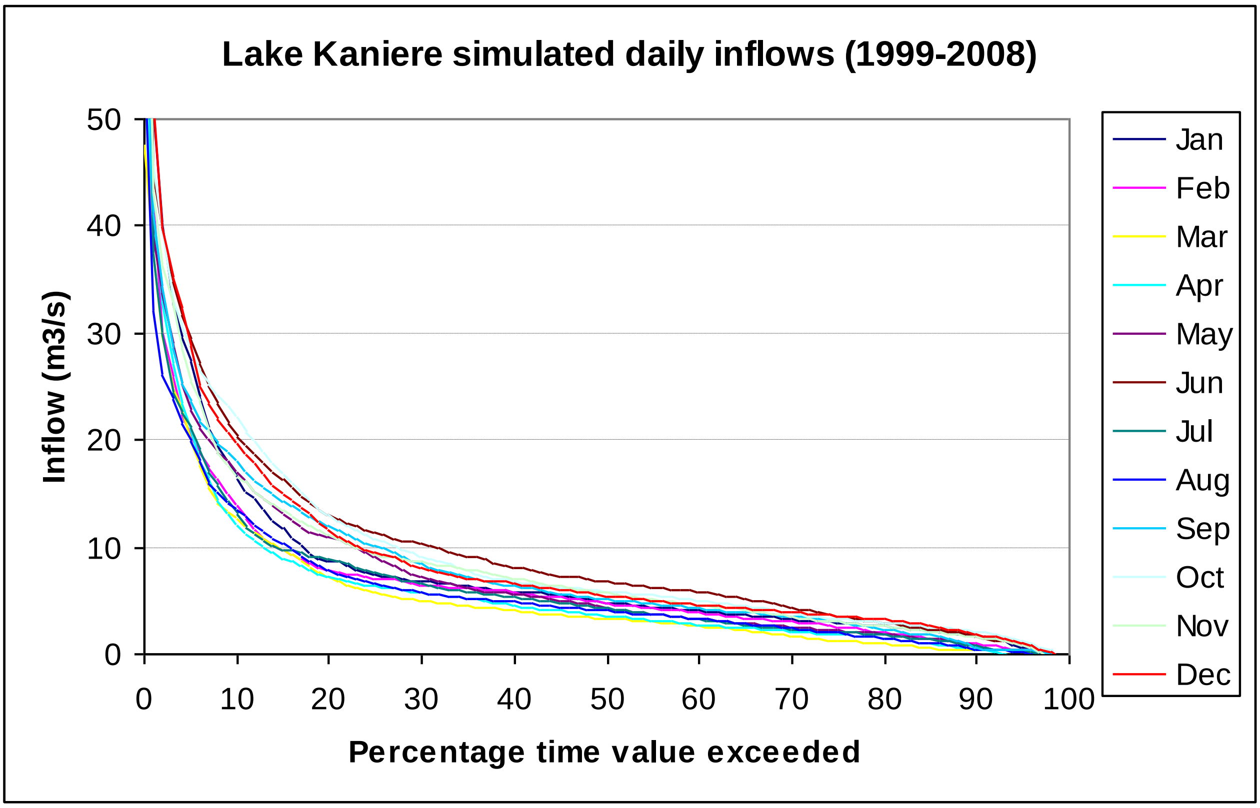

Figure 5.2.7. Lake Kaniere simulated inflow distribution by month for the period 1999 to 2008. Daily averaged data used.

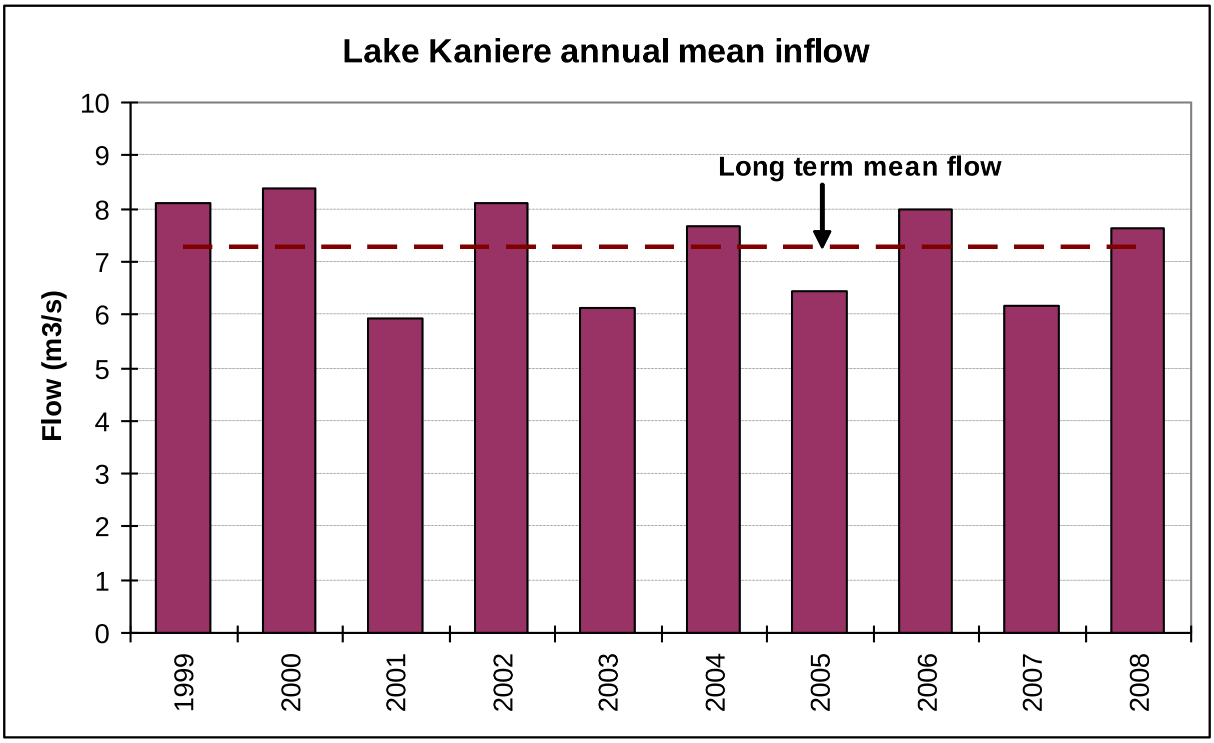

Figure 5.2.8. Lake Kaniere simulated average annual inflow.

5.2.6 Kaniere River flow at downstream Wards

In Section 6 a new power station is simulated that utilises Lake Kaniere water and discharges this water back to the Kaniere River in he vicinity of Wards Road, approximately 2.5 km downstream from Lake Kaniere. A flow series is generated for this location which combines the Kaniere River downstream of Lake Kaniere flow record (Section 5.2.3) with a local tributary flow series. This local tributary flow series represents a 4 km^2 catchment from Lake Kaniere to Wards Road, and has been simulated from the Butchers Creek flow record factored by catchment area. As this local catchment and Butchers Creek (3.9 km^2) are about the same size, the tributary flow reflects this Butchers Creek record (mean flow about 0.3 m^3/s and median flow 0.08 m^3/s).

The flow distribution for this Kaniere River at Wards Road is presented in Figure 5.8.1 for the 3 year period from July 2005 (along with the other Kaniere River series). The monthly median flow is presented in Figure 5.8.2, and mean monthly flows in Figure A1.10. As expected the flow series is dominated by the Lake Kaniere outflow series, with the exception of local catchment based fresh events.

5.3 Kaniere River flow at McKays weir

Water for the McKays race and hence power station is diverted from the Kaniere River at the McKays weir (Photo 6 & 7). The weir is situated approximately 5.5 km downstream (as the crow flies) from Lake Kaniere. Flow into the McKays race is via two manually controlled gates at the weir (Photo 13), with the downstream residual flow to the Kaniere River of 0.20 m^3/s maintained via a residual flow slot in the weir (Photo 8). Spill and losses from the weir augment the downstream flow. The weir spans 39m across the Kaniere River.

Three gaugings in 2008 by TrustPower confirmed that the residual flow was being maintained for weir levels above 1.80m. The gaugings along with the rating is illustrated in Figure A1.6 and A1.7. The higher rating flows are derived from a sharp crested weir equation ($1.84*Length*Height^{1.5}$) with an offset for the residual flow and weir losses.

The Kaniere River flow-series downstream of McKays weir is illustrated in Figure 5.3.1. Several periods of missing record exist, the largest over several months in 2004. The monthly flow distribution (Figure 5.3.2) indicates a median flow downstream of McKays weir of 1.3 m^3/s over the 2002 to 2009 period, with flows above 0.50 m^3/s occurring for 82% of the time. The records indicate that the downstream flow is above the minimum flow of 0.20 m^3/s for 98% of the time. The lowest levels recorded occurred in April 2003, and it is not known whether this is associated with upgrade work at this location, or whether alternative means of providing the required flow were in place. An analysis of the available records indicates that the McKays Creek power station was not generating at the time, and so any water in the Kaniere River at McKays weir was most likely being past downstream. This period also coincides with low levels observed in Lake Kaniere.

The flow distributions and monthly mean flows is presented for the Kaniere River upstream and downstream of McKays weir, and for the McKays race for the period 2002-2009 in Figure 5.3.3 and Figure 5.3.4 respectively. The period mean for the McKays race flow as determined from the McKays Creek station flow is nearly 4 m^3/s (comprises about 0.2 m^3/s Greens race flow, but excludes leakage or spill from the race), with the Kaniere River flow immediately downstream of the weir averaging 2.8 m^3/s (note, several gaps exist within this record). This produces a total flow at the weir of about 6.6 m^3/s.

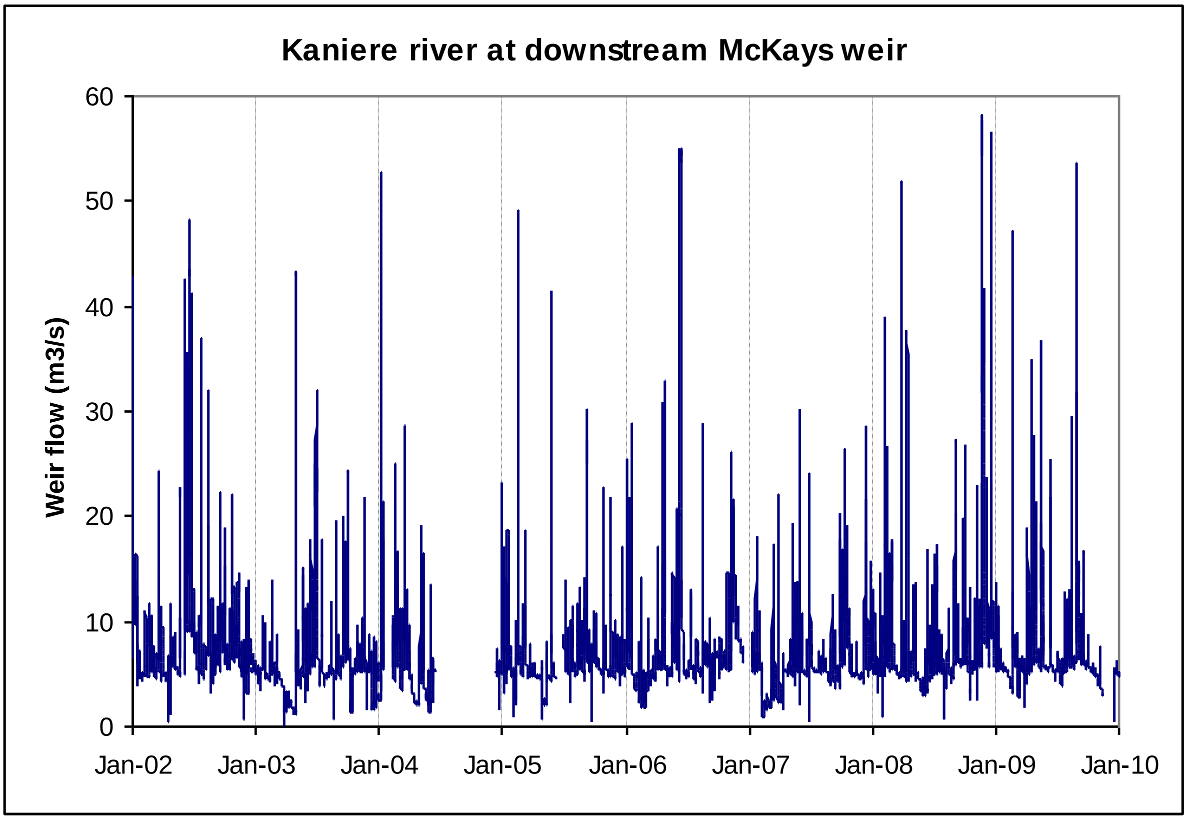

Figure 5.3.1. Kaniere River downstream of McKays weir (3 hourly averaged data).

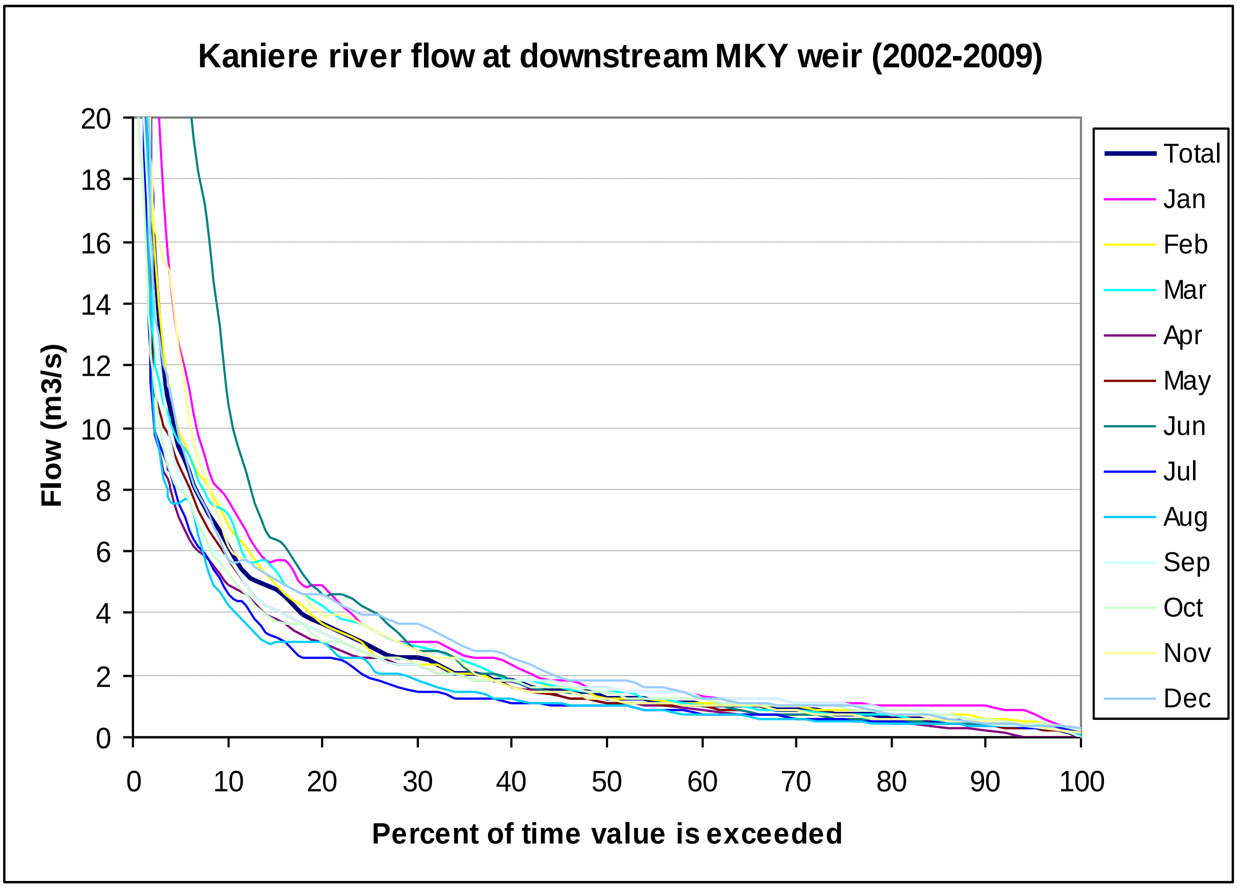

Figure 5.3.2. Kaniere River downstream of McKays weir flow distributions by month for the period 2002 to 2009.

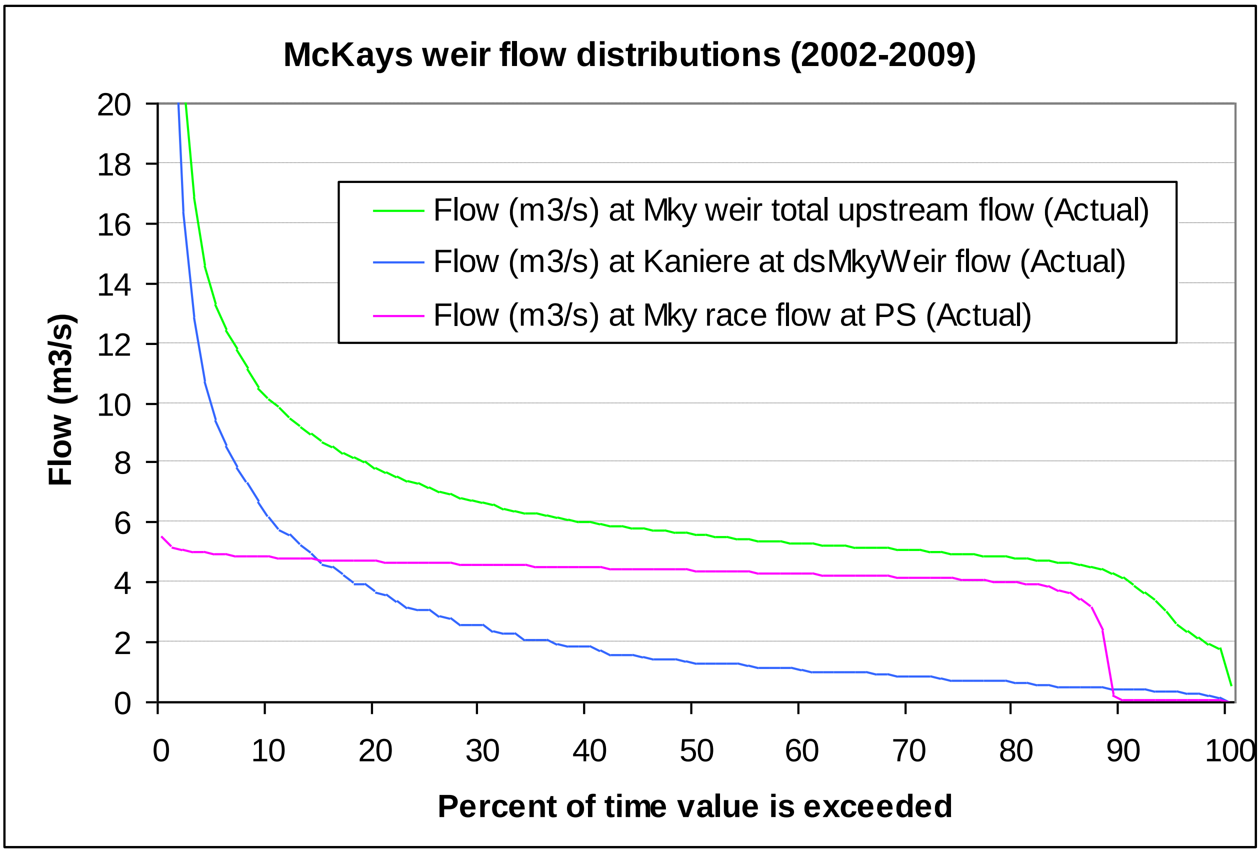

Figure 5.3.3. Flow distributions by month for the Kaniere River flow series at McKays weir for the period 2002 to 2009.

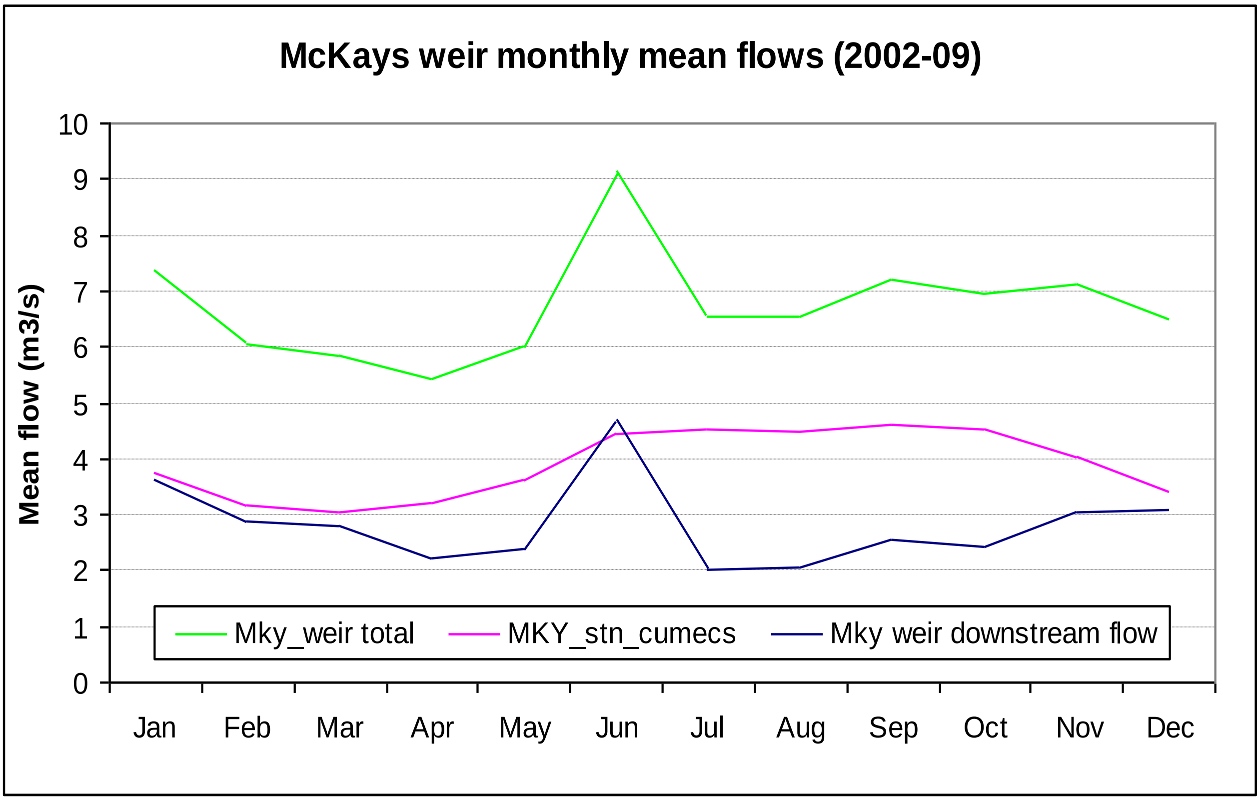

Figure 5.3.4. Monthly mean flows over the period 2002 to 2009, for the Kaniere River flow series at McKays weir.

5.4 Kaniere River flow and Kaniere Forks power station discharge

5.4.1 Kaniere Forks Power Station

The Kaniere Forks power station receives up to 1 m^3/s of water from Lake Kaniere and discharges this water back into the Kaniere River about 6.8 km from Lake Kaniere (and about 1.8 km of River channel downstream of McKays weir). The Kaniere Forks power station flow data has been determined from half hourly generation data since 1 April 1999, and has over this time been generating at near maximum output for 80% of the time. The Kaniere Forks station flow series is cover in Section 5.2, with the time series graph and monthly flow distribution for Kaniere Forks presented in Figure A1.1 and A1.2.

5.4.2 Kaniere River downstream of Kaniere Forks discharge

The Kaniere River downstream of Kaniere Forks discharge (Photo 11) receives water from the power station, the residual and fresh flow from McKays weir, and flow from another 21.7 km^2 of Kaniere River catchment downstream of McKays weir including Coal Creek and the Blue Bottle Creek residual and fresh flow. This additional tributary flow has been factored from Butchers Creek, with the Blue Bottle Creek water diverted at the Greens Creek intake simulated and subtracted from this flow (these two series are described later in Section 5.6). A time-series from 2002 has been developed for this Kaniere River downstream of the Kaniere Forks power station location. For most of the time the Kaniere Forks power station adds about 1 m^3/s to this flow (see previous section).

The time-series graph is illustrated in Figure 5.4.1, and any gaps in the record used to simulate this series is incorporated into the new record.

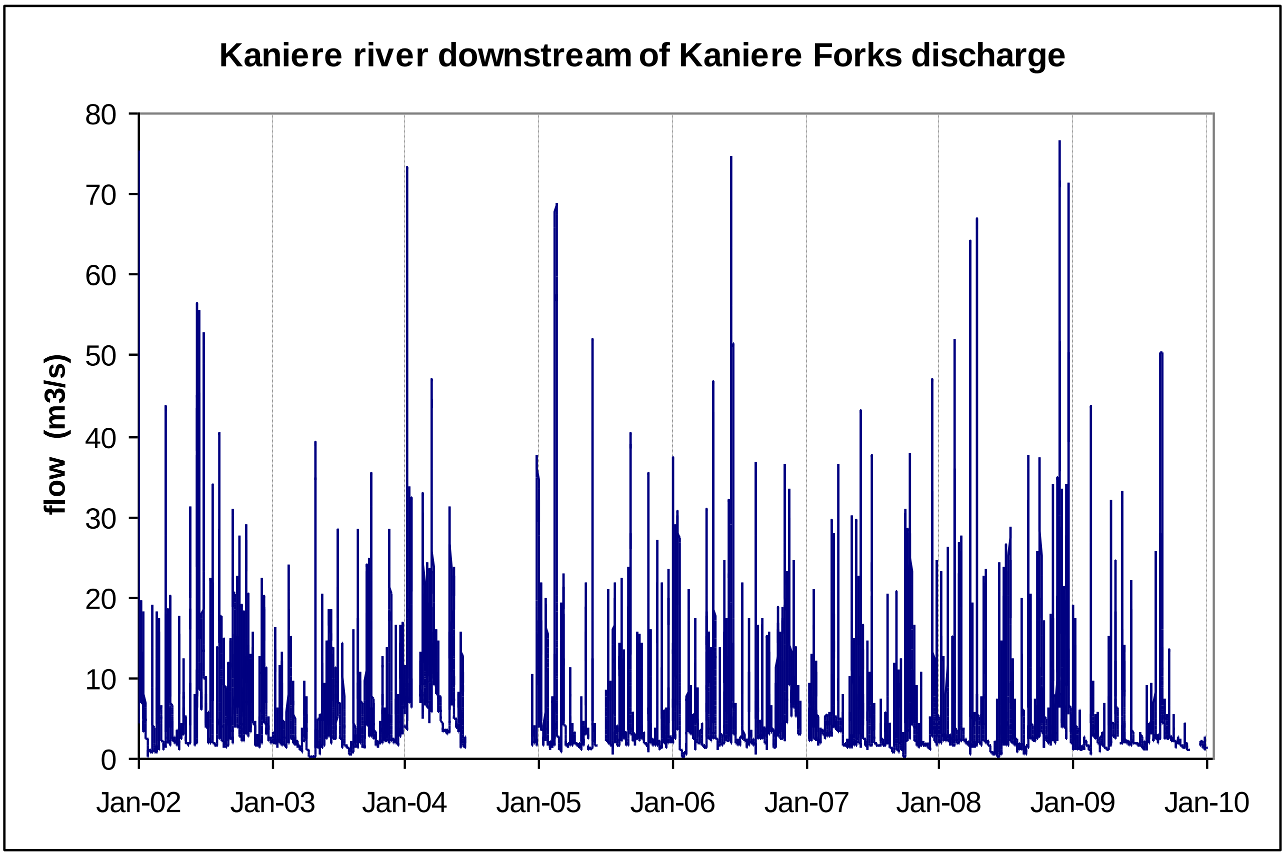

Figure 5.4.1. Kaniere River downstream of Kaniere Forks station discharge (3 hourly average data).

The monthly flow distributions for the period 2002 to 2009 indicates a median flow of 2.7 m^3/s, and a mean flow of around 4.8 m^3/s. Due to the discharge from Kaniere Forks power station, the flow at this location is greater than 1.0 m^3/s for 95% of the time.

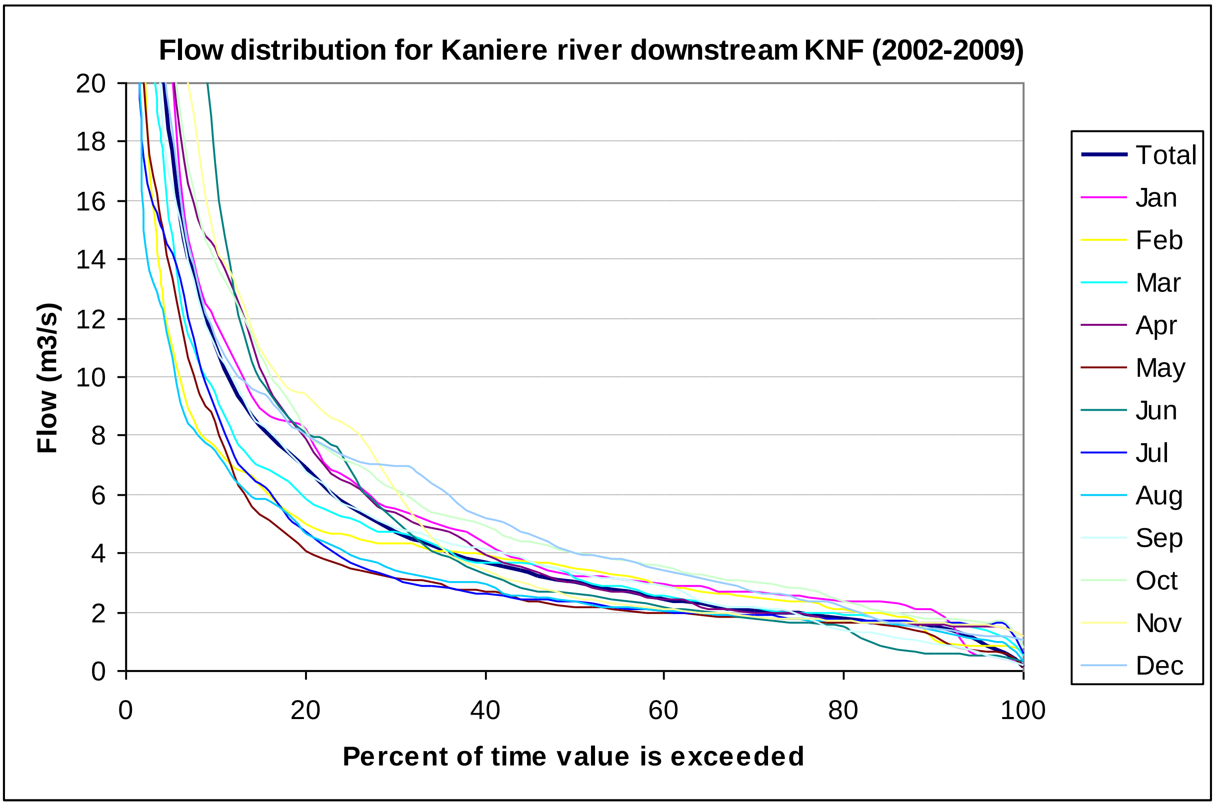

Figure 5.4.2. Monthly flow distributions for Kaniere River downstream of Kaniere Forks station discharge, for the period 2002 to 2009.

5.5 Kaniere River flow and McKays Creek station discharge

5.5.1 McKays Creek Power Station

The McKays Creek power station is situated on the left bank of the Kaniere River approximately 8 km downstream from Lake Kaniere, and 2.5 km downstream of the McKays weir. The discharge from the station enters a tailrace that joins with the Kaniere River about another 1 km downstream. The length of River channel from the Kaniere Forks station discharge to McKays Creek station discharge is about 3.3 km.

The station takes up to 5 m^3/s of water from the Kaniere River at McKays weir, with up to another 1 m^3/s of water from the McKays race tributaries – primarily from Greens Creek. The 4 km long McKays race includes the Coal Creek flume, a siphon over the Blue Bottle Creek, a 432 m tunnel, and several overflow structures (Photos 14). The Greens Creek intake situated approximately 2 km upstream of the Blue Bottle Creek confluence with the Kaniere River diverts up to 1 m^3/s from Blue Bottle Creek (Photo 15 and 16).

The McKays Creek power station flow has been determined from half hourly generation (MW) data since 1 April 1999 to the end of 2009, and has a mean generation of 0.86 MW. A conversion of 4.55 cumecs per MW has been used for this period, but due to factors such as debris in the intakes, machine maintenance and the like, this conversion value would at times over and under-estimate flows. This conversion gives a median flow of 4.4 m^3/s, a mean flow of 4.0 m^3/s, and a maximum of 5.6 m^3/s. Approximately 0.2 m^3/s of this long term mean flow comes from the Green Creek diversion (Section 5.6). The conversion of 4.55 cumecs per MW was based from design criteria for the station, with McKays race flow gaugings on 20 August 2008 (Appendix 1 Table A1.2) of 4.32 m^3/s and 4.20 m^3/s (and assuming no canal net gains or losses) indicated a conversion to MW of 4.55 m^3/s. A gauging immediately downstream of McKays Creek station in the tailrace on 3 November 2009 of 3.69 m^3/s produced a conversion of 4.25 cumecs per MW.

The McKay Creek station 3-hourly generation flow is illustrated in Figure 5.5.1 and the distribution of the data in Figure 5.5.2. Several large outages have occurred over this period of record, the longest in 2004. Including these outages the station has a capacity factor around 80%.

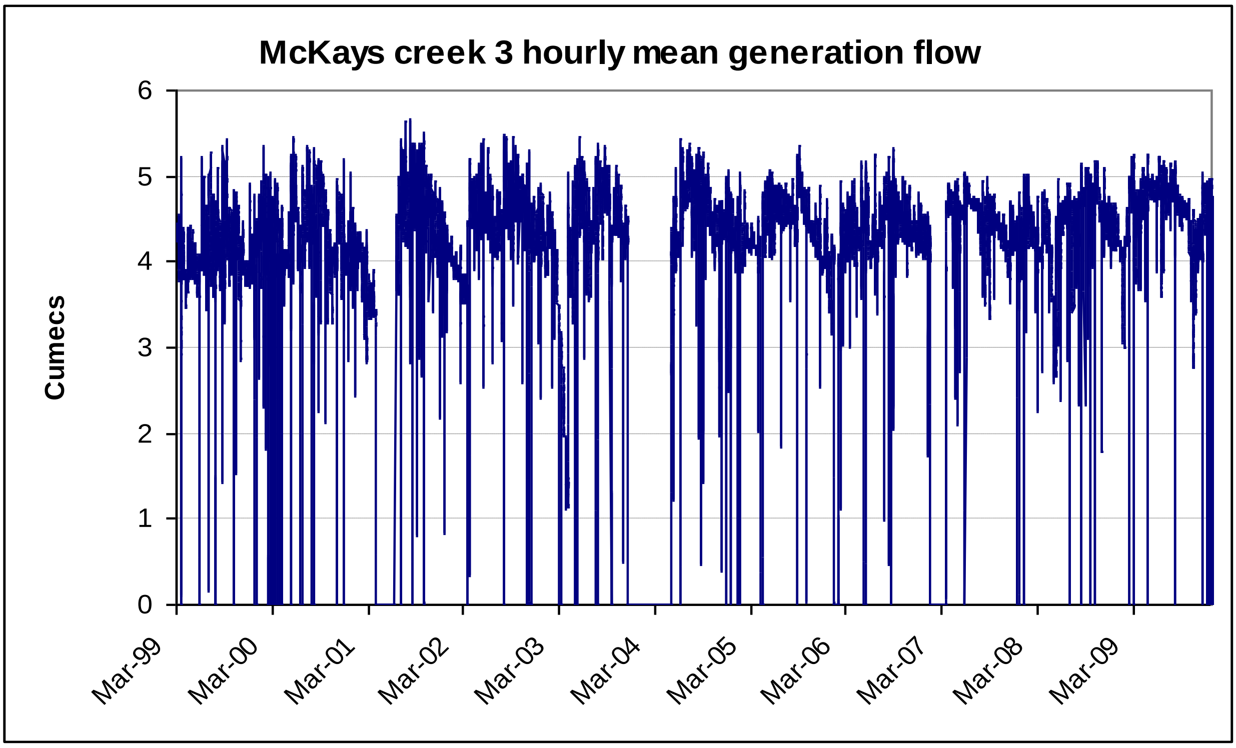

Figure 5.5.1. McKays Creek station output (3-hourly averaged data)

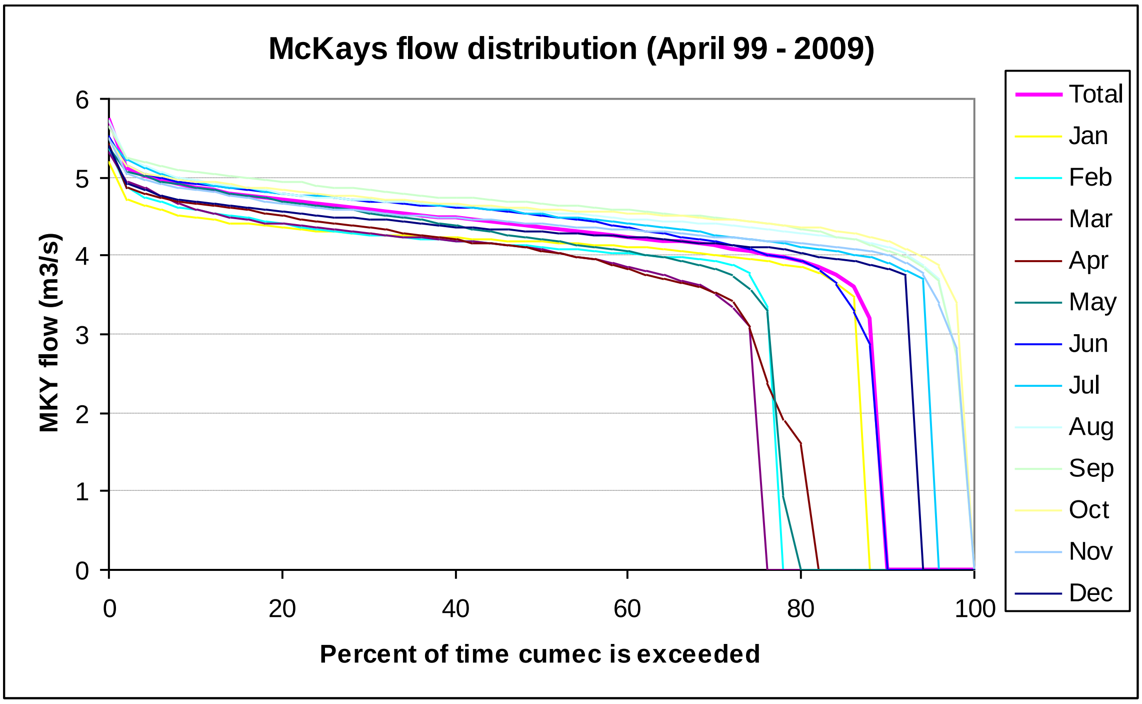

Figure 5.5.2. Monthly flow distribution for McKays Creek station output for the period April 1999 to 2009.

5.5.2 Kaniere River downstream of McKays Creek station discharge

The Kaniere River downstream of McKays Creek station discharge receives water from the Kaniere Forks and McKays Creek power stations, the residual and fresh flow from McKays weir, and other local tributary flows. Two larger tributaries join the Kaniere River between the Kaniere Forks and McKays Creek station discharge and include Kennedy Creek (16.8 km^2) and McKays Creek (3.8 km^2) and together comprise most of the 23.4 km^2 of local catchment between the two station's discharges. This additional flow has been factored from Butchers, and a time-series developed for this Kaniere River location (Figure 5.5.3).

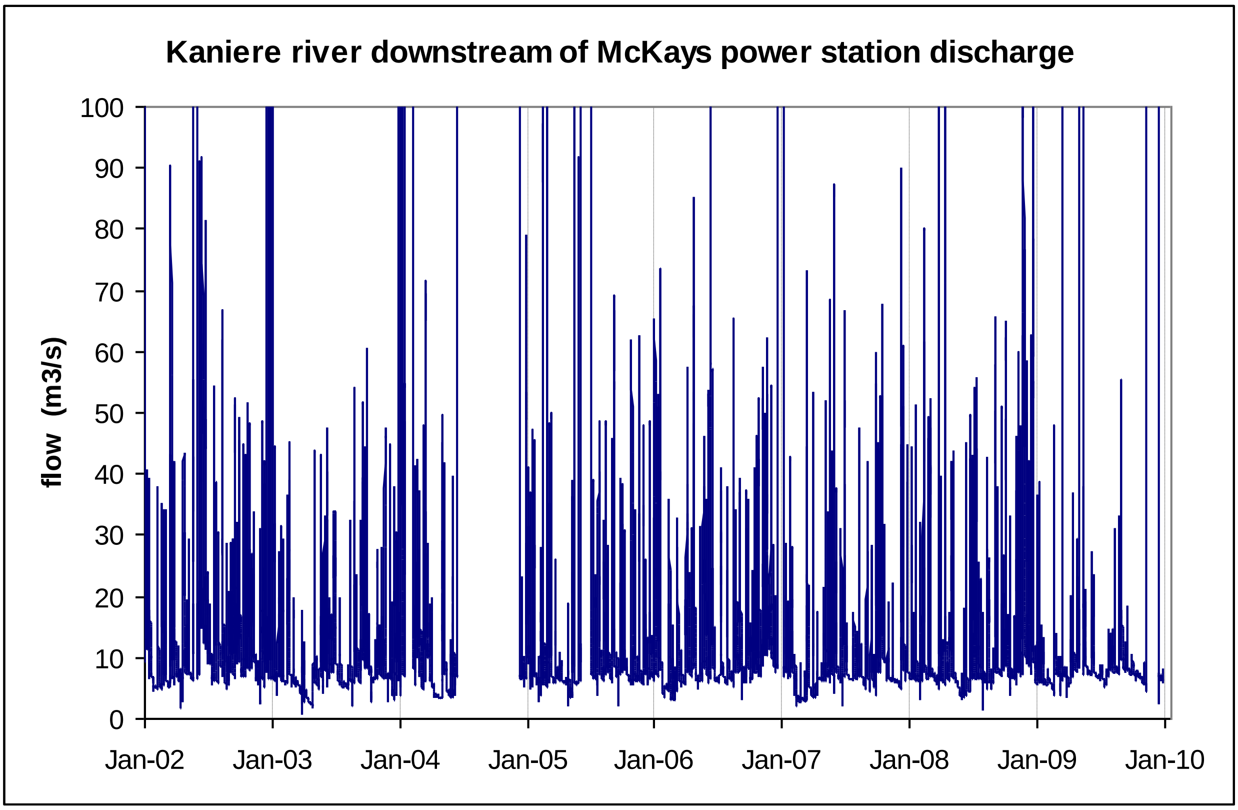

Figure 5.5.3. Kaniere River downstream of McKays Creek station discharge (3 hourly average data).

The flow distribution for Kaniere River downstream of McKays Creek power station for the 2002 to 2009 period (Figure 5.5.4) illustrates the influence of the McKays Creek power station discharge at this Kaniere River location, with an increase in the median flow to 7.5 m^3/s (mean flow of 10.4 m^3/s) with flows greater than 4.0 m^3/s for around 95% of the time.

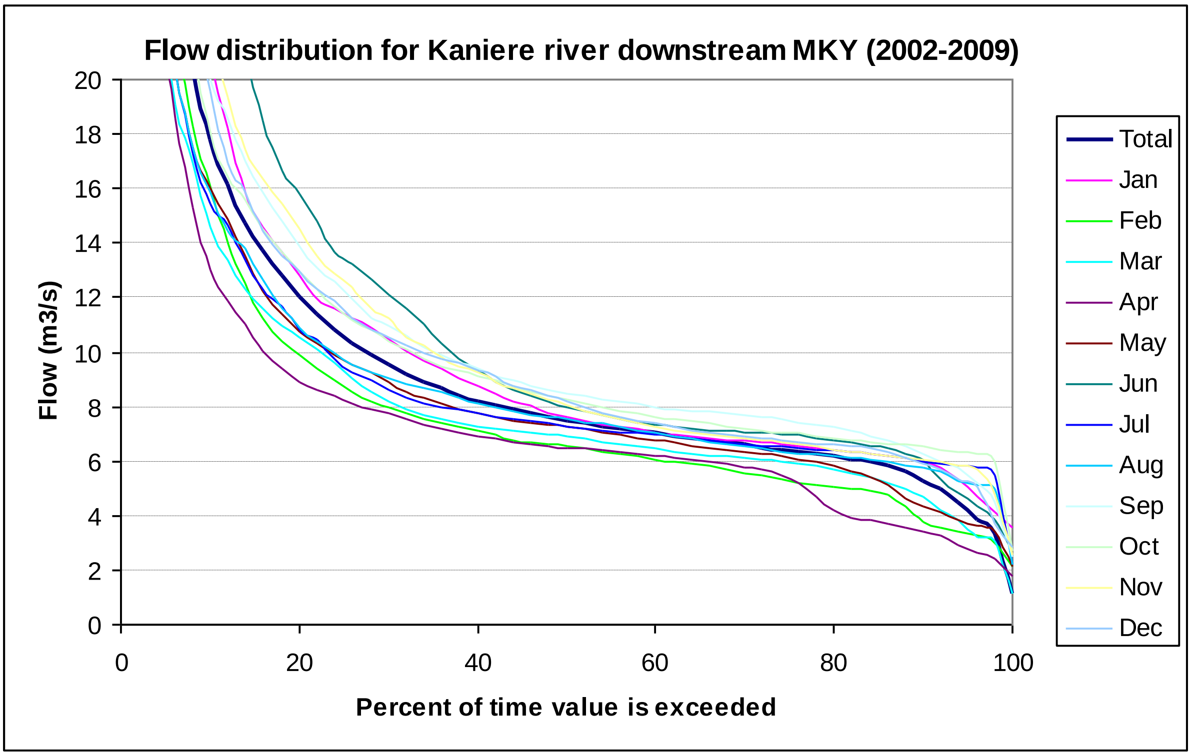

Figure 5.5.4. Monthly flow distributions for the Kaniere River downstream of McKays Creek station discharge for the period 2002 to 2009.

5.6 Blue Bottle Creek and Greens Intake

Blue Bottle Creek joins the Kaniere River about 1.5 km downstream of McKays weir with a catchment area of approximately 11 km^2. A weir with intake on Blue Bottle creek diverts flow from approximately 10.3 km^2 of this catchment and diverts this into Greens Creek (Photo 15 and 16). Greens Creek flows into the McKays race with a consented take from McKays race tributaries of 1 m^3/s. The natural Greens Creek catchment adds another 1.05 km^2 of catchment area. As little or no flow records existed for the period up to the beginning of 2009, the hydrology for Blue Bottle Creek and Greens Creek was factored based on catchment area from the Butchers Creek flow site. It was assumed that the Greens Creek intake captured 80% of the Blue Bottle Creek flow up to the maximum take of 1.0 m^3/s (based on gaugings undertaken in October 2008)[1].

A seven year gap exists in the Butchers Creek record (1994-2001) and several gaps exist thereafter. These gaps are carried through into the simulated records for Greens Creek. The flow distributions for Butchers Creek, and the simulated flow for Blue Bottle Creek flow at (upstream of) Greens Creek intake, the residual Blue Bottle Creek flow, and Greens race flow is illustrated in Figure 5.6.1. For the 1971 to 2008 record the median flow for the total Blue Bottle Creek at Greens Intake is 0.21 m^3/s, and the simulated median downstream Blue Bottle Creek flow is 0.06 m^3/s (Table 5.6.1). The Green Creek race is at full (1.0 m^3/s) capacity for 15% of the time, with a median flow of 0.17 m^3/s and average flow of 0.29 m^3/s.

Table 5.6.1- Flow statistics in m^3/s for Butchers Creek, and for records simulated from Butchers Creek (1971-2008)

Flow Site	Minimum	Median	Mean	Maximum
Butchers Creek	0.001	0.08	0.34	55
Blue Bottle total at Greens Intake	0.002	0.21	0.86	119 (1)
Blue Bottle residual flow	0.000	0.06	0.63	118 (1)
Green Creek race	0.002	0.17	0.29	1

Note (1) – Upper 1% flows factored by catchment area to power of 0.8

Time-series data for Blue Bottle and Greens Creek has been collected since March 2009. An analysis of this data indicated that simulated tributary flows based on catchment area are underestimated for these locations especially for low or receding flows (Figure A1.8 and A1.9). For low to median flows the simulated Blue Bottle series at Greens Intake is under-estimated by 0.040 m^3/s to 0.130 m^3/s. As the simulations were not rerun based on this new information, the tributary flows to the Kaniere River will be under-estimated (covered further in Section 5.7).

The comparison of the actual and simulated data for the Blue Bottle Creek residual flow and Greens Creek flow for the period May to December 2009 (Figure A1.8) indicated a measured median flow at Greens Creek just upstream of McKays race of 0.29 m^3/s, and a simulated median of 0.16 m^3/s. The analysis of the actual Greens Creek record at McKays race indicates that flows above 1.0 m^3/s occur for about 6% of the time, a result of rainfall events on the local. Any flows above the consented McKays race take would be spilled from the McKays race from one of the several overflow structures.

The actual and simulated median flow for Blue Bottle Creek flow downstream of the Greens intake was around 0.05 m^3/s for the measured and the simulated data. Measured flows at the residual Blue Bottle Creek location are higher than for the simulated flows for flows above the median (due to the simulate series under-estimating total Blue Bottle flows, and over-estimating Greens intake flow capture efficiency).

[1] Subsequent analysis based on measured data from May 2009, indicates that the Greens Creek intake captures around 80% to 90% of the Blue Bottle Creek flow for Blue Bottle Creek flows below 0.50 m^3/s. This flow capture (as a percentage) reduces as the Blue Bottle Creek flows increase. At 1 m^3/s flow at the weir the Greens intake capture is at about 40%, and a flow of above 5 m^3/s upstream of the weir is required to achieve the maximum take at the intake of 1 m^3/s. However there is quite a lot of variation about this. Although the capture efficiency of the intake is lower than modelled, this is partially offset by the simulated Blue Bottle Creek flows at the weir (as determined from Butchers Creek flows) being under-estimated.

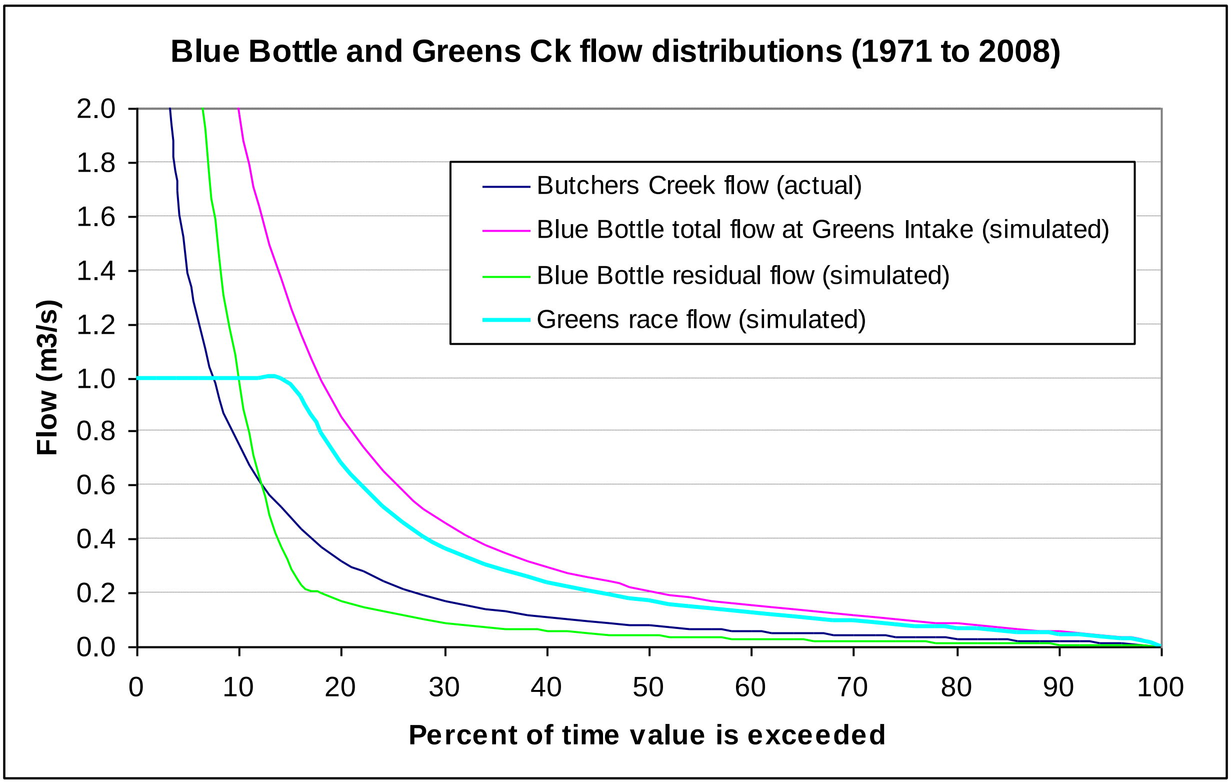

Figure 5.6.1 – Flow distributions for Butchers Creek, and the simulated flows for total Blue Bottle Creek at Greens intake, the Blue Bottle Creek downstream of the intake, and Greens race flow (1971- 2008).

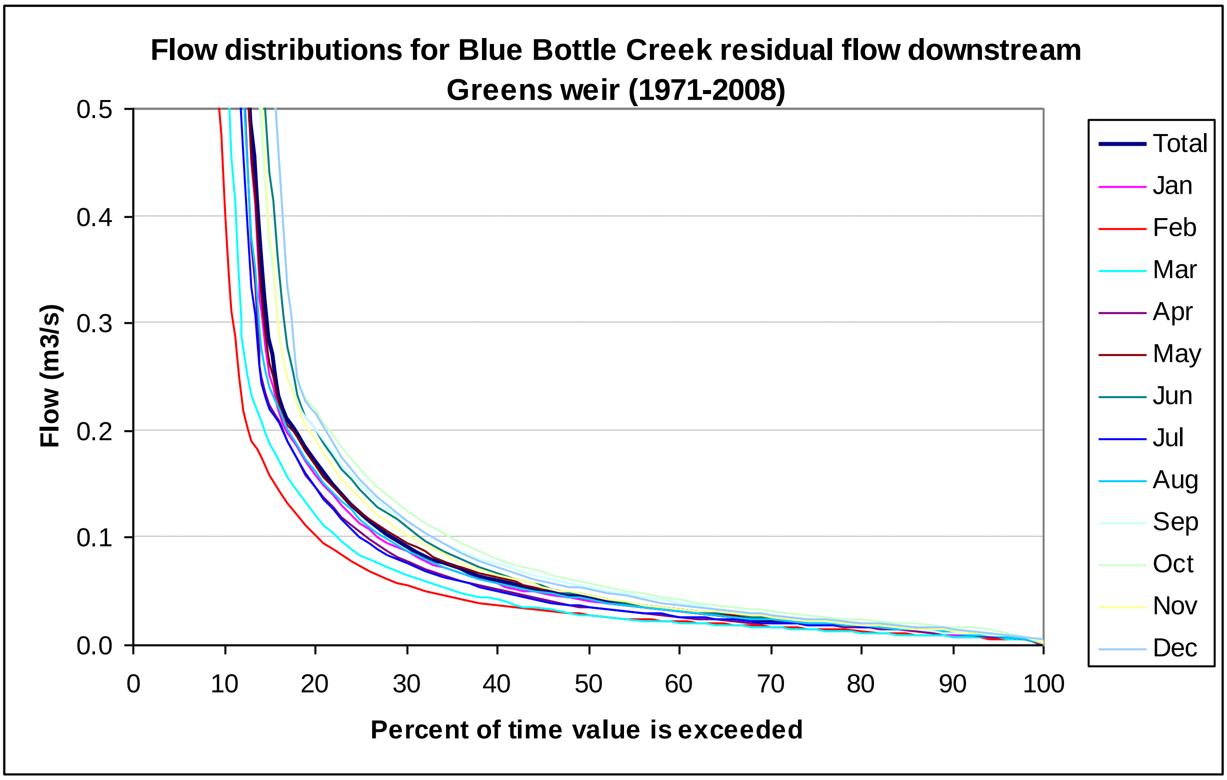

Figure 5.6.2 – Monthly flow distributions for the simulated Blue Bottle Creek downstream of Greens weir (1971- 2008).

5.7 Other locations

5.7.1 Kaniere River below McKays weir gauging runs

Concurrent gaugings were performed at locations on the Kaniere River downstream of the McKays weir to determine the local tributary flow pick-up (Table 5.7.1). Flows were gauged on the Kaniere River at; downstream of the McKays weir, immediately upstream of the Kaniere Forks station discharge, and at the McKays station ford (about 1 km upstream from the tailrace discharge to the Kaniere River and upstream of the McKays Creek tributary). The Blue Bottle Creek residual flow at the McKays race siphon was also gauged, and station flows determined from MW output conversion. Values in Table 5.7.1 that were not gauged (i.e. estimated, taken from ratings, or converted from MW) are shaded yellow.

Table 5.7.1 –Concurrent gaugings on the Kaniere River. Flows not gauged are shaded yellow.

Location –	10-May-09	11-Feb-10	23-Mar-10	12-Apr-10
Kaniere River at downstream McKays weir	1.42	0.65	3.1	0.49
Blue Bottle Creek residual flow	0.32	0.004	1.00	0.001
Kaniere River at upstream Kaniere Forks station	1.89	1.06	-	0.91
Kaniere Forks station flow	0.98	0.98	0.58	0.99
Kaniere River at McKays ford	3.75	1.99	6.53	2.06
McKays Creek station flow	4.47	4.48	0	4.78
Kaniere River at downstream McKays station	8.38	6.53	6.75	6.86

This gauging data has been used to derived the Kaniere River tributary flow from McKays weir to upstream of Kaniere Forks station discharge, and from McKays weir to McKays ford (Table 5.7.2). These flows have been compared to the tributary flows derived from Butcher Creek flow based on catchment area (plus the Blue Bottle residual flow). Table 5.7.2 presents the difference between the gauged and simulated flows from Butchers. Positive values indicate that the tributary flows calculated based on catchment area are under-estimated, and this is partially due to the catchment area approach slightly under-estimating flows, and also so due to leakage (and possibly spill) from the McKays race. An example of such leakage is from Coal Creek flume (Section 5.7.2).

Table 5.7.2 –Kaniere tributary gauged flow less derived flow for two locations on the Kaniere River.

Kaniere River tributary flow for;	10-May-09	11-Feb-10	23-Mar-10	12-Apr-10
McKays weir to upstream Kaniere Forks station	0.07	0.24	-	0.37
McKays weir to upstream McKays ford	1.33	0.87	0.91	1.44

5.7.2 Coal Creek gaugings and McKays race losses.

The McKays race passes over Coal Creek through a wooden flume. Water from this flume leaks into Coal Creek, and the flume also has an overflow feature that will limit flows to around the maximum consented flow. Discussions with operational staff indicate that the leakage rates will vary, but tend to be highest when flows recommence in the race after it has been shut down or low for awhile.

Coal Creek gaugings upstream and downstream of the McKays race flume on the 28 May 2010 indicate a 0.075 m^3/s loss from the flume, a value which appears about typical. The race was not spilling from the flume at the time of the gaugings. This loss has not been included in the modelling, and will be partially offset by non-specific flow to the race.

Other losses from the race can occur at any of the race overflow structures, and from dewatering sluices/ gates. In Section 6 losses from the race have not been modelled other than limiting the race flows to 5 m^3/s to 8 m^3/s at the McKays weir (depending on scenario modelled), and to 5 m^3/s to 9 m^3/s at the station.

5.8 Kaniere River Flow Summary

The following actual flow series have been derived from actual and simulated records for the Kaniere River at;

- Lake Kaniere outflow – (excludes Kaniere Forks race flow, and includes Lake Kaniere spill flow)
- Lake Kaniere total outflow – (includes Kaniere Forks race flow and spill)
- Kaniere River immediately downstream of Wards Road.
- Kaniere River immediately upstream of McKays weir.
- Kaniere River immediately downstream of McKays weir.
- Kaniere River immediately downstream of Kaniere Forks station discharge.
- Kaniere River immediately downstream of McKays Creek station discharge.

Time-series for these locations were simulated as they were considered of interest for the re-consenting process, and represent points of hydrological change. These records were simulated from actual time-series record which was generally available from at least 2002, but some large gaps in the record exist. For the locations downstream of McKays weir there is 12% missing record in the period up to the end of 2008. The period from July 2005 to June 2008 has only 2% missing record and this has been compared, and is presented as a distribution (Figure 5.8.1), as a monthly median plot (Figure 5.8.2), and as amonthly mean plot (Figure A1.11). Flow statistics for this and the longer period to 2008 are given in Table 5.8.1.

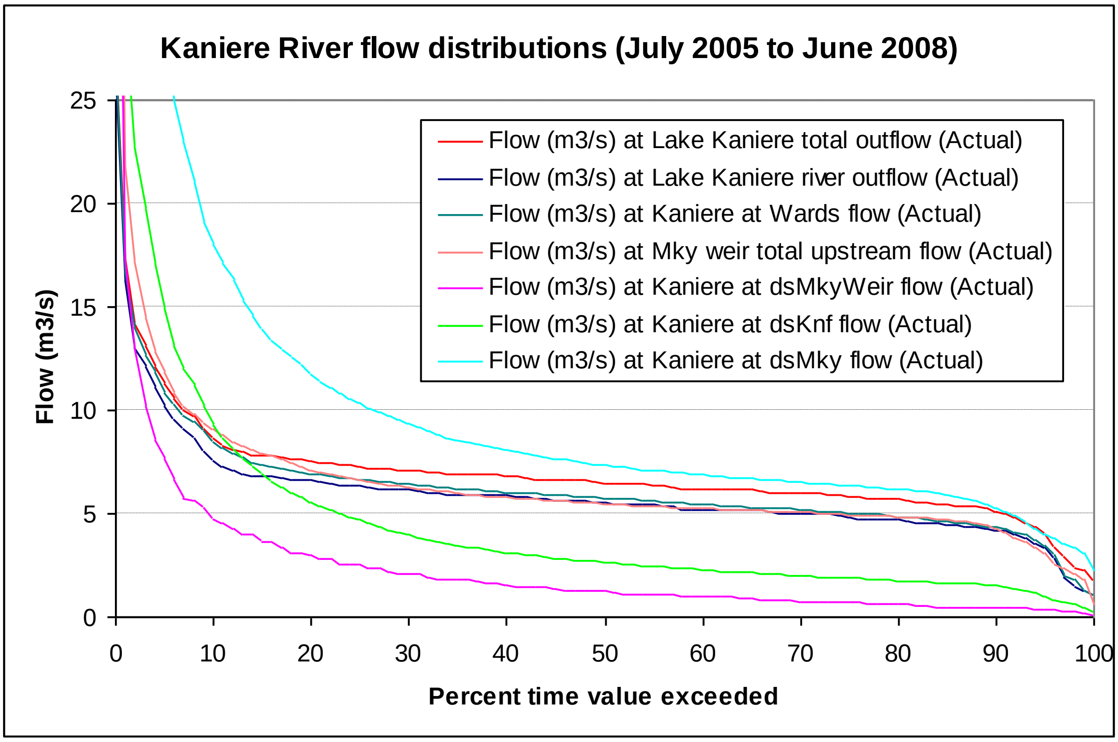

Figure 5.8.1. Lake Kaniere and Kaniere River flow distributions for the period July 2005 to June 2008.

There is about 0.5 m^3/s imbalance between Kaniere outflow with that of McKays weir less local tributary pickup. Measurement or conversion error between either of these series could account for this error. As little in the way of quality checks have been made to the Kaniere or McKays data over time it was decided to make no adjustment to any of the series. This inconsistency with the McKays weir data is also reflected in the Wards Road data which is derived from Kaniere outflow data with the tributary flows added.

Over this same July 2005 to June 2008 period Butchers Creek recorded a mean flow of 0.3 m^3/s (median flow was 0.08 m^3/s), which when factored by catchment area, generates a local pickup to Wards Road of 0.3 m^3/s, to McKays weir of 1.0 m^3/s, and another 3.5 m^3/s from the weir to McKays power station discharge. As previously mentioned factoring local tributary flow based on Butchers creek appears to under-estimate the lower flows. An analysis of the 2002 to 2008 record (which has 12% missing record) indicates that the flows on average were 5% to 10% higher that the 2005 to 2008 record.

Table 5.8.1. Summary statistics for Lake Kaniere and the Kaniere River locations.

	Catchment Area [1]	Mean & (Median) 2005-08	Mean & (Median) 2002-08
Location:	(Km^2)	(m^3/s)	(m^3/s)
Lake Kaniere Inflows	52.3	6.8 (5.7)	7.0 (5.8)
Lake Kaniere Total Outflows	52.3	6.8 (6.4)	7.0 (6.4)
Kaniere River at			
-Lake Kaniere [2]	52.3	5.9 (5.5)	6.1 (5.5)
-Wards Road	56.3	6.2 (5.8)	6.4 (5.8)
-McKays weir (total) [3]	65.9	6.4 (5.5)	6.8 (5.6)
-downstream McKays weir	65.9	2.3 (1.2)	2.9 (1.4)
-downstream Kaniere Forks discharge [4]	87.6	4.5 (2.7)	5.1 (2.8)
-downstream MKY discharge [5]	111.0	10.4 (7.4)	10.8 (7.5)

Notes (1) - Catchment areas from Rileys "Hydrology Scoping Study Wahapo and McKays Creek HEP report (2005)".
(2) – excludes Kaniere Forks race flow which had a mean flow of 0.90 m^3/s and median of 0.99 m^3/s over this period.
(3) – McKays weir total comprises the McKays race flow and the downstream weir flow.
(4) – Includes Kaniere Forks station discharge & (5) – Includes McKays Creek station discharge

Table 5.8.2. Summary statistics for local Kaniere tributary flows for the period July 2005 to June 2008.

	Local Catchment Area	Mean flow
Location: Kaniere River tributary flow	(Km^2)	(m^3/s)
Butchers Ck	3.9	0.3
Lake Kaniere to Wards Rd	4.0	0.3
Wards rd to McKays weir	9.6	0.7
McKays weir to Kaniere Forks discharge	21.7 [1]	1.7
Kaniere Forks discharge to McKays Creek discharge	23.4	1.8

Notes (1) – includes 10.3 km^2 as part of the Blue Bottle ck diversion to Greens ck. Greens ck flow to McKay race averaged about 0.3 m^3/s over this period, and also includes flow from the local Greens Creek catchment.

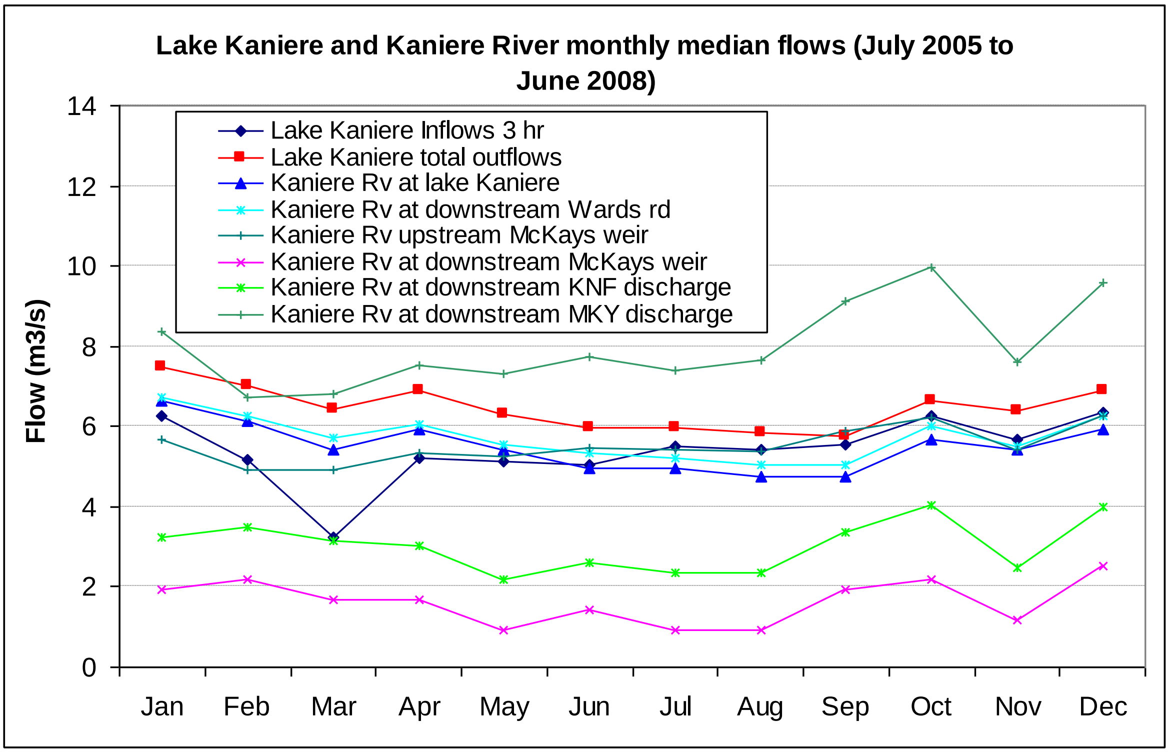

Figure 5.8.2. Lake Kaniere and Kaniere River monthly median flows for the period July 2005 to June 2008.

6 Hydrological Analysis – Station upgrades

6.1 Simulation overview

The "Hydstra Modelling" software was used to create a hydrological model to simulate the current McKays and Kaniere Forks power station operation, and to investigate the potential hydrological effects of increasing the generating capacity of each station. A new power station which would discharge Lake Kaniere water back to the Kaniere River in the vicinity of Wards Road was also included in the modelling. The hydrological model used actual and simulated flows, and endeavoured to replicate the current management of Lake Kaniere. A description of the model inputs and model assumptions is attached as Appendix 2.

To calibrate and check the model the Kaniere Forks and McKays Creek scheme was modelled which endeavoured to replicate the hydrology and current management of the existing McKays and Kaniere Forks power schemes (for reference called "*Basecase*"). Also modelled was a "*Wards8_Mky8*" scenario that included McKays Creek station upgraded to take 8 m^3/s from the Kaniere River, a new Wards station installed at 8 m^3/s, and which had the Kaniere Forks station decommissioned (Table 6.1.1). For both scenarios the Green Creek flows were simulated which allowed up to another 1 m^3/s of flow through the McKays Creek station, a situation as currently consented. Thus the upgraded McKays Creek station would have a maximum capacity of 9 m^3/s.

Existing minimum flow conditions from Lake Kaniere to the Kaniere River is 0.20 m^3/s, as is the minimum flow for the Kaniere River for downstream of the McKays weir (0.20 m^3/s). Under the enhancement scenario "Wards8_Mkys8", minimum flows are proposed (and modelled) as 0.3 m^3/s to the Kaniere River from the Lake, and downstream of McKays weir. Additional minimum flow requirements are also proposed and modelled and included 0.40 m^3/s in the Kaniere River at Wards Road, and 0.50 m^3/s in the Kaniere River at McKays Ford (a location just upstream of McKays Creek, and which is the access ford to the McKays Creek power station).

The models were run over the 2002 to 2008 (inclusive) period in hourly time-steps. Section 5 describes the nature of the data used in the simulations, and Section 5.2.5 describes the wet and dry years over this period. The quality of this record is affected by gaps in the information, and the limited quality checks on the data over time. The analysis of the simulated data is presented in Section 6.2, and the results from the selected scenarios discussed further in Section 7.

Table 6.1.1. Existing operation (Actual data) and modelling scenarios with station's maximum flow rates

Scenarios	Scenario identifier	Kaniere station (m^3/s)	New station at Wards Road (m^3/s)	McKays station (m^3/s)
Description		KNF	WARDS	MKY
Existing data and consent limits	*Actual*	1	0	6 (1)
Existing Scheme modelled	*Basecase*	1	0	5 (1)
Enhancement Wards at 8 m^3/s, MKY at 8 m^3/s	*Ward8_Mky8 (W8M8K0)*	0	8	9 (2)

Note 1. Current consents for McKays Creek station permit up to 5 m^3/s from the Kaniere River at McKays weir, and another 1 m^3/s from Kaniere River tributaries (i.e. Greens Creek). The station's maximum discharge is about 5 m^3/s, but the consented maximum discharge back to the Kaniere River is 6 m^3/s.
Note 2. Includes up to 8 m^3/s from the Kaniere River at McKays weir and another 1 m^3/s from Kaniere River tributaries.

6.2 Results

6.2.1 Model calibration

The model was calibrated to the current Kaniere Forks and McKays Creek scheme configuration and minimum flows, using the available and simulated scheme hydrometric data. An operating scenario was establish for Lake Kaniere based on lake level, with the model calibrated to maximise flow through the McKays Creek station, and limit non–spill flow immediately downstream of McKays weir to the minimum flow (0.2 m^3/s).

Figure 6.2.1 illustrates the Kaniere River flow at Lake Kaniere and the downstream McKays weir actual and Modelled flow distributions for the seven year period 2002 through to 2008 inclusive. The simulated data reflects the operating scenario for the Lake Kaniere with the outflow to the River managed at 4.5 m^3/s with flows greater than this due to spill from the Lake. The actual lake outflow to the River record indicates that the outflows may not be managed as optimally as the model with generally more flow released from the lake and consequently greater flows downstream of McKays weir. In part this is due to the manual operation of the Lake Kaniere gates. An upgrade to the instruments and communications associated with the Lake Kaniere and McKays weir gates commenced in 2009, which will result in the gates being able to be remotely operated. This is expected to enable better management of the flows to the Kaniere Forks and McKays Creek power schemes.

The Modelled data for downstream of McKays weir illustrates overall lower flows than observed over the 2002 to 2008 record (Figure 6.2.1), as the model placed more of the Kaniere River flow through the McKays power station and consequently less water below the McKays weir. This is in part due to no station outages being modelled, lower modelled flow releases from Lake Kaniere, and greater use of the available flows at McKays weir. Also the replacement of the McKays race flume across Blue Bottle Creek in early 2007 increased the flow capacity of this part of the McKays race. A review of the McKays Creek station generation for the 2 year period prior to the flume replacement (2005 and 2006 inclusive) with that after the upgrade (2008 to 2009 inclusive) indicate that the station generation has been higher, which may reflect higher flows (but still within the consented 5 m^3/s) being passed along the McKays race since the flume replacement (Appendix A2 Figure A2.10). The distributions for the Kaniere River flow upstream of the McKays weir is presented for these same two periods in Figure A2.11.

Analysis of this modelled Basecase and actual measured data indicated a modelled average flow through the McKays Creek power station of 4.8 m^3/s, but only around 4.0 m^3/s being measured over the 2002 to 2008 period. Likewise the Kaniere River flow downstream of the McKays weir were modelled at being near the minimum flow of 0.2 m^3/s for around 50% of the time, with a median flow of 0.4 m^3/s. Measured data was near the minimum flow for less than 5% of the time with a median flow of 1.4 m^3/s. The measured Lake Kaniere mean and median lake level over the 2002 to 2009 period was 0.89m and 0.94m respectively, with the modelled Basecase levels about 0.05m higher than this, a reflection that the simulated managed lake outflow was generally slightly less than historically measured.

A comparison of the Modelled data for Kaniere River downstream of McKays weir against various periods of historic actual record indicate that the latter periods produce results nearer the modelled data (Figure 6.2.2). Due to the manual operation of the McKays race gates, and the rapid nature that the Kaniere River tributaries respond to rain events, it is unlikely that the minimum flow at McKays weir could be maintained at 0.20 m^3/s, without automation of the gate control systems. It is also likely in practice that flows slightly above 0.20 m^3/s are released as to better ensure compliance to the minimum flow requirement.

The minimum flow of 0.20 m^3/s was used in the model, and outages were not simulated. Should outages or a minimum flow buffer be incorporated in the modelled scenarios, the relative percentage changes would remain the same between the scenarios. Therefore the model was considered reflective of how the current power schemes could be operated within the current consents.

The following sections will illustrate using graphs of distributions and monthly flows, and tables of the hydrological statistics, the results from the modelling of the Wards8_Mky8 enhancement scenario, for Lake Kaniere and the Kaniere River locations down to McKays Creek station discharge. Also presented will be the "Actual data" (the available 2002 to 2008 measured data).

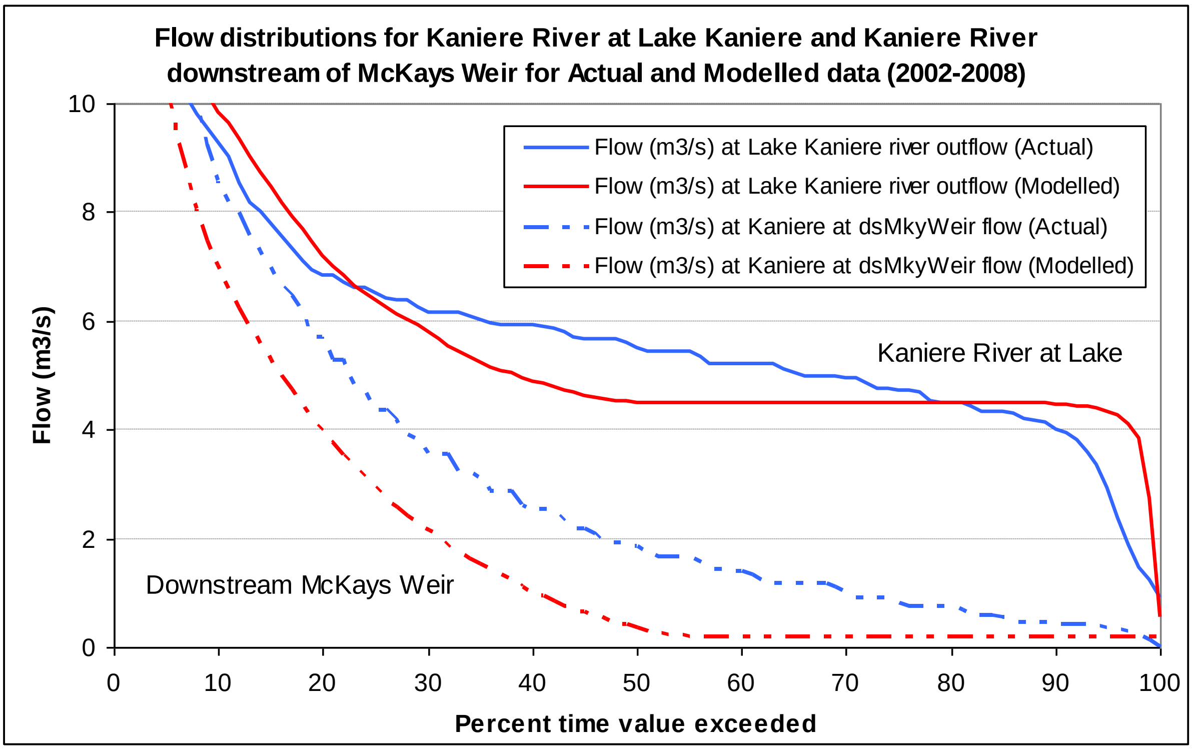

Figure 6.2.1. Modelled and actual data flow distributions.

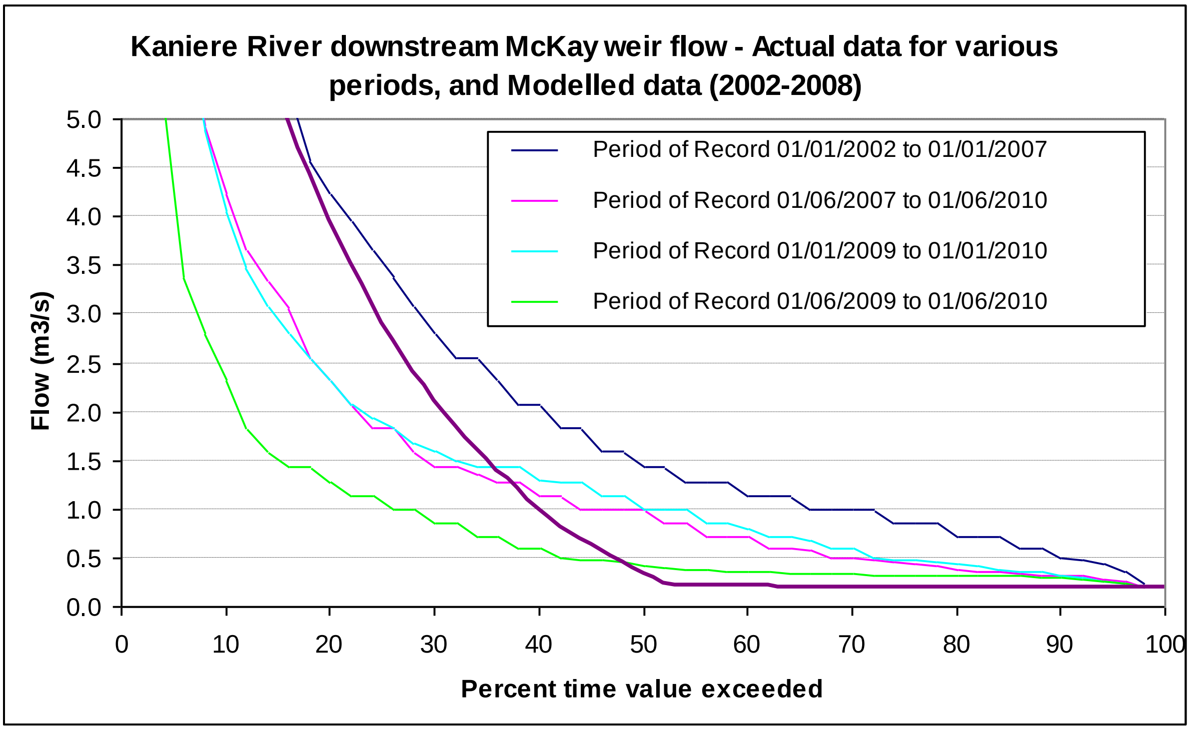

Figure 6.2.2. Modelled and actual data flow distribution for downstream of McKays weir.

6.2.2 Lake Kaniere level

The simulated Lake Kaniere level is influenced by the Wards Road and McKays Creek power scheme outflow operation modelled for the lake. At Lake Kaniere levels of -0.10m or lower, the simulation had the total Lake Kaniere outflows limited to the minimum flow of 0.30 m^3/s from the Lake (or slightly greater to maintain the 0.40 m^3/s flow at Wards Road). Thus there is no release for either the Wards or McKays Creek power schemes. For the Wards8_Mky8 scenario with lake levels between -0.1m and 0.2m, the managed lake release for the Wards station was 4 m^3/s, with the minimum flow maintained to the Kaniere River. For this same scenario and with lake levels above 0.20m, Kaniere release to the Wards station was modelled at 7.5 m^3/s, but if the Lake was spilling (above 1.0m) the Wards station release increased to 8 m^3/s. For periods when the lake was not spilling, this 0.5 m^3/s buffer between the Wards station maximum release, and the modelled McKays race take from the Kaniere River, is to allow for capture of the Kaniere River tributary flow at the McKays weir location. Appendix 2 provides greater detail on the lake management modelled for the scenarios. Spill from the lake occurs at levels above 1.0 m.

As expected the upgrade scenario (Wards8_McKays8) was associated with lower Lake Kaniere levels (Table 6.2.1 and Figure 6.2.3). For this Wards8_Mky8 scenario, Lake Kaniere was simulated to be at or above 0.2 m for 72% of the time. Consequently the lake would be releasing 7.5 m^3/s or higher to the Wards Road station (Figure 6.2.16) except for periods when outflow was limited due to spill at the McKays weir. The Actual measured lake level from 2002 to 2008 was above 0.2m for 98% of the time (Table 6.2.1).

With a Wards8_Mky8 scenario there is a reduction in spill from the lake to 8% of the time (Table 6.2.1). Measured Lake Kaniere spill occurs greater than 40% of the time. The 2002 to 2008 average Lake Kaniere level for the upgrade scenario was around 0.40 m lower than the actual data.

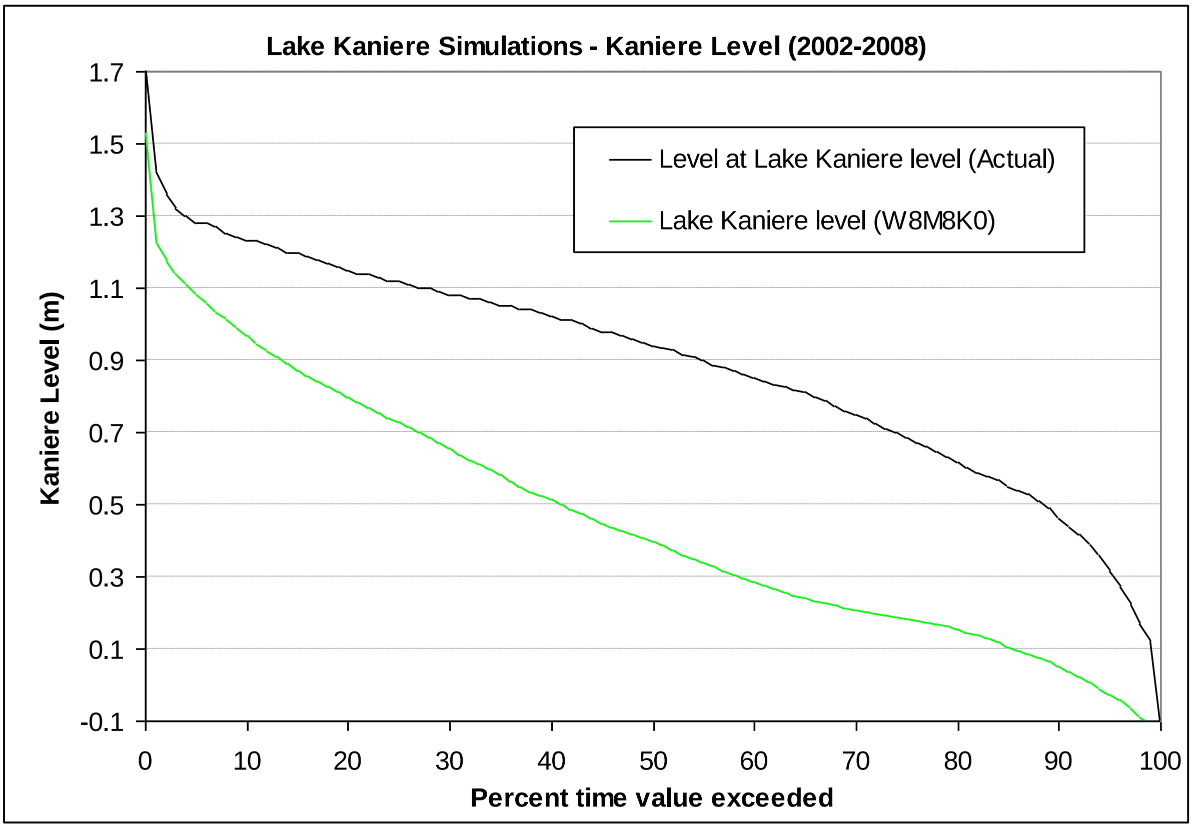

Figure 6.2.3. Lake Kaniere level distribution for the period 2002 to 2008.

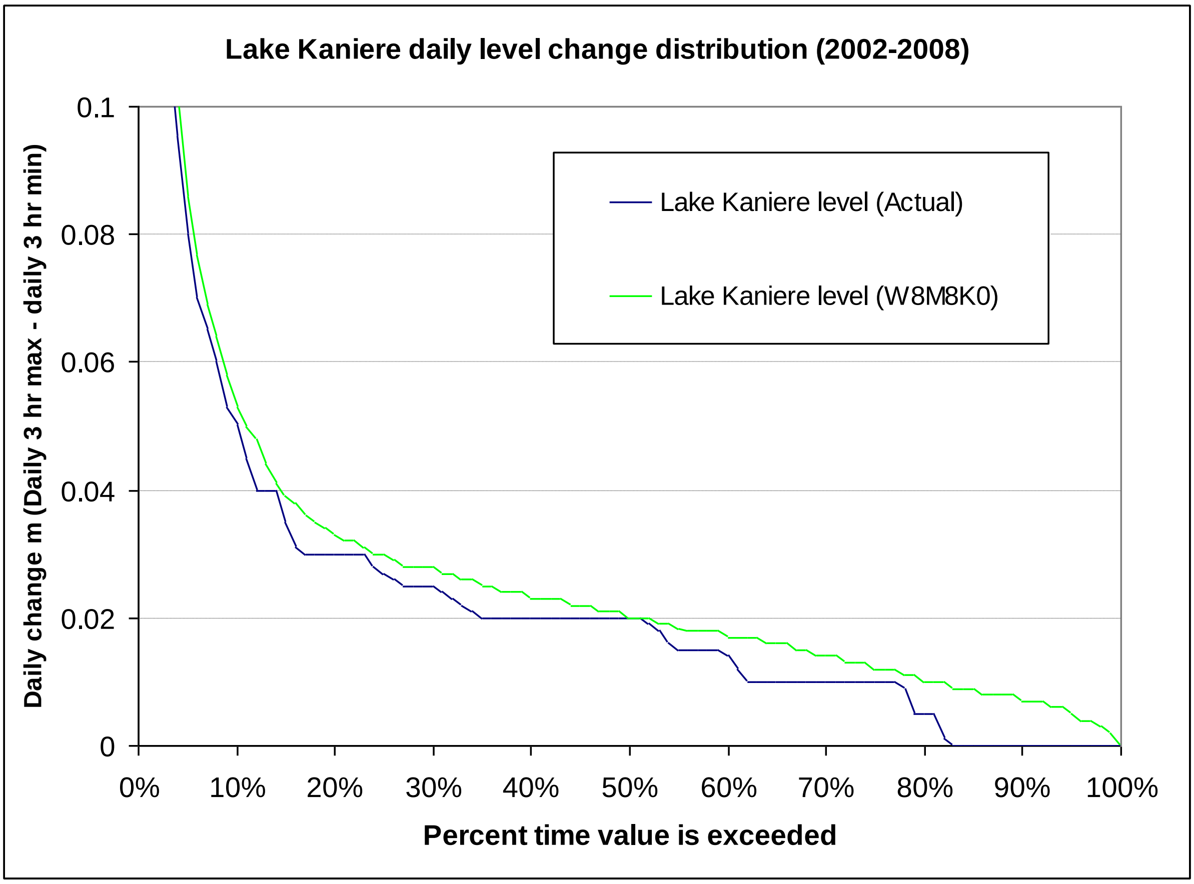

Figure 6.2.4. Distribution of Lake Kaniere daily level change (m).

The distribution of the change between the daily 3-hourly maximum and 3-hourly minimum level is presented in Figure 6.2.4. As expected due to the relatively large volume of the lake (compared to outflows), that even with no inflows to the lake and a maximum outflow of 8 m^3/s, that a maximum daily drawdown of less than 0.05 m could be achieved. Thus the higher daily level changes are associated with level increases due to rainfall events. The systems used to measure the Lake Kaniere level have a 0.01m dead-band, hence the apparent 'steps' in the actual data in Figure 6.2.4.

Table 6.2.1. Statistics for the Lake Kaniere level and spill (2002 to 2008).

Scenario identifier	Lake Kaniere Level	Lake Kaniere Level	Lake Kaniere Level	Lake Kaniere Spill
	Mean (m)	Median (m)	Percent of time level below 0.2 m	Percent of time level above 1.0 m
Actual	0.89	0.94	2	42
Wards8_ Mky8	0.46	0.40	28	8

6.2.3 Kaniere River at Lake Kaniere down to Wards Road

The distribution of the actual data for the Lake Kaniere outflow to the Kaniere River (which includes spill), indicates that flows are below 4 m^3/s for 10% of the time and not often (<1%) below 1 m^3/s or at minimum flow – Table 6.2.2 and Figure 6.2.5. With a Wards Road power station, water is diverted to this station as opposed to being released to the Kaniere River, and hence the River is below 0.5 m^3/s for 92% of the time. Flows in the Kaniere River are restored with the Wards Road power station discharge back to the Kaniere River, with the flows downstream of Wards Road greater than 4 m^3/s for 98% of the time (Table 6.2.2 and Figure 6.2.6). The local tributary catchment area between the lake and Wards Road is around 4 km^2 and would provide on average an additional 0.50 m^3/s of flow based on Butchers Creek flow data (but less than 0.1 m^3/s as a median flow).

Table 6.2.2 summaries the flow distribution data presented in Figure 6.2.5 and Figure 6.2.6 for flows of <4 m^3/s, <1 m^3/s, and <0.3 m^3/s for Kaniere River locations at Lake Kaniere outflow and at Wards Road.

Table 6.2.2. Percent of the time that flows are below certain flow thresholds for the Kaniere River at the lake outflow and downstream of Wards Road (2002 to 2008).

Scenario identifier	Kaniere River at lake < 4 m^3/s	Kaniere River at lake < 1 m^3/s	Kaniere River at lake < 0.5 m^3/s	Kaniere River ds Wards < 4 m^3/s	Kaniere River ds Wards <1 m^3/s	Kaniere River ds Wards <0.5 m^3/s
Actual	10	<1	0	8	<1	<1
Wards8_ Mky8	97	94	92	<2	<2	<2

Note: The actual minimum flow at the lake is 0.20 m^3/s,and the Wards8_Mky8 scenario was modelled at 0.30 m^3/s from the Lake and 0.40 m^3/s at Wards Road.

The monthly minimum flow simulated over the 2002 to 2008 record for the Kaniere River at Lake Kaniere outflow are at or near minimum for the scenario with a Wards Road power station (Figure 6.2.7). As previously mentioned the flows in the Kaniere River are restored with the discharge from the Wards Road station (Figure 6.2.8).

Graphs of the monthly mean flows over the period 2002 to 2008 for the Kaniere River at Lake Kaniere and for Wards Road are illustrated in Appendix 2 Figures A2.5 and A2.6. These graphs again illustrate the influence of the Wards Road station on Kaniere River flows at the Lake Kaniere and at Wards Road locations.

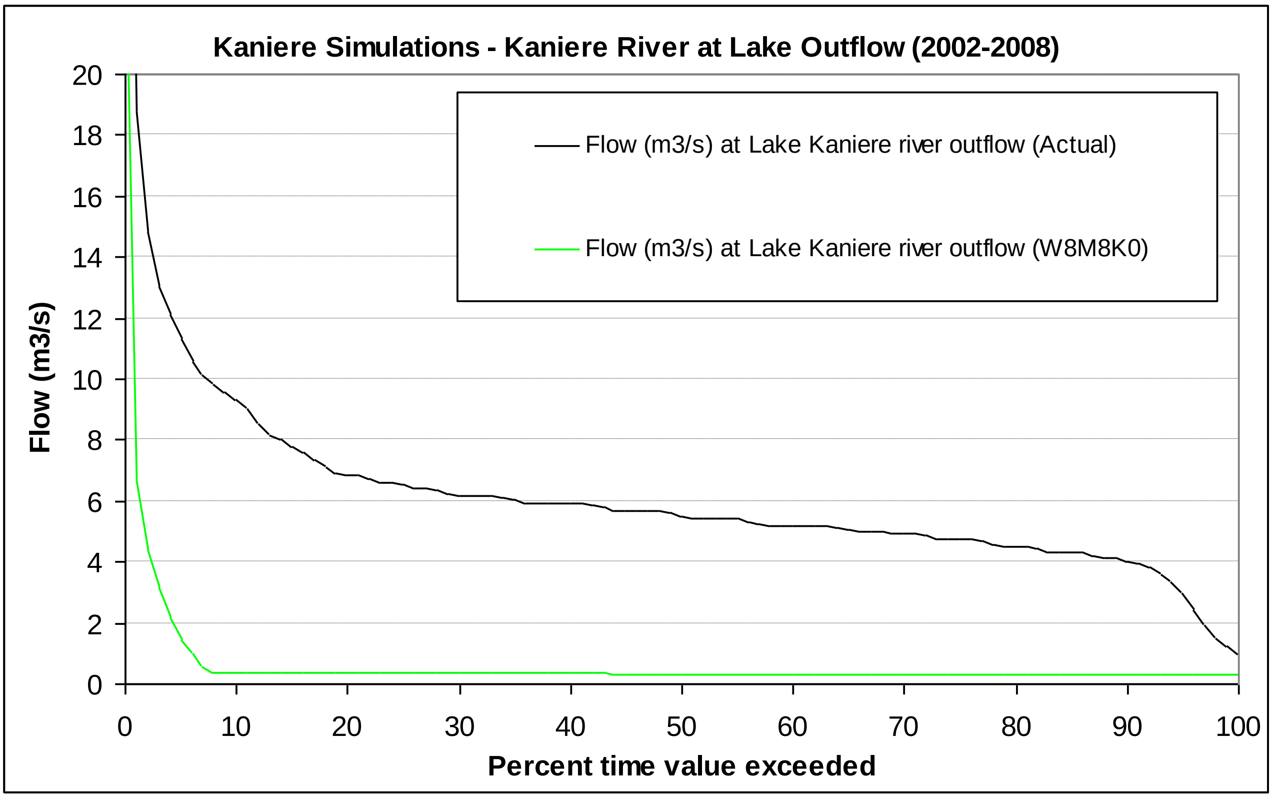

Figure 6.2.5. Kaniere River at Lake Kaniere flow distributions (2002-08).

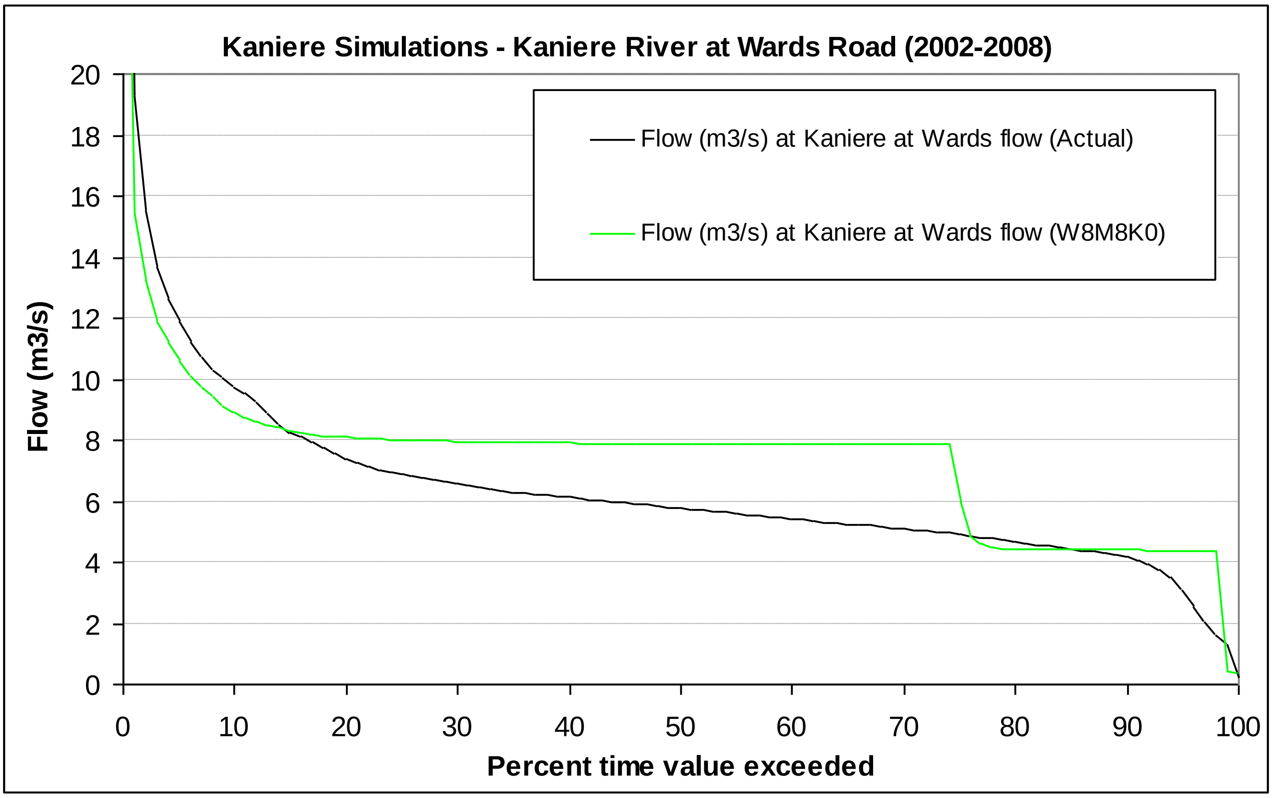

Figure 6.2.6. Kaniere River downstream of Wards Road flow distributions (2002-08).

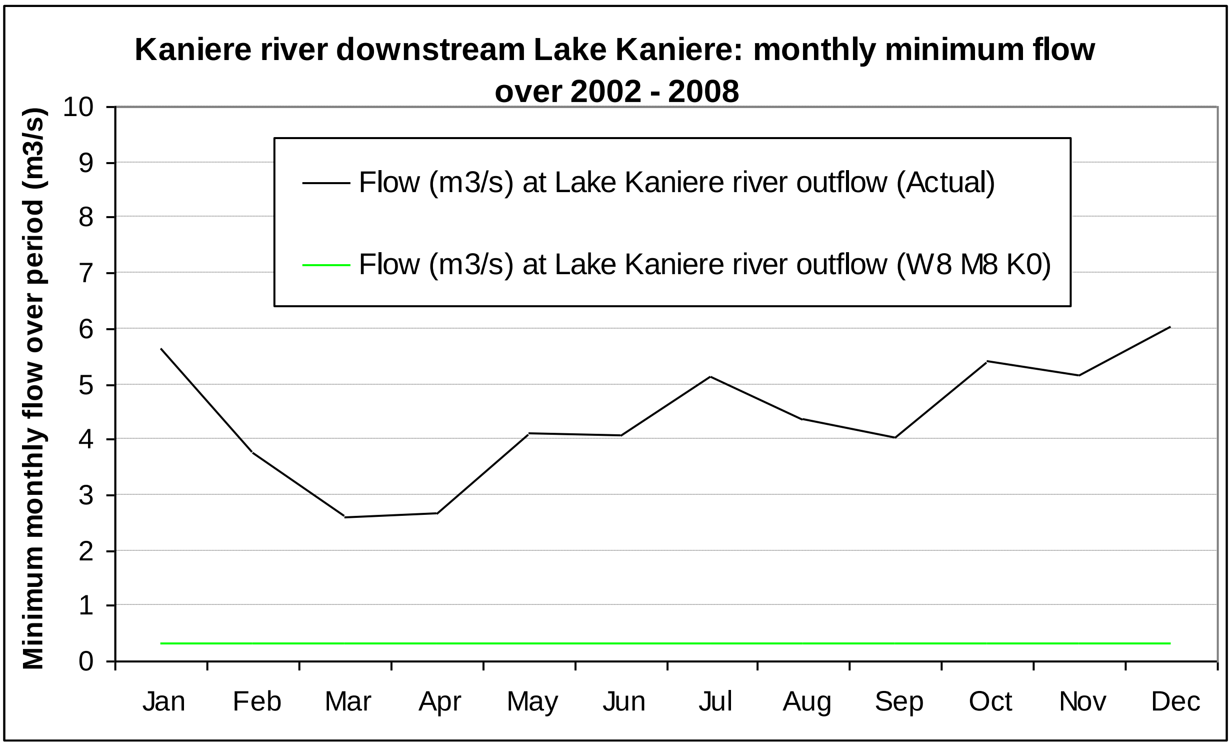

Figure 6.2.7. Kaniere River at Lake Kaniere, monthly minimum flow over the period 2002-08.

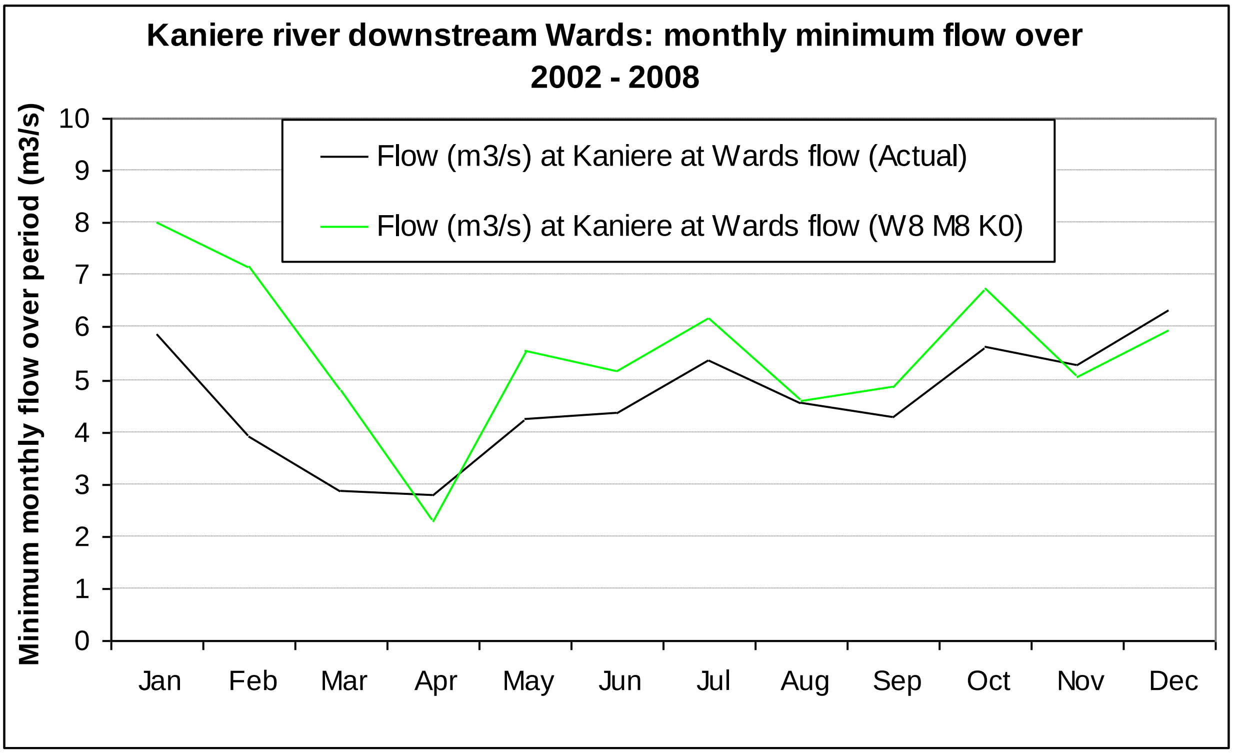

Figure 6.2.8. Kaniere River downstream of Wards, monthly minimum flow over the period 2002-08.

6.2.4 Kaniere River downstream of McKays Weir

Figures A2.2 to A2.4 in Appendix 2 presents the distributions for the simulations for the three Kaniere River locations downstream of McKays weir. The information is summarised for flows below 1.0 m^3/s and 0.50 m^3/s, for these locations in Table 6.2.3. Kaniere River flows immediately downstream of the McKays weir historically have been observed to be below 0.5 m^3/s for 13% of the time, and this increases to 64% of the time for the Wards8_Mky8 scenario. Flows below 1 m^3/s increase from 35% for the actual data to 78% of the time with the station enhancements. When the model was calibrated based on existing consents (Basecase), and the operation was modelled to limit non-spill flow past the weir to the minimum flows, then minimum flows were observed to occur nearly 50% of the time (Figure 6.2.1). Thus with the McKays station upgrade to take 8 m^3/s from the Kaniere River, there is an increase of around 15% in the occurrence of flows near minimum, as compared to what could be achieved within the existing scheme consents.

The increase in the occurrence of flows near minimum are a result of better simulated management of flows from Lake Kaniere and into McKays race, and also due to the uprating of McKays Creek station to 8 m^3/s, allowing greater opportunity to capture Kaniere River tributary flows. As example the Lake Kaniere levels are lower for the upgrade scenario which results in Lake Kaniere releases for Wards station limited to 4 m^3/s for over 20% of the time (Figure 6.2.16) which would provide an extra 4 m^3/s of McKays race capacity to capture additional Kaniere River (tributary) flow at McKays weir.

Kaniere River flows increase going downstream from McKays weir with the discharge to the River of Kaniere Forks power station (approximately 1.8 km of River channel down from the weir) then latter from McKays Creek station discharge (another 2.2 km of River channel further down), and from local tributary flow. As expected the upgrade scenario which does not include a Kaniere Forks station, has a higher percentage of lower flows at the downstream Kaniere Forks discharge location, with flows below 0.5 m^3/s increasing to 27% of the time, and flows below 1 m^3/s increases to 66% of the time. Below McKays Creeks power station discharge flows are seldom below 1 m^3/s.