Government of **Western Australia**
Department of **Water**

Wellington Reservoir water balance simulations

A summary of the TwoRes modelling scenarios

Looking after all our water needs

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Department of Water

Surface water hydrology series

Report no. HY36

April 2011

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April 2011

ISSN 1836-9626 (print)
ISSN 1836-9634 (online)

ISBN 978-1-921789-86-1 (print)
ISBN 978-1-921789-87-8 (online)

Acknowledgements

The Department of Water would like to thank the following for their contribution to this publication. Mark Pearcey.

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Summary

The Wellington Reservoir is an important water supply in the south-west of Western Australia. The reservoir was originally built as an irrigation supply system in the 1930s but there has been recent demand for water from the system for other purposes.

The TwoRes model was developed in 2003 to assess the impact of catchment management scenarios on Wellington Reservoir. In these early simulations the model was primarily used to assess the impact of various catchment management options on the reliability of supply of the irrigation demand.

Currently there is interest in using water from the reservoir for power generation cooling water and other industrial purposes in addition to the existing irrigation use. The TwoRes model has been updated to assess the impact of additional draws on the reliability of supply for the existing irrigation licensed entitlement. Daily future climate data was available from the CSIRO *South-west Western Australia sustainable yields project* (CSIRO 2009). This future climate data provided an opportunity to assess the risk associated with basing water entitlements on the historical climate in a drying climate.

The 2003 version of the model adopted an environmental water provision (EWP) regime based on a 'building block' approach. Recent work suggests that the previous EWP regime may not be appropriate. The current TwoRes model has examined two new approaches to providing an EWP regime. The adequacy of the resulting EWP regimes from the various simulations has not been assessed as part of this study.

Modelling scenarios were based on combinations of climate scenarios (historical and future), EWP regimes and demands from the reservoir. Three scenarios are presented in detail, which are considered to be of most interest from a water allocation perspective.

Results from the modelling show that the current level of use of the Wellington Reservoir is relatively low compared to the water available. However, if the additional demands for industry and power generation cooling water are included then there is significant pressure on the Wellington Reservoir system to reliably supply the water. Under the drier 2030 future climate scenarios the modelling shows that with all of the current and potential draws included the target annual reliabilities cannot be achieved, particularly if the historical climate EWP is retained.

1 Introduction

The Collie River is located approximately 160 km south of Perth in Western Australia. The lower Collie River is regulated by Wellington Dam 35 km east of Bunbury. Originally constructed in 1933 as an irrigation water supply reservoir, the 19 m high Wellington Dam was raised to its current height of 34 m in 1961 (Heritage Council of Western Australia 2010). Characteristics of the dam and catchment are provided in Table 1 while Table 2 details critical levels at the dam. Figure 1 shows the elevation–surface area–storage capacity relationship for Wellington Reservoir.

Table 1 Wellington Dam and reservoir characteristics

Characteristic	**Value**
Full supply level	166.56 m AHD
Wall height	34 m above ground level
Full supply storage capacity	185 GL
Surface area at full supply level	16.1 km^2
Crest length	367 m
Reservoir catchment area	2829 km^2 (including the 382 km^2 Harris Dam catchment)
Spillway type	Uncontrolled overflow section on dam
Spillway capacity	1430 m^3s^{-1}

Table 2 Wellington Dam significant levels and volumes

	Level m AHD	**Volume (GL**
Base of reservoir	135.16	0.00
Bottom offtake	135.85	0.01
Central offtake	149.95	24.40
Top offtake	151.02	29.8
Crest elevation	166.56	185.00

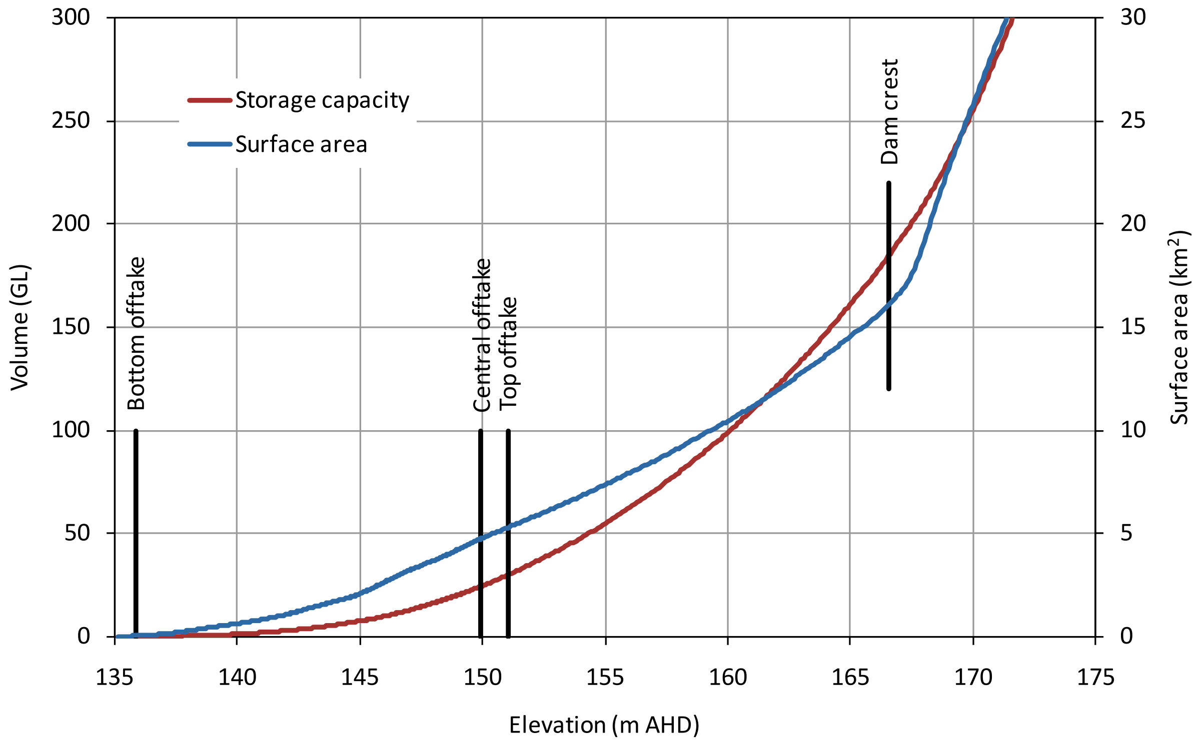

Figure 1 Wellington Reservoir surface area–elevation–storage capacity relationship

Upstream of Wellington Dam, the Collie River has two main tributaries, Collie River South Branch and Collie River East Branch (Figure 2). During the 1950s Wellington Reservoir was also used to supply water to the Great Southern Towns Water Supply Scheme (GSTWSS). Clearing of the catchment led to increases in the reservoir's inflow salinities from around 280 mg/L in the 1930s to 945 mg/L in the 1990s (Platt et al 2008) making it no longer useable as a potable water supply. Harris Dam was constructed in the 1990s as a potable water source to supply the GSTWSS.

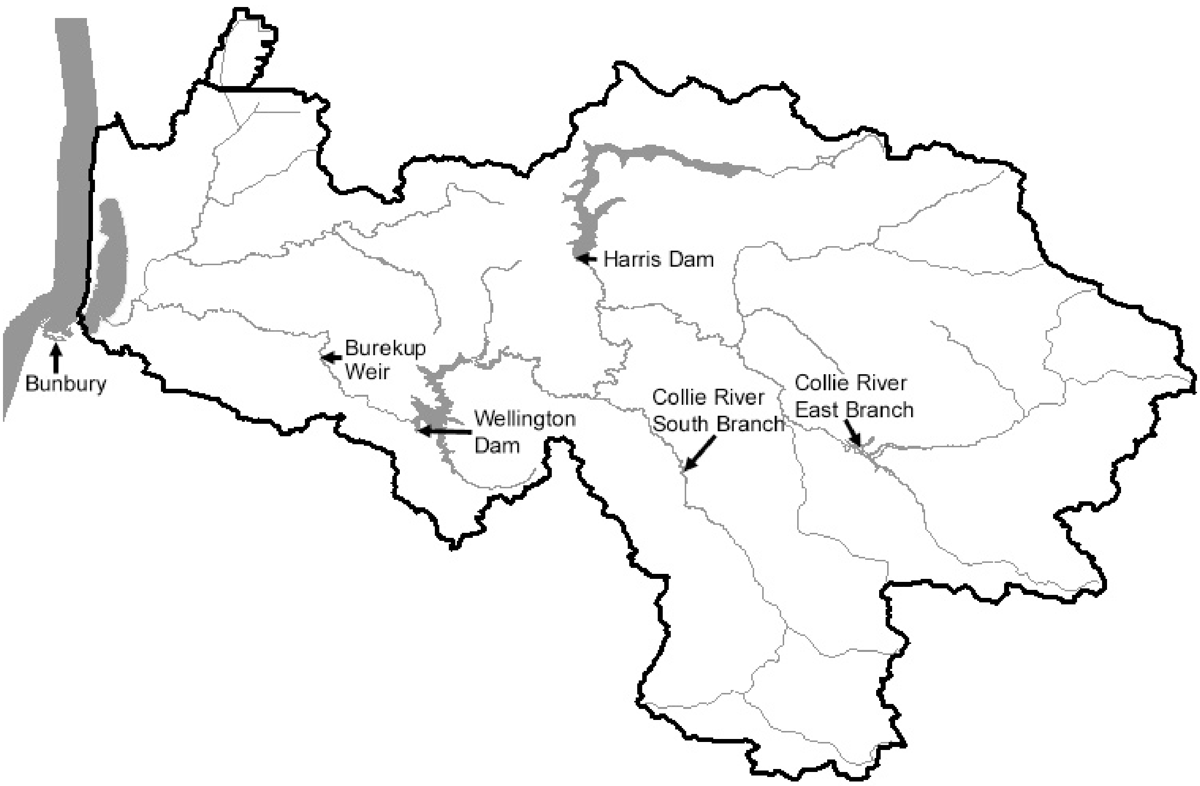

Figure 2 Collie River Basin showing the location of Wellington Dam

The physical behaviour of the reservoir is well understood and has been reported previously (Loh 1977; Hookey and Loh 1985) and is briefly summarised here. At the start of winter, the reservoir is in a well-mixed state. Early winter inflows typically have a high salt load. These relatively cold and dense winter inflows typically flow to the bottom of the reservoir with some dilution through entrainment. Conversely, summer and autumn inflows typically have a low salt load and tend to the surface of the reservoir. Over the summer months, strong solar heating results in stratification of the water body. By May, with cooling surface waters and strong mixing winds, the water body again tends to a well-mixed system.

Inflows to Wellington Reservoir have been relatively low in recent years (Figure 3). The mean annual inflow over the last four years is approximately 37% lower than the mean annual inflow for the period 1975 to 1996. However, the relatively low use in recent years has still resulted in spills from the reservoir in 1998, 1999, 2000, 2005, 2007 and 2009 (Figure 4).

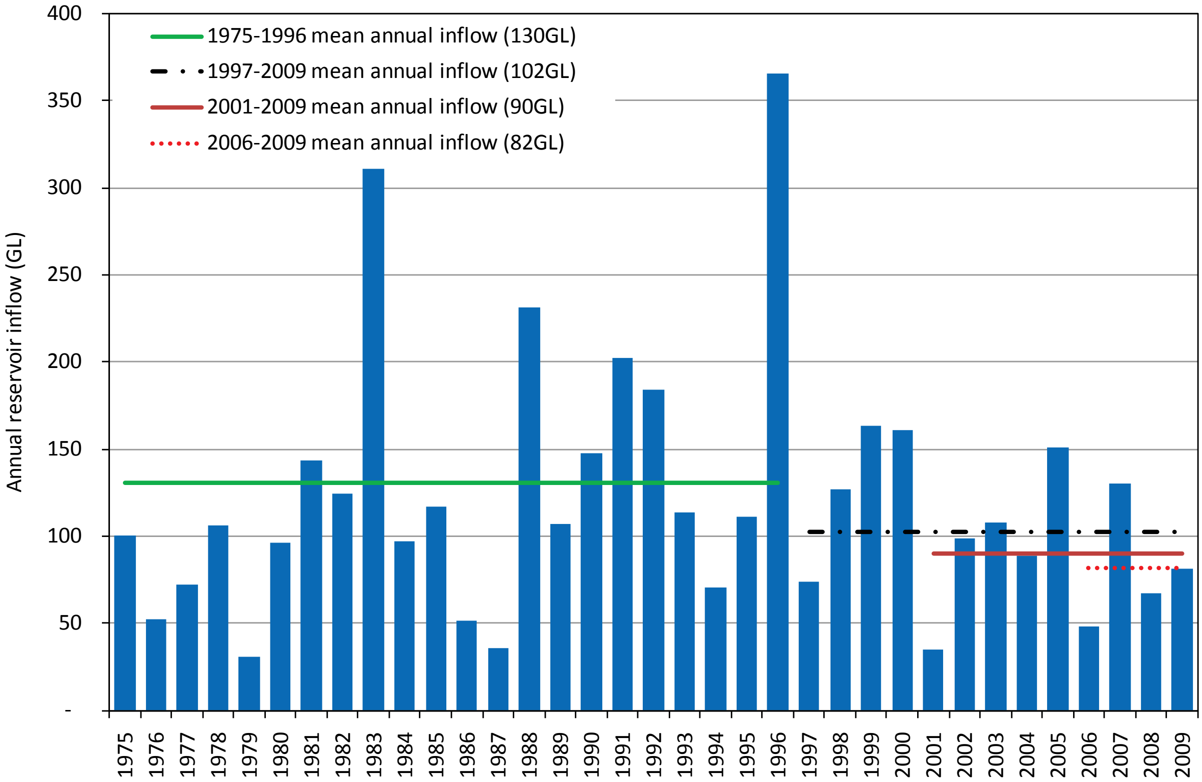

Figure 3 Annual inflows to Wellington Reservoir since 1975

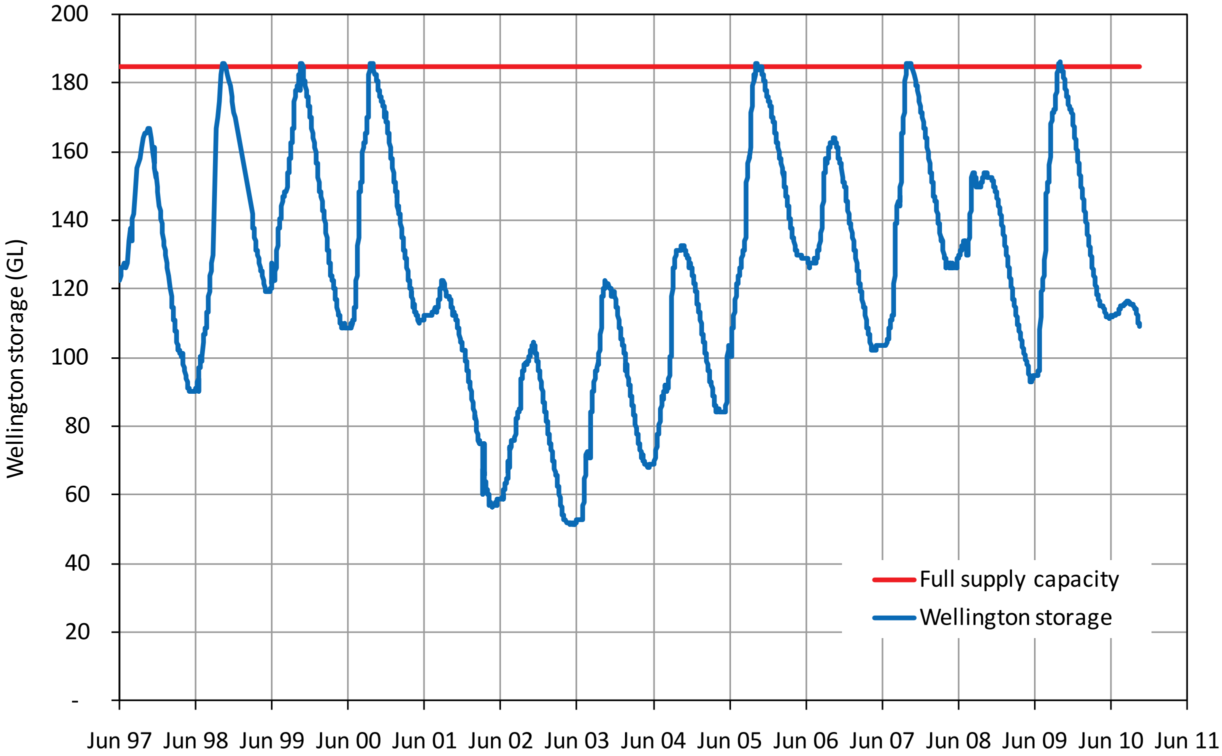

Figure 4 Stored volume in Wellington Reservoir since 1997

2 The TwoRes model

The TwoRes model is a semi-empirical, two-layer Wellington Reservoir daily water and salt balance model. The model was developed as a management tool to assess the impact of demand scenarios and upstream land use changes on supply reliabilities and the salinity in the reservoir (Pearcey 2003).Demand for water from Wellington Reservoir is increasing with interest for cooling water for power generation in addition to a potential new industrial demand. This increased demand, in addition to projections of a drier and warmer future climate (CSIRO 2009), has the potential to push the reservoir beyond its capacity to reliably supply the water. The TwoRes model has been updated with revised input data, system draws and environmental water provisions to examine the impact of the proposed operation of the water supply system on current and proposed draws and under historical and future climate scenarios.

2.1 Demands from Wellington Reservoir

Irrigation demand

Harvey Water currently has a licensed annual entitlement of 68.0 GL, released from Wellington Reservoir for diversion at Burekup Weir. Analysis of the volume diverted at Burekup Weir compared to the volume released from Wellington Reservoir (Durrant 2009) indicated there is an efficiency factor of 85%. That is, for a 68.0 GL annual release from Wellington Dam only 57.8 GL is available for diversion at Burekup Weir. Earlier estimates of the transmission losses suggested that 61.2 GL would be available (Loh 2003). Annual diversions at Burekup Weir (October to September) are shown in Figure 5.

In recent years, demand for irrigation water has been less than the licensed annual entitlement of 68.0 GL. With the exception of the unusually long irrigation season and hence high irrigation diversion of 56.7 GL at Burekup Weir in 2000–01, the maximum volume of water diverted at Burekup was 50.7 GL in the 1998–99 season. Since the 2000–01 irrigation season, the maximum diversion at Burekup Weir of 50.1 GL occurred in 2006–07. This has been adopted as an upper limit for the diversions and corresponds to a maximum release from Wellington Reservoir of approximately 59.0 GL. A constant daily demand over the irrigation season (October to April inclusive) has been adopted.

Since the 2000–01 irrigation season the mean annual irrigation diversion at Burekup was 45.6 GL which corresponds to approximately 53.6 GL released from Wellington Reservoir. For modelling purposes a 53.0 GL irrigation release from Wellington Reservoir has been adopted to reflect the mean release in recent years.

Reliability of supply of the irrigation water is an important factor. For town water supplies there is generally an expectation of high annual reliabilities, typically in the order of 90 to 95%. That is the annual demand is satisfied in 90 to 95% of years. Irrigation systems typically have a lower annual reliability, but this can vary based on the location and the crop type. In these simulations an irrigation annual reliability of 85% has been adopted as the base case for reference.

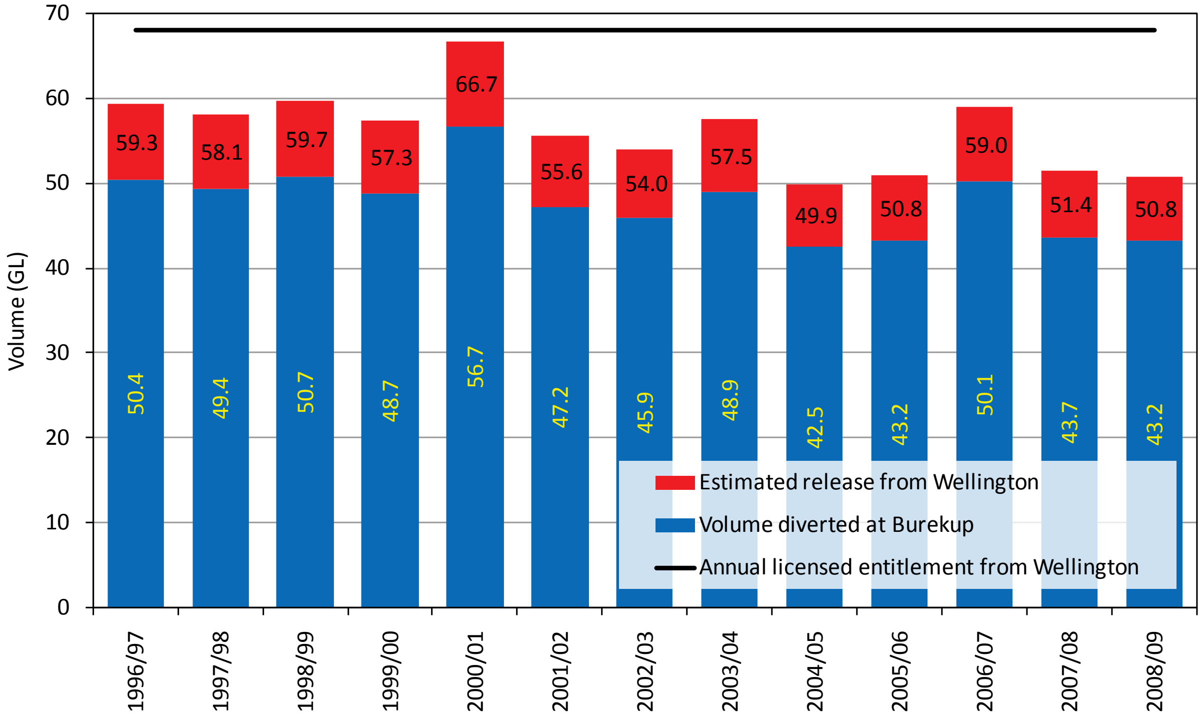

Figure 5 Annual irrigation diversion at Burekup Weir and release from Wellington Reservoir

Power station cooling water demand

An annual demand of 5.1 GL has been adopted for cooling water for power generation. This has been modelled as a constant daily demand of 14.0 ML/d. Due to the nature of power generation, this demand has been assigned an annual reliability of 100%. That is, the daily demand must be satisfied every day.

This water demand is not a current licensed entitlement and as such has not been included in all of the modelled scenarios.

Industrial demand

An annual demand of 12.0 GL for industry has been included in a number of the modelled scenarios. This demand has been simulated as a uniform daily demand throughout the year.

The irrigation and industrial demands have been assigned the same restriction policy in the TwoRes model, producing identical annual reliabilities. The industrial demand is typically modelled with the irrigation demand to achieve an 85% annual reliability. However, the desired annual reliability of the industrial demand is 100% and hence trades will be required to satisfy the demand shortfall. An assessment of the range of annual shortfalls for the various simulations has been undertaken.

2.2 Model parameters and input data

Reservoir starting conditions

The initial reservoir starting conditions were based on the observed reservoir characteristics on 1 April 1974 and are shown in Table 3. These values are not too dissimilar to the values for 1 April in other years and the model is not overly sensitive to the relative layer values as the water body becomes fully mixed in May every year.

Table 3 Wellington Reservoir starting conditions

Parameter	Value
Bottom layer starting volume (ML)	2 105
Bottom layer starting salinity (mg/L)	550
Top layer starting volume (ML)	105 587
Top layer starting salinity (mg/L)	490

Dam offtake levels

The TwoRes model has the ability to simulate draws from all three of the Wellington Dam offtake locations. In all of these simulations the bottom offtake (135.85 m AHD) has been used for all draws. While this is typically the worst quality water available in the reservoir, use of this offtake provides a scour function in the absence of a regular salinity scour regime under high total demand scenarios.

Critical storage levels

A minimum storage of 10 GL has been set in the model. However, due to the operating rules for the various draws the minimum volume does not drop below 25 GL.

The annual irrigation and industrial draws from the reservoir are based on the volume of water stored in Wellington Reservoir on 1 October of each year. Both irrigation and industrial users have the same restriction policy (Figure 6) which was derived in early simulations and has been retained for all subsequent simulations. Effectively, when the storage is greater than 115 GL on 1 October there are no restrictions applied to the irrigation and industrial demands. However, as the storage level on 1 October reduces, the level of restrictions increase, at a linear rate, until full restrictions apply when the volume stored on 1 October reaches 25 GL.

As discussed previously, the power station cooling water demand does not have a restriction policy as this demand is required to have a 100% annual reliability.

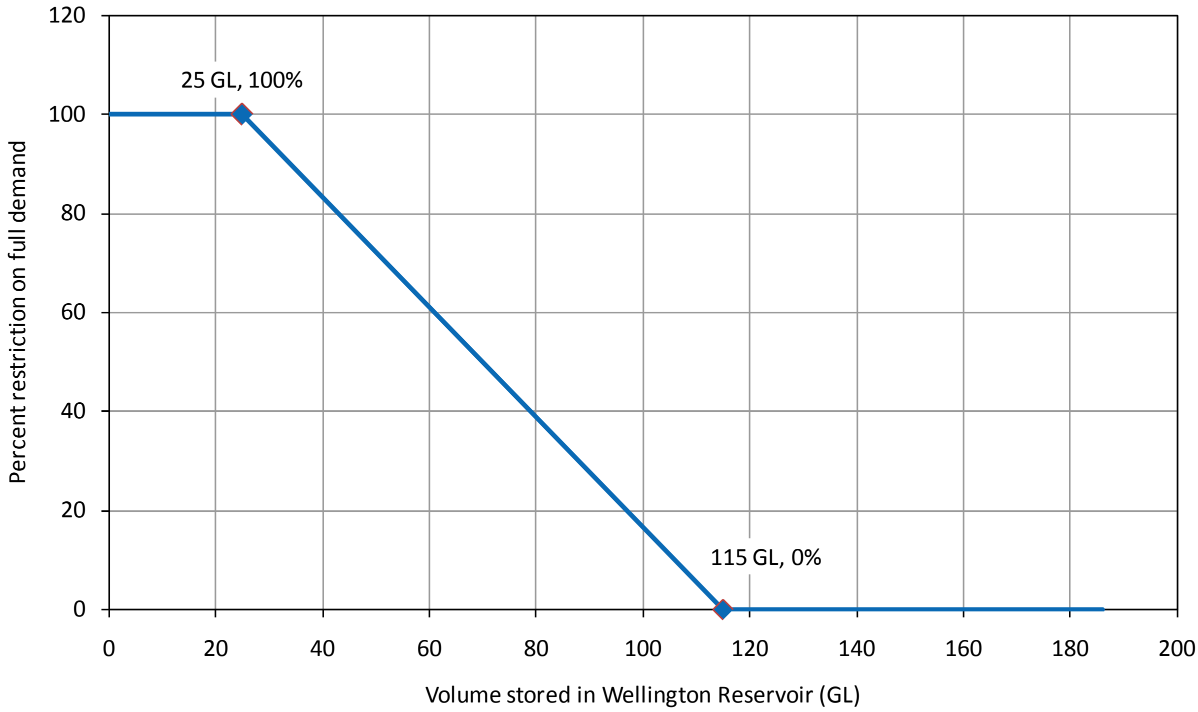

Figure 6 Restriction policy for irrigation and industrial draws from Wellington

Winter scour regime

The TwoRes model has the ability to simulate the Wellington Reservoir winter scour regime that is used to improve the reservoir water quality. Scour typically occurs during winter, and the period June to September inclusive was adopted for the TwoRes modelling in an attempt to remove the salty inflows from the base of the reservoir. Over time, criteria have been developed that determine the optimum times when scour should occur. The original scour release valve had a maximum capacity of 825 ML/d but recent maintenance work on the valve has reduced the capacity to 500 ML/d.

As the TwoRes model is a simplified model of the actual reservoir behaviour, some of the actual scour calculations have also been simplified. In the original development of the TwoRes model (Pearcey 2003) it was shown that these simplifications did not have an adverse impact on the model calibration.

In the TwoRes model scour can occur from the reservoir if the date falls within the period 1 June to 30 September, the volume stored in the reservoir is greater than the minimum stored volume criteria and either the ‘bottom layer salinity trigger’ or the ‘salinity difference between the top and bottom layers trigger’ is met.

Table 4 shows the scour parameters adopted in these simulations. It should be noted that the ‘minimum stored volume for scouring’ is set to the full supply capacity of the reservoir. This effectively prevents scour from occurring in the simulations. The rationale for ‘turning the scour off’ in these simulations is that as demand from the reservoir increases, water that would previously have been released for salinity scouring is required to satisfy the demands from the system. Additionally, the winter

EWP regime acts as a surrogate for the scour by removing the salty winter inflows from the reservoir.

Table 4 Adopted model scour parameters

Parameter	Value
Bottom layer salinity trigger (mg/L)	1 000
Salinity difference between the top and bottom layers trigger (mg/L)	400
Minimum top layer salinity to permit top layer scouring (mg/L)	1 000
Minimum stored volume for scouring (ML)	186 000

Climate data

The LUCICAT hydrologic model was used to provide streamflow and salinity data as inputs to the TwoRes model, based on historical rainfall and evaporation data from 1976 to 2007 from the Bureau of Meteorology rainfall station at Collie (009028). The same climate data was adopted in the TwoRes model. A ‘pan to lake’ evaporation factor of 0.9 was adopted in the model (Luke et al 1988).

The historical climate data was repeated to obtain a total period of record of 58 years. From 1 January 2008, a repeat of the climate data for 1 January 1976 to 31 December 2003 was adopted. This meant that the observed 1976 climate data was used to represent 1976, 2008 and 2036 in the LUCICAT model. The same data sequence was adopted for consistency in the TwoRes model.

While the historical climate data extends to dates into the future, it is only repeats of the observed data. This is not intended to suggest that that is what the climate will be into the future, it is just used to provide an extended period of record of the current climate for analysis.

Streamflow and salinity

The total Wellington Reservoir inflow is not measured directly. The streamflow gauging station on the Collie River at Mungalup Tower (612002) records flow from 90% of the Wellington Dam catchment (2546 km^2 of the 2829 km^2 total catchment area). Flow from the remainder of the Wellington Reservoir catchment (referred to as the ‘local inflow’ in the TwoRes model), including Hamilton and Bussell brooks, was formerly estimated from a relationship with the flows recorded at Stones Brook (612005), Hamilton Brook (612004) and Bussell Brook (612019). However, since the closure of the stations on Stones and Bussell brooks this has not been possible.

A LUCICAT hydrologic model has been developed and calibrated for the Collie catchment upstream of Wellington Dam (Bari and Smettem 2003). This model produces daily flow and salinity data for response units in the Collie River catchment upstream of Wellington Dam. Streamflow from Harris Dam is included in the LUCICAT inflow data used in the TwoRes model. The LUCICAT model has been calibrated against the Water Corporation’s reverse water balance model of the

Wellington Reservoir. This has resulted in different reservoir inflow estimates from the LUCICAT model than previous estimates.

The LUCICAT model uses a time series of leaf-area index for resource units in the model to simulate the impacts of land-use change over time. For the current simulations the ‘2007 reforestation’ scenario was adopted.

The Water Corporation reverse water balance model that LUCICAT was calibrated against has a monthly time-step as opposed to the LUCICAT daily time-step. In the LUCICAT model the monthly reservoir draws are uniformly distributed through the month. When separating the contributions at Mungalup Tower compared to the contributions from the catchment downstream of Mungalup Tower this uniform distribution of the reservoir draws produced instances of negative ‘local inflows’. Where the model generated negative flows they were set to zero in the TwoRes input data. This means that the TwoRes monthly inflows into the reservoir may be slightly larger than those estimated from the reverse water balance.

As discussed previously, the LUCICAT model used historical rainfall and evaporation data from 1976 to 2007. For the remainder of the simulation period, a repeat of the climate data for 1976 to 2003 was adopted. This means that the observed 1976 climate data was used to represent 1976, 2008 and 2036 in the LUCICAT model.

In some of the early model scenarios, an option that included diversion of saline flows upstream of Wellington Reservoir was assessed. In the LUCICAT model, the pumped diversion began in LUCICAT year 2010 which corresponds to a climate year of 1978 in the 1976 to 2003 climate repeat sequence. This resulted in 1978 in the second climate sequence being adopted as the first year of simulation in the TwoRes model. A comparison of the TwoRes, climate and LUCICAT years is shown in Table 5.

The adopted climate and streamflow sequence in the TwoRes model is a 54-year sequence that is representative of the climate from 1976 to 2003.

Table 5 TwoRes, climate and LUCICAT year relationship

TwoRes year	Climate year	LUCICAT year	Comment
1978	1978	2010	First year of simulation
2003	2003	2035	End of climate repeat sequence
2004	1976	2036	Start of climate repeat sequence
2031	2003	2063	End of climate repeat sequence

Future climate

Research suggests that the south-west of Western Australia will be warmer and drier in the future (CSIRO 2007). The TwoRes model was used to examine the impact of a drier future climate on the reliability of supply for all potential and current users of water from the reservoir. The *South West Western Australia sustainable yields* *project* (CSIRO 2009) assessed the impact of three warming scenarios on fifteen global climate models across the south-west of Western Australia. This process generated forty-five daily climate sequences of thirty-three years length that are representative of a 2030 climate. For simplicity, the CSIRO (2009) study focused on a 'wet' sequence (2030 wet future climate), a 'median' sequence (2030 median future climate) and a 'dry' sequence (2030 dry future climate). These three future climate (rainfall and potential evapotranspiration) scenarios have also been adopted in the TwoRes scenarios.

LUCICAT hydrologic simulations for the Collie catchment were undertaken with the future climate projections as part of the sustainable yields project (CSIRO 2009). The resulting streamflows, and stream salinities, were used as inputs to the TwoRes model to assess the impact of future climate projections on the reliability of supply of current and future potential users. It should be noted that due to the different time scales and sequences adopted for the historical and future climate and streamflow data, they do not align 'year-to-year'. However, comparisons can be made against the respective regimes.

Environmental water provisions

Two approaches to calculating the environmental water provision from Wellington Reservoir were assessed in the TwoRes model. These EWP approaches were developed by the Water Allocation Planning Branch in recognition of problems associated with the EWP developed in earlier assessments (Welker Environmental Consultancy and Streamtec Pty Ltd 2002).

EWP approach 1 A variable monthly volume, based on the volume of water stored in the reservoir at the start of each month.

EWP approach 2 A fixed winter volume in addition to a variable monthly volume, based on the volume of water stored in the reservoir at the start of each month.

The basic premise of the EWP regime in the TwoRes model is for EWP releases to mimic a natural flow regime that would occur if the dam was not there – a 'translucent dam' approach. Given the large summer irrigation releases from Wellington Reservoir it is unlikely that a natural flow regime can be achieved. The fundamental difference between the two EWP approaches is that in very dry years EWP approach 1 may not provide sufficient environmental water to protect any of the key ecological values. EWP approach 2 provides a fixed minimum EWP sufficient to meet the needs of the key ecological values regardless of the variability in the monthly storage volume. Given the highly seasonal nature of streamflow in south-west Western Australia, both EWP approaches are only specified for the winter–spring period of June to October, inclusive. EWP approach 2 also has a fixed EWP volume for May.

To account for variability in the winter–spring EWP releases across wet and dry years, two distributions were used – the IL and the KB distribution (Table 6). The IL distribution is based on the historical Wellington Reservoir winter scour regime while the KB distribution is based on the distribution of the historical inflows to the reservoir. The IL distribution tends to provide less EWP water in low flow years than the KB distribution, but provides more water in the wetter years. These distributions are both presented as a percentage of the median winter–spring target EWP.

The ‘median winter–spring target EWP volume’ is an input to the TwoRes model and is the total EWP release that would occur in a median inflow year to the reservoir. The actual value of the parameter is not critical but it is used in the TwoRes model as a means of manipulating the EWP releases to satisfy the annual reliabilities of the various demands. The adequacy of the resulting EWP regime in satisfying the critical ecological thresholds has not been assessed in this report.

The natural monthly winter–spring flow distributions for a range of annual flow percentiles at Mt Lennard (Table 7) show that the higher flow years generally have a wetter June than the drier years. This natural monthly distribution was used to calculate the target EWP release for both EWP distributions. That is, the monthly EWP target release was calculated as the product of the natural winter–spring monthly flow distribution at Mt Lennard) and the total winter–spring EWP as a percentage of the median winter–spring EWP (Table 6).

Table 6 Winter–spring EWP as a percentage of the target median winter–spring EWP

Inflow percentile	KB distribution %	IL distribution %
5th	32	3
10th	40	6
20th	66	19
30th	78	38
40th	90	63
50th	100	100
75th	171	188
90th	282	313
95th	293	500

Table 7 Natural winter–spring monthly flow distribution at Mt Lennard

Inflow percentile	June %	July %	August %	September %	October %
5th	0	15	45	28	12
10th	2	28	35	25	10
20th	2	28	35	25	10
30th	2	30	35	25	8
40th	3	30	35	24	8
50th	4	30	35	23	8
75th	8	28	32	23	9
90th	11	27	30	23	9
95th	11	24	26	30	9

The minimum monthly storage volumes in Wellington Reservoir were assessed for a range of inflow years (Table 8). These volumes were based on the results from early simulations of the TwoRes model using the 2002 ecological water requirement (EWR) (Welker Environmental Consultancy and Streamtec Pty Ltd 2002). The minimum monthly storage volumes can be used as a surrogate for the inflow percentile in determining the EWP release for each month.

Table 9 shows the storage levels for the start of each month and the corresponding monthly EWP release, as a percentage of the median winter–spring EWP target. The monthly EWP release is recalculated based on the volume stored in Wellington Reservoir on the first day of each month. The monthly EWP is distributed uniformly across the month.

For example, in a 30th percentile inflow year and adopting the KB distribution the August EWP release as a percentage of the median winter–spring EWP can be calculated as 78% (Table 6) of 35% (Table 7) or 27.3%.

Table 8 Minimum monthly recorded volume stored in Wellington Reservoir for a range of inflow percentiles

Inflow percentile	**June ML**	**July ML**	**August ML**	**September ML**	**October ML**
5th	31 318	37 340	49 963	63 524	63 280
10th	33 517	41 864	56 372	74 765	90 952
20th	41 761	50 300	74 056	97 875	100 992
30th	46 716	58 110	94 170	112 345	115 869
40th	86 676	90 843	110 131	130 897	145 827
50th	94 133	99 362	127 807	150 804	155 401
75th	107 482	113 490	142 563	168 845	175 928
90th	112 797	124 860	168 452	184 784	181 206
95th	120 552	131 704	171 934	184 916	183 666

Table 9 EWP release as a percentage of the median winter–spring EWP, for each month, based on storage on 1st of the month

June			July			August			September			October		
	Monthly release			Monthly release			Monthly release			Monthly release			Monthly release	
Storage ML	IL %	KB %	Storage ML	IL %	KB %	Storage ML	IL %	KB %	Storage ML	IL %	KB %	Storage ML	IL %	KB %
0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
31 318	0.0	0.0	37 340	0.4	4.8	49 963	1.1	14.4	63 524	0.7	9.0	63 280	0.3	3.8
33 517	0.1	0.8	41 864	1.8	11.2	56 372	2.2	14.0	74 765	1.6	10.0	90 952	0.6	4.0
41 761	0.4	1.3	50 300	5.3	18.5	74 056	6.6	23.1	97 875	4.7	16.5	100 992	1.9	6.6
46 714	0.8	1.6	58 110	11.3	23.4	94 170	13.1	27.3	112 345	9.4	19.5	115 869	3.0	6.2
86 676	1.9	2.7	90 843	18.8	27.0	110 131	21.9	31.5	130 897	15.0	21.6	145 827	5.0	7.2
94 133	4.0	4.0	99 362	30.0	30.0	127 807	35.0	35.0	150 804	23.0	23.0	155 401	8.0	8.0
107 482	15.0	13.7	113 490	52.5	47.9	142 563	60.0	54.7	168 845	43.1	39.3	175 928	16.9	15.4
112 797	34.4	31.0	124 860	84.4	76.1	168 452	93.8	84.6	184 784	71.9	64.9	181 206	28.1	25.4
120 552	55.0	32.2	131 704	120.0	70.3	171 934	130.0	76.2	184 916	150.0	87.9	183 666	45.0	26.4
200 000	55.0	32.2	200 000	120.0	70.3	200 000	130.0	76.2	200 000	150.0	87.9	200 000	45.0	26.4

Catchment flows downstream of Wellington Dam

A daily flow sequence, from 1975 to 2007, was developed for the natural catchment flows, downstream of Wellington Dam, at Mt Lennard (Burekup Weir) in the *South West Western Australia sustainable yields project* (CSIRO 2009). The same climate repeat sequence as discussed previously was used downstream of Wellington Dam. This sequence was combined with Wellington Reservoir output from the TwoRes model (including EWP release, scour, spill and irrigation release) to provide an estimate of the total daily flow at Mt Lennard. The daily flow regime for each scenario at Mt Lennard was assessed by the Water Allocation Planning Branch against environmental flow thresholds to ensure the scenario is acceptable from an ecological perspective.

The *South West Western Australia sustainable yields project* (CSIRO 2009) reported a 9% reduction in mean annual rainfall and a 24% reduction in runoff across the Collie River basin under the Cmid scenario compared to the historical (1975–2007) mean annual rainfall and runoff. Under the Cwet and Cdry scenarios the reduction in mean annual runoff, compared to the historical data, was 7% and 41% respectively. At the time the future climate scenarios were developed, the daily streamflows at Mt Lennard under future climate scenarios was not available. For simplicity, a 30% reduction in daily streamflows was applied for all future climate scenarios. While this approach overestimates the reduction under the Cmid and Cdry future climate scenarios it was considered acceptable given the uncertainty in the future climate estimates.

3 TwoRes modelling scenarios

This section describes the various scenarios simulated in the present round of assessment with the TwoRes model. 'Cases' are based on assumptions about the demands from the reservoir and resource objectives. Within each case, scenarios are based on combinations of the four different climate scenarios (historical, 2030 dry future, 2030 median future and 2030 wet future) and EWP regimes (variable monthly EWP with IL and KB distributions, fixed and variable monthly EWP with the KB distribution). Not all possible combinations have been simulated. Table 10 summarises the TwoRes modelling scenarios that have been undertaken. Descriptions of each case and the scenarios within them are given after the table.

Table 10 Summary of TwoRes modelling scenarios

Case	Climate scenario	Irrigation GL	Industry GL	Power GL	EWP distribution	Fixed EWP GL	Variable EWP GL
Case α	Historical	68.0	0.0	0.0	–	–	–
Case 0.1	Historical	59.0	12.0	5.1	IL	–	25.0
Case 0.2	Historical & future (wet, median and dry)	59.0	12.0	5.1	KB	–	17.0
Case 0.3	Historical & median future	59.0	12.0	5.1	KB	2.1	13.7
Case 1.1	Historical	53.0	0.0	0.0	IL	–	75.0
Case 1.2	Historical	53.0	0.0	0.0	KB	–	38.0
Case 2.1	Historical	68.0	0.0	0.0	IL	–	50.0
Case 2.2	Historical	68.0	0.0	0.0	KB	–	30.0
Case 3.1	Historical & future (wet, median and dry)	68.0	12.0	0.0	IL	–	8.0
Case 3.2	Historical & future (wet, median and dry)	68.0	12.0	0.0	IL	–	25.0
Case 3.3	Historical & future (wet, median and dry)	68.0	12.0	0.0	KB	–	6.0
Case 3.4	Historical & future (wet, median and dry)	68.0	12.0	0.0	KB	–	13.0
Case 3.5	Historical & future (wet, median and dry)	68.0	12.0	0.0	KB	–	17.5
Case 4.1	Historical & future (wet, median and dry)	68.0	12.0	5.1	IL	–	8.0
Case 4.2	Historical & future (wet, median and dry)	68.0	12.0	5.1	KB	–	17.5
Case 4.3	Historical & future (wet, median and dry)	68.0	12.0	5.1	KB	–	6.0
Case 4.4	Historical	68.0	12.0	5.1	KB	5.3	17.5
Case 4.5	Historical	68.0	12.0	5.1	KB	5.3	0.0
Case 4.6	Historical	68.0	12.0	5.1	KB	2.1	17.5
Case 4.7	Historical & median future	68.0	12.0	5.1	KB	2.1	2.7
Case 4.8	Historical & median future	68.0	12.0	5.1	KB	2.1	17.1
Case 5	A re-analysis of other cases with trades from irrigation to industry to achieve an annual industry reliability of 100%						
Case 6	This scenario was not simulated						
Case 7.1	Dry future	34.7	6.1	5.1	KB	–	6.0

Case	Climate scenario	Irrigation GL	Industry GL	Power GL	EWP distribution	Fixed EWP GL	Variable EWP GL
Case 7.2	Median future	50.3	8.9	5.1	KB	–	6.0
Case 7.3	Wet future	64.6	11.4	5.1	KB	–	6.0
Case 8.1	Future (wet, median and dry)	49.3	8.7	3.7	IL	–	5.8
Case 8.2	Future (wet, median and dry)	49.3	8.7	3.7	KB	–	12.7
Case 8.3	Future (wet, median and dry)	49.3	8.7	3.7	KB	–	4.3

3.1 Case α

Case α was developed as a baseline scenario with which to compare the other scenarios. The only demand from the reservoir is for the irrigation water and this is set at the current licensed entitlement of 68 GL. No EWP releases are simulated but the scour regime is implemented with the 'minimum stored volume for scouring' trigger set at 100 000 ML. This is the only scenario that explicitly models a winter scour regime. This scenario was only simulated under the historical climate sequence.

3.2 Case 0

This case reflects the maximum historical annual use of irrigation water, which in recent years has been 59 GL from Wellington Reservoir, combined with proposed demands for industry and power cooling water. The annual Industrial water demand was set at 12 GL while the annual demand for power cooling water was set at 5.1 GL.

Both EWP approaches (variable and variable plus fixed components) and both EWP distributions (KB and IL) were simulated. For all three simulations under the historical climate, the median winter–spring EWP volume was adjusted to achieve an annual reliability of 85% for the irrigation and industrial demands under the historical climate. Simulations were undertaken for historical and future climate scenarios, with the median winter–spring EWP volume from the historical simulations kept the same under the respective future climate scenarios.

3.3 Case 1

Case 1 provided for the current mean use at an 85% annual reliability. This scenario was similar to Case 0 except that instead of the irrigation annual demand being set to the maximum historical use it was set to the mean historical use of 53 GL from Wellington Reservoir. Industrial and power cooling water demands were not included as this reflects the current (2010) licensed entitlements.

EWP releases during winter and spring were modelled to maximise environmental benefits and minimise supply salinities by avoiding excessive accumulation of saline water at the base of the reservoir. The EWP regime for Case 1 was limited to the EWP approach 1 with both the IL and KB distributions simulated. For all simulations, the median winter–spring EWP volume was adjusted to achieve 85% reliability for the irrigation demand.

3.4 Case 2

Demands in this scenario reflect current licensed entitlements with a 68 GL demand for irrigation and no demand for power cooling water or industrial use. EWP approach 1 with both the KB and IL distributions were assessed. For all simulations the median winter–spring EWP volume was adjusted until the irrigation demand had an annual reliability of 85%. This case was only simulated under the historical climate.

3.5 Case 3

The objective of Case 3 was to provide for the irrigation licensed entitlement of 68 GL and a 12 GL annual industrial demand at 85% annual reliabilities under the historical climate. Two EWP distributions were assessed (KB and IL distributions) under the EWP approach 1 with the median winter–spring EWP volume adjusted to ensure the 85% annual reliability for the irrigation and industrial demands. An additional three scenarios were assessed where the Case 3 median winter–spring EWP volume was adopted for the KB and IL EWP distributions. Case 3 was assessed under both historical and future climate scenarios.

3.6 Case 4

Case 4 includes the current licensed entitlement for irrigation (68 GL) as well as a 12 GL industrial demand and a 5.1 GL demand for power cooling water. The two EWP approaches and both EWP distributions were assessed in various combinations with historical and future climate scenarios.

Case 4.1 and Case 4.3 were considered to be the starting points for the EWP approach 1 with the IL and KB distributions, respectively. That is, for these cases under the historical climate the median winter–spring EWP volume was adjusted such that the irrigation and industrial demands achieved an 85% annual reliability. The median winter–spring EWP volumes for these simulations were then adopted for other cases.

3.7 Case 5

Case 5 was a variation of Case 4 with the objective of achieving a 100% annual reliability for the 12 GL industrial demand. This was simulated with the shortfall from the 12 GL annual industrial demand being met through a trade from the water supplied to irrigation.

3.8 Case 6

Case 6 was a modified version of Case 4, investigating how an additional 8 GL of releases could provide the most environmental benefit between the Wellington Reservoir and Burekup Weir. The additional 8 GL of releases was taken as part of the water savings that might be obtained through piping of the Collie irrigation district. Case 6 was not simulated in this scope of work.

3.9 Case 7

Case 7 was developed to examine the reduction in demands required under the three future climate scenarios to maintain the 100% annual reliability for power station cooling water and the 85% annual reliability for the irrigation and industrial users if the 6 GL median winter–spring EWP volume with the KB distribution was adopted. This 6 GL median winter–spring EWP volume was adopted as it gave an 85% irrigation and industrial reliability under the historical climate in Case 4.3.

3.10 Case 8

Case 8 was developed to determine the uniform reduction required for all demands, including the EWP, to maintain 85% annual reliabilities for irrigation, industry and 100% annual reliability for power cooling water under the future climate scenario. The demands and EWP regime for cases 8.1, 8.2 and 8.3 were scaled demand and EWP regimes from cases 4.1, 4.2 and 4.3 respectively.

4 Modelling results

Results from the simulations under the historical climate are detailed in Table 14. Results for simulations at 2030 under a wet, median and dry future climate regime are presented in Table 15, Table 16 and Table 17, respectively. Selected cases are presented in more detail below for information. Case α is presented as a base case for comparison while the other three cases presented, Case 0.3, Case 4.7 and Case 4.8, were considered to be of most interest from a water allocation perspective.

Results presented in this report do not show actual years, instead they show the annual sequence number. This was done to prevent a comparison of individual years between scenarios. Additionally this approach highlights that a climate regime has been assessed and the results should be read as the variability that occurs within that regime.

4.1 Case α

Case α was set up as a base case against which the results of the other simulations could be compared. The only demand from the system is the 68 GL annual irrigation draw. The total use from the reservoir is low compared to the inflow (Figure 7) and frequent spills occur when the water level in the reservoir exceeds the full supply level (Figure 8). Spills occur in 68% of years in the simulation. The 68 GL annual irrigation draw was achieved in every year.

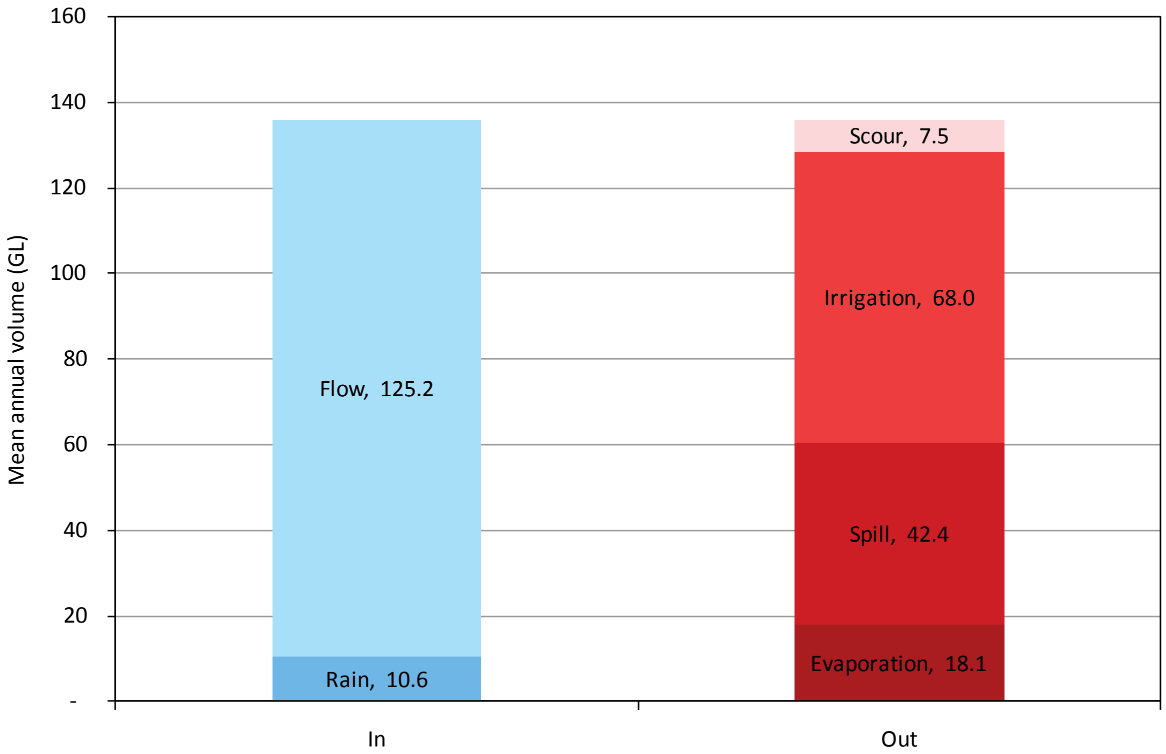

Figure 7 Mean annual water balance for Case α

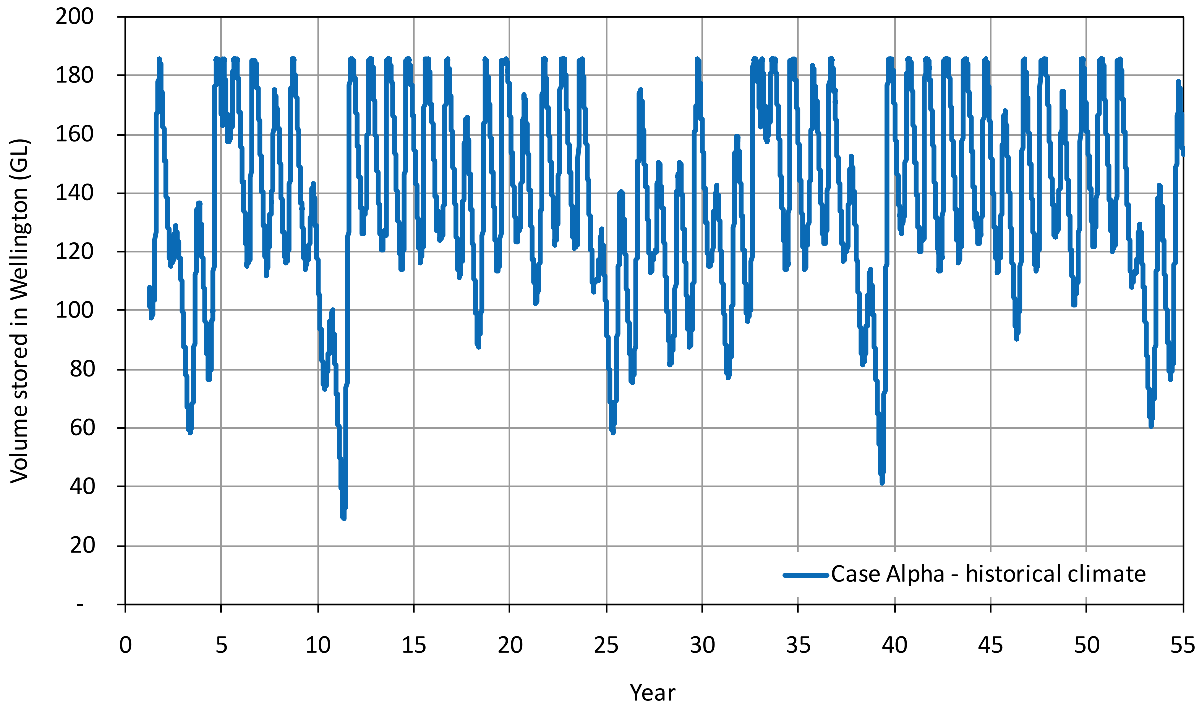

Figure 8 Wellington Reservoir stored volume for Case α

4.2 Case 0.3

In Case 0.3, the draws from the system were set at the maximum historical annual use (59 GL) for the irrigation, with 12 GL adopted for the industrial demand and 5.1 GL for the power station cooling water demand. The EWP approach 2 was adopted using the KB distribution. The median winter–spring EWP volume was adjusted so that the irrigation demand, and consequently the industrial demand, achieved an annual reliability of 85%.

With the increased total draw under Case 0.3, compared to Case α, the frequency of annual spills dropped to 40% under the historical climate. This can be seen in Figure 9 with the reduced frequency of the stored volume reaching the full supply volume of 185 GL.

Under the median future climate at 2030, the impact of reduced rainfall and streamflows on the system is apparent in the reduced annual reliabilities for the irrigation and industrial demands – down to 56%. Similarly, the frequency of annual spills drops even further to 13% (Table 16). Figure 10 shows the range in the volume of water stored in Wellington Reservoir under Case 0.3, for the historical and median future climate at 2030, compared to Case α and the observed regime.

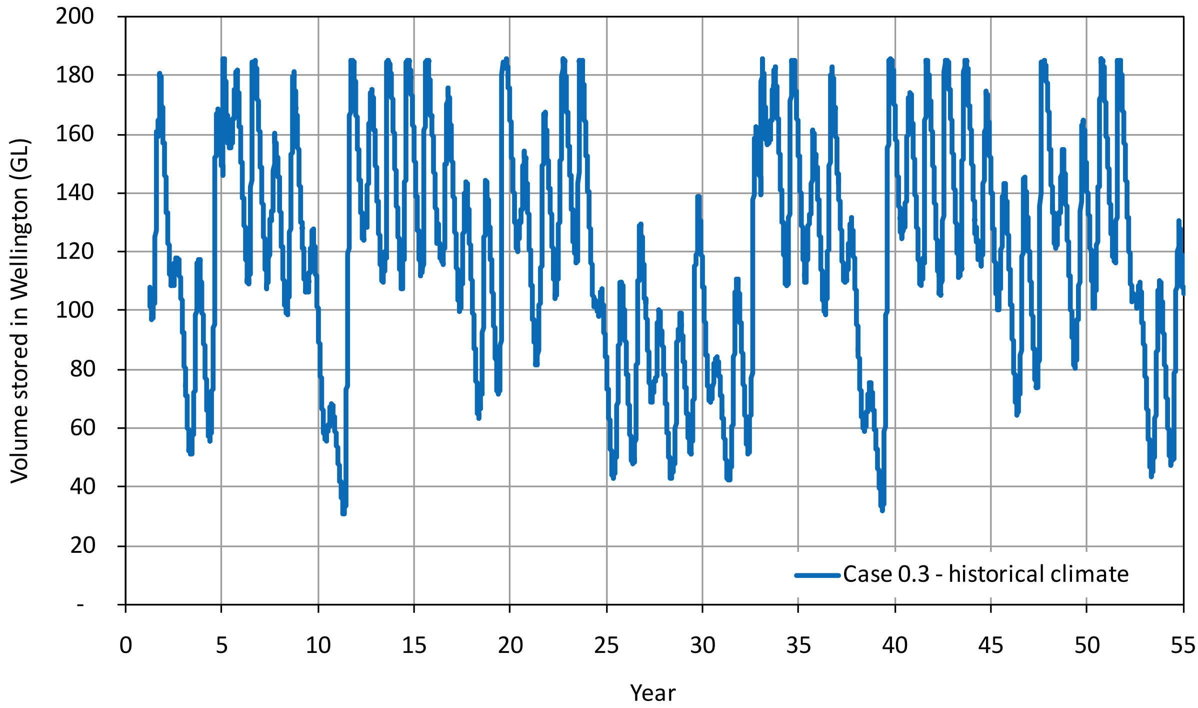

Figure 9 Volume stored in Wellington Reservoir for Case 0.3 under the historical climate

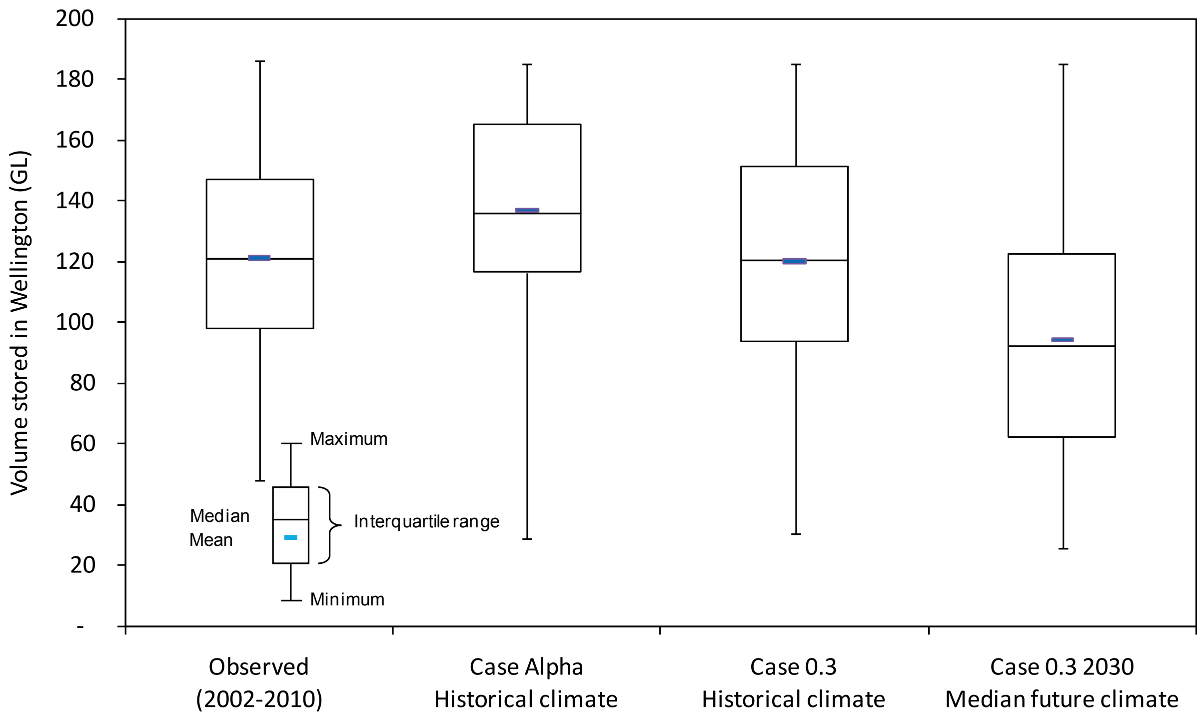

Figure 10 Range of volumes stored in Wellington Reservoir for Case 0.3

Figure 11 shows the mean annual water balance values for Case 0.3 under the historical and future median climate scenarios. A striking feature is the large reduction in inflows to the system under the 2030 median future climate, with the resulting reduction in mean annual outflows.

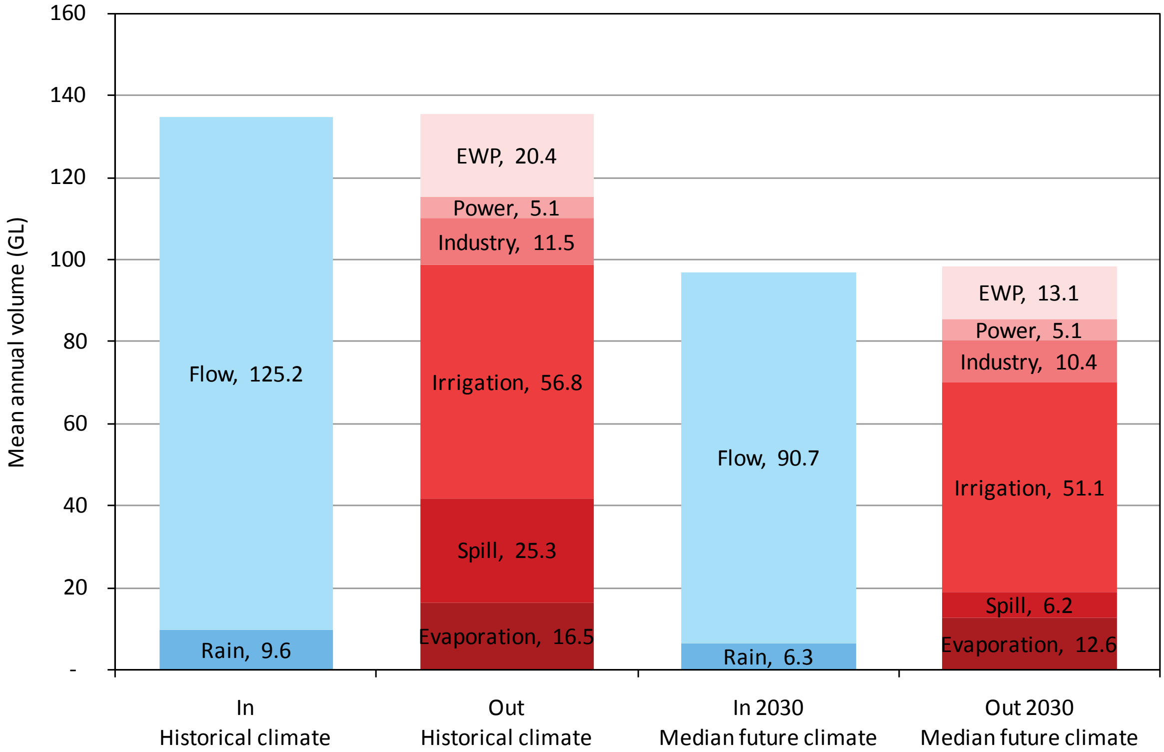

Figure 11 Mean annual water balances for Case 0.3

While the annual reliability of the industrial demand has been tied to the annual reliability of the irrigation demand – typically at 85% – it is noted that in reality the industrial demand requires a highly reliable water supply. Assessments of the annual shortfalls in supply for the industrial demand are presented in Table 11. This table shows that under the median future climate at 2030 shortfalls in supply occur almost every other year compared to approximately 1 in 5 years under the historical climate with an increase in the median shortfall volume (Figure 12).

Table 11 Industrial demand annual shortfalls for Case 0.3

	Historical climate	**Median future climate (2030)**
Years with a shortfall in supply	19%	44%
Maximum annual shortfall (GL)	6.25	8.75
Median of the annual shortfalls (GL)	1.49	2.81
Mean of the annual shortfalls (GL)	2.41	3.69

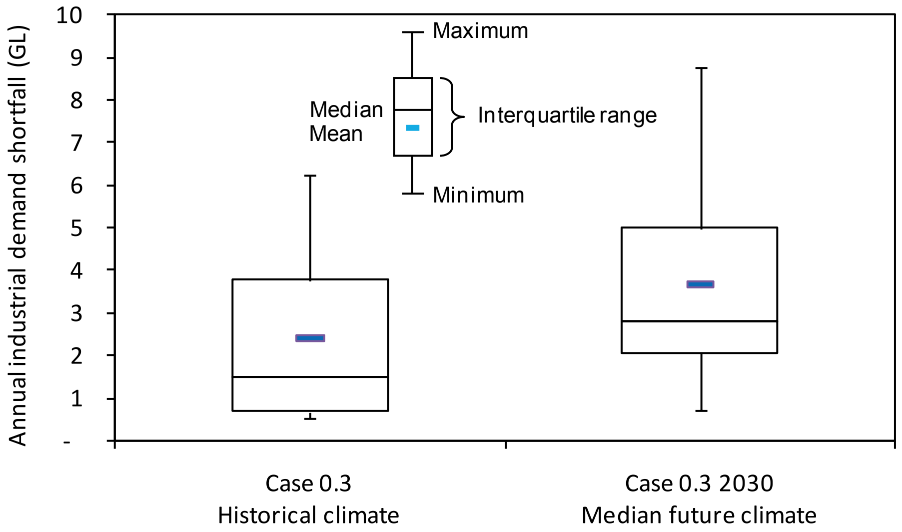

Figure 12 Range of industrial demand shortfalls for Case 0.3

4.3 Case 4.7

Case 4.7 has a 68 GL annual irrigation demand, based on the current licensed entitlement, with a 12 GL industrial demand and a demand of 5.1 GL for power station cooling water. The EWP regime was based on EWP approach 2 with the KB distribution. The median winter–spring EWP volume was adjusted until the irrigation and industrial draws achieved an annual reliability of 85%.

The variation in volume stored in Wellington Reservoir over the simulation period for Case 4.7 is similar to that under Case 0.3 (Figure 13). The mean daily differences in volume stored between Case 0.3 and Case 4.7 is −0.4 GL. This similarity is due to the fact that while the annual irrigation demand, and hence supply, is greater in Case 4.7 there is a corresponding reduction in the variable mean annual EWP from Case 0.3.

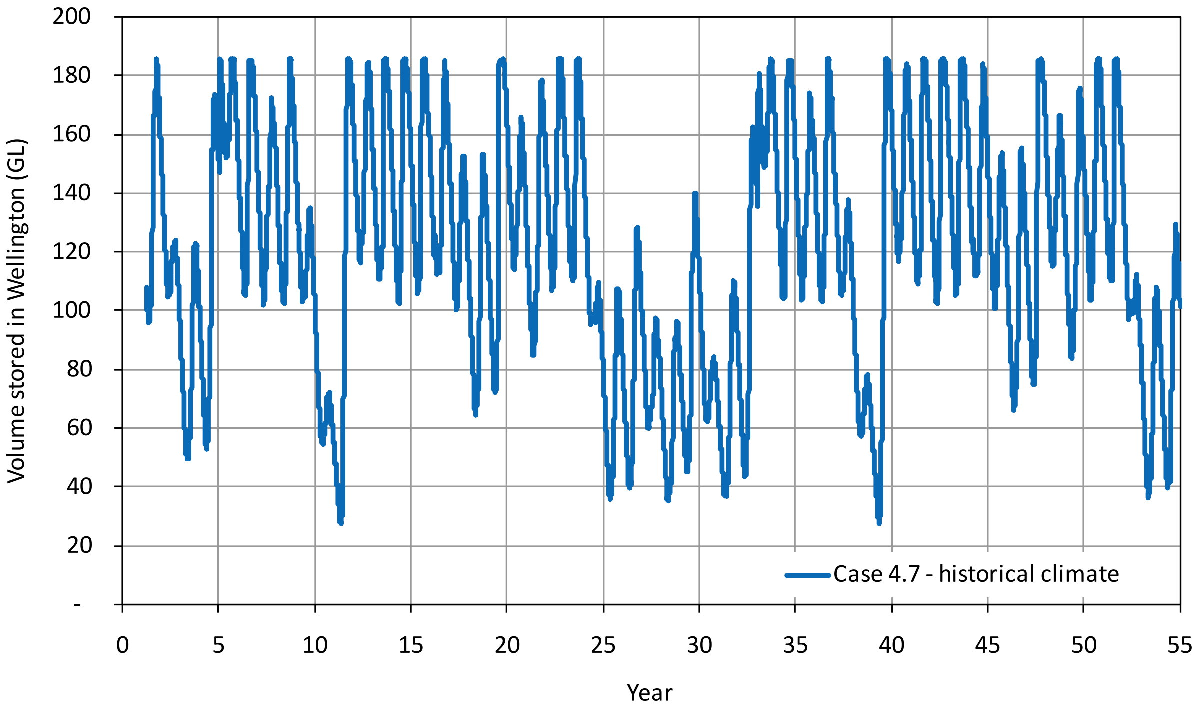

Figure 13 Volume stored in Wellington Reservoir for Case 4.7 under the historical climate

Figure 14 shows the range in volume stored in Wellington Reservoir for Case 4.7 under the historical and median future climate at 2030 in addition to Case α and the observed regime. The larger inter-quartile range for Case 4.7, compared to Case α, reflects the larger total draw on the system. This increased draw also results in a lower mean and median volume stored in Wellington.

The mean annual water balances for Case 4.7 are shown in Figure 15. With the large reduction in inflows projected for the 2030 median future climate, there is a corresponding reduction in the outflows. The relative proportion of the irrigation supply increases slightly as the model tries to satisfy the 85% reliability requirement but the largest proportional change is the 75% reduction in mean annual reservoir spill volumes under the future climate scenario.

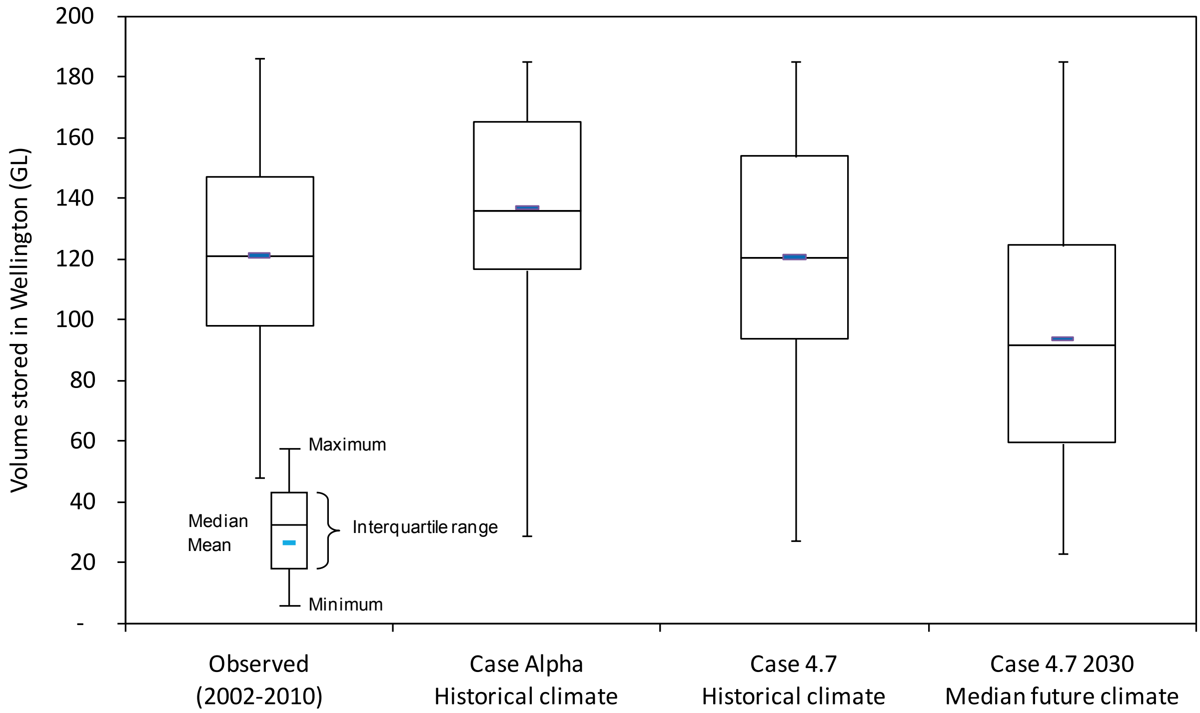

Figure 14 Volume stored in Wellington Reservoir for Case 4.7

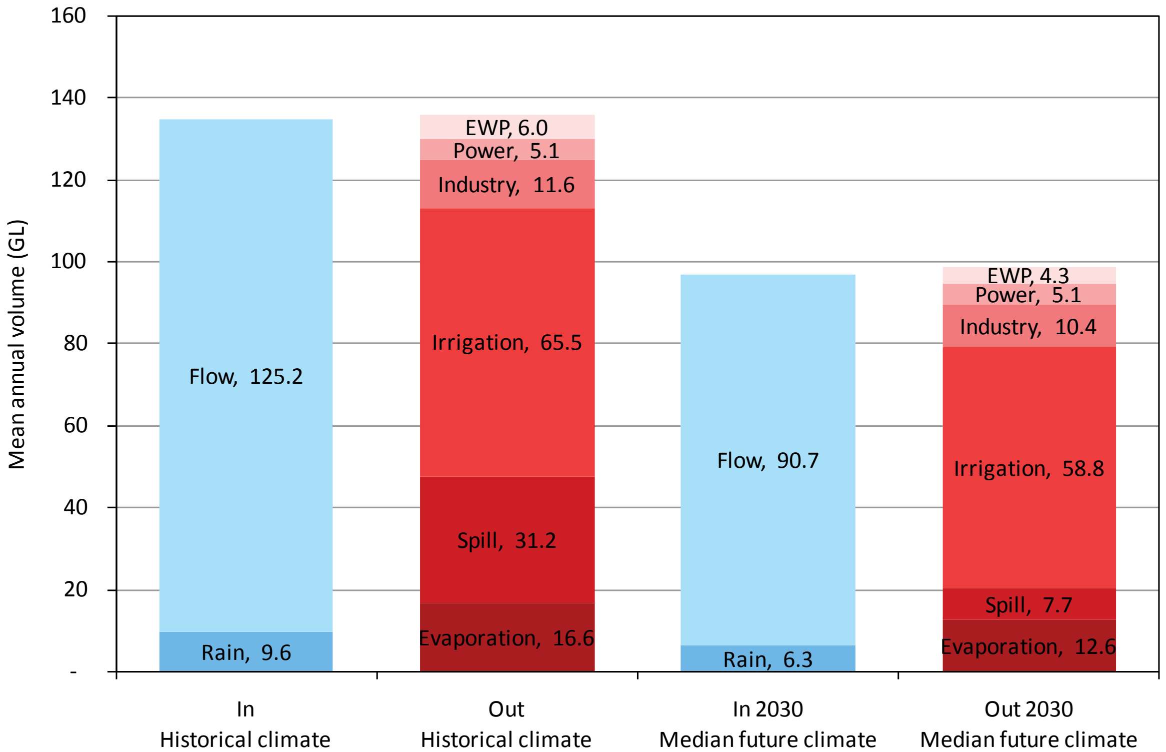

Figure 15 Mean annual water balances for Case 4.7

As discussed previously, the industrial demand requires a high reliability for its annual demand. An assessment of the annual shortfalls in demand is shown in Table 12 and Figure 16. Under the historical climate demand shortfalls occur approximately 1 in 5 years with a median shortfall of 1.64 GL. Under the 2030 median future climate, both the frequency and volume of the annual shortfalls increase.

Table 12 Industrial demand annual shortfalls for Case 4.7

	Historical climate	**Median future climate (2030)**
Years with a shortfall in supply	19%	44%
Maximum annual shortfall (GL)	5.68	9.15
Median of the annual shortfalls (GL)	1.64	3.04
Mean of the annual shortfalls (GL)	2.38	3.70

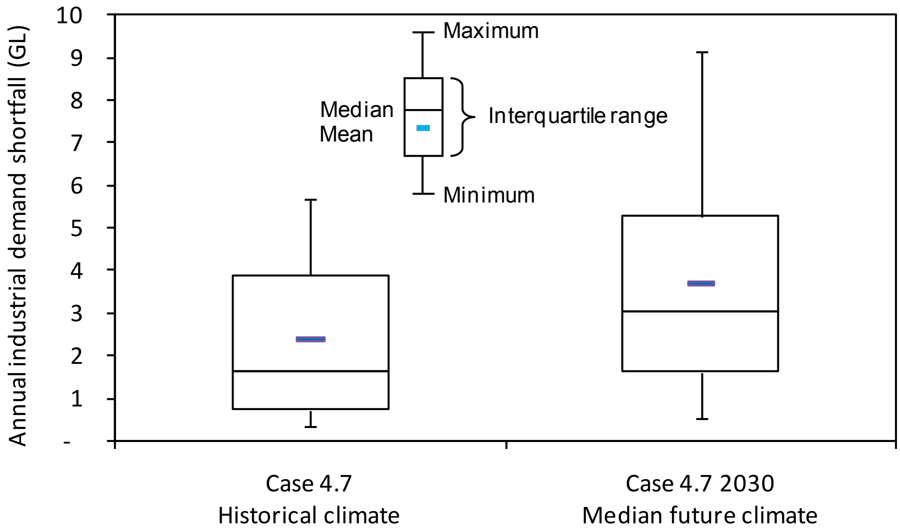

Figure 16 Range of industrial demand shortfalls for Case 4.7

4.4 Case 4.8

Case 4.8 was developed as a variation of Case 4.7 with identical annual demands for irrigation, industry and power generation cooling water. The difference between the two scenarios is that under Case 4.8 the target annual reliability for the irrigation and industrial demands was 75% instead of 85%. This change resulted in more water being available for the variable component of the EWP regime – that is, Case 4.8 had a higher fixed median winter–spring EWP volume than Case 4.7.

The time-series graph of variation in the volume stored in Wellington Reservoir (Figure 17) shows a tendency towards lower volumes than for Case 4.7. This tendency is exacerbated under the 2030 median future climate (Figure 18). Under the 2030 median future climate scenario, the median volume stored in Wellington Reservoir is less than the 25th percentile volume under the historical climate scenario.

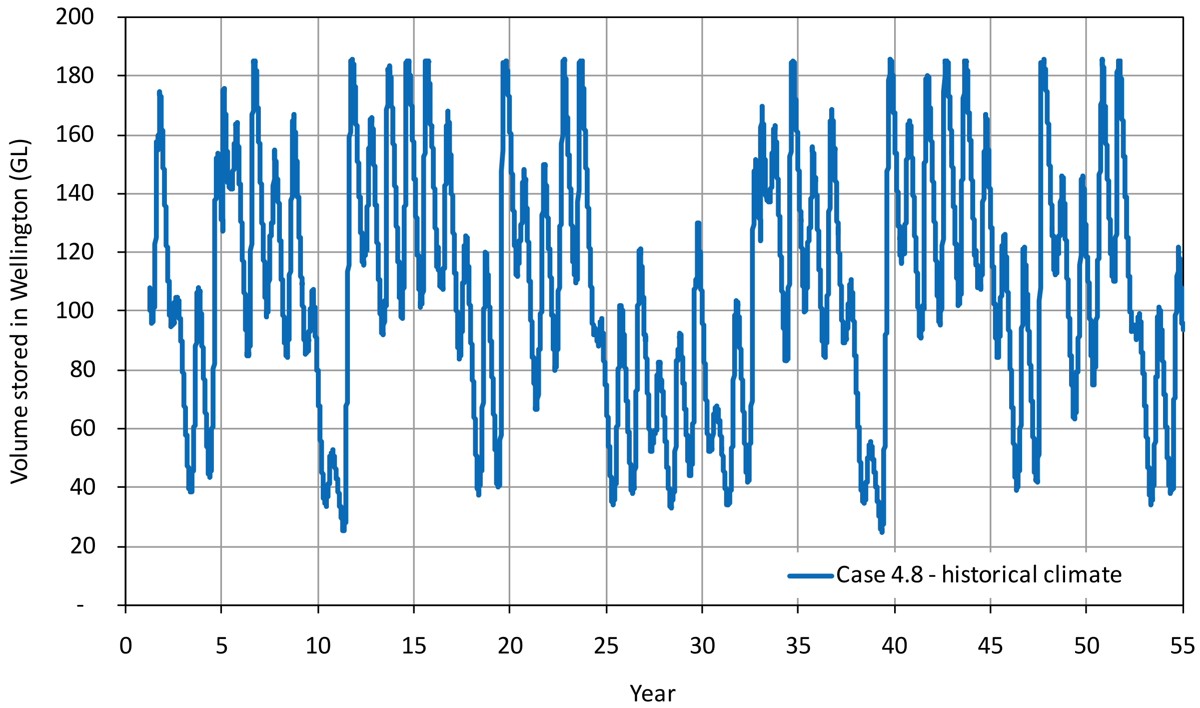

Figure 17 Volume stored in Wellington Reservoir for Case 4.8 under the historical climate

The mean annual water balances for Case 4.8 (Figure 19) again show the large reduction in water under the 2030 median future climate scenario. As with Case 4.7, there is a small increase in the relative proportion of the irrigation, industrial and power station cooling water mean annual supply. This is offset by a 78% reduction in the mean annual spill volume.

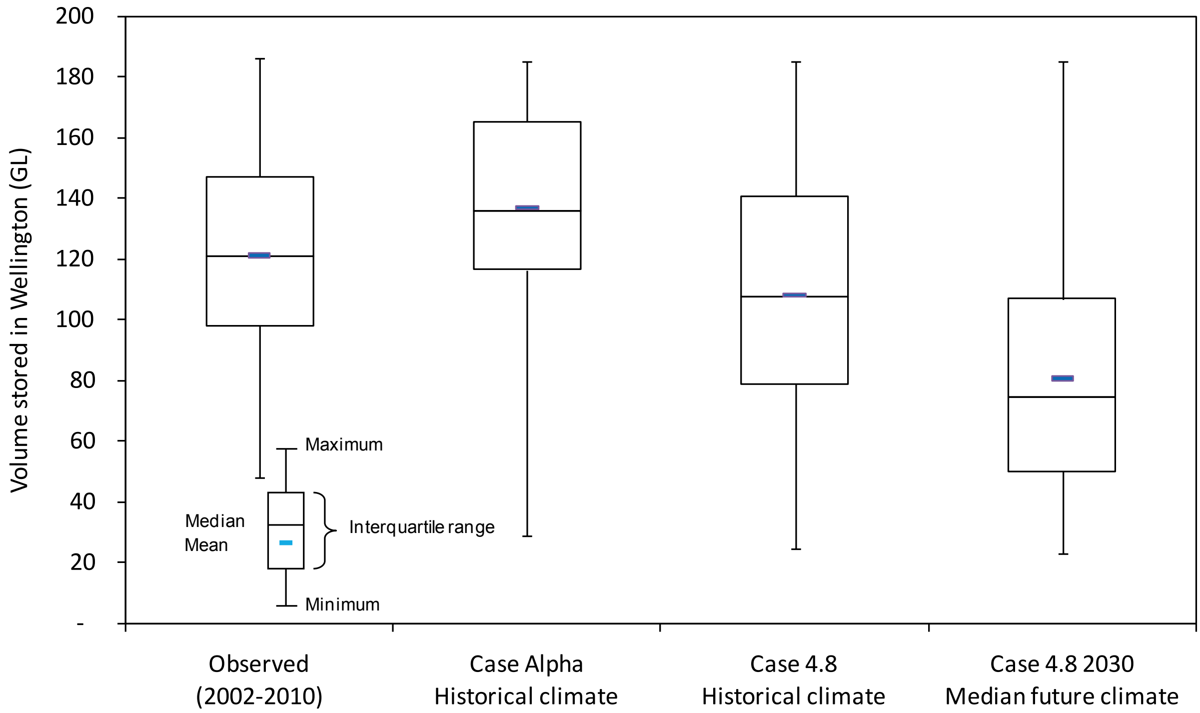

Figure 18 Volume stored in Wellington Reservoir for Case 4.8

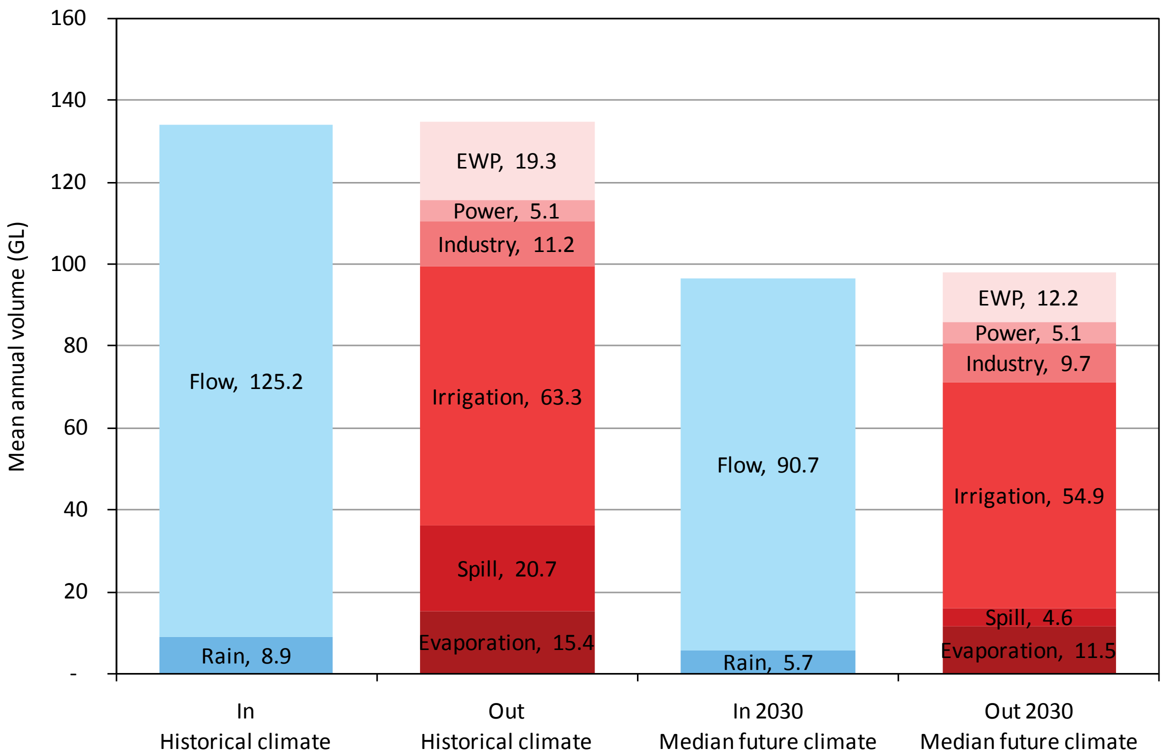

Figure 19 Mean annual water balances for Case 4.8

An assessment of the annual shortfalls in the industrial demand reveals that under the historical climate, shortfalls occur in approximately 1 out of 4 years with a mean annual shortfall of 3.16 GL (Table 13). Under the 2030 median future climate the shortfalls occur approximately every other year with a mean annual shortfall of 4.35 GL. The distribution of annual shortfalls for Case 4.8 is shown in Figure 20.

Table 13 Industrial demand annual shortfalls for Case 4.8

	Historical climate	**Median future climate (2030)**
Years with a shortfall in supply	26%	53%
Maximum annual shortfall (GL)	8.28	9.27
Median of the annual shortfalls (GL)	1.96	4.66
Mean of the annual shortfalls (GL)	3.16	4.35

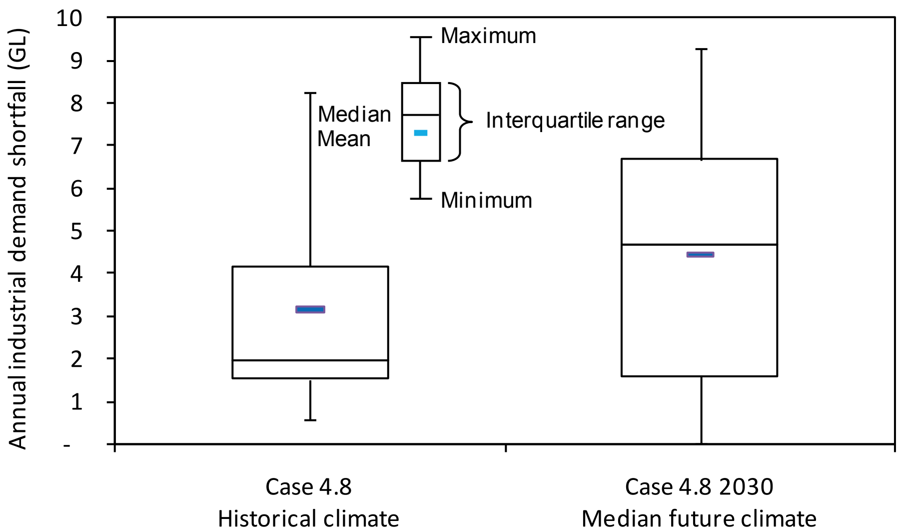

Figure 20 Range of industrial demand shortfalls for Case 4.8

Table 14 Summary of simulation results under the historical climate

Case	Mean annual inflow GL	Mean annual EWP GL	Reservoir spill: Annual frequency %	Reservoir spill: Mean annual volume GL	Irrigation: Annual demand GL	Irrigation: Annual reliability %	Irrigation: Mean annual supply GL	Industrial: Annual demand GL	Industrial: Annual reliability %	Industrial: Mean annual supply GL	Power cooling water: Annual demand GL	Power cooling water: Annual reliability %	Power cooling water: Mean annual supply GL
Case α	125	7.5*	68	42.4	68.0	100	68.0	–	–	–	–	–	–
Case 0.1	125	24.5	34	20.8	59.0	85	57.0	12.0	85	11.6	5.1	100	5.1
Case 0.2	125	21.5	40	24.3	59.0	85	56.7	12.0	85	11.5	5.1	100	5.1
Case 0.3	125	20.4	40	25.8	59.0	85	56.8	12.0	85	11.5	5.1	100	5.1
Case 1.1	125	46.8	34	20.7	53.0	85	51.3	–	–	–	–	–	–
Case 1.2	125	44.9	36	22.8	53.0	85	51.1	–	–	–	–	–	–
Case 2.1	125	34.5	32	19.7	68.0	85	65.6	–	–	–	–	–	–
Case 2.2	125	33.5	34	20.9	68.0	85	64.9	–	–	–	–	–	–
Case 3.1	125	12.1	47	28.6	68.0	92	66.6	12.0	92	11.7	–	–	–
Case 3.2	125	22.2	32	20.4	68.0	85	65.3	12.0	85	11.5	–	–	–
Case 3.3	125	9.0	53	32.0	68.0	91	66.4	12.0	91	11.7	–	–	–
Case 3.4	125	16.7	40	25.5	68.0	85	65.4	12.0	85	11.5	–	–	–
Case 3.5	125	20.2	34	22.9	68.0	83	64.3	12.0	83	11.4	–	–	–
Case 4.1	125	10.1	45	26.7	68.0	85	65.6	12.0	85	11.6	5.1	100	5.1
Case 4.2	125	18.1	30	21.2	68.0	77	63.8	12.0	77	11.3	5.1	100	5.1
Case 4.3	125	7.9	47	29.2	68.0	85	65.5	12.0	85	11.6	5.1	100	5.1
Case 4.4	125	21.9	34	19.2	68.0	74	62.4	12.0	74	11.0	5.1	100	5.1
Case 4.5	125	5.3	49	32.2	68.0	83	65.2	12.0	83	11.5	5.1	100	5.1
Case 4.6	125	19.6	30	20.4	68.0	74	63.2	12.0	74	11.2	5.1	100	5.1
Case 4.7	125	6.0	49	31.2	68.0	85	65.5	12.0	85	11.6	5.1	100	5.1
Case 4.8	125	19.3	30	20.7	68.0	76	63.3	12.0	76	11.2	5.1	100	5.1

* *for Case α, the mean annual scour is reported as there is no EWP regime*

Table 15 Summary of simulation results under the wet future climate (Cwet) at 2030

Case	Mean annual inflow GL	Mean annual EWP GL	Reservoir spill Annual frequency %	Reservoir spill Mean annual volume GL	Irrigation Annual demand GL	Irrigation Annual reliability %	Irrigation Mean annual supply GL	Industrial Annual demand GL	Industrial Annual reliability %	Industrial Mean annual supply GL	Power cooling water Annual demand GL	Power cooling water Annual reliability %	Power cooling water Mean annual supply GL
Case 0.2	114	20.3	31	15.8	59.0	78	55.6	12.0	78	11.3	5.1	100	5.1
Case 3.1	114	11.0	44	19.3	68.0	88	65.7	12.0	88	11.6	–	–	–
Case 3.2	114	20.3	25	12.5	68.0	81	64.3	12.0	81	11.3	–	–	–
Case 3.3	114	8.0	44	22.5	68.0	91	65.6	12.0	91	11.6	–	–	–
Case 3.4	114	15.3	34	17.2	68.0	78	64.3	12.0	78	11.4	–	–	–
Case 3.5	114	18.7	28	14.9	68.0	78	63.7	12.0	78	11.2	–	–	–
Case 4.1	114	9.2	34	17.7	68.0	78	64.7	12.0	78	11.4	5.1	100	5.1
Case 4.2	114	17.5	25	13.0	68.0	78	62.5	12.0	78	11.0	5.1	100	5.1
Case 4.3	114	7.1	38	20.1	68.0	78	64.5	12.0	78	11.4	5.1	100	5.1
Case 7.3	114	7.9	41	21.7	64.6	84	62.1	11.4	84	11.0	5.1	100	5.1
Case 8.1	114	14.6	59	29.7	49.3	100	49.3	8.7	100	8.7	3.7	100	3.7
Case 8.2	114	20.8	47	24.5	49.3	94	48.8	8.7	94	8.6	3.7	100	3.7
Case 8.3	114	8.6	66	35.5	49.3	100	49.3	8.7	100	8.7	3.7	100	3.7

Table 16 Summary of simulation results under the median future climate (Cmid) at 2030

			Reservoir spill		Irrigation			Industrial			Power cooling water		
Case	**Mean annual inflow GL**	**Mean annual EWP GL**	**Annual frequency %**	**Mean annual volume GL**	**Annual demand GL**	**Annual reliability %**	**Mean annual supply GL**	**Annual demand GL**	**Annual reliability %**	**Mean annual supply GL**	**Annual demand GL**	**Annual reliability %**	**Mean annual supply GL**
Case 0.2	90.7	13.4	13	5.8	59.0	59	51.1	12.0	59	10.4	5.1	100	5.1
Case 0.3	90.7	13.1	13	6.2	59.0	56	51.1	12.0	56	10.4	5.1	100	5.1
Case 3.1	90.7	5.4	19	8.1	68.0	66	61.4	12.0	66	10.8	–	–	–
Case 3.2	90.7	11.0	13	4.9	68.0	62	59.9	12.0	62	10.5	–	–	–
Case 3.3	90.7	5.3	22	8.8	68.0	69	61.0	12.0	69	10.8	–	–	–
Case 3.4	90.7	10.0	13	6.3	68.0	59	59.3	12.0	59	10.5	–	–	–
Case 3.5	90.7	12.2	13	5.5	68.0	59	58.1	12.0	59	10.3	–	–	–
Case 4.1	90.7	4.4	19	6.8	68.0	59	59.4	12.0	59	10.5	5.1	100	5.1
Case 4.2	90.7	10.8	9	4.8	68.0	53	55.9	12.0	53	9.9	5.1	100	5.1
Case 4.3	90.7	4.8	19	7.0	68.0	59	58.9	12.0	59	10.4	5.1	100	5.1
Case 4.7	90.7	4.3	19	7.7	68.0	59	58.8	12.0	59	10.4	5.1	100	5.1
Case 4.8	90.7	12.2	9	4.6	68.0	53	54.9	12.0	53	9.7	5.1	100	5.1
Case 7.2	90.7	8.0	25	14.4	50.3	84	48.3	8.9	84	8.5	5.1	100	5.1
Case 8.1	90.7	9.3	25	14.2	49.3	94	48.0	8.7	94	8.5	3.7	100	3.7
Case 8.2	90.7	15.1	22	11.1	49.3	81	46.5	8.7	81	8.2	3.7	100	3.7
Case 8.3	90.7	6.5	28	16.9	49.3	94	48.0	8.7	94	8.5	3.7	100	3.7

Table 17   Summary of simulation results under the dry future climate (Cdry) at 2030

Case	Mean annual inflow GL	Mean annual EWP GL	Reservoir spill: Annual frequency %	Reservoir spill: Mean annual volume GL	Irrigation: Annual demand GL	Irrigation: Annual reliability %	Irrigation: Mean annual supply GL	Industrial: Annual demand GL	Industrial: Annual reliability %	Industrial: Mean annual supply GL	Power cooling water: Annual demand GL	Power cooling water: Annual reliability %	Power cooling water: Mean annual supply GL
Case 0.2	64.4	7.5	9	0.6	59.0	28	39.9	12.0	28	8.1	5.1	100	5.1
Case 3.1	64.4	1.6	9	1.1	68.0	31	49.8	12.0	31	8.8	–	–	–
Case 3.2	64.4	4.1	9	0.8	68.0	31	47.8	12.0	31	8.4	–	–	–
Case 3.3	64.4	2.7	9	0.9	68.0	31	49.0	12.0	31	8.6	–	–	–
Case 3.4	64.4	5.5	9	0.6	68.0	28	46.9	12.0	28	8.3	–	–	–
Case 3.5	64.4	7.1	6	0.5	68.0	28	45.6	12.0	28	8.1	–	–	–
Case 4.1	64.4	1.3	9	0.7	68.0	28	46.3	12.0	28	8.2	5.1	100	5.1
Case 4.2	64.4	6.0	6	0.3	68.0	28	42.6	12.0	28	7.5	5.1	100	5.1
Case 4.3	64.4	2.3	9	0.6	68.0	28	45.5	12.0	28	8.0	5.1	100	5.1
Case 7.1	64.4	7.6	19	6.2	34.7	91	33.5	6.1	91	5.9	5.1	100	5.1
Case 8.1	64.4	2.9	9	2.5	49.3	56	43.2	8.7	56	7.6	3.7	100	3.7
Case 8.2	64.4	8.4	9	1.5	49.3	53	39.8	8.7	53	7.0	3.7	100	3.7
Case 8.3	64.4	3.3	9	2.4	49.3	56	43.0	8.7	56	7.6	3.7	100	3.7

5 Discussion

A large number of simulations of the TwoRes model have been undertaken to assess the performance of the Wellington Reservoir system under a range of conditions. In addition to assessing a range of future climate projection scenarios, the model was also run with various draw and EWP regimes.

Currently, Wellington Reservoir only has a single licensed entitlement – 68 GL for irrigation – and a winter scour regime as draws on the system. The winter scour regime is used to improve the quality of the stored water. The full irrigation entitlement is not currently used and hence the total draw from the system is less than the total inflow – even compared to the recent extended low inflow period. Consequently spills from the reservoir still frequently occur. In the period 2002 to 2010 reservoir spills occurred in 2005, 2007 and 2009. Reservoir spills occur much less frequently in the current TwoRes simulations as the pressure on the available water increases. Under the historical climate simulations reservoir spills typically occur on average around 1 in 3 years. This reduces to 1 in 5 and 1 in 10 years under the 2030 median and dry future climates.

With the increase in demand from the system in the current simulations, the scour regime was effectively switched off in the model. This was done to maximise the water available for the consumptive demands. The EWP regime implemented in the model acts as a surrogate for the scour regime by releasing water from the reservoir during the winter period.

For the majority of the simulations, the goal of the modelling was to achieve the target annual reliabilities of the irrigation, industrial and power station cooling water annual demands. This was typically achieved by varying the variable EWP contribution by adjusting the median winter–spring EWP volume. Where future climate scenarios were run in addition to an historical climate scenario, the EWP regime from the historical climate scenario was retained under the future climate scenarios. This approach generally resulted in the target annual reliabilities for the irrigation and industrial demands not being achieved under the future climates. An assessment of the adequacy of the EWP regime for the various simulations to satisfy defined ecological threshold values has not been undertaken as part of this modelling.

The simulations clearly demonstrate that there is significant pressure on the Wellington Reservoir system under the historical climate when industrial and power generation cooling water demands are included. Under all of the future climate scenarios there will be insufficient water available from Wellington Reservoir to satisfy all of the demands at the target annual reliabilities if the historical climate EWP is retained.

Appendix — Summary of modelling results for individual cases

Case α - historical climate

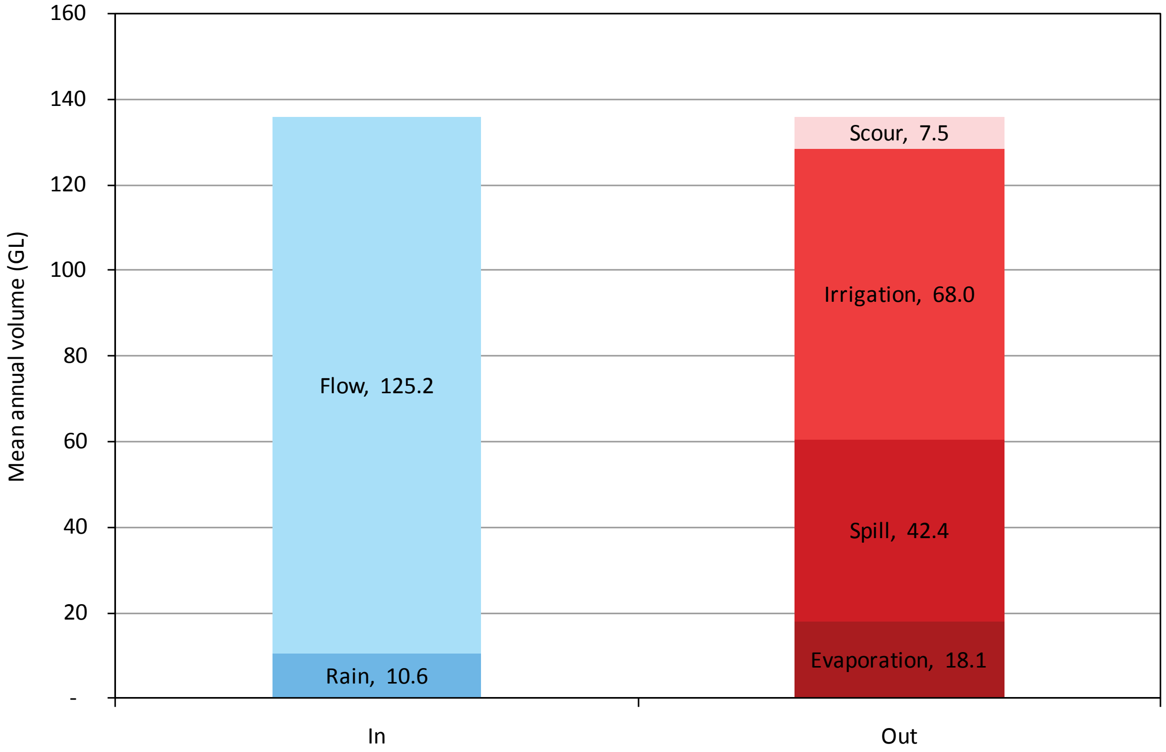

Figure 21 Mean annual water balance for Case α - historical climate

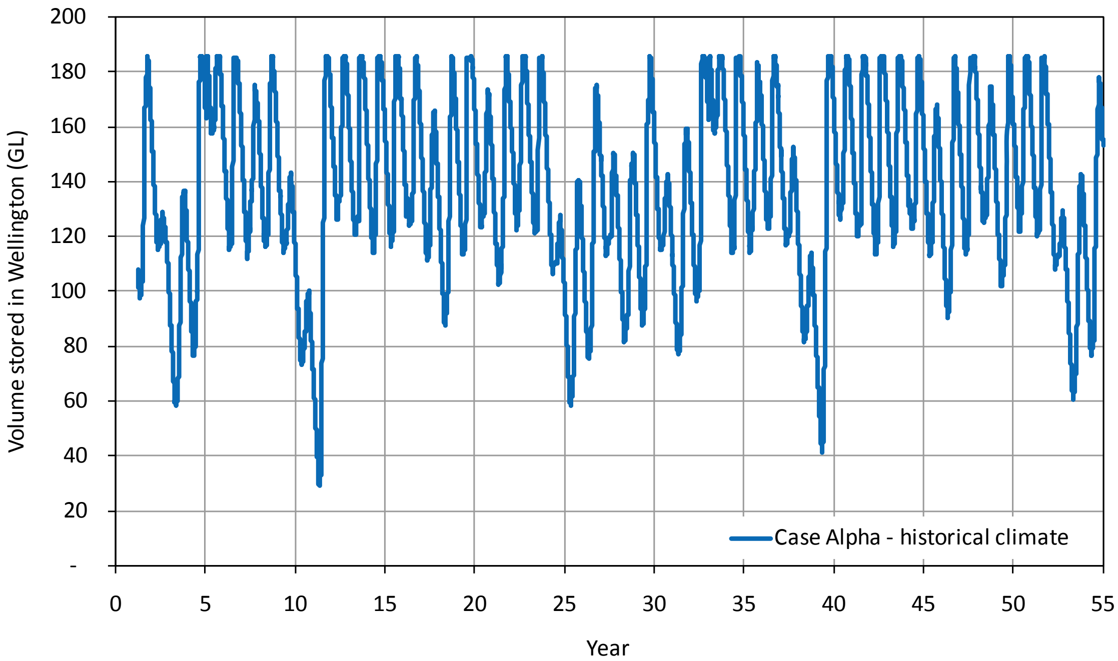

Figure 22 Annual volume stored in Wellington Reservoir for Case α – historical climate

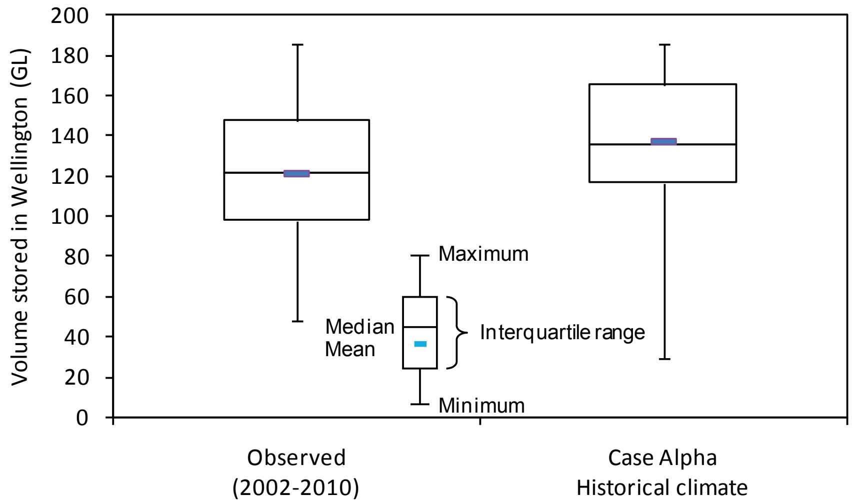

Figure 23 Distribution of annual volume stored in Wellington Reservoir for Case α–historical climate

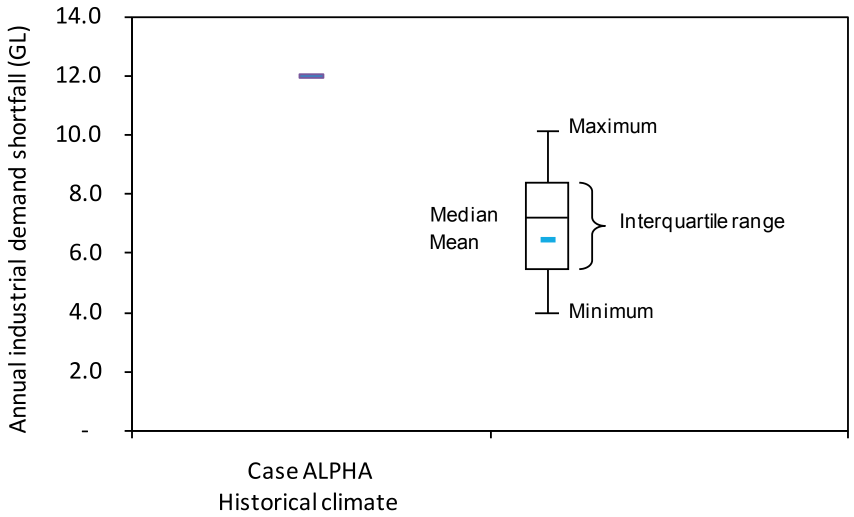

Figure 24 Range of industrial demand shortfalls for Case α – historical climate

Table 18 Annual industrial supply shortfalls for Case α – historical climate

	Historical climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	12.0
Median of the annual shortfalls (GL)	12.0
Mean of the annual shortfalls (GL)	12.0

Case 0.1 – historical climate

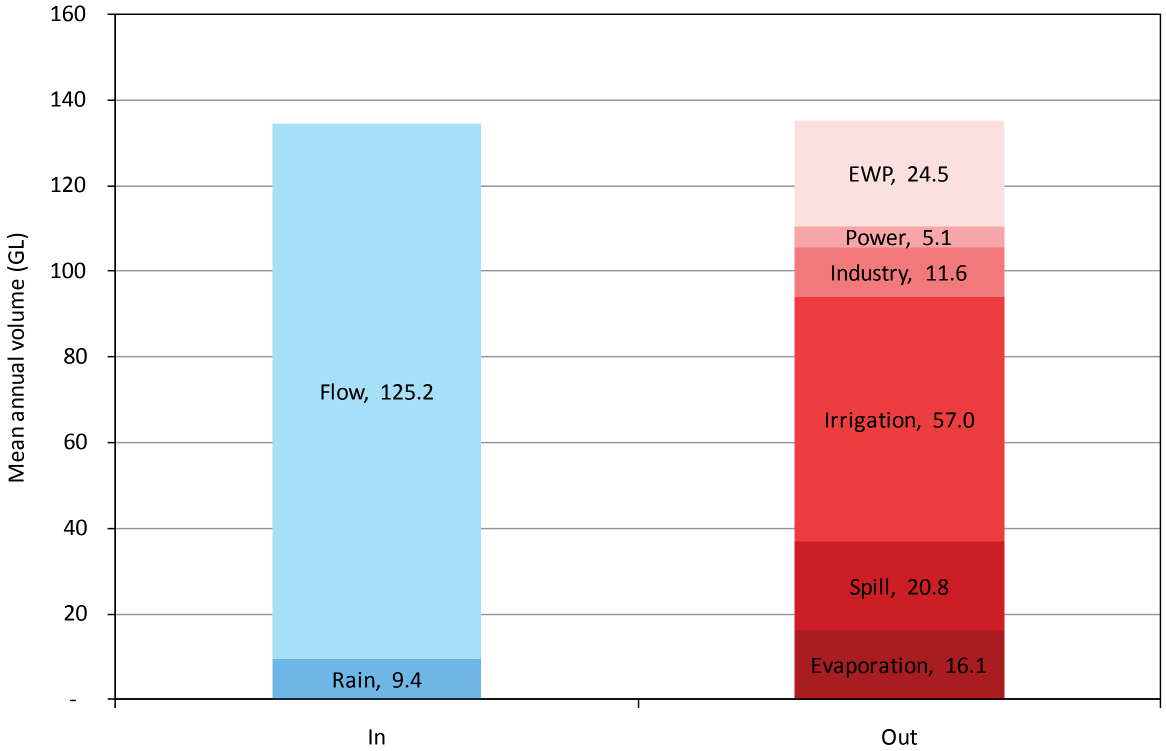

Figure 25 Mean annual water balance for Case 0.1 - historical climate

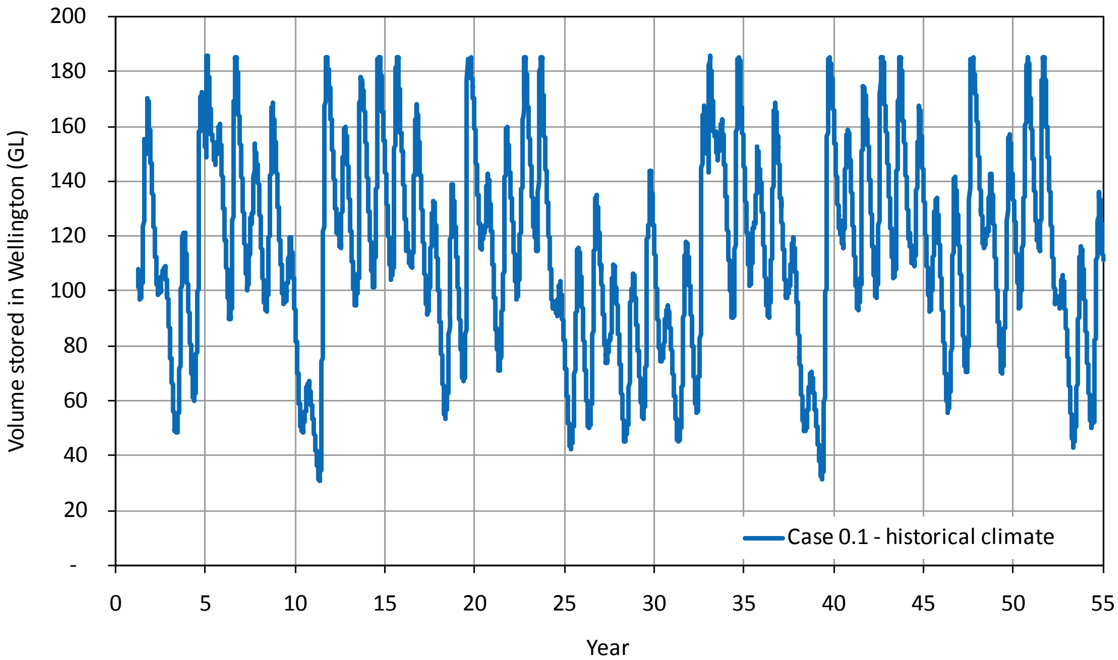

Figure 26 Annual volume stored in Wellington Reservoir for Case 0.1 – historical climate

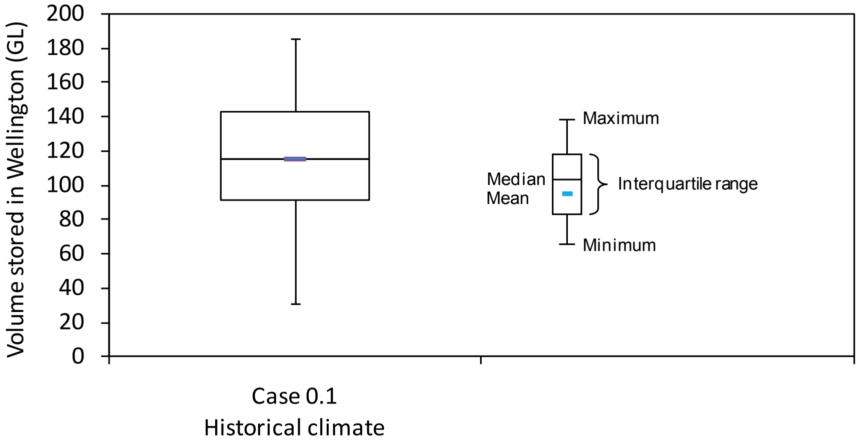

Figure 27 Distribution of annual volume stored in Wellington Reservoir for Case 0.1 – historical climate

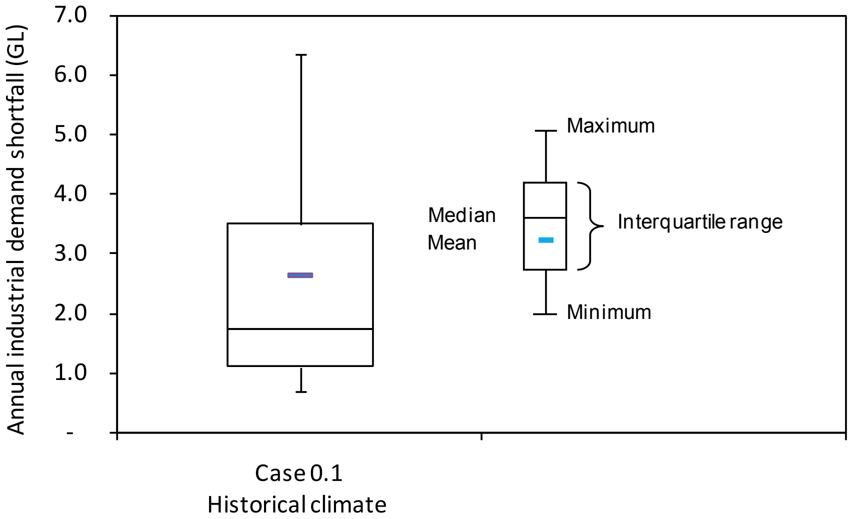

Figure 28 Range of industrial demand shortfalls for Case 0.1 – historical climate

Table 19 Annual industrial supply shortfalls for Case 0.1 – historical climate

	Historical climate
Years with a shortfall in supply	15%
Maximum annual shortfall (GL)	6.37
Median of the annual shortfalls (GL)	1.75
Mean of the annual shortfalls (GL)	2.64

Case 0.2 – historical climate

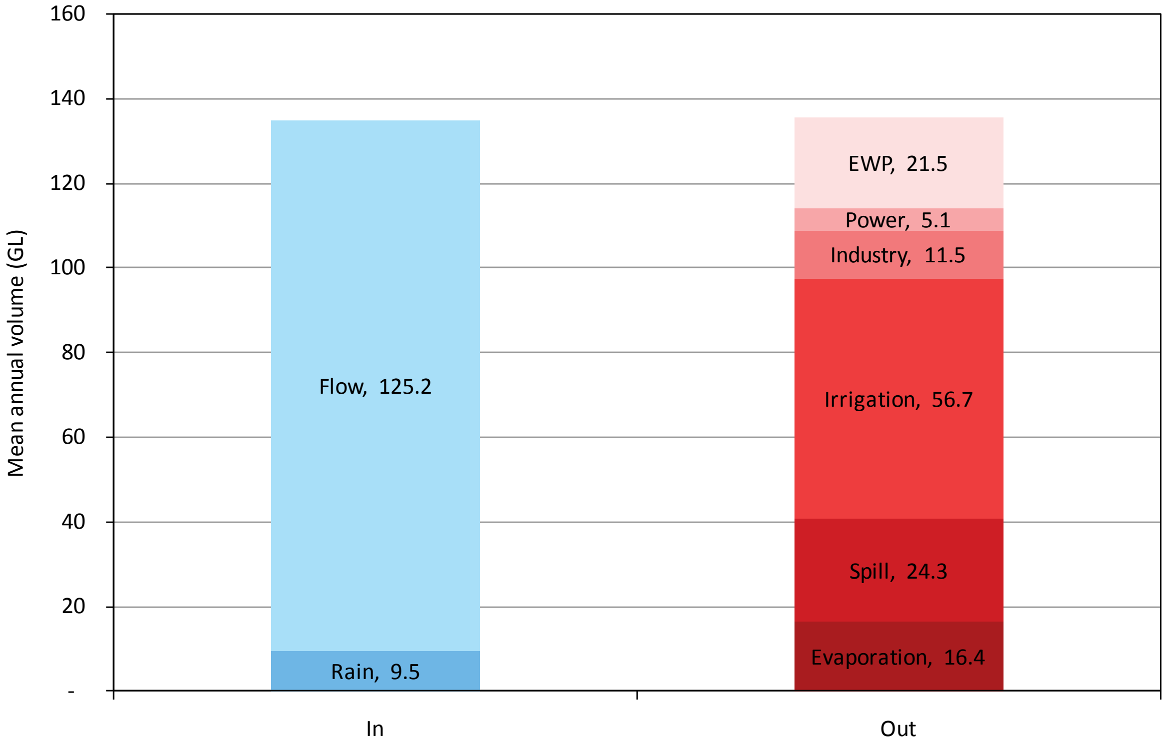

Figure 29 Mean annual water balance for Case 0.2 - historical climate

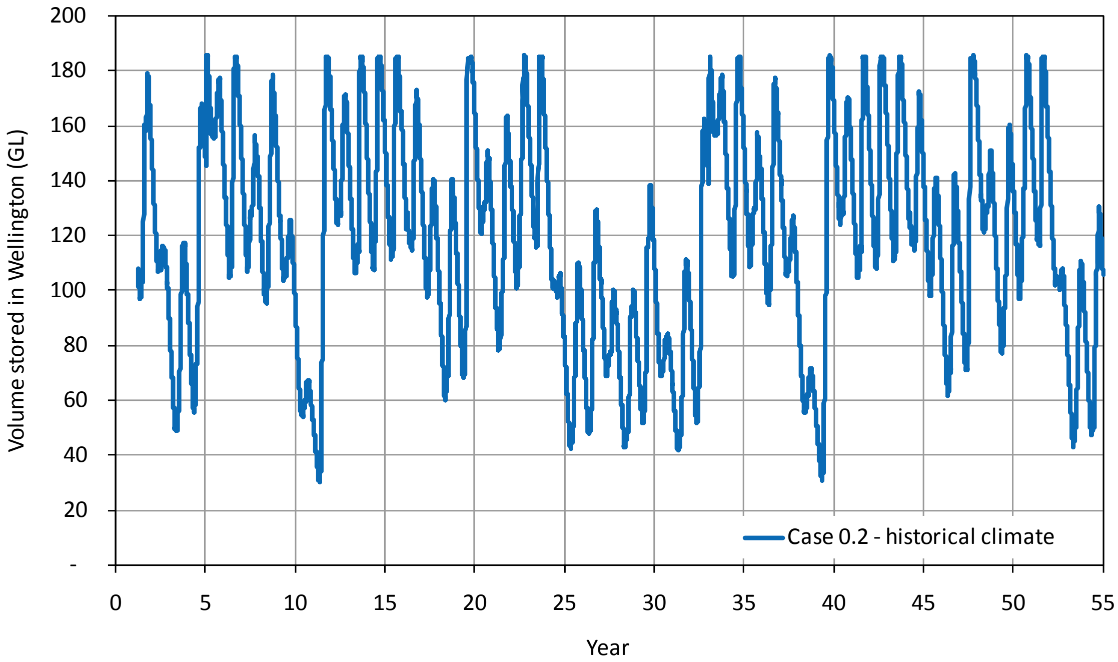

Figure 30 Annual volume stored in Wellington Reservoir for Case 0.2 – historical climate

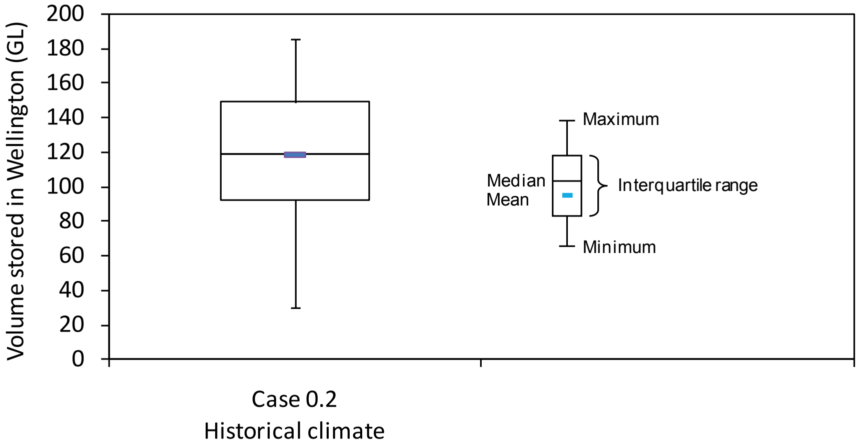

Figure 31 Distribution of annual volume stored in Wellington Reservoir for Case 0.2 – historical climate

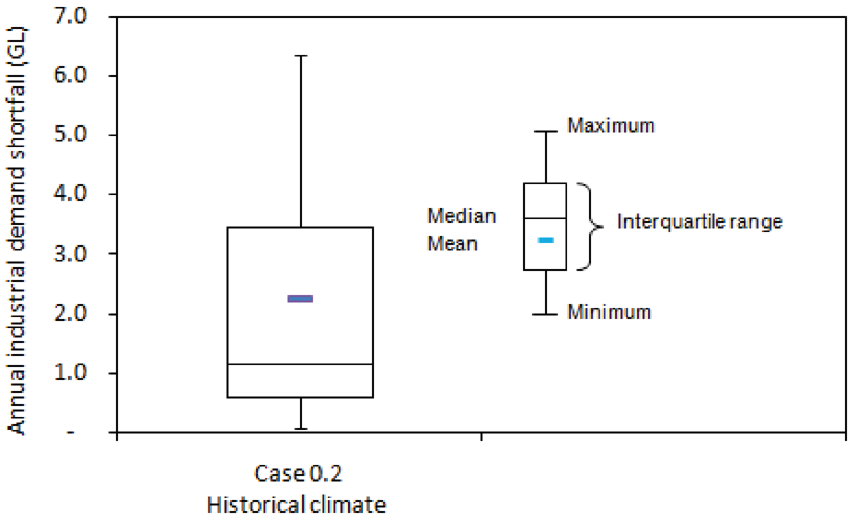

Figure 32 Range of industrial demand shortfalls for Case 0.2 – historical climate

Table 20 Annual industrial supply shortfalls for Case 0.2 – historical climate

	Historical climate
Years with a shortfall in supply	21%
Maximum annual shortfall (GL)	6.35
Median of the annual shortfalls (GL)	1.16
Mean of the annual shortfalls (GL)	2.25

Case 0.2 – 2030 wet future climate

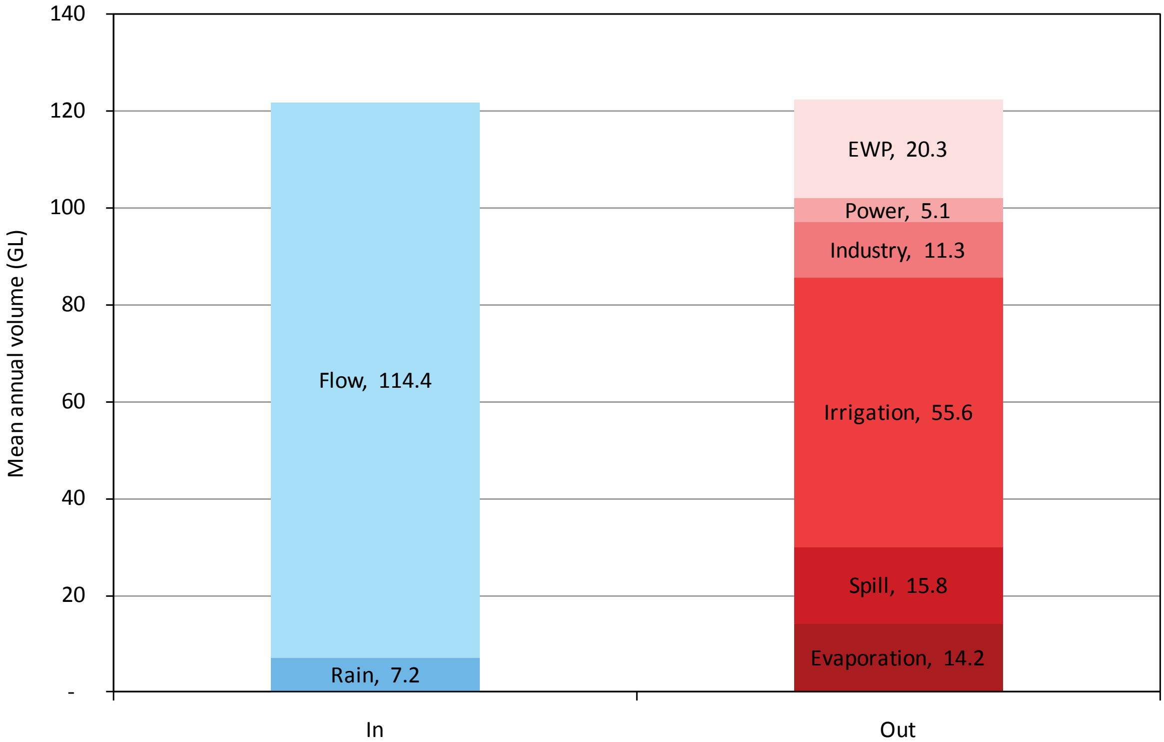

Figure 33 Mean annual water balance for Case 0.2 – 2030 wet future climate

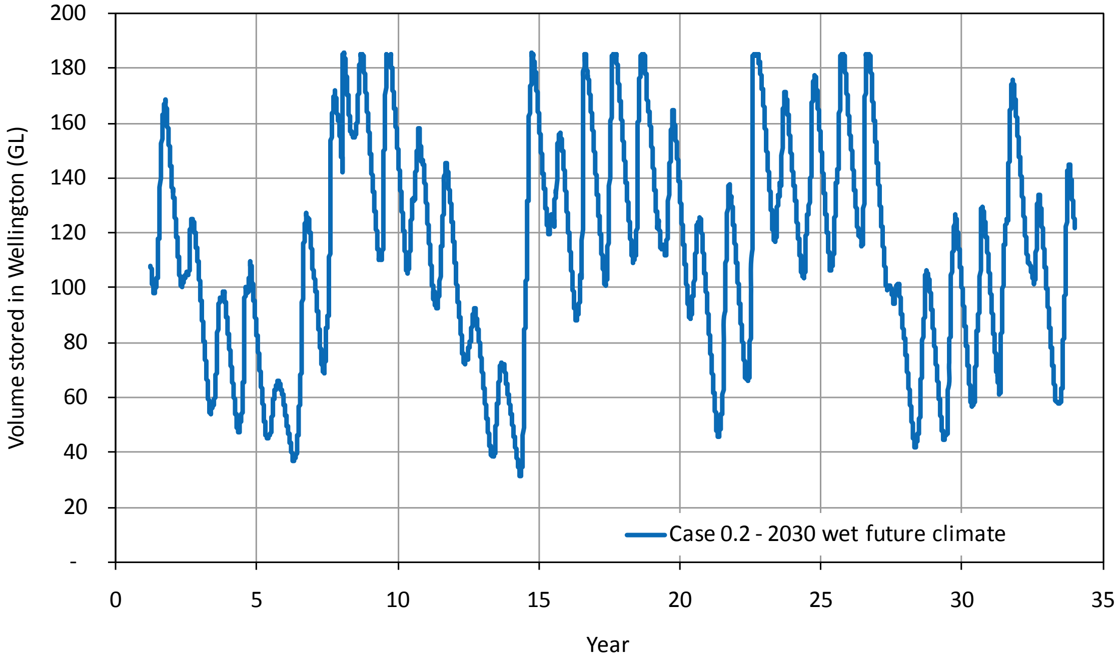

Figure 34 Annual volume stored in Wellington Reservoir for Case 0.2 – 2030 wet future climate

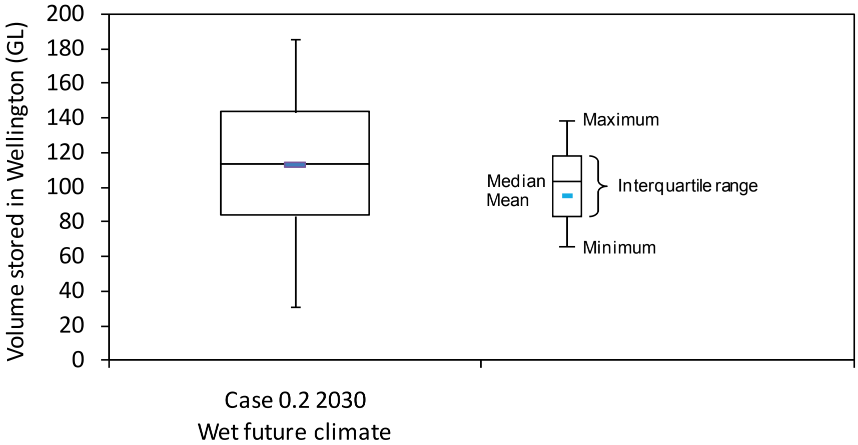

Figure 35 Distribution of annual volume stored in Wellington Reservoir for Case 0.2 – 2030 wet future climate

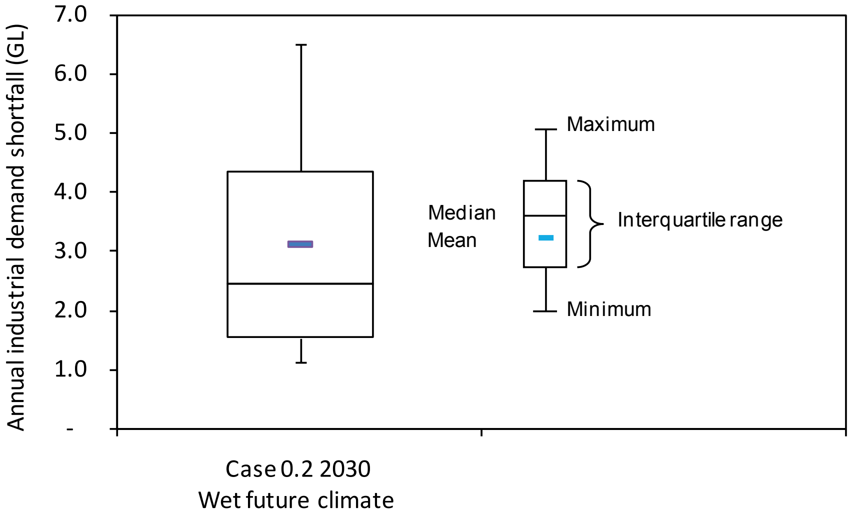

Figure 36 Range of industrial demand shortfalls for Case 0.2 – 2030 wet future climate

Table 21 Annual industrial supply shortfalls for Case 0.2 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.50
Median of the annual shortfalls (GL)	2.44
Mean of the annual shortfalls (GL)	3.13

Case 0.2 – 2030 median future climate

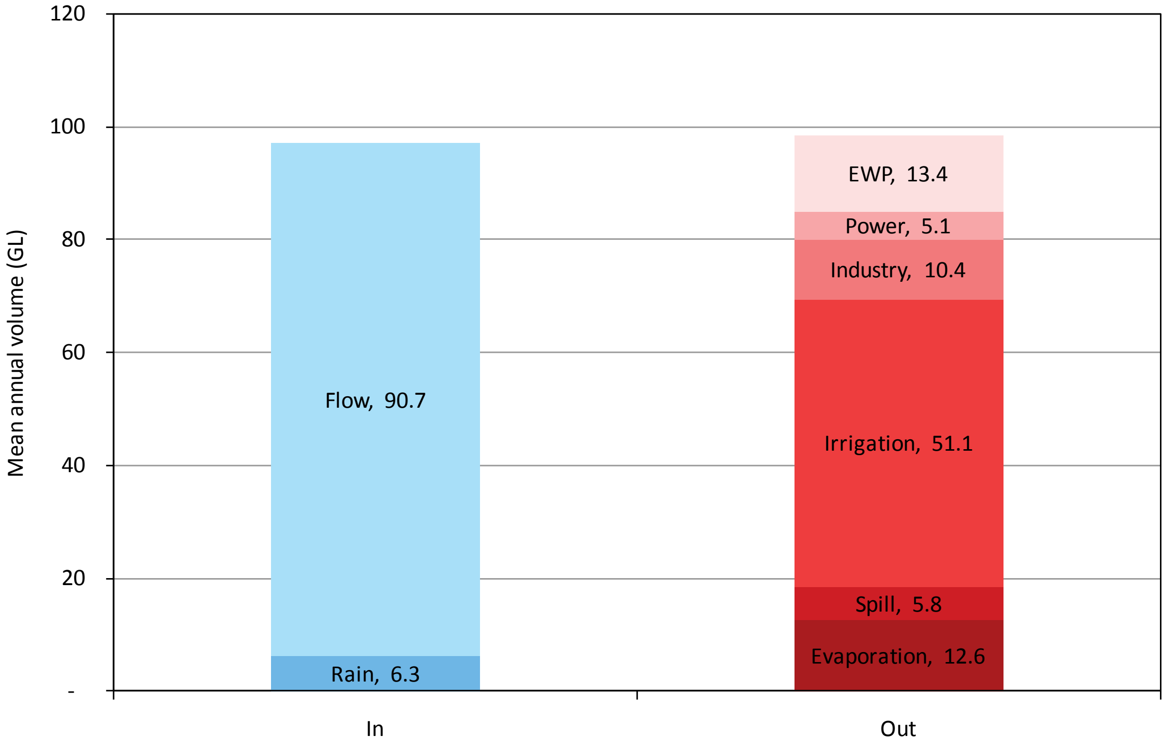

Figure 37 Mean annual water balance for Case 0.2 – 2030 median future climate

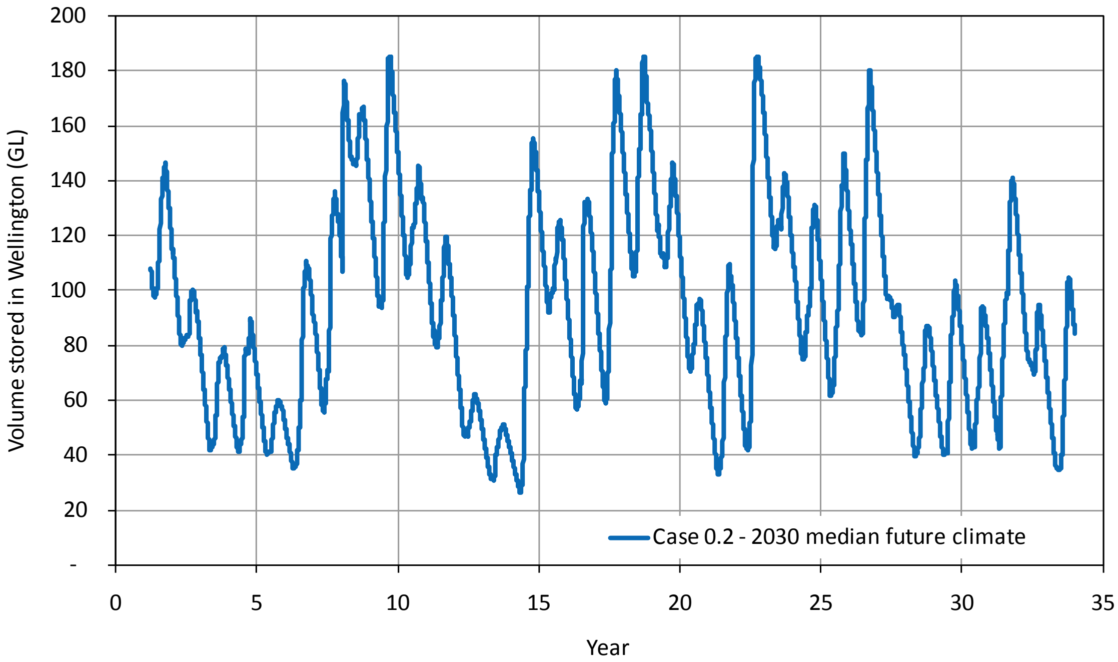

Figure 38 Annual volume stored in Wellington Reservoir for Case 0.2 – 2030 median future climate

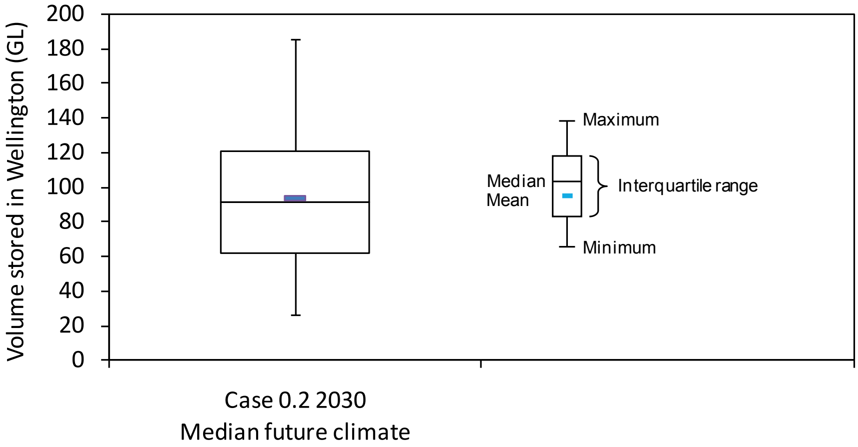

Figure 39 Distribution of annual volume stored in Wellington Reservoir for Case 0.2 – 2030 median future climate

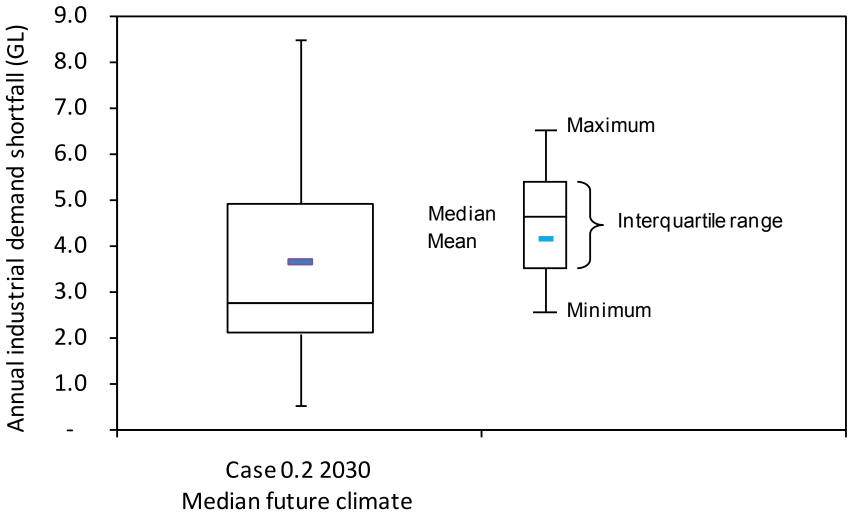

Figure 40 Range of industrial demand shortfalls for Case 0.2 – 2030 median future climate

Table 22 Annual industrial supply shortfalls for Case 0.2 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	44%
Maximum annual shortfall (GL)	8.50
Median of the annual shortfalls (GL)	2.76
Mean of the annual shortfalls (GL)	3.66

Case 0.2 – 2030 dry future climate

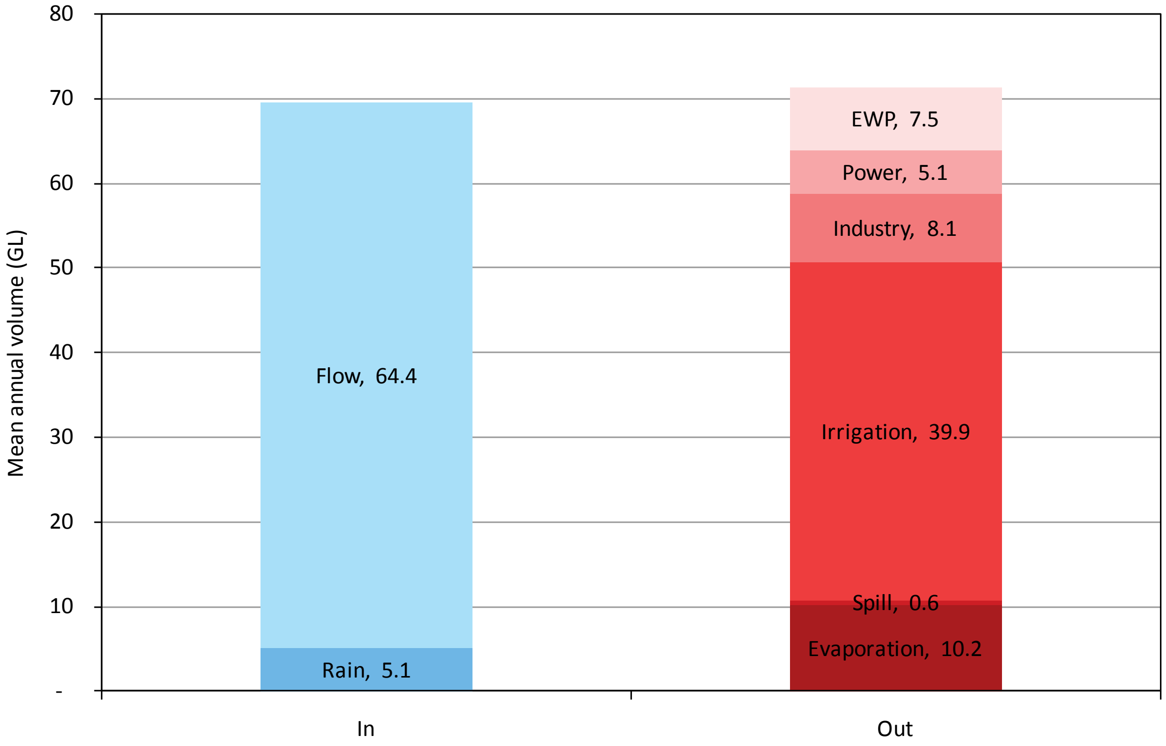

Figure 41 Mean annual water balance for Case 0.2 – 2030 dry future climate

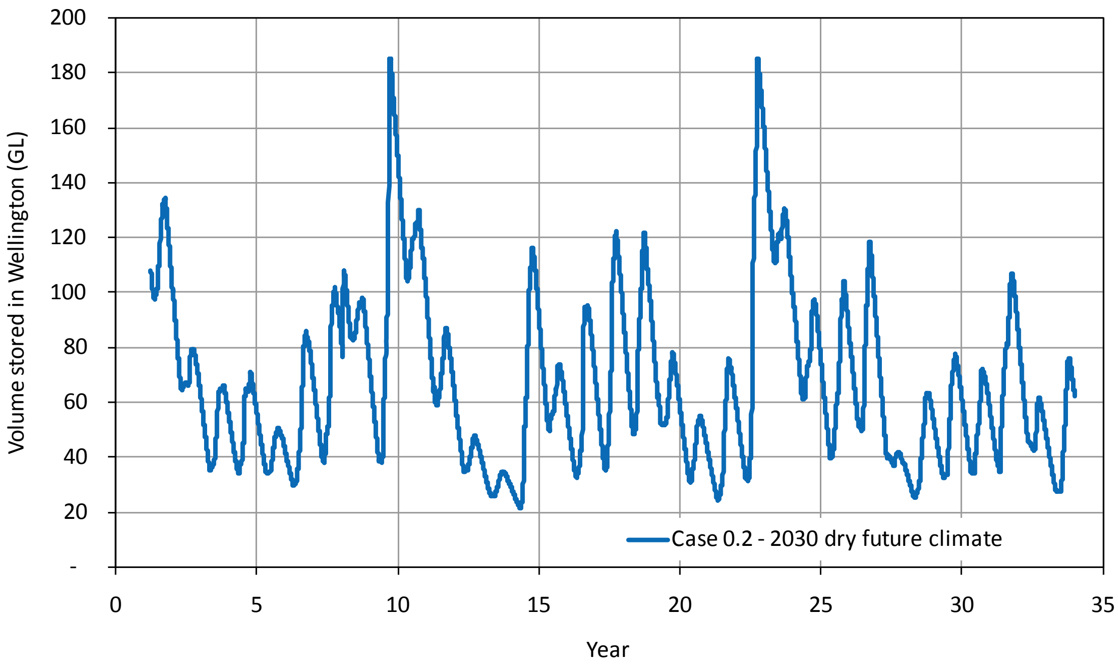

Figure 42 Annual volume stored in Wellington Reservoir for Case 0.2 – 2030 dry future climate

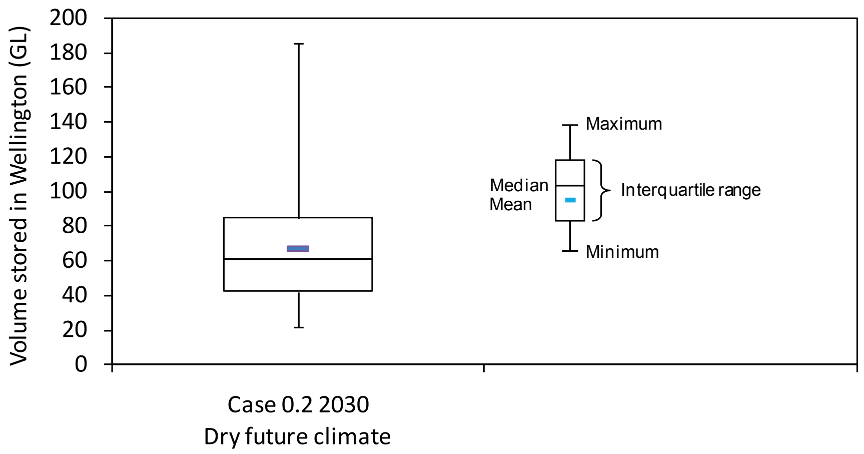

Figure 43 Distribution of annual volume stored in Wellington Reservoir for Case 0.2 – 2030 dry future climate

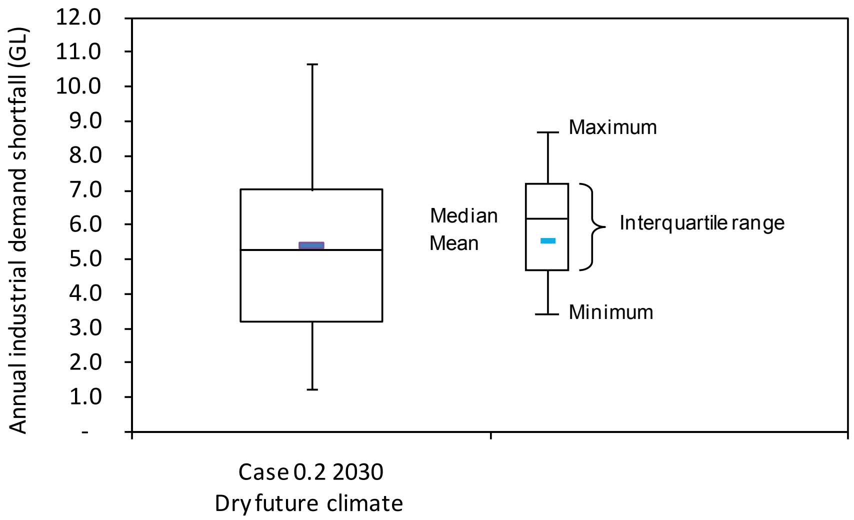

Figure 44 Range of industrial demand shortfalls for Case 0.2 – 2030 dry future climate

Table 23 Annual industrial supply shortfalls for Case 0.2 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	10.7
Median of the annual shortfalls (GL)	5.25
Mean of the annual shortfalls (GL)	5.40

Case 0.3 – historical climate

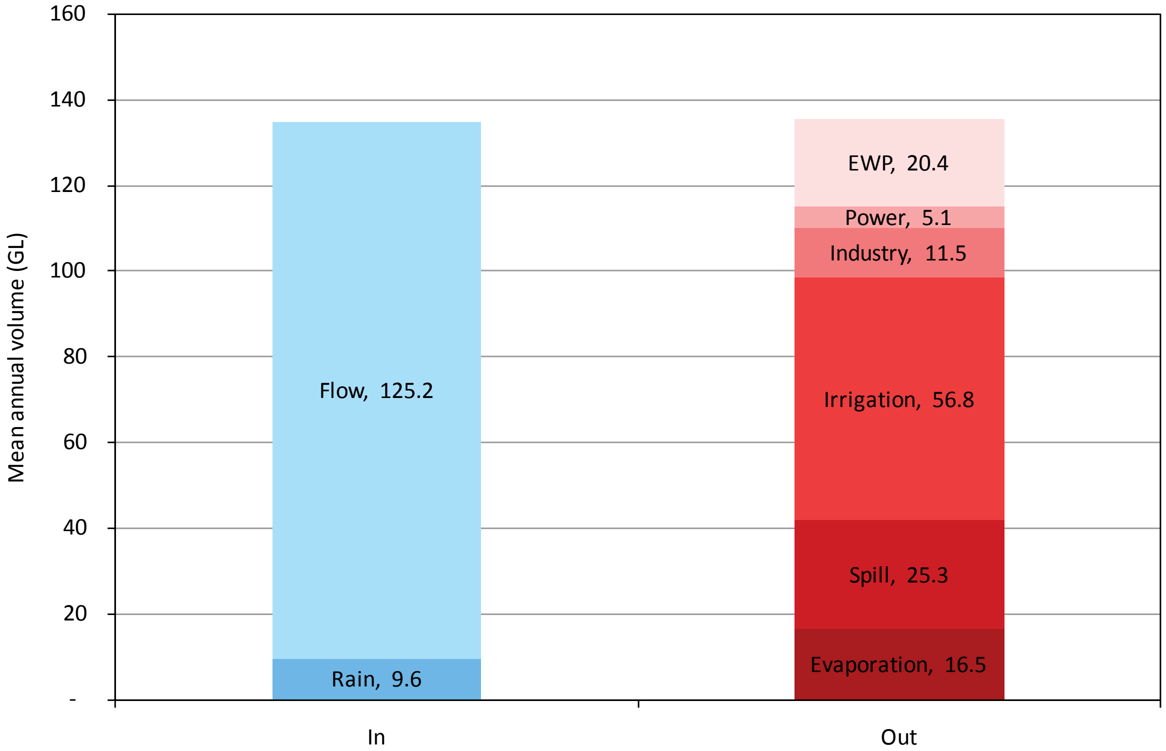

Figure 45 Mean annual water balance for Case 0.3 - historical climate

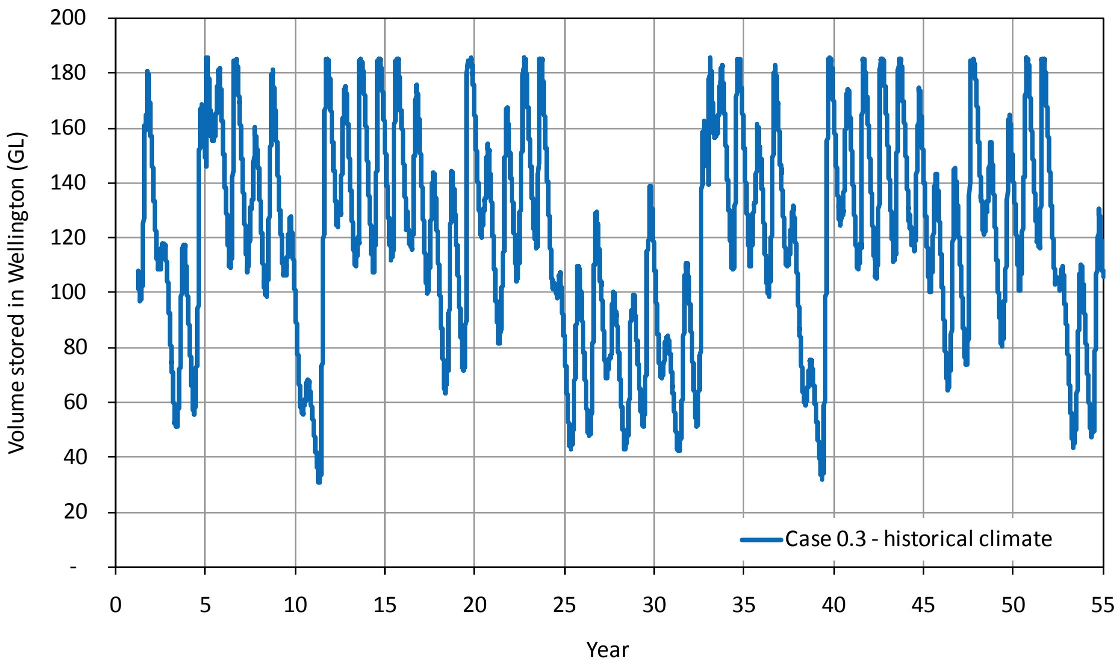

Figure 46 Annual volume stored in Wellington Reservoir for Case 0.3 – historical climate

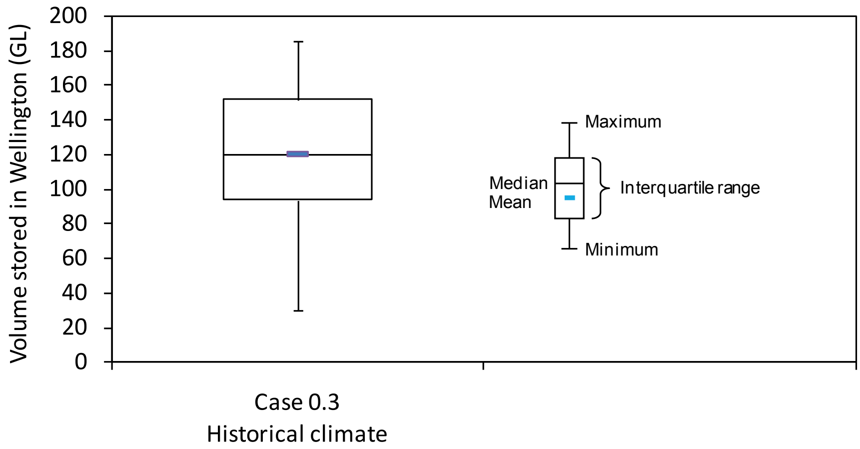

Figure 47 Distribution of annual volume stored in Wellington Reservoir for Case 0.3 – historical climate

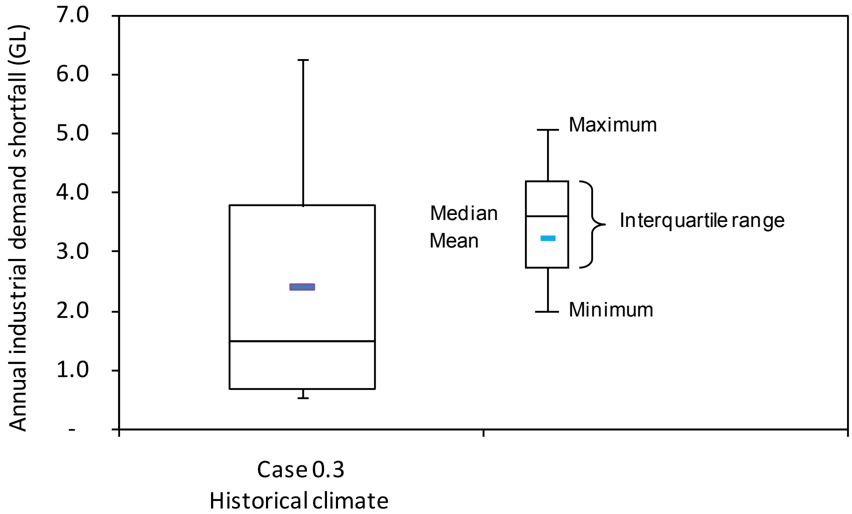

Figure 48 Range of industrial demand shortfalls for Case 0.3 – historical climate

Table 24 Annual industrial supply shortfalls for Case 0.3 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	6.25
Median of the annual shortfalls (GL)	1.49
Mean of the annual shortfalls (GL)	2.41

Case 0.3 – 2030 median future climate

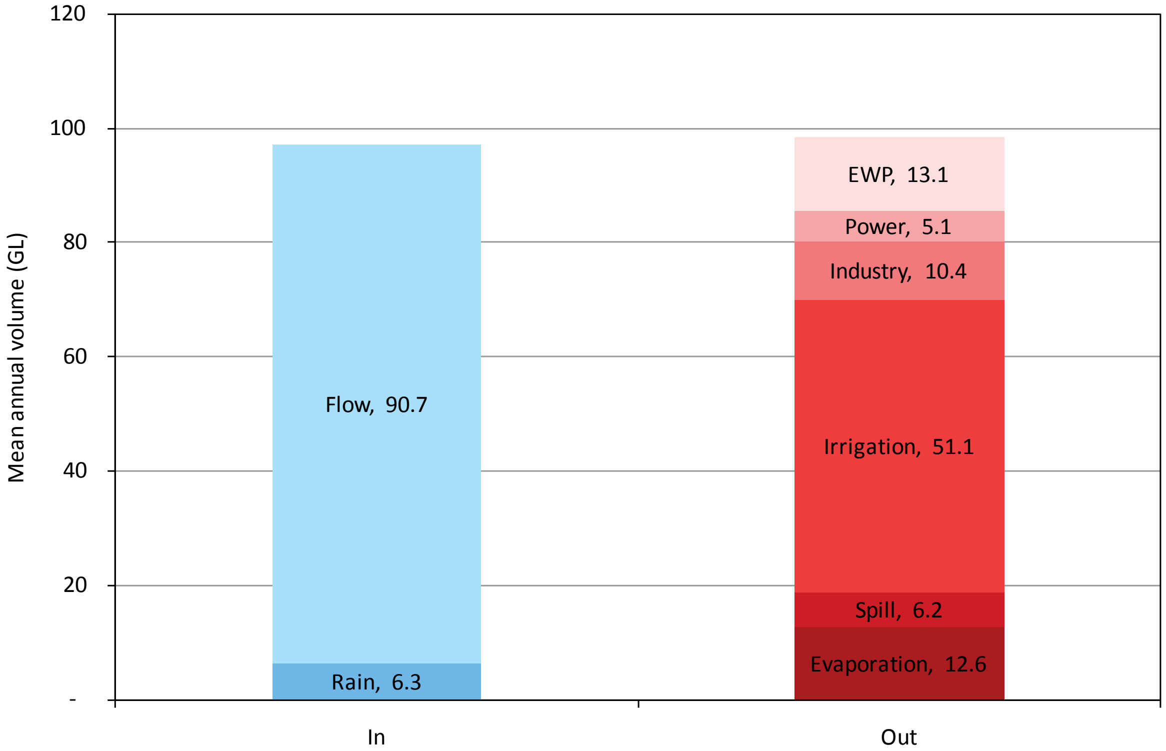

Figure 49 Mean annual water balance for Case 0.3 – 2030 median future climate

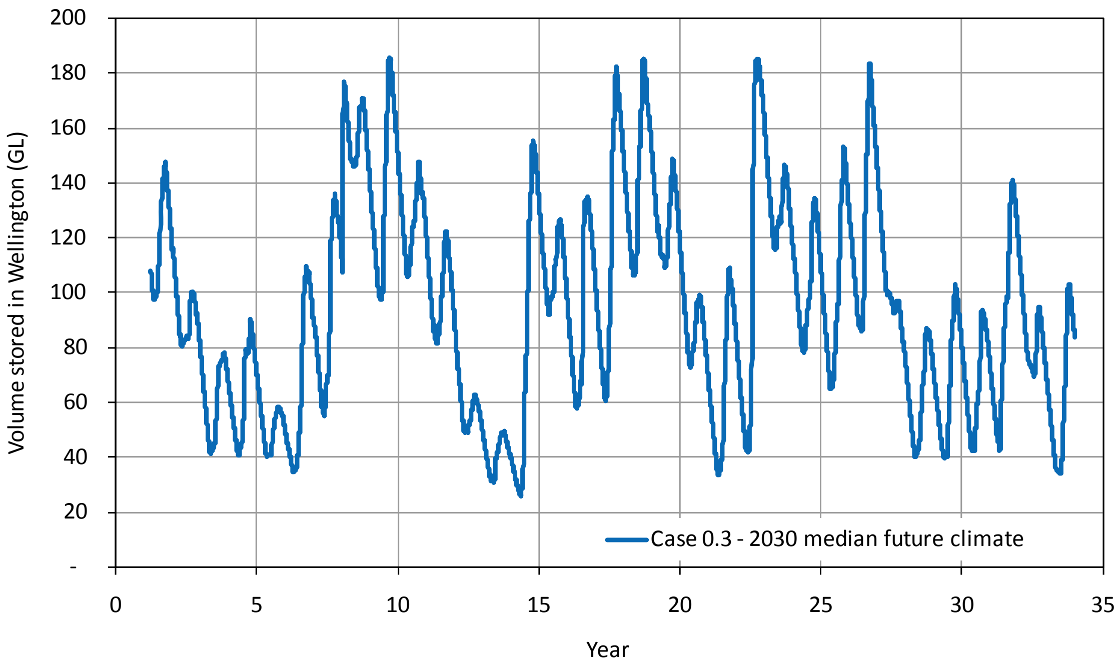

Figure 50 Annual volume stored in Wellington Reservoir for Case 0.3 – 2030 median future climate

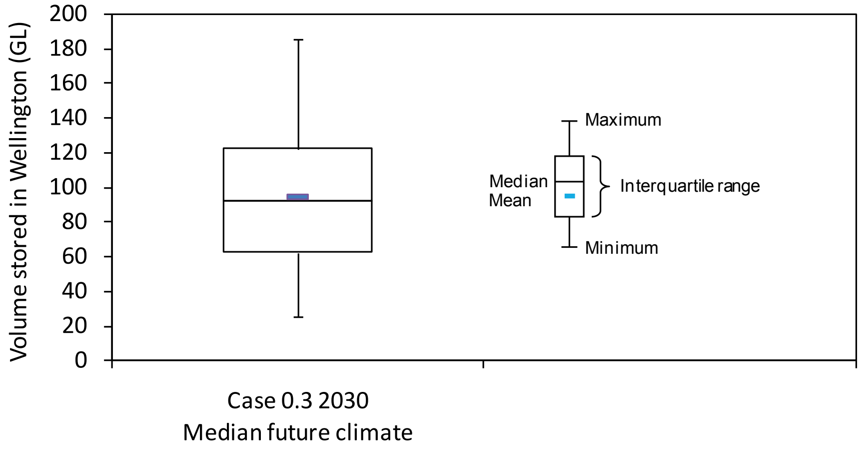

Figure 51 Distribution of annual volume stored in Wellington Reservoir for Case 0.3 – 2030 median future climate

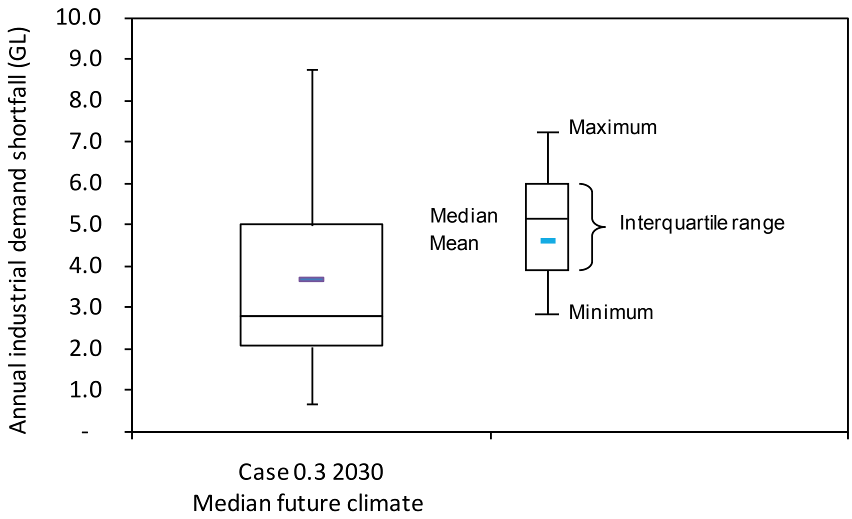

Figure 52 Range of industrial demand shortfalls for Case 0.3 – 2030 median future climate

Table 25 Annual industrial supply shortfalls for Case 0.3 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	44%
Maximum annual shortfall (GL)	8.75
Median of the annual shortfalls (GL)	2.81
Mean of the annual shortfalls (GL)	3.69

Case 1.1 – historical climate

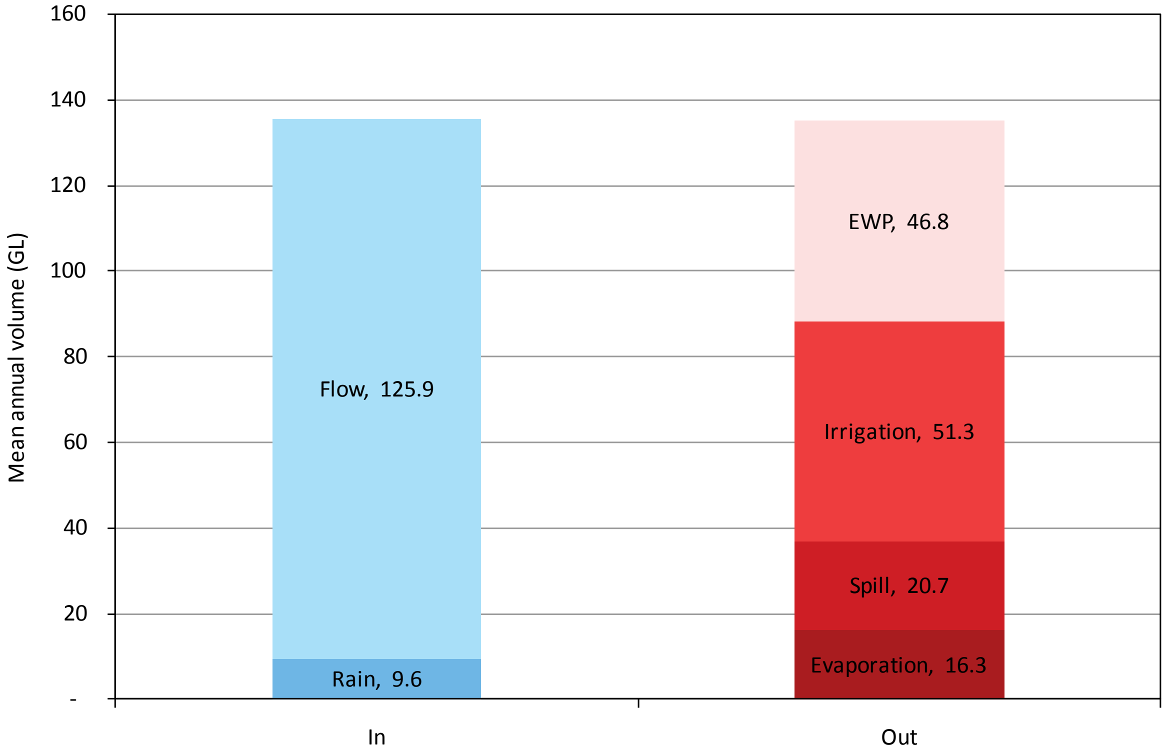

Figure 53 Mean annual water balance for Case 1.1 - historical climate

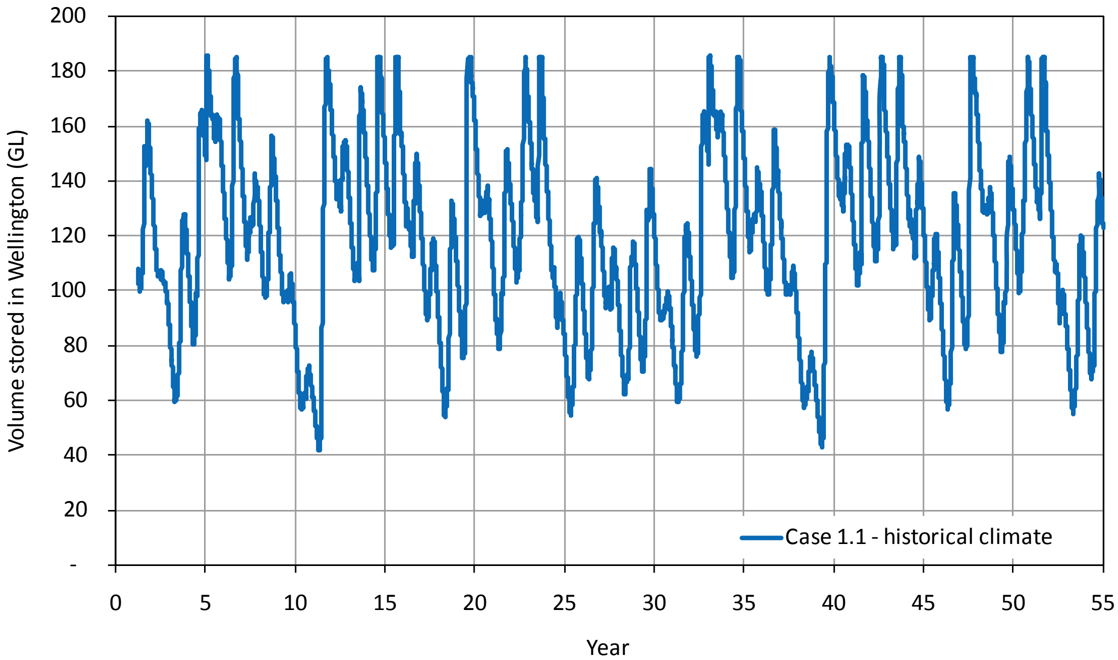

Figure 54 Annual volume stored in Wellington Reservoir for Case 1.1 – historical climate

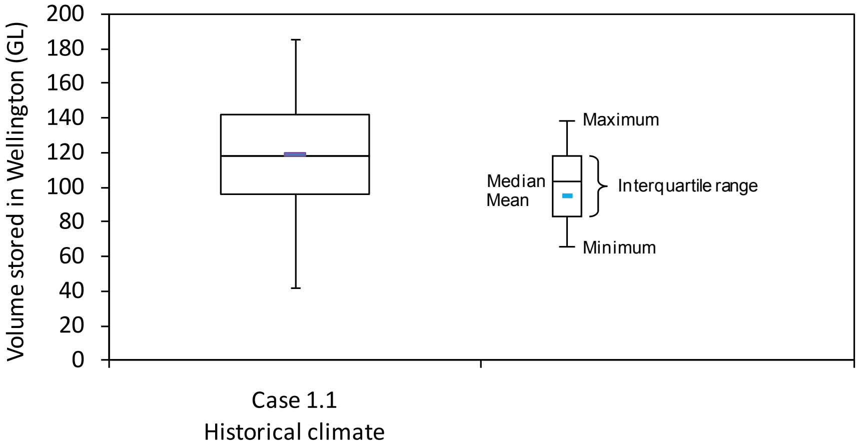

Figure 55 Distribution of annual volume stored in Wellington Reservoir for Case 1.1 – historical climate

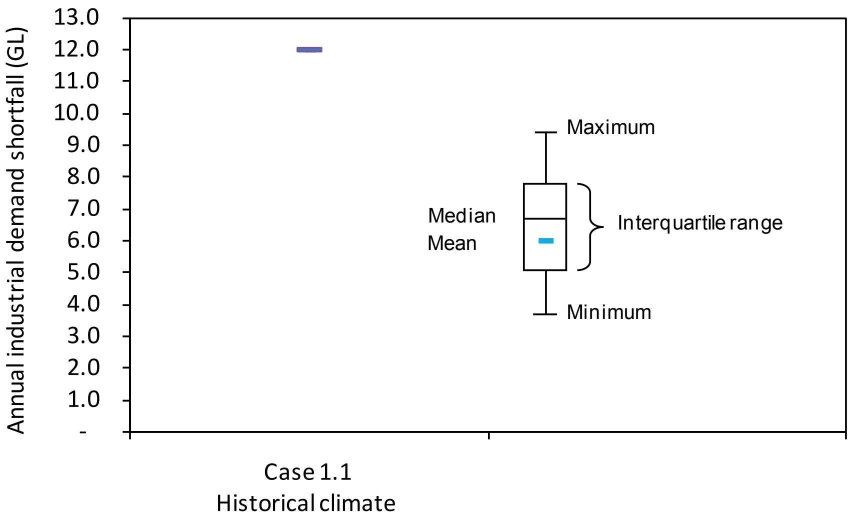

Figure 56 Range of industrial demand shortfalls for Case 1.1 – historical climate

Table 26 Annual industrial supply shortfalls for Case 1.1– historical climate

	Historical climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	12.0
Median of the annual shortfalls (GL)	12.0
Mean of the annual shortfalls (GL)	12.0

Case 1.2 – historical climate

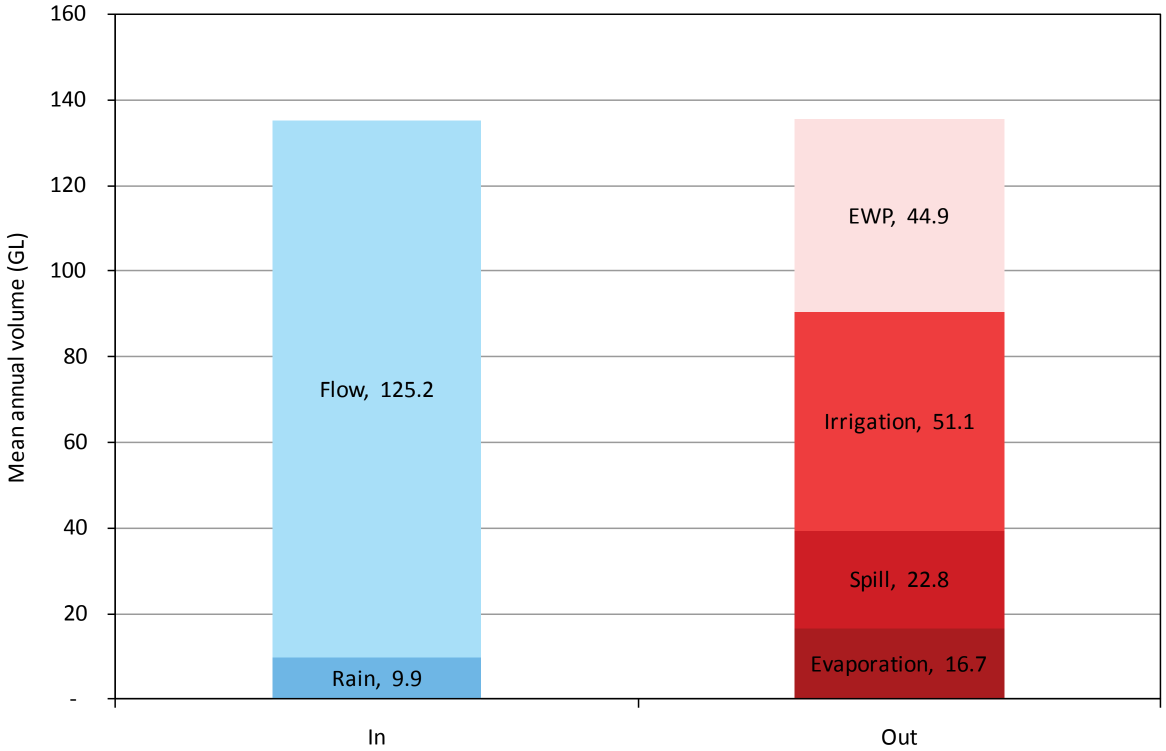

Figure 57 Mean annual water balance for Case 1.2 - historical climate

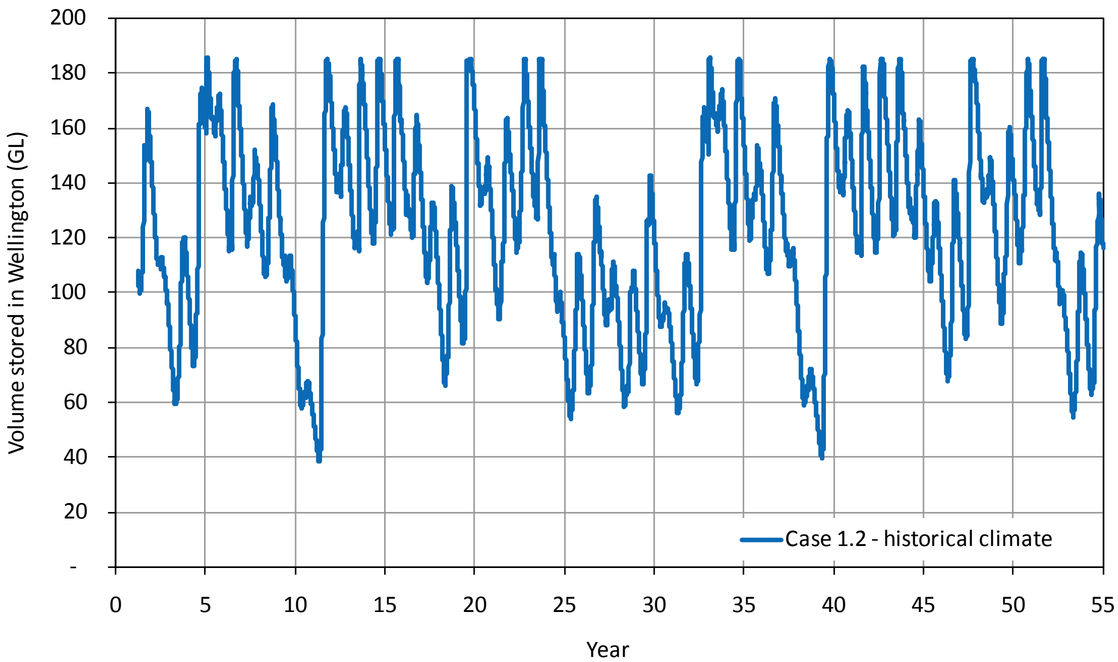

Figure 58 Annual volume stored in Wellington Reservoir for Case 1.2 – historical climate

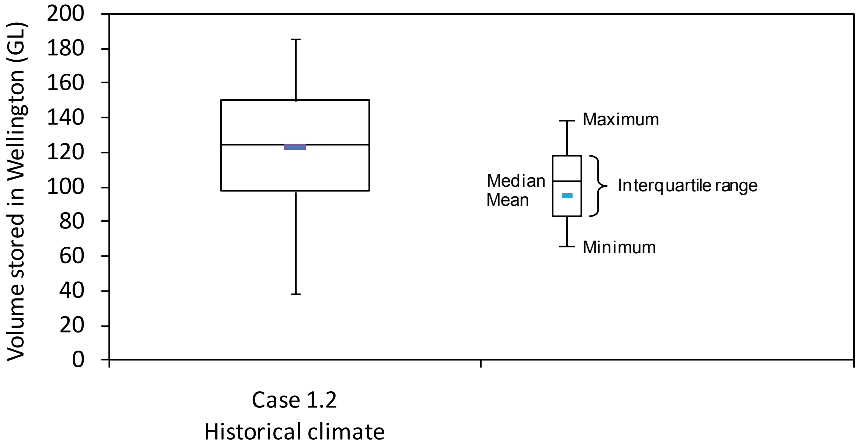

Figure 59 Distribution of annual volume stored in Wellington Reservoir for Case 1.2 – historical climate

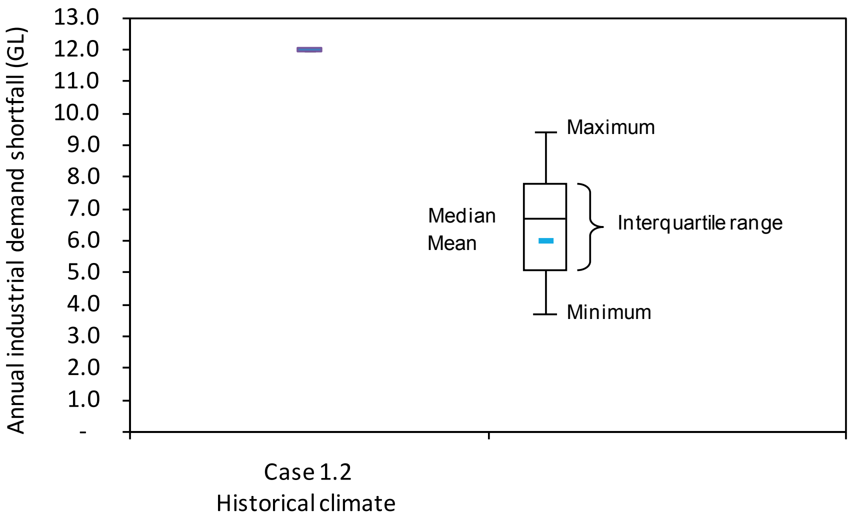

Figure 60 Range of industrial demand shortfalls for Case 1.2 – historical climate

Table 27 Annual industrial supply shortfalls for Case 1.2 – historical climate

	Historical climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	12.0
Median of the annual shortfalls (GL)	12.0
Mean of the annual shortfalls (GL)	12.0

Case 2.1 – historical climate

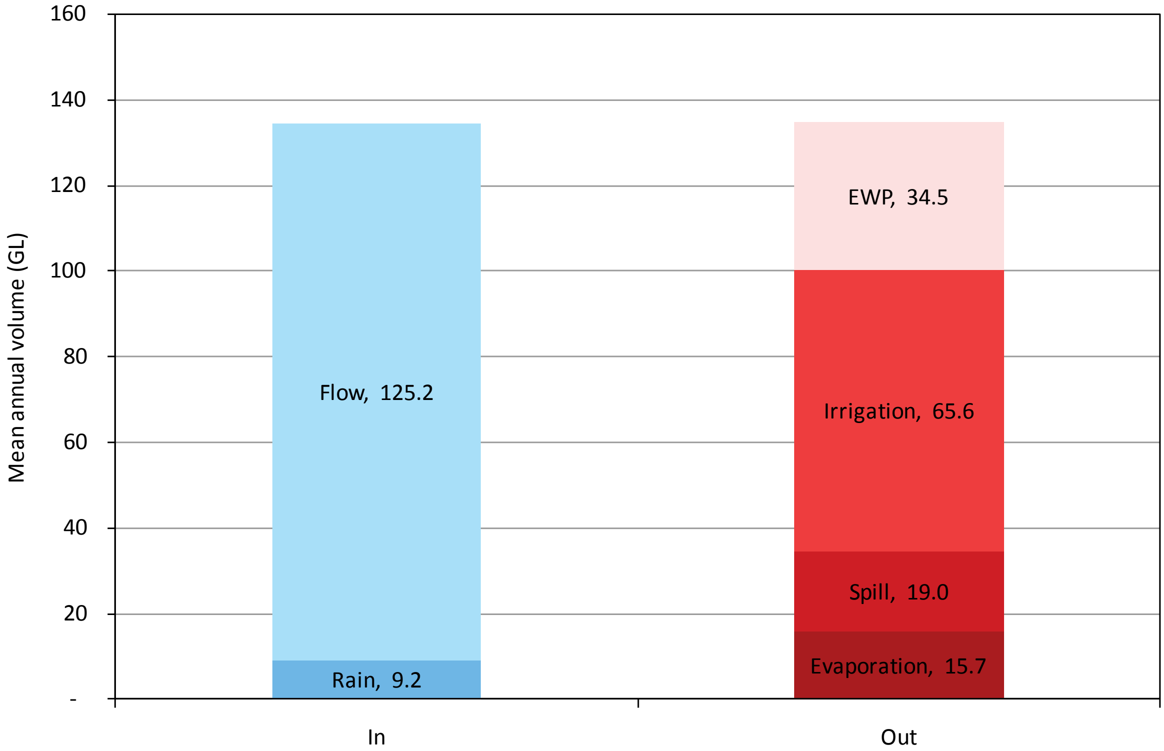

Figure 61 Mean annual water balance for Case 2.1 - historical climate

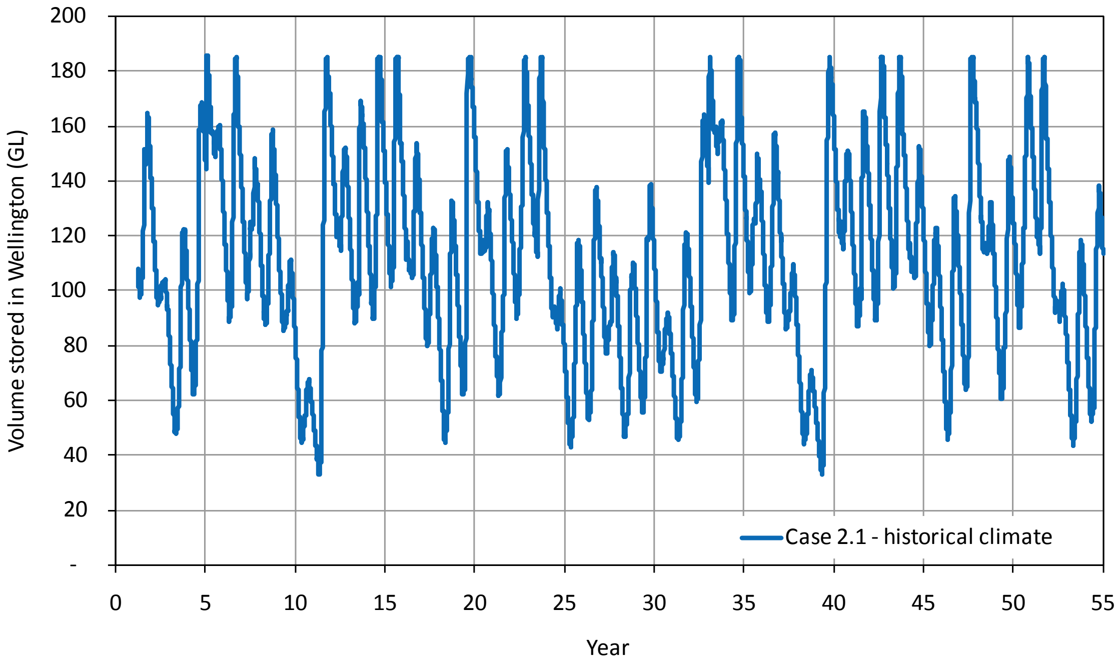

Figure 62 Annual volume stored in Wellington Reservoir for Case 2.1 – historical climate

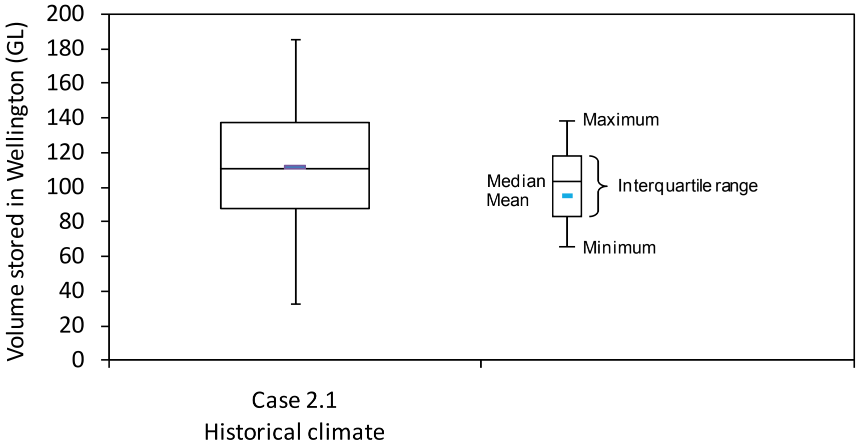

Figure 63 Distribution of annual volume stored in Wellington Reservoir for Case 2.1 – historical climate

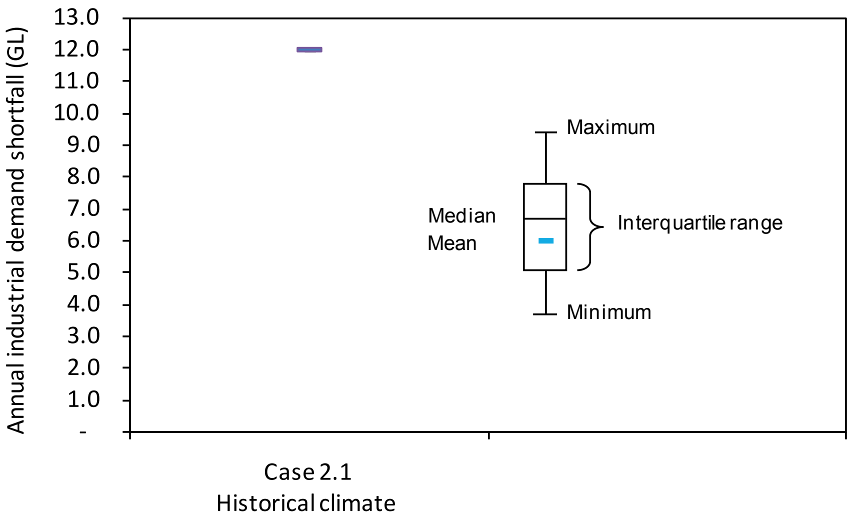

Figure 64 Range of industrial demand shortfalls for Case 2.1 – historical climate

Table 28 Annual industrial supply shortfalls for Case 2.1 – historical climate

	Historical climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	12.0
Median of the annual shortfalls (GL)	12.0
Mean of the annual shortfalls (GL)	12.0

Case 2.2 – historical climate

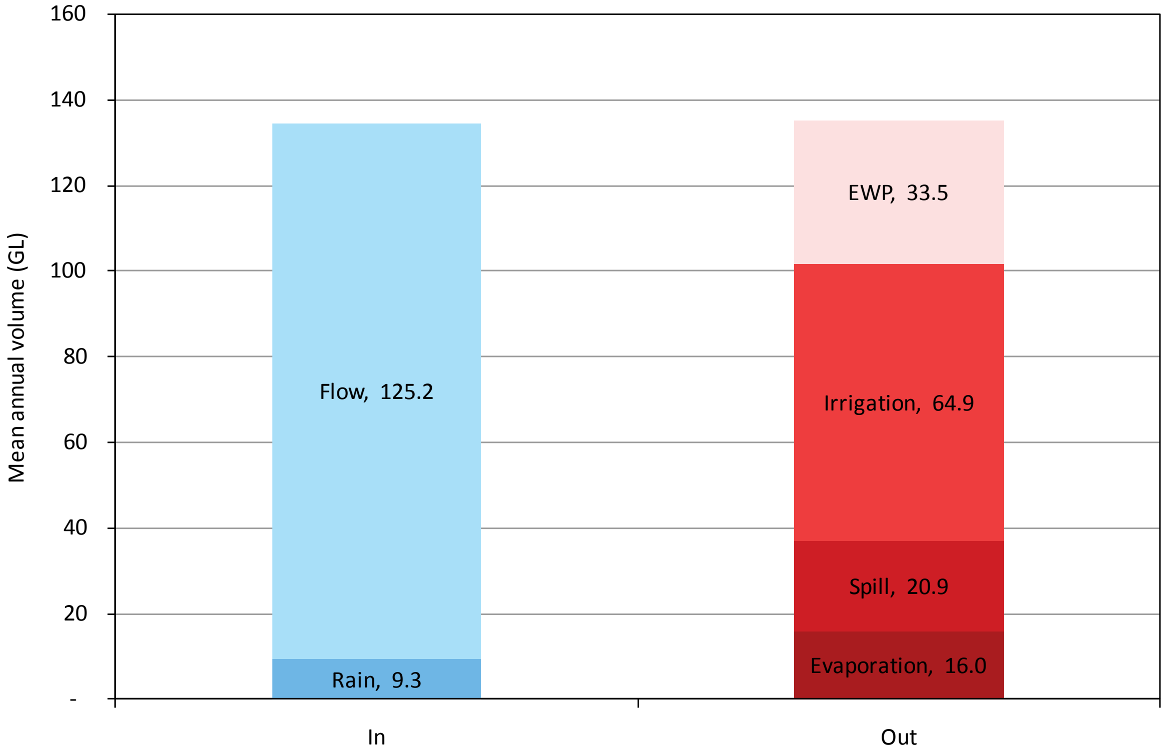

Figure 65 Mean annual water balance for Case 2.2 - historical climate

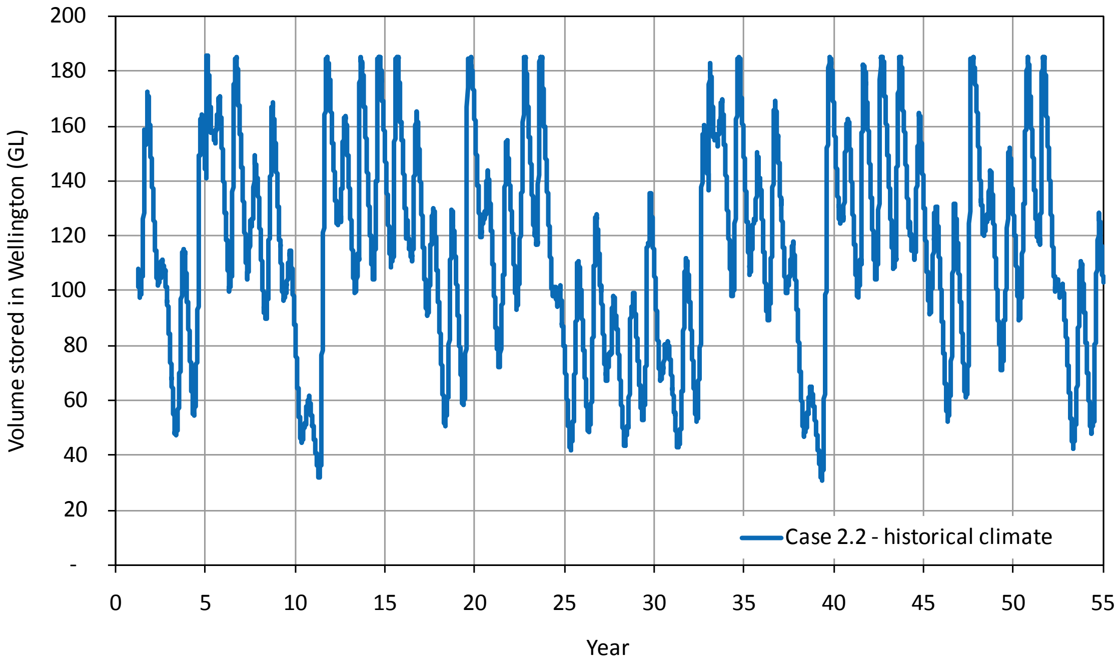

Figure 66 Annual volume stored in Wellington Reservoir for Case 2.2 – historical climate

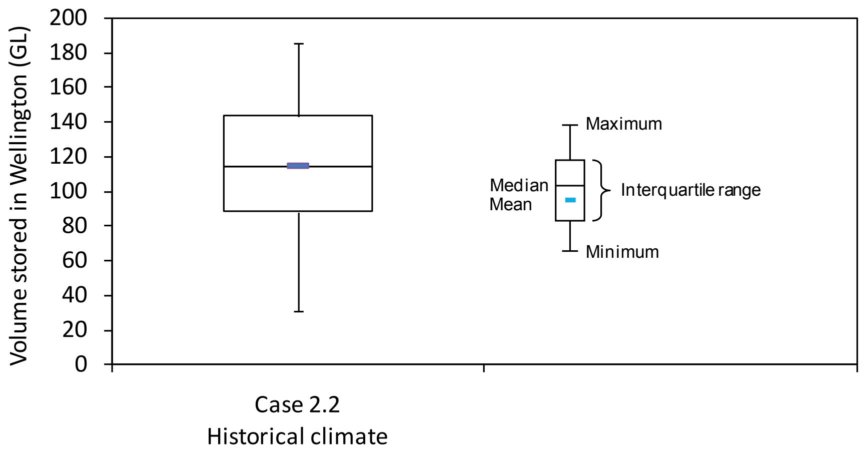

Figure 67 Distribution of annual volume stored in Wellington Reservoir for Case 2.2 – historical climate

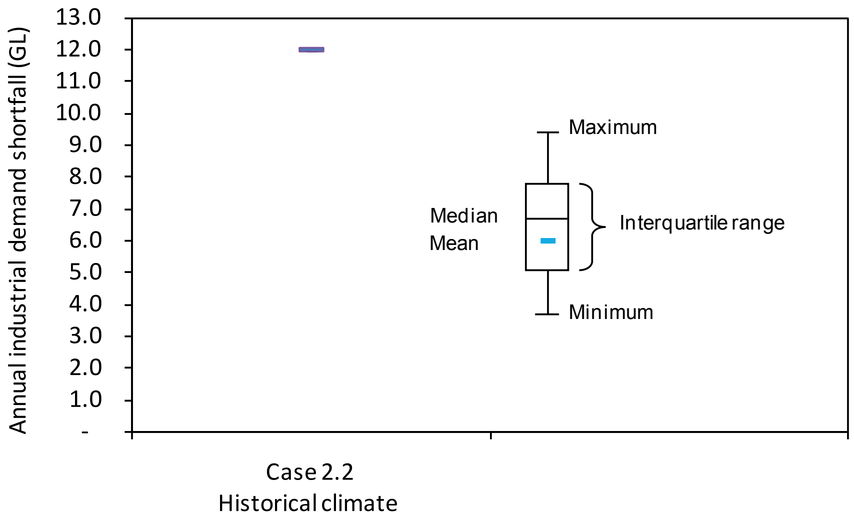

Figure 68 Range of industrial demand shortfalls for Case 2.2 – historical climate

Table 29 Annual industrial supply shortfalls for Case 2.2 – historical climate

	Historical climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	12.0
Median of the annual shortfalls (GL)	12.0
Mean of the annual shortfalls (GL)	12.0

Case 3.1 – historical climate

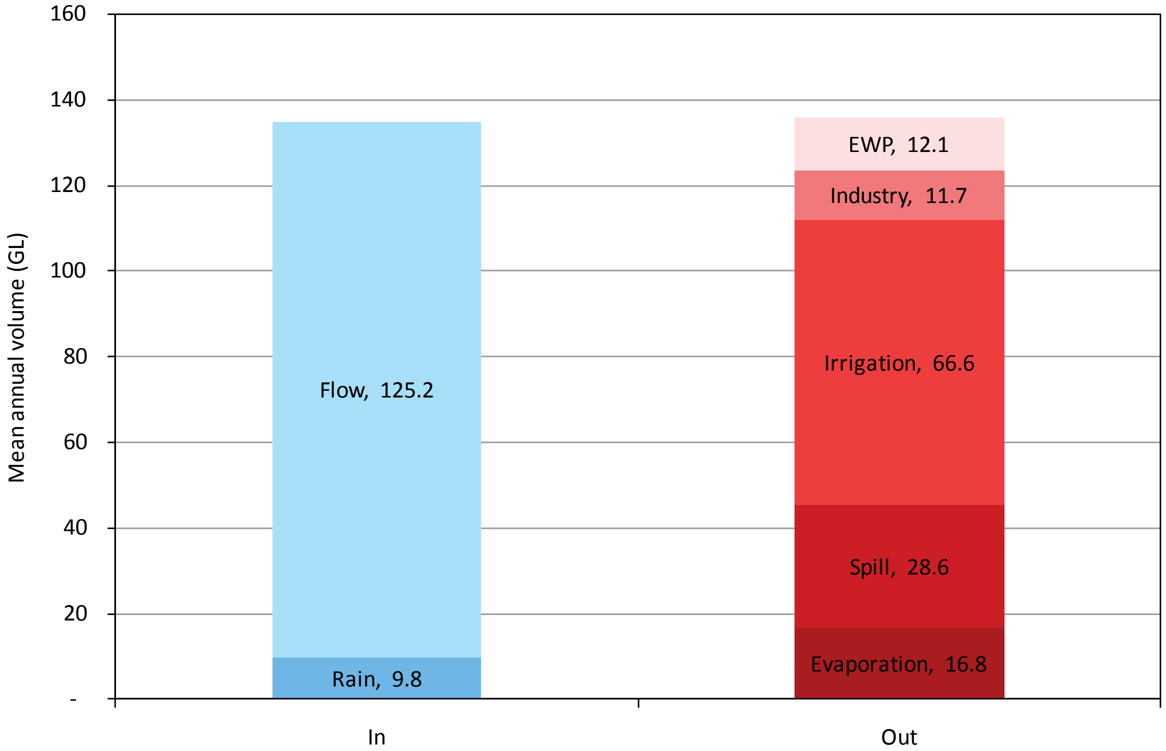

Figure 69 Mean annual water balance for Case 3.1 - historical climate

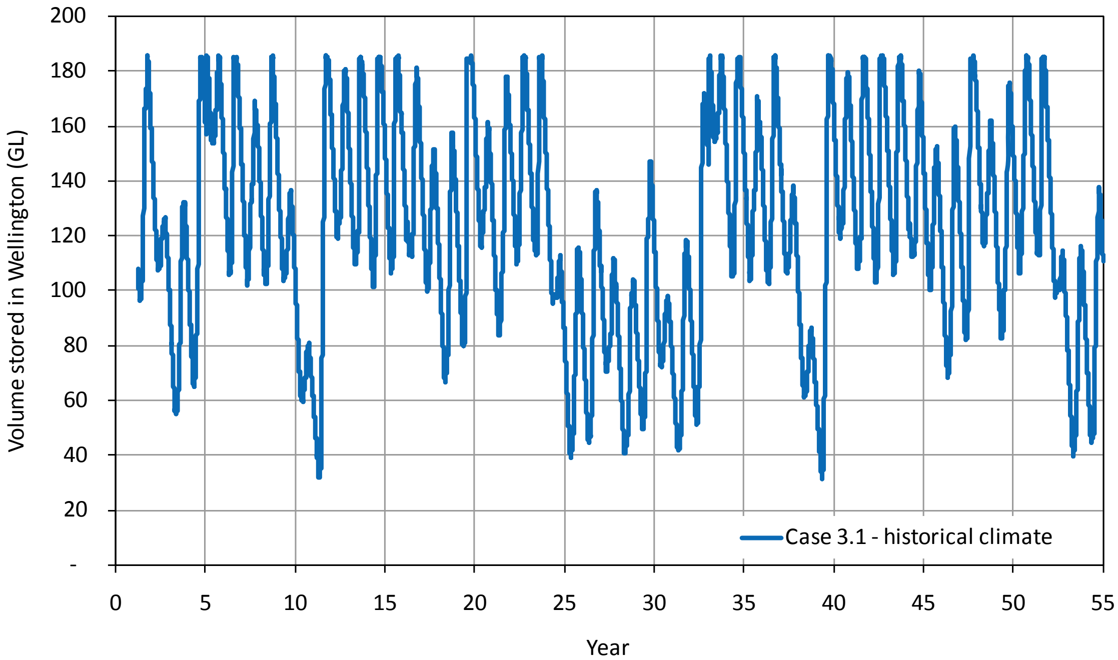

Figure 70 Annual volume stored in Wellington Reservoir for Case 3.1 – historical climate

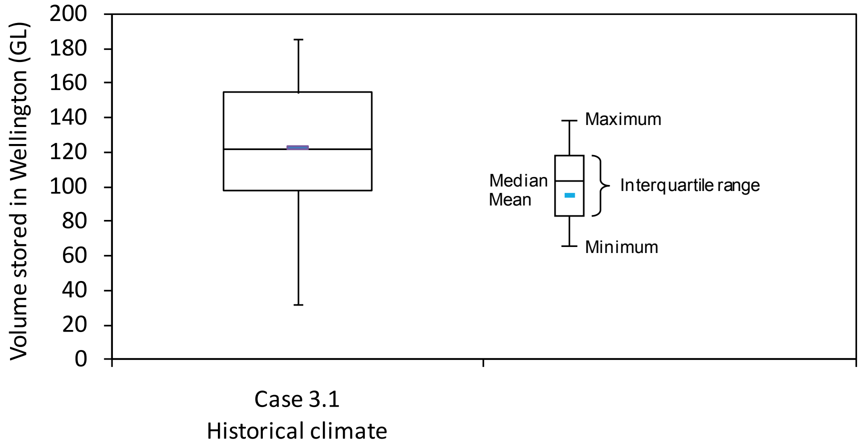

Figure 71 Distribution of annual volume stored in Wellington Reservoir for Case 3.1 – historical climate

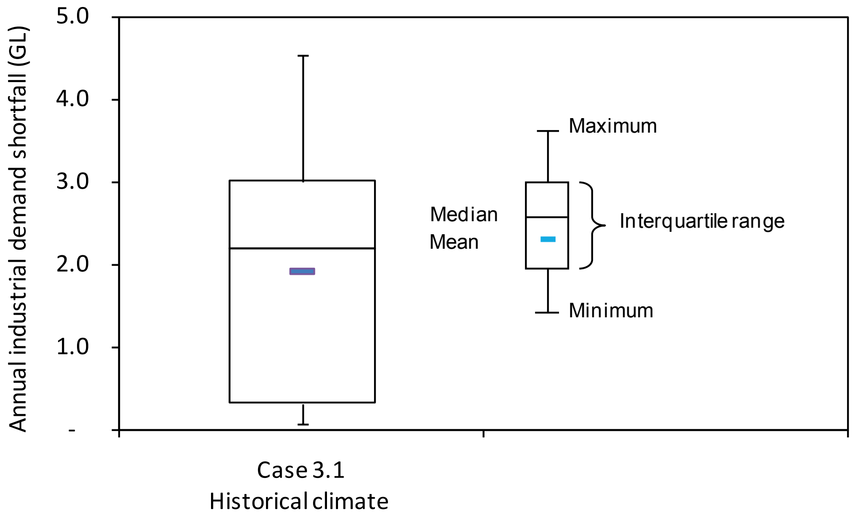

Figure 72 Range of industrial demand shortfalls for Case 3.1 – historical climate

Table 30 Annual industrial supply shortfalls for Case 3.1 – historical climate

	Historical climate
Years with a shortfall in supply	13%
Maximum annual shortfall (GL)	4.54
Median of the annual shortfalls (GL)	2.19
Mean of the annual shortfalls (GL)	1.93

Case 3.1 – 2030 wet future climate

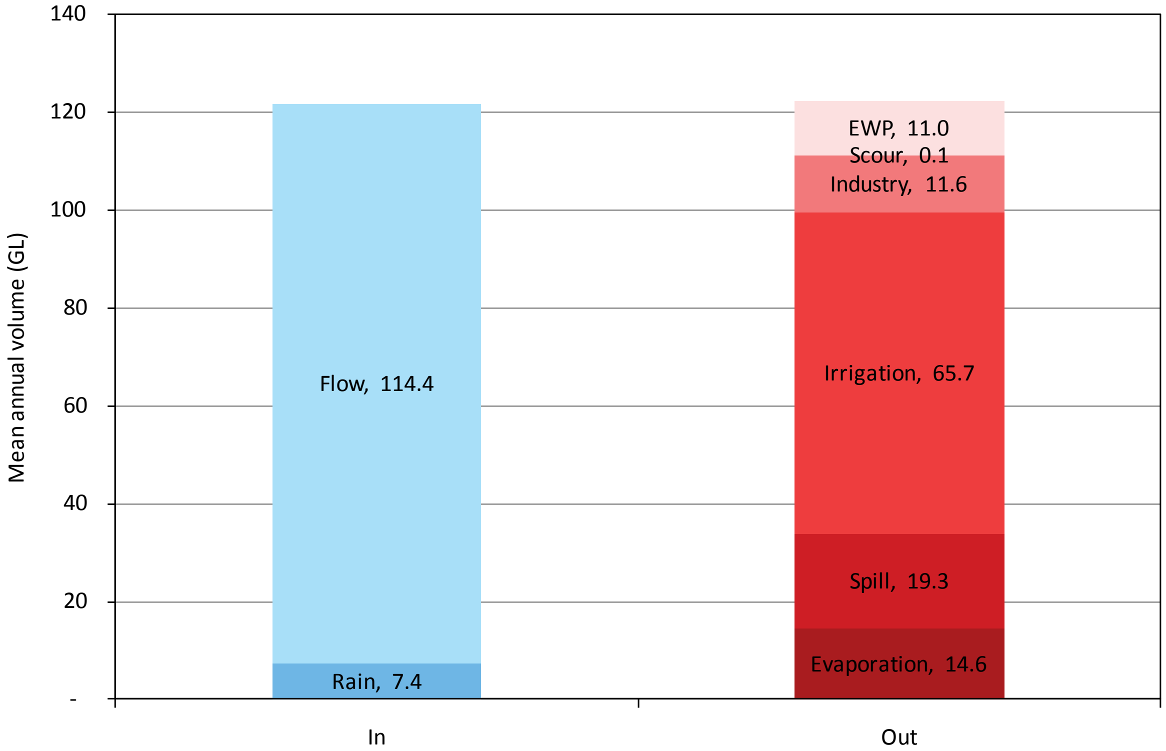

Figure 73 Mean annual water balance for Case 3.1 – 2030 wet future climate

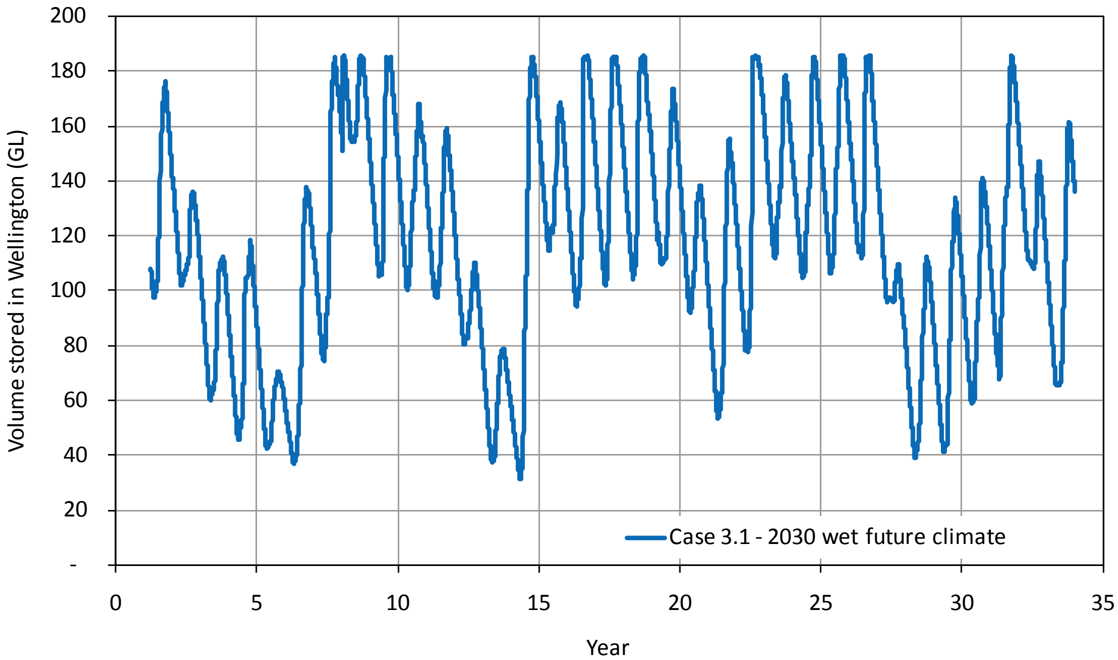

Figure 74 Annual volume stored in Wellington Reservoir for Case 3.1 – 2030 wet future climate

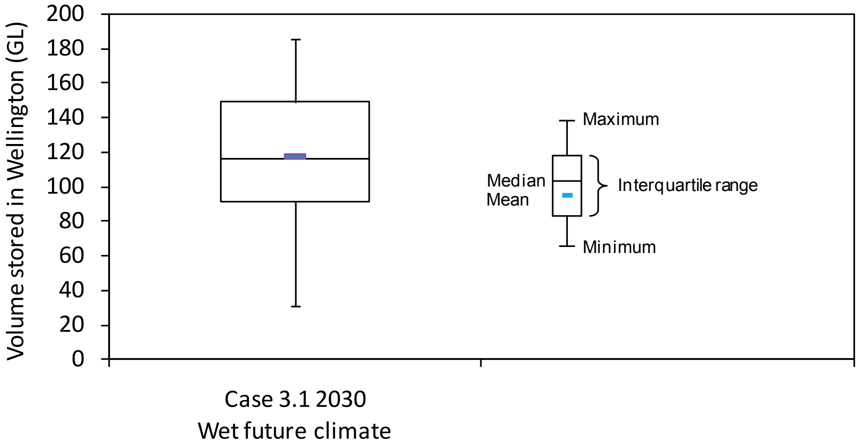

Figure 75 Distribution of annual volume stored in Wellington Reservoir for Case 3.1 – 2030 wet future climate

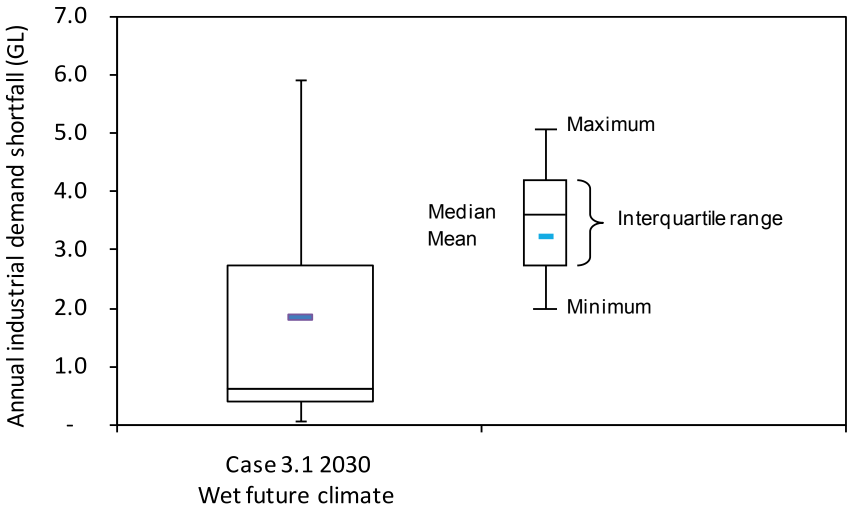

Figure 76 Range of industrial demand shortfalls for Case 3.1 – 2030 wet future climate

Table 31 Annual industrial supply shortfalls for Case 3.1 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	5.91
Median of the annual shortfalls (GL)	0.63
Mean of the annual shortfalls (GL)	1.85

Case 3.1 – 2030 median future climate

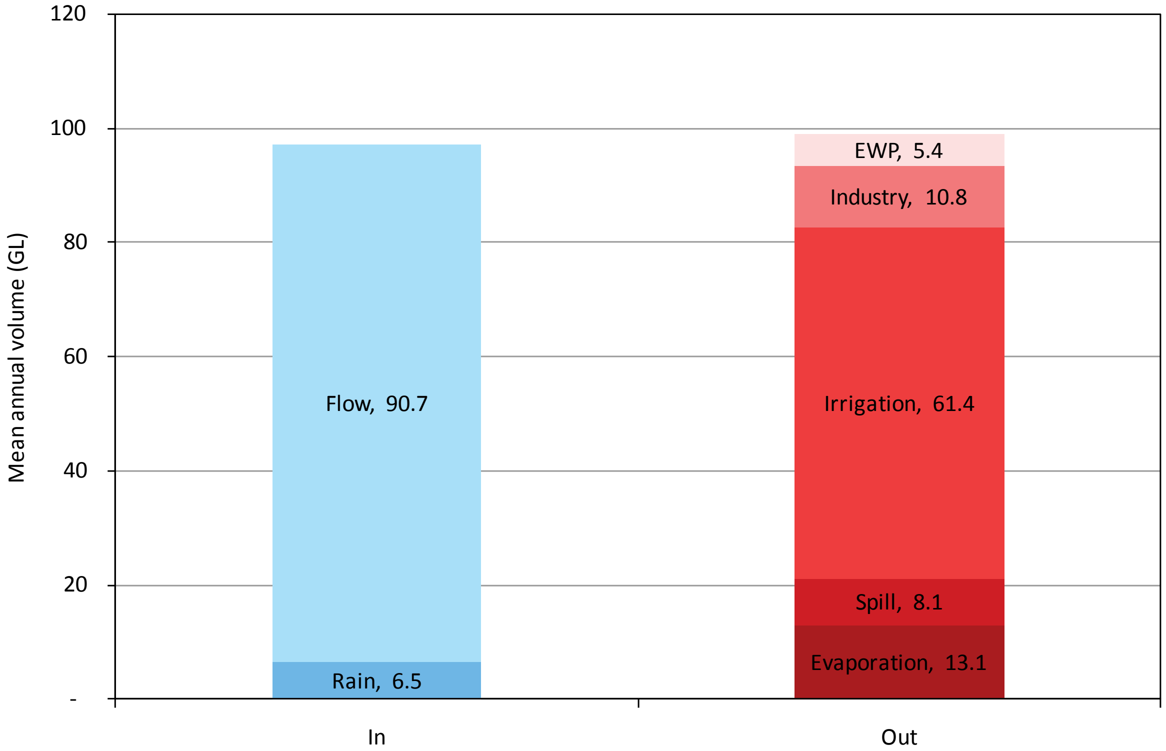

Figure 77 Mean annual water balance for Case 3.1 – 2030 median future climate

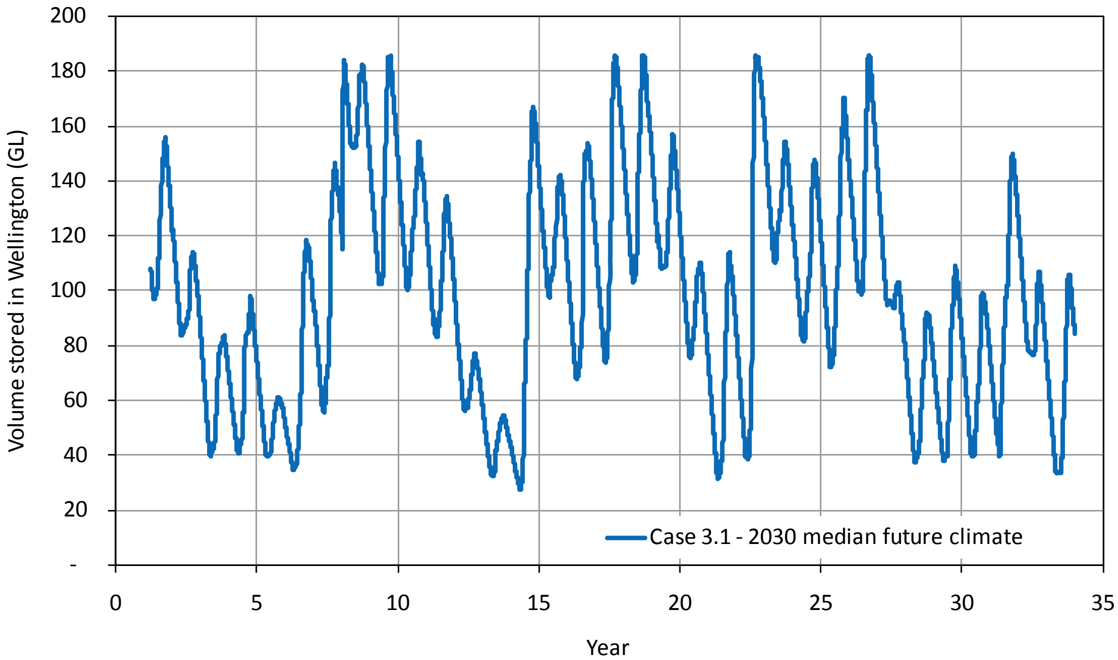

Figure 78 Annual volume stored in Wellington Reservoir for Case 3.1 – 2030 median future climate

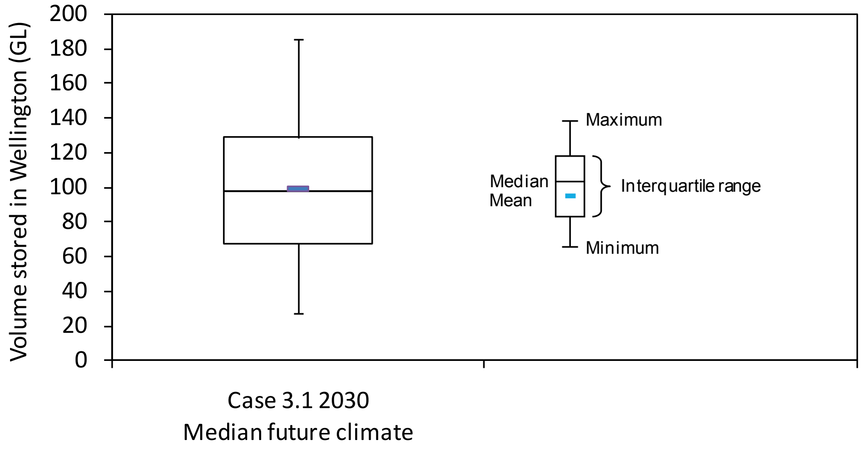

Figure 79 Distribution of annual volume stored in Wellington Reservoir for Case 3.1 – 2030 median future climate

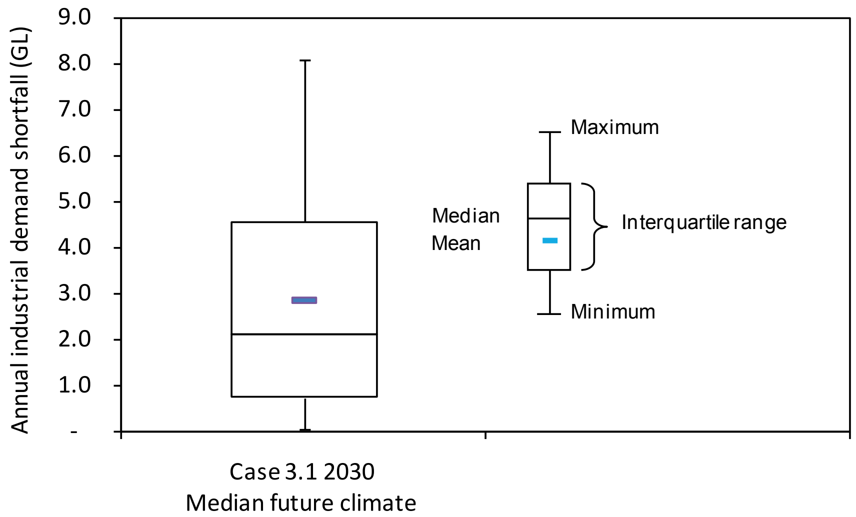

Figure 80 Range of industrial demand shortfalls for Case 3.1 – 2030 median future climate

Table 32 Annual industrial supply shortfalls for Case 3.1 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	41%
Maximum annual shortfall (GL)	8.08
Median of the annual shortfalls (GL)	2.10
Mean of the annual shortfalls (GL)	2.85

Case 3.1 – 2030 dry future climate

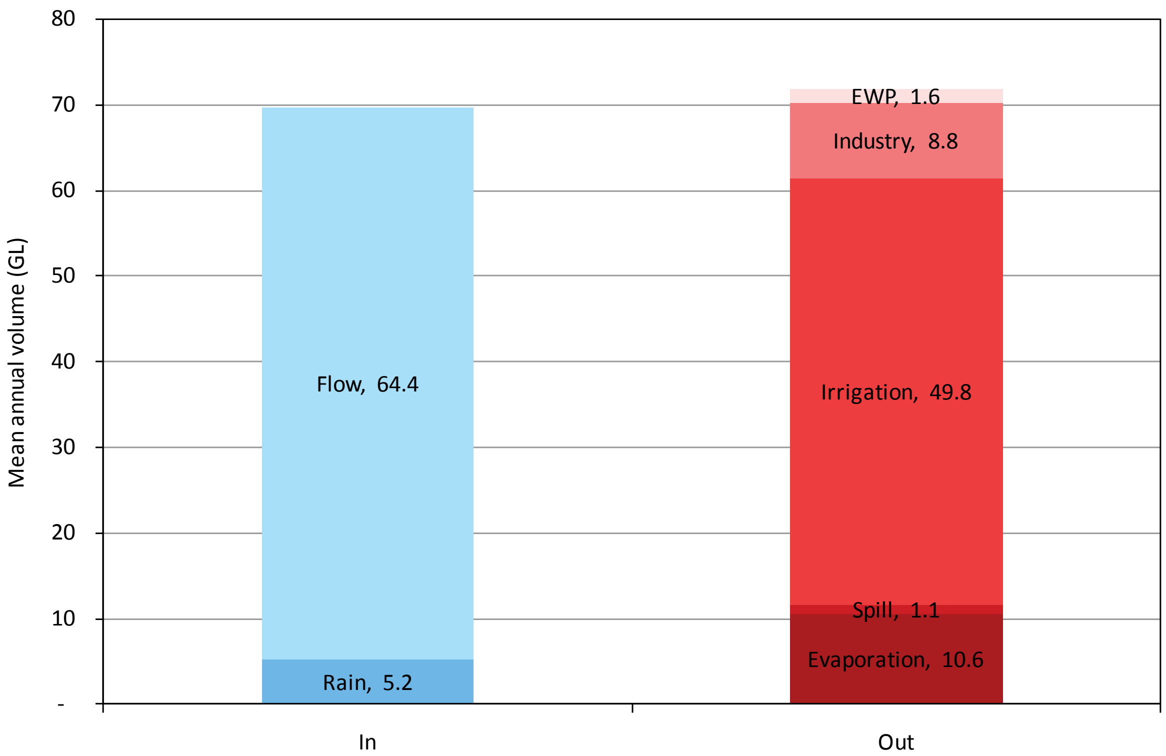

Figure 81 Mean annual water balance for Case 3.1 – 2030 dry future climate

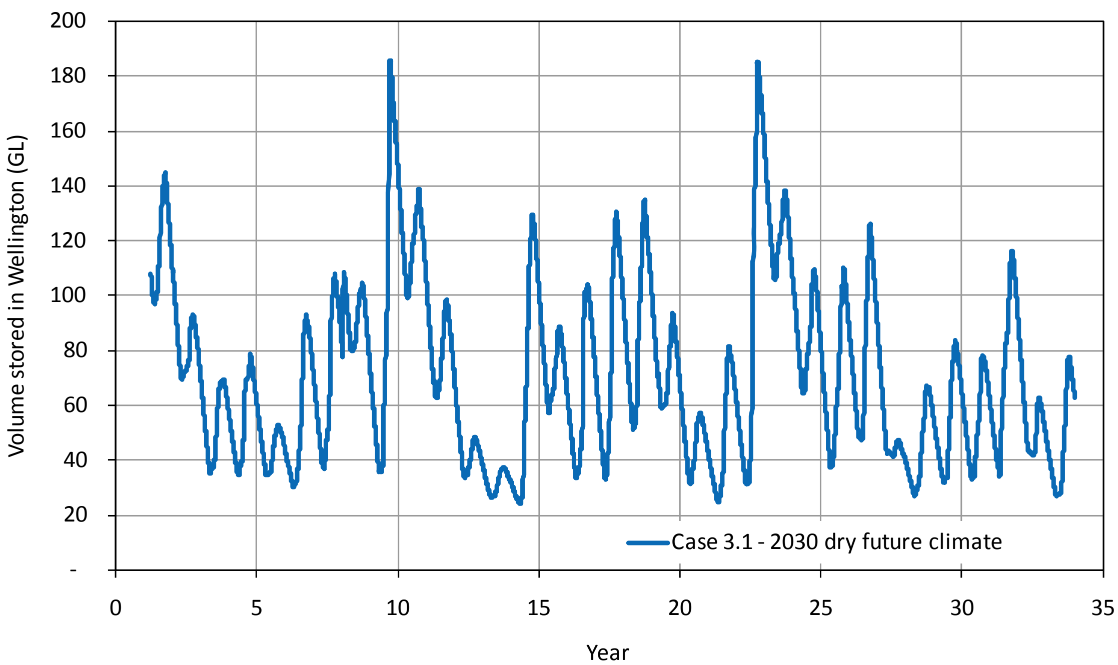

Figure 82 Annual volume stored in Wellington Reservoir for Case 3.1 – 2030 dry future climate

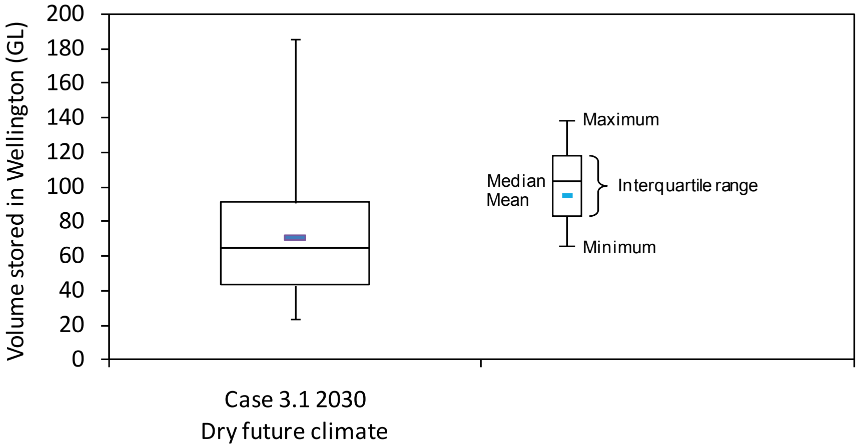

Figure 83 Distribution of annual volume stored in Wellington Reservoir for Case 3.1 – 2030 dry future climate

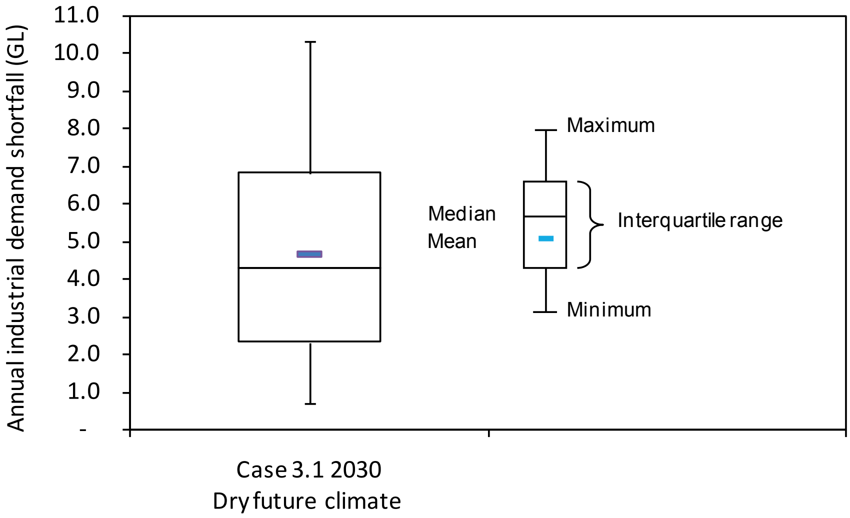

Figure 84 Range of industrial demand shortfalls for Case 3.1 – 2030 dry future climate

Table 33 Annual industrial supply shortfalls for Case 3.1 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	69%
Maximum annual shortfall (GL)	10.3
Median of the annual shortfalls (GL)	4.29
Mean of the annual shortfalls (GL)	4.67

Case 3.2 – historical climate

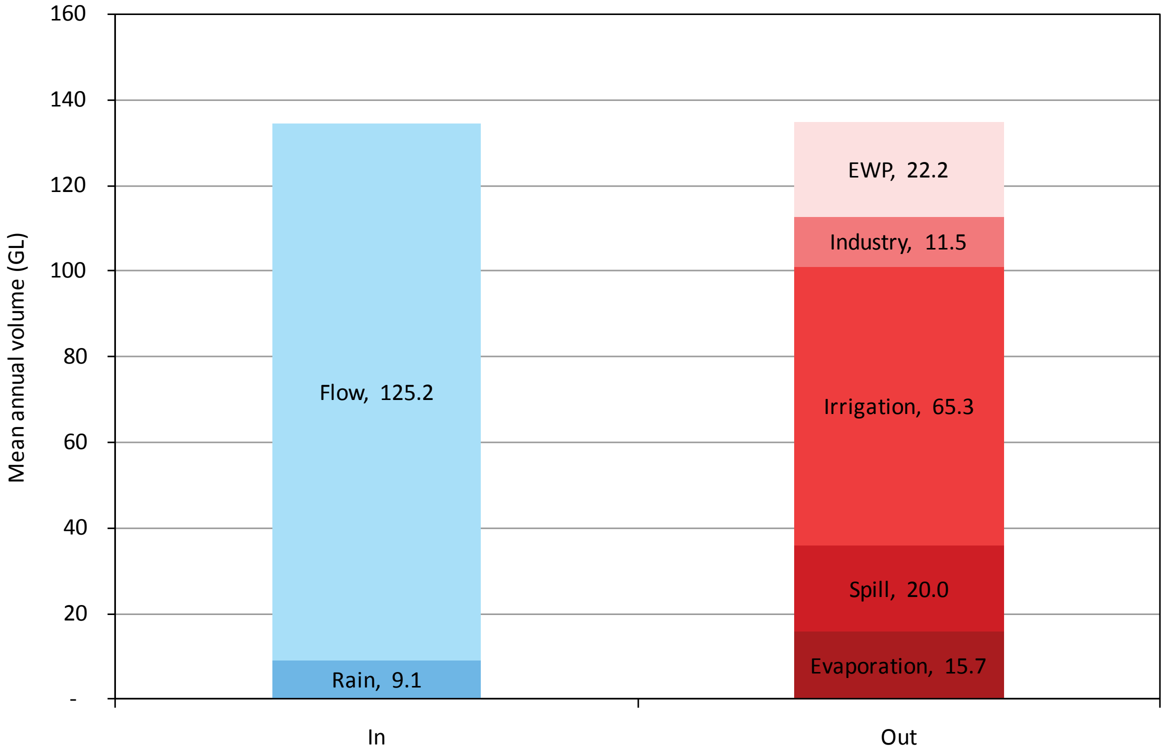

Figure 85 Mean annual water balance for Case 3.2 - historical climate

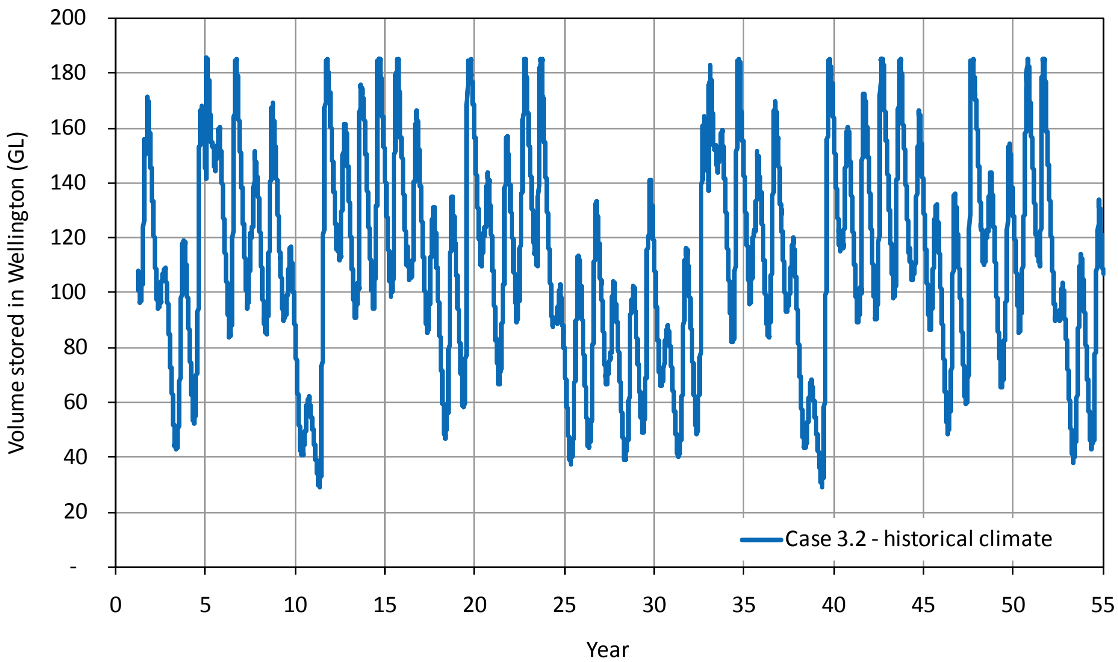

Figure 86 Annual volume stored in Wellington Reservoir for Case 3.2 – historical climate

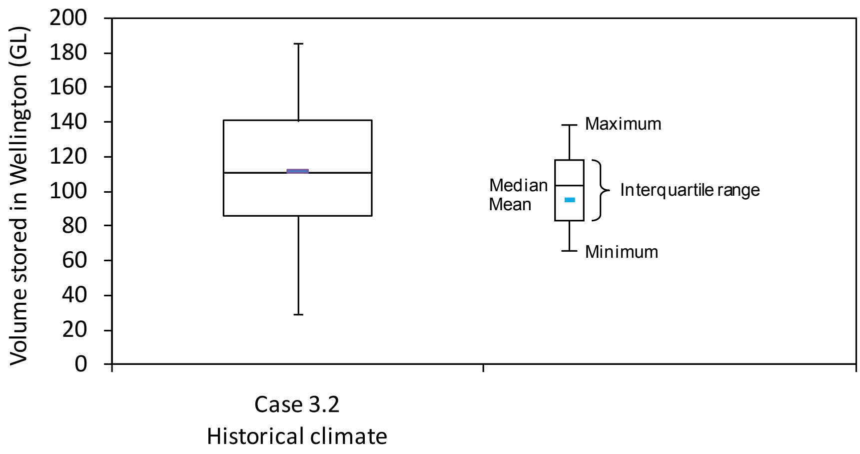

Figure 87 Distribution of annual volume stored in Wellington Reservoir for Case 3.2 – historical climate

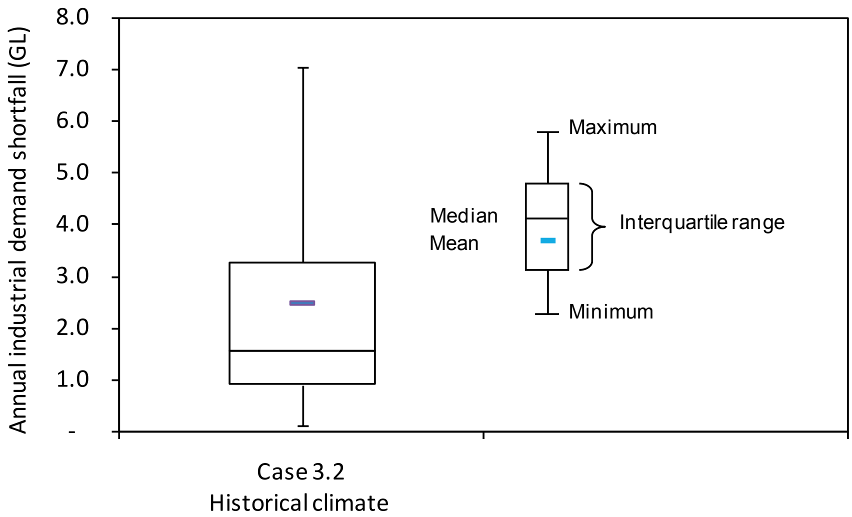

Figure 88 Range of industrial demand shortfalls for Case 3.2 – historical climate

Table 34 Annual industrial supply shortfalls for Case 3.2 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	7.03
Median of the annual shortfalls (GL)	1.56
Mean of the annual shortfalls (GL)	2.48

Case 3.2 – 2030 wet future climate

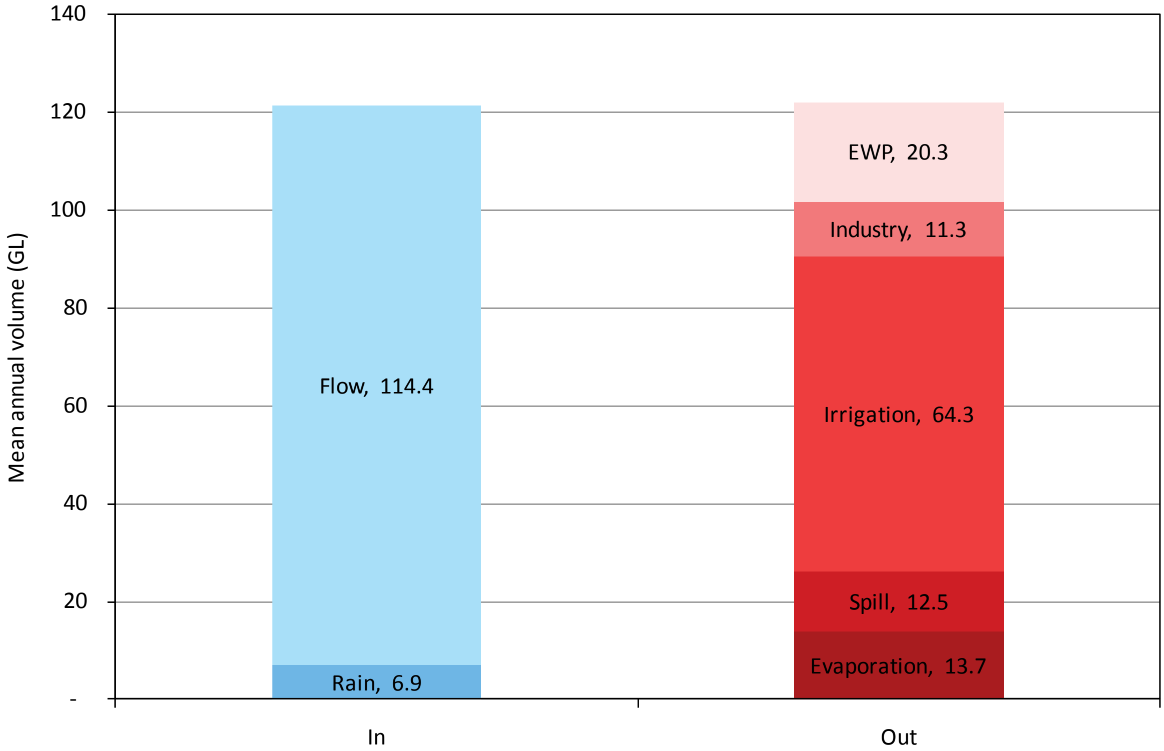

Figure 89 Mean annual water balance for Case 3.2 – 2030 wet future climate

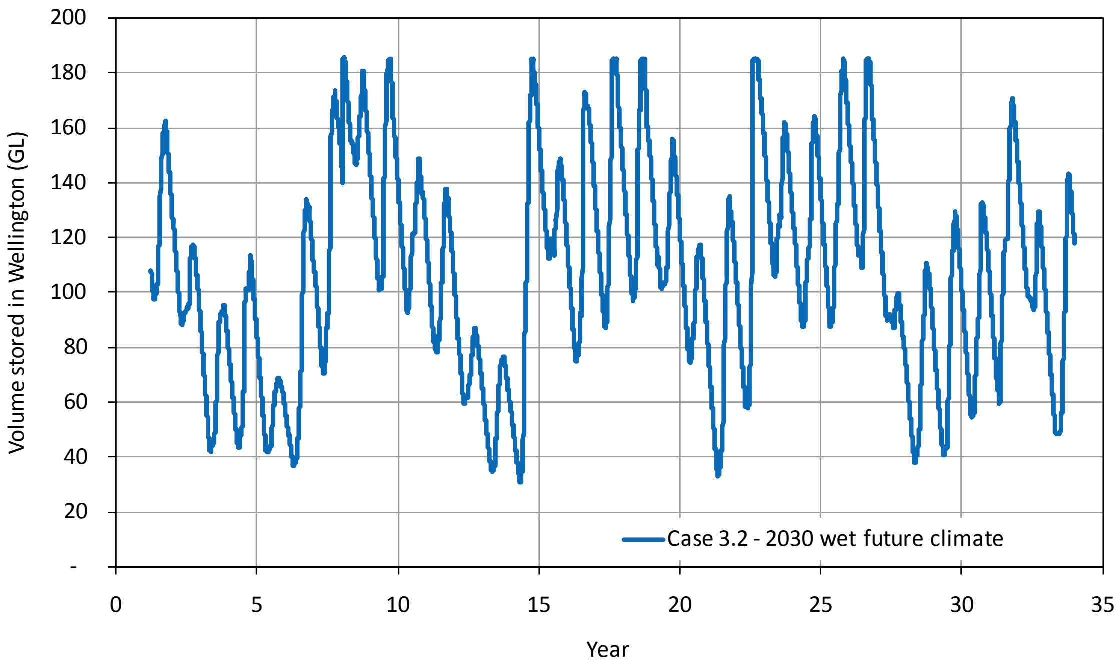

Figure 90 Annual volume stored in Wellington Reservoir for Case 3.2 – 2030 wet future climate

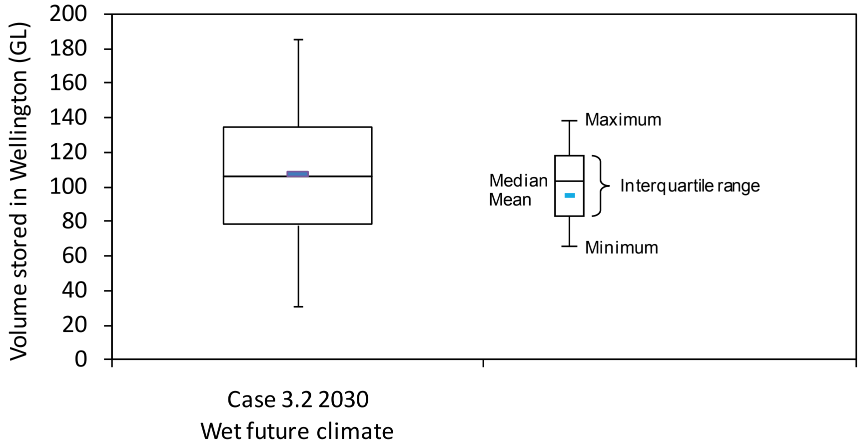

Figure 91 Distribution of annual volume stored in Wellington Reservoir for Case 3.2 – 2030 wet future climate

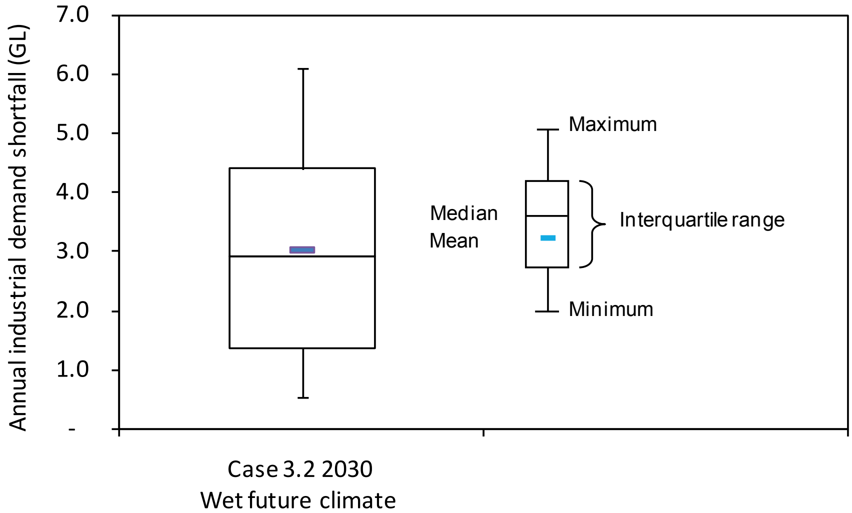

Figure 92 Range of industrial demand shortfalls for Case 3.2 – 2030 wet future climate

Table 35 Annual industrial supply shortfalls for Case 3.2 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.12
Median of the annual shortfalls (GL)	2.91
Mean of the annual shortfalls (GL)	3.02

Case 3.2 – 2030 median future climate

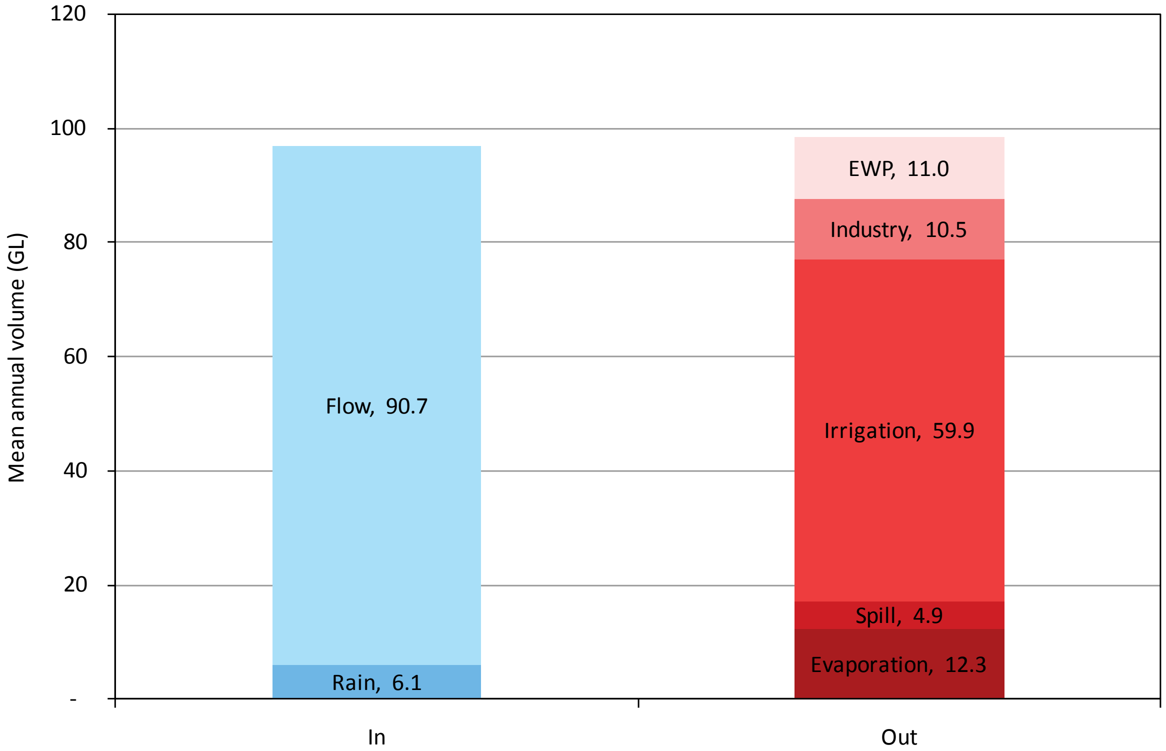

Figure 93 Mean annual water balance for Case 3.2 – 2030 median future climate

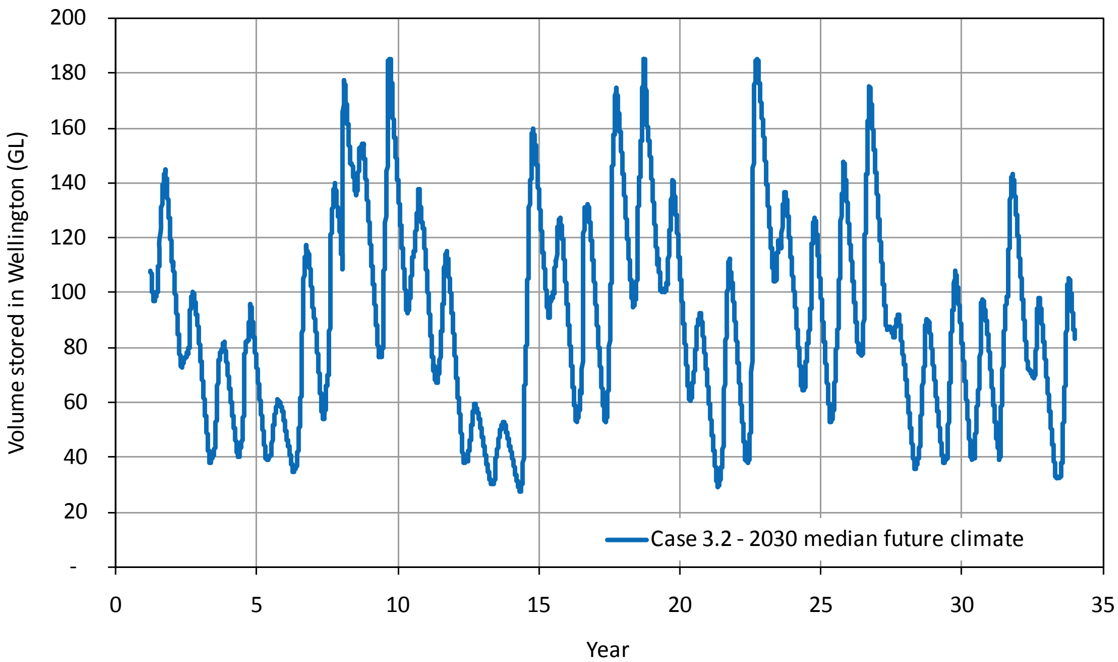

Figure 94 Annual volume stored in Wellington Reservoir for Case 3.2 – 2030 median future climate

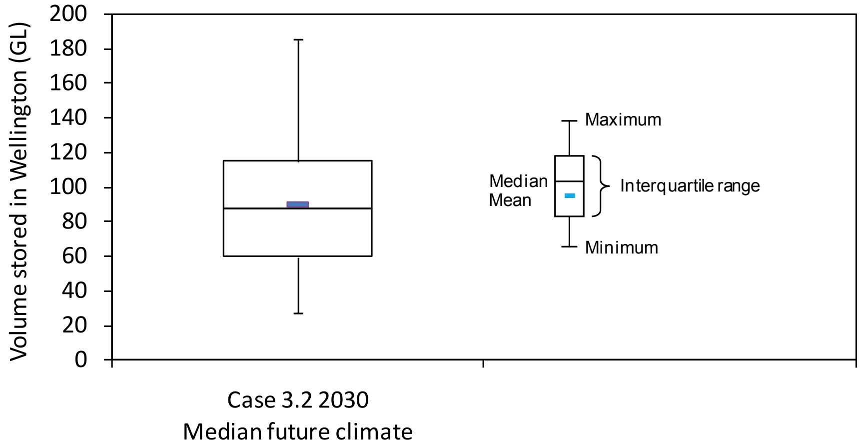

Figure 95 Distribution of annual volume stored in Wellington Reservoir for Case 3.2 – 2030 median future climate

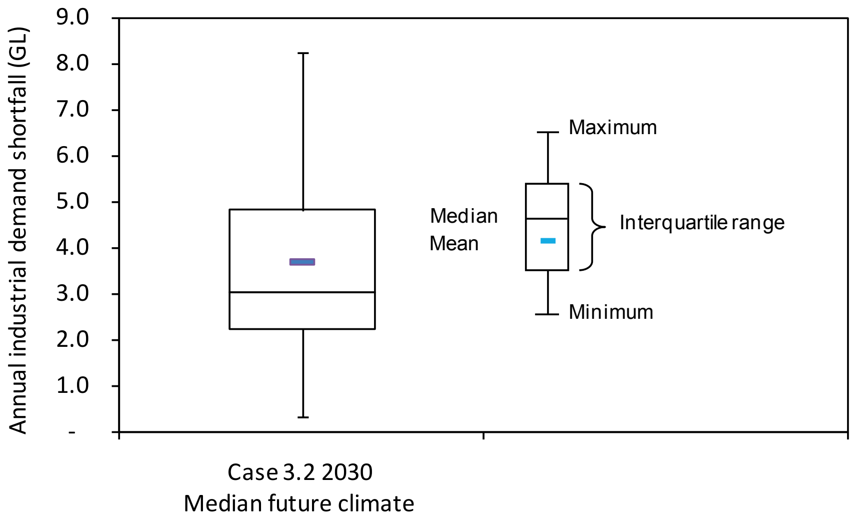

Figure 96 Range of industrial demand shortfalls for Case 3.2 – 2030 median future climate

Table 36 Annual industrial supply shortfalls for Case 3.2 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	41%
Maximum annual shortfall (GL)	8.25
Median of the annual shortfalls (GL)	3.05
Mean of the annual shortfalls (GL)	3.69

Case 3.2 – 2030 dry future climate

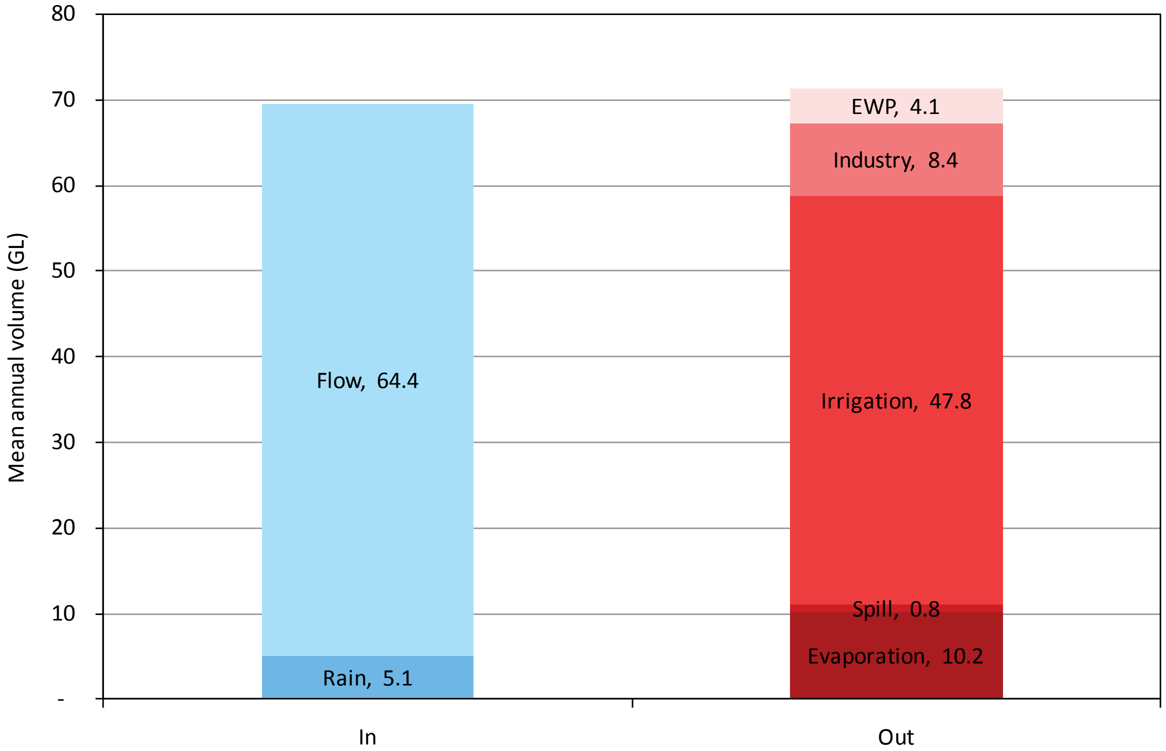

Figure 97 Mean annual water balance for Case 3.2 – 2030 dry future climate

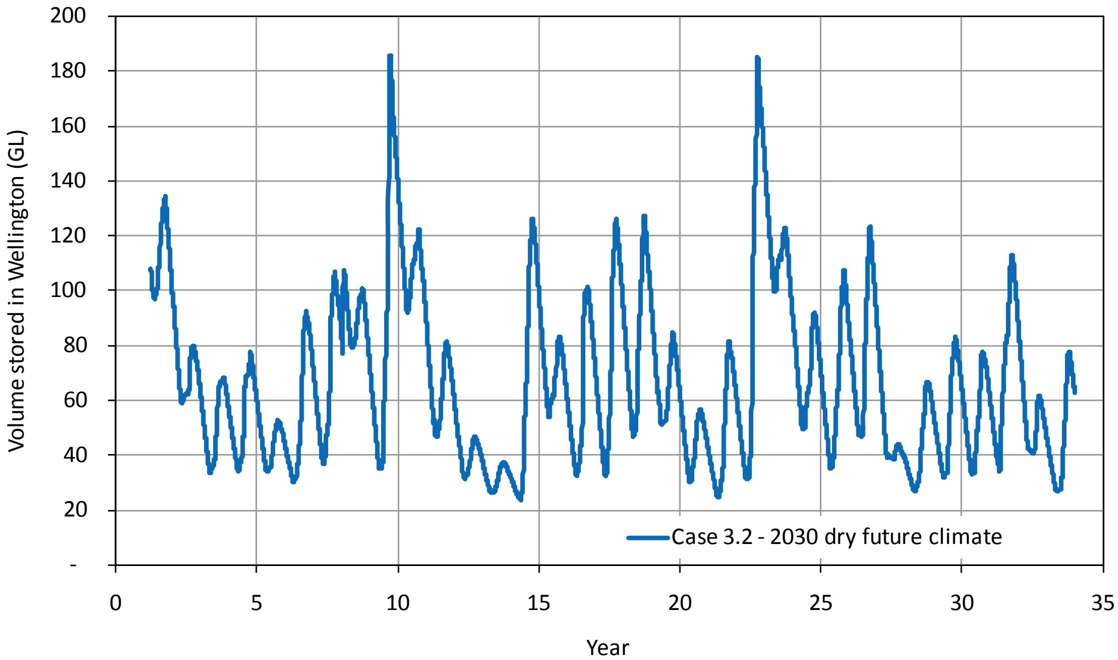

Figure 98 Annual volume stored in Wellington Reservoir for Case 3.2 – 2030 dry future climate

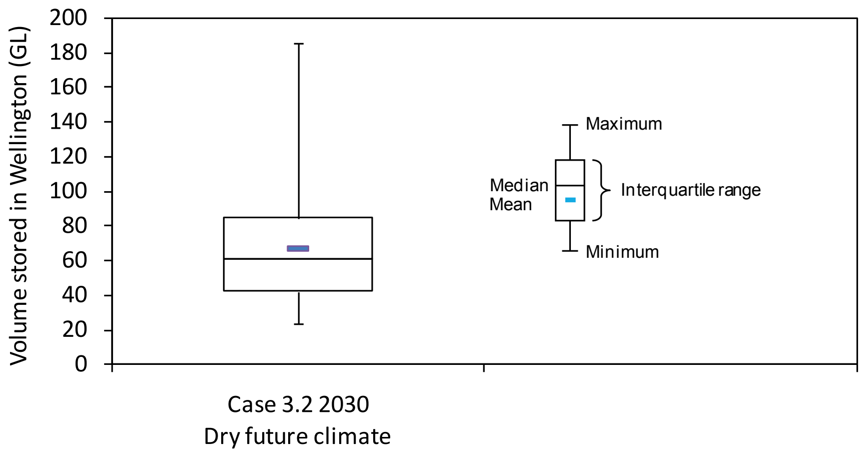

Figure 99 Distribution of annual volume stored in Wellington Reservoir for Case 3.2 – 2030 dry future climate

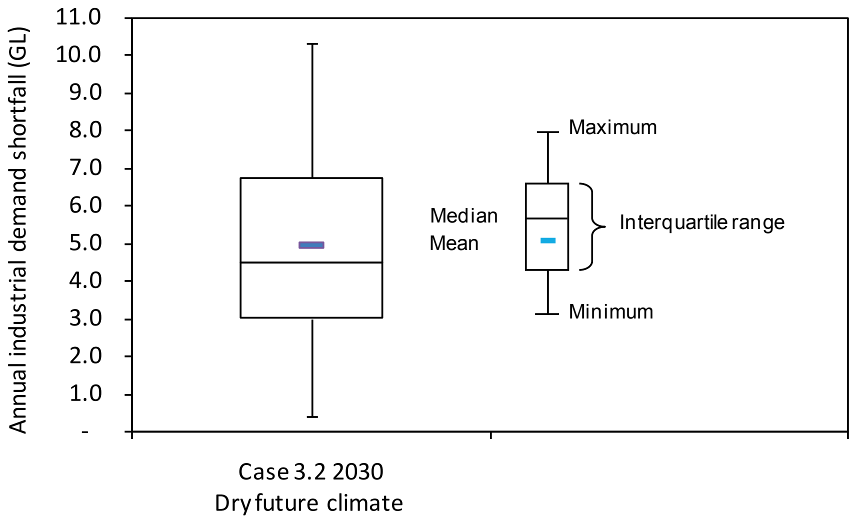

Figure 100 Range of industrial demand shortfalls for Case 3.2 – 2030 dry future climate

Table 37 Annual industrial supply shortfalls for Case 3.2 2030 – dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	10.3
Median of the annual shortfalls (GL)	4.49
Mean of the annual shortfalls (GL)	4.96

Case 3.3 – historical climate

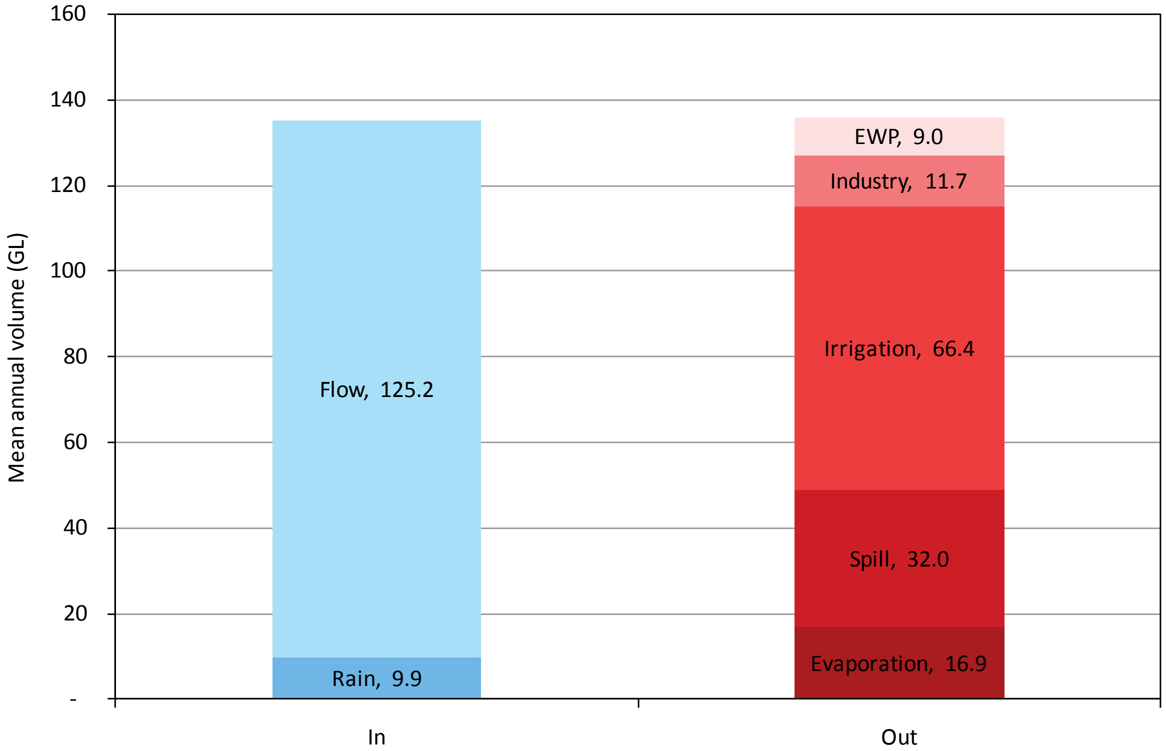

Figure 101 Mean annual water balance for Case 3.3 - historical climate

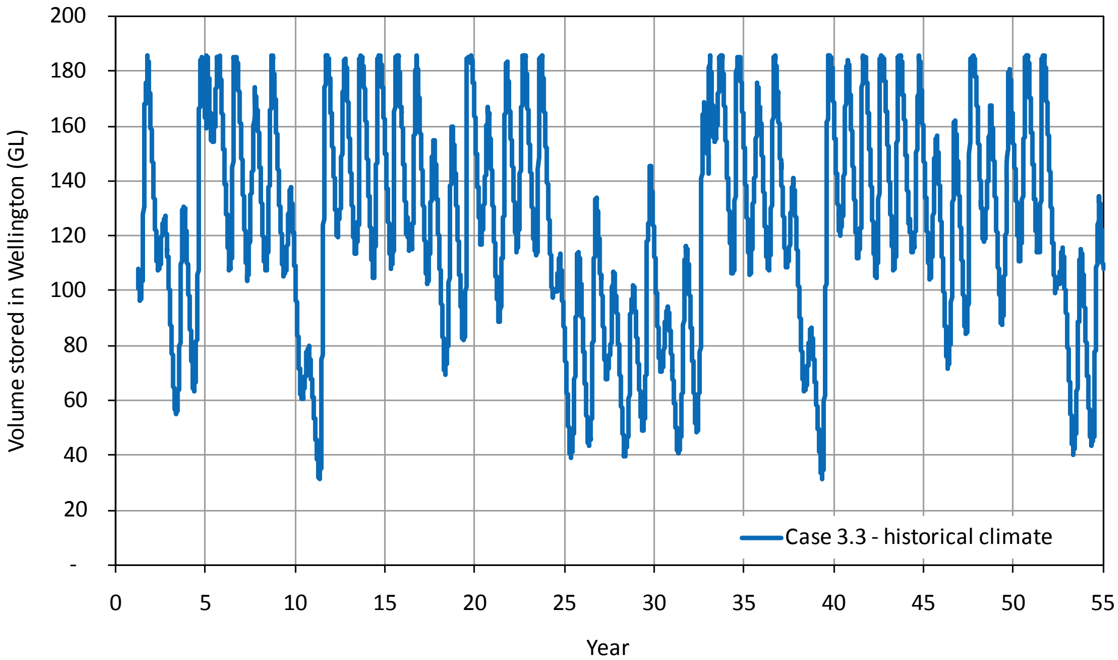

Figure 102 Annual volume stored in Wellington Reservoir for Case 3.3 – historical climate

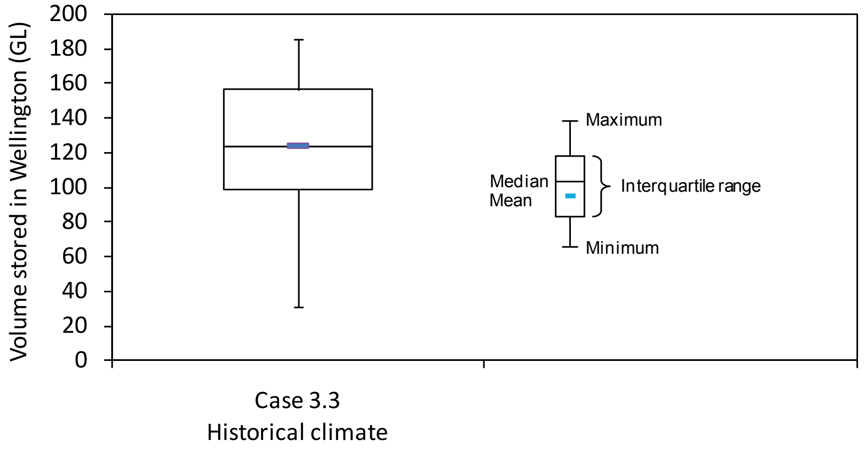

Figure 103 Distribution of annual volume stored in Wellington Reservoir for Case 3.3 – historical climate

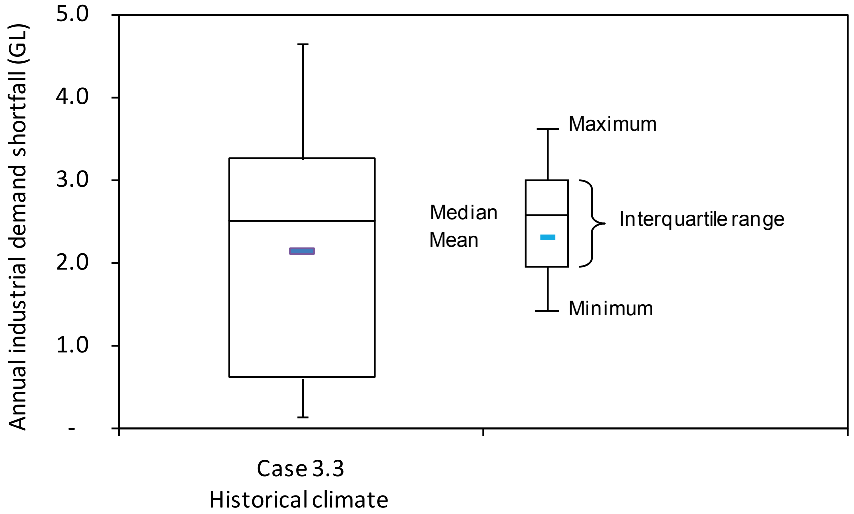

Figure 104 Range of industrial demand shortfalls for Case 3.3 – historical climate

Table 38 Annual industrial supply shortfalls for Case 3.3 – historical climate

	Historical climate
Years with a shortfall in supply	13%
Maximum annual shortfall (GL)	4.64
Median of the annual shortfalls (GL)	2.52
Mean of the annual shortfalls (GL)	2.15

Case 3.3 – 2030 wet future climate

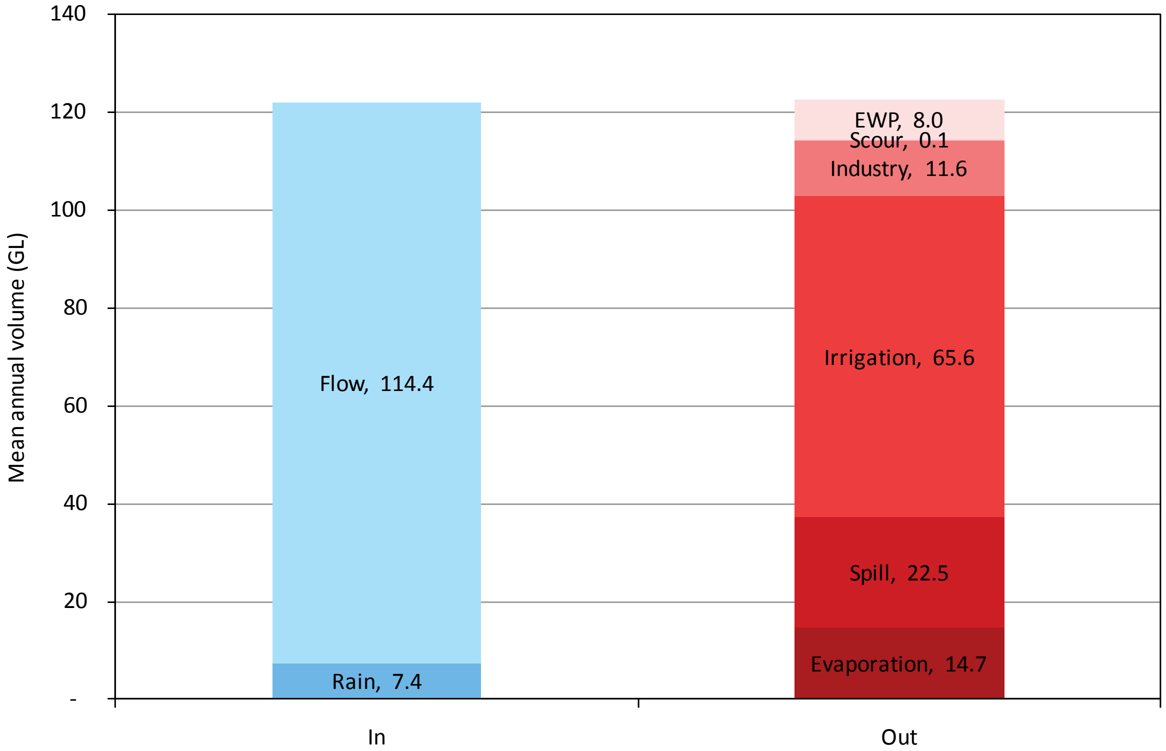

Figure 105 Mean annual water balance for Case 3.3 – 2030 wet future climate

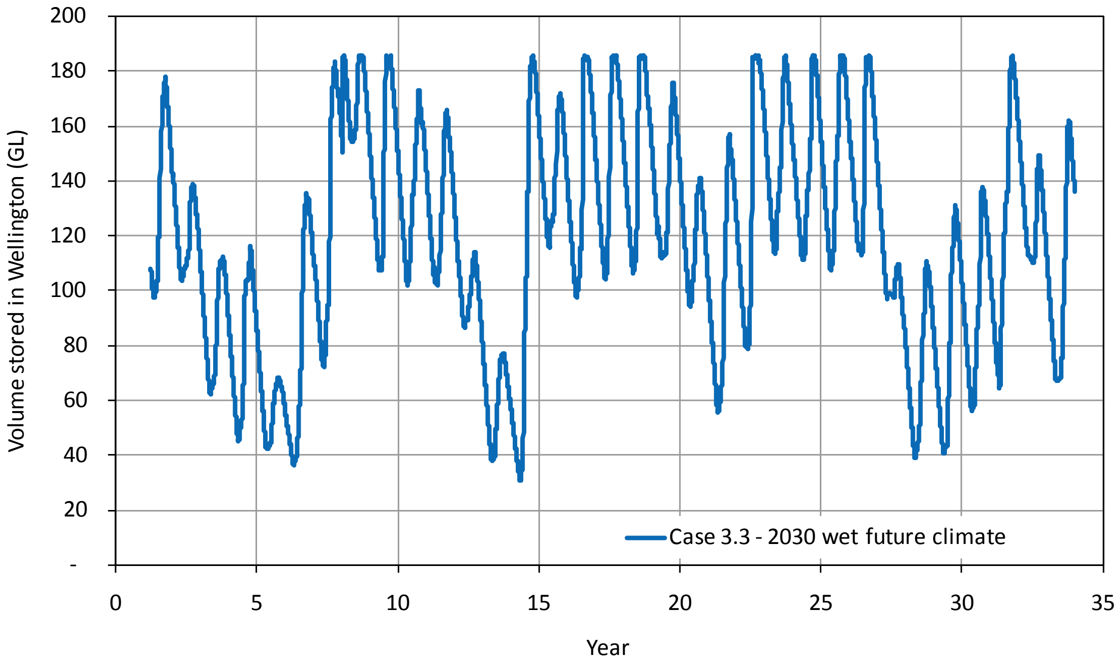

Figure 106 Annual volume stored in Wellington Reservoir for Case 3.3 – 2030 wet future climate

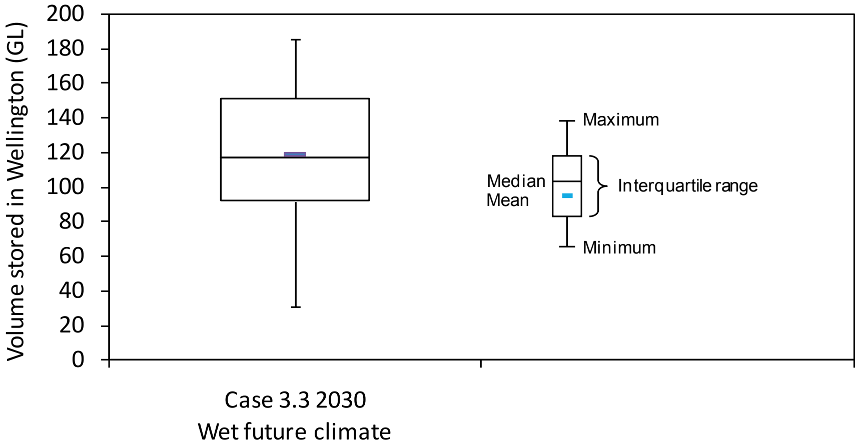

Figure 107 Distribution of annual volume stored in Wellington Reservoir for Case 3.3 – 2030 wet future climate

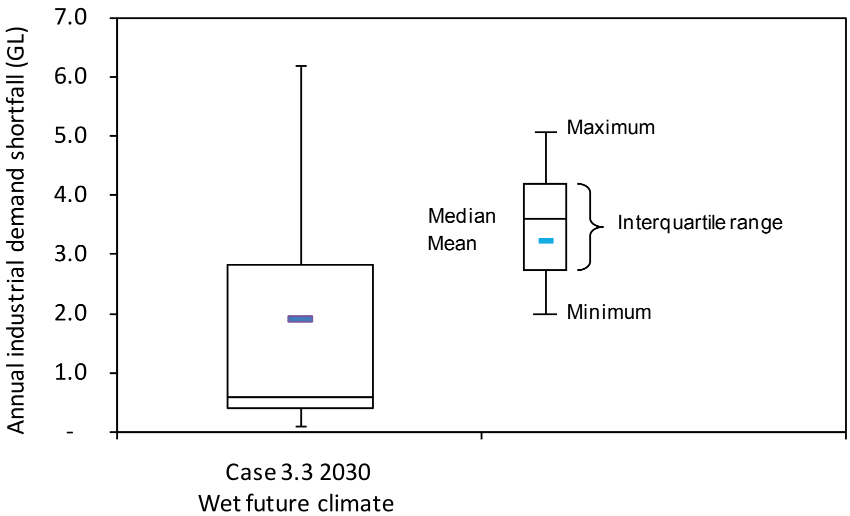

Figure 108 Range of industrial demand shortfalls for Case 3.3 – 2030 wet future climate

Table 39 Annual industrial supply shortfalls for Case 3.3 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.19
Median of the annual shortfalls (GL)	0.58
Mean of the annual shortfalls (GL)	1.91

Case 3.3 – 2030 median future climate

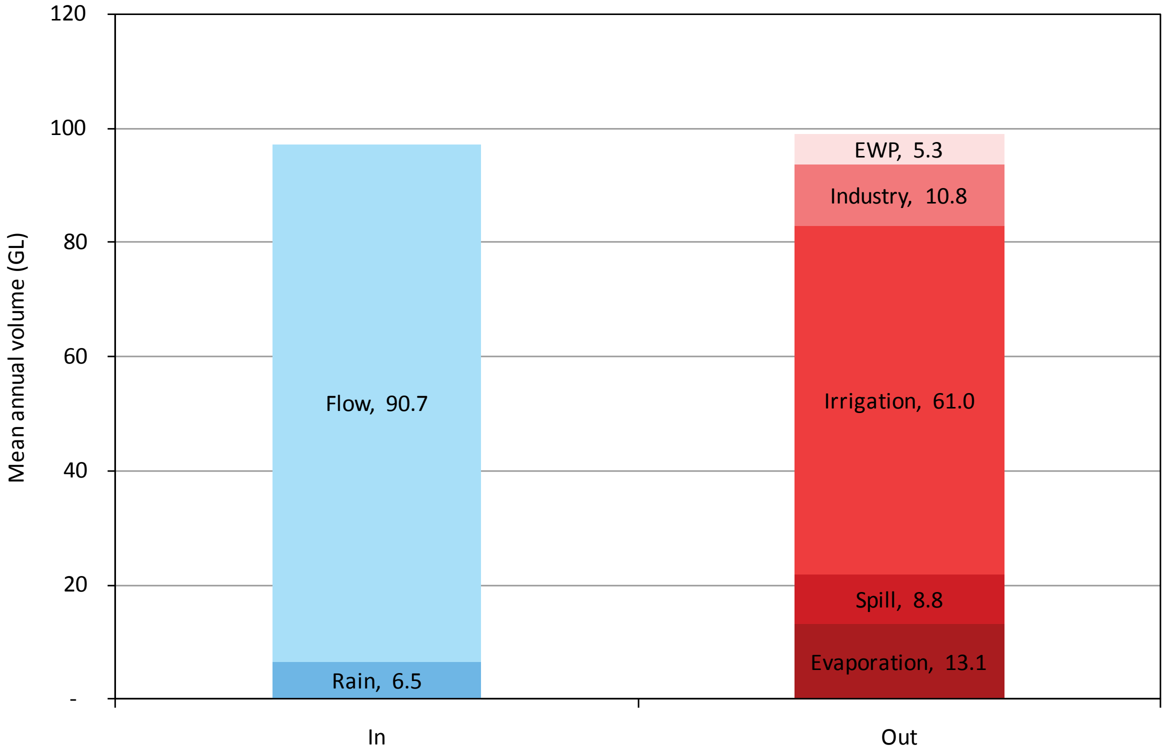

Figure 109 Mean annual water balance for Case 3.3 – 2030 median future climate

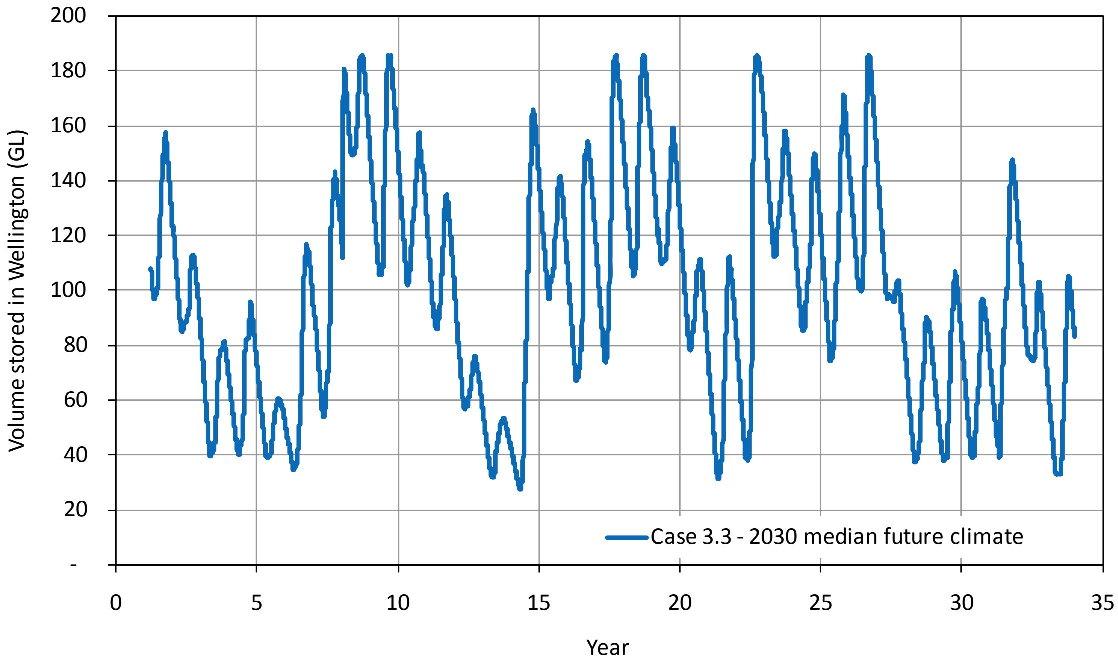

Figure 110 Annual volume stored in Wellington Reservoir for Case 3.3 – 2030 median future climate

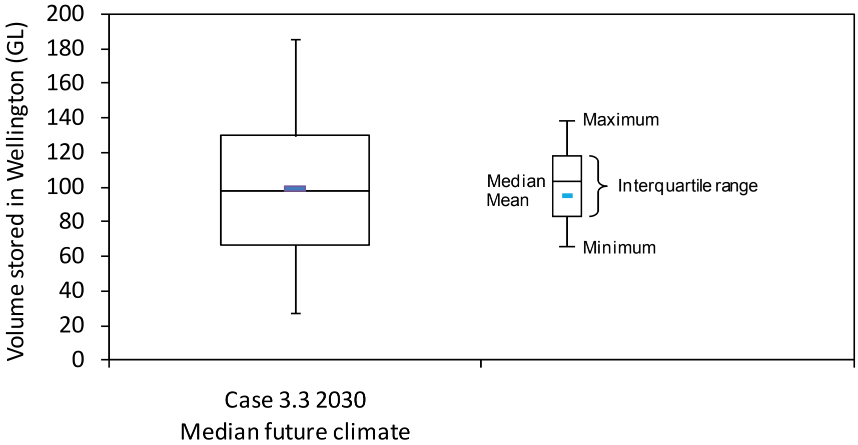

Figure 111 Distribution of annual volume stored in Wellington Reservoir for Case 3.3 – 2030 median future climate

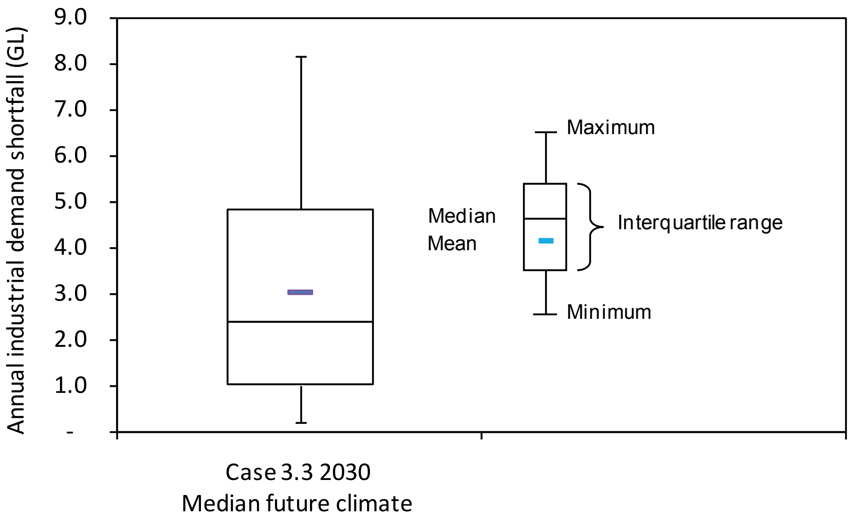

Figure 112 Range of industrial demand shortfalls for Case 3.3 – 2030 median future climate

Table 40 Annual industrial supply shortfalls for Case 3.3 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	41%
Maximum annual shortfall (GL)	8.19
Median of the annual shortfalls (GL)	2.40
Mean of the annual shortfalls (GL)	3.03

Case 3.3 – 2030 dry future climate

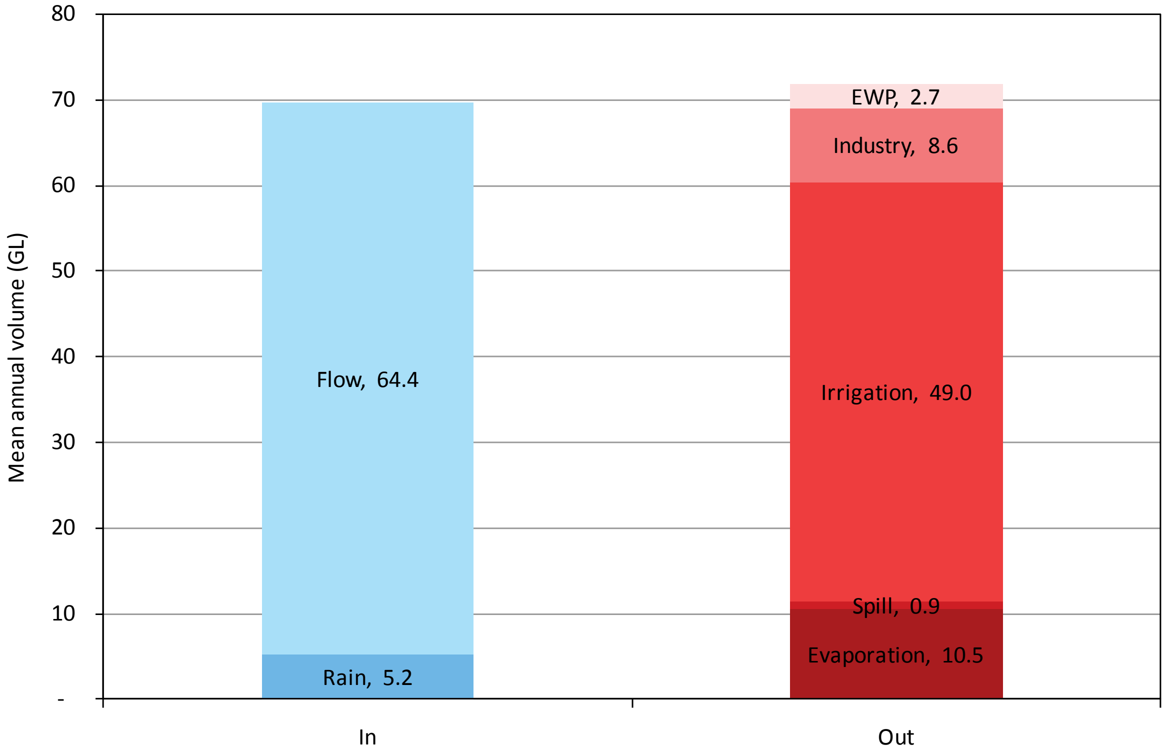

Figure 113 Mean annual water balance for Case 3.3 – 2030 dry future climate

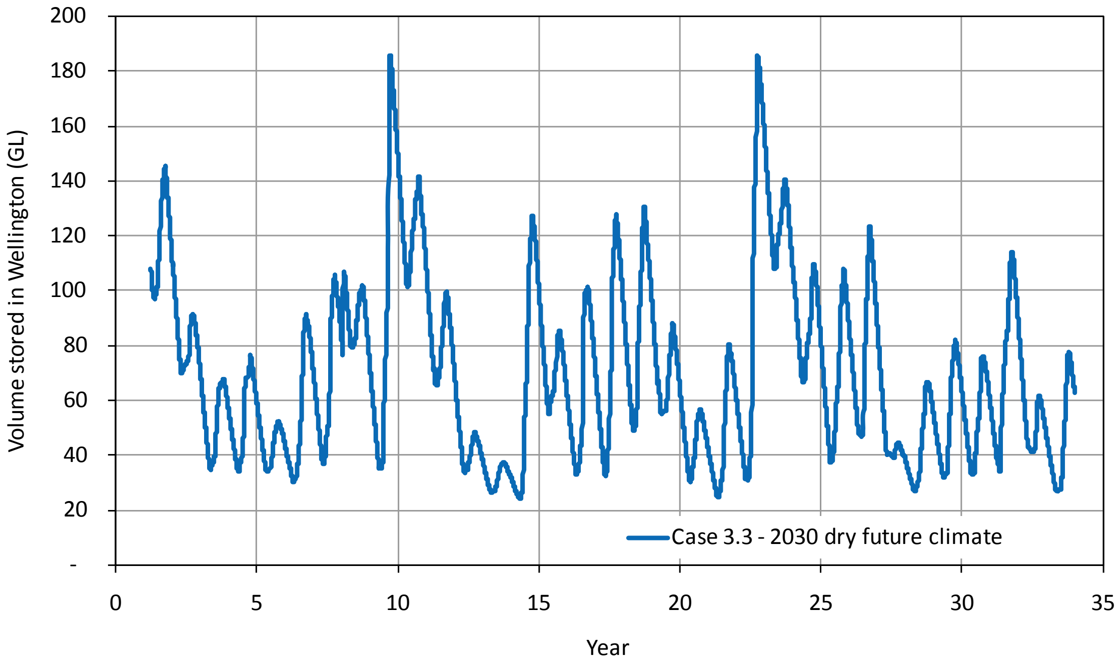

Figure 114 Annual volume stored in Wellington Reservoir for Case 3.3 – 2030 dry future climate

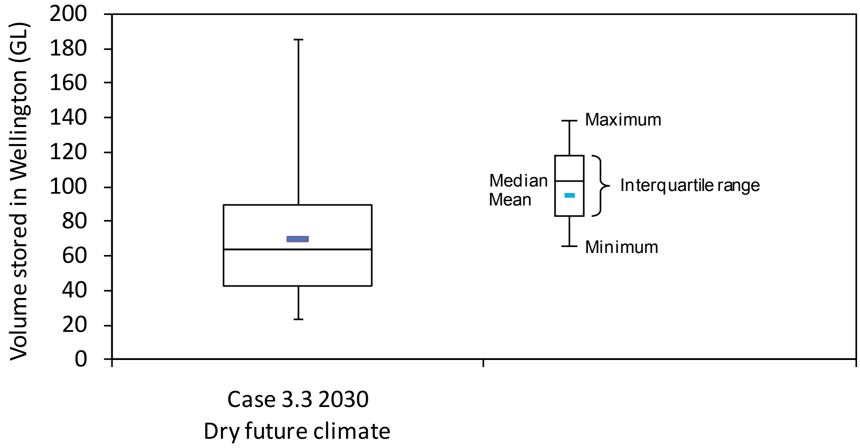

Figure 115 Distribution of annual volume stored in Wellington Reservoir for Case 3.3 – 2030 dry future climate

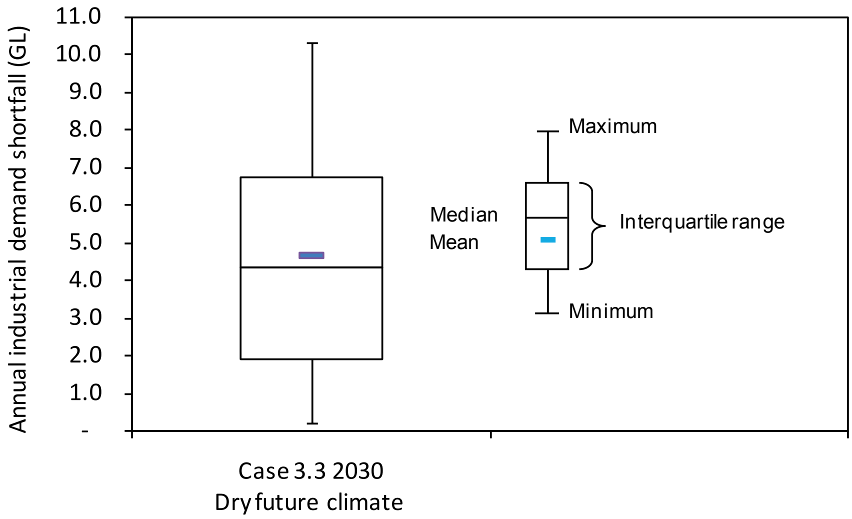

Figure 116 Range of industrial demand shortfalls for Case 3.3 – 2030 dry future climate

Table 41 Annual industrial supply shortfalls for Case 3.3 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	10.3
Median of the annual shortfalls (GL)	4.35
Mean of the annual shortfalls (GL)	4.67

Case 3.4 – historical climate

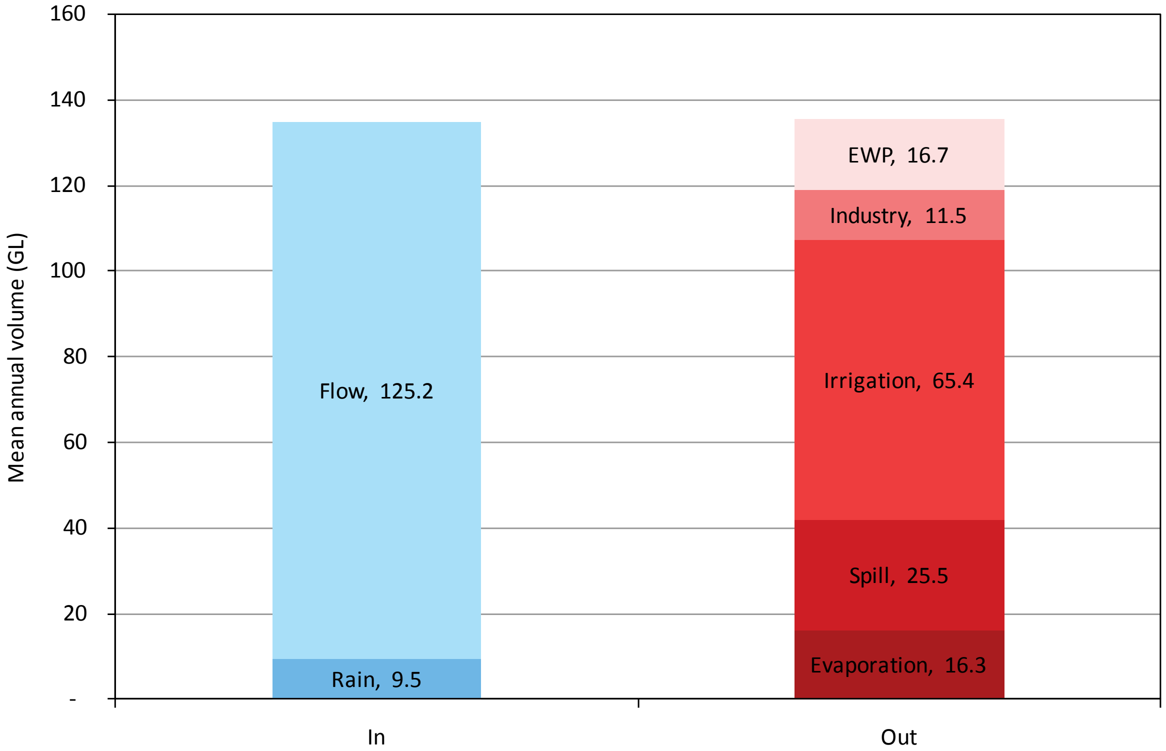

Figure 117 Mean annual water balance for Case 3.4 - historical climate

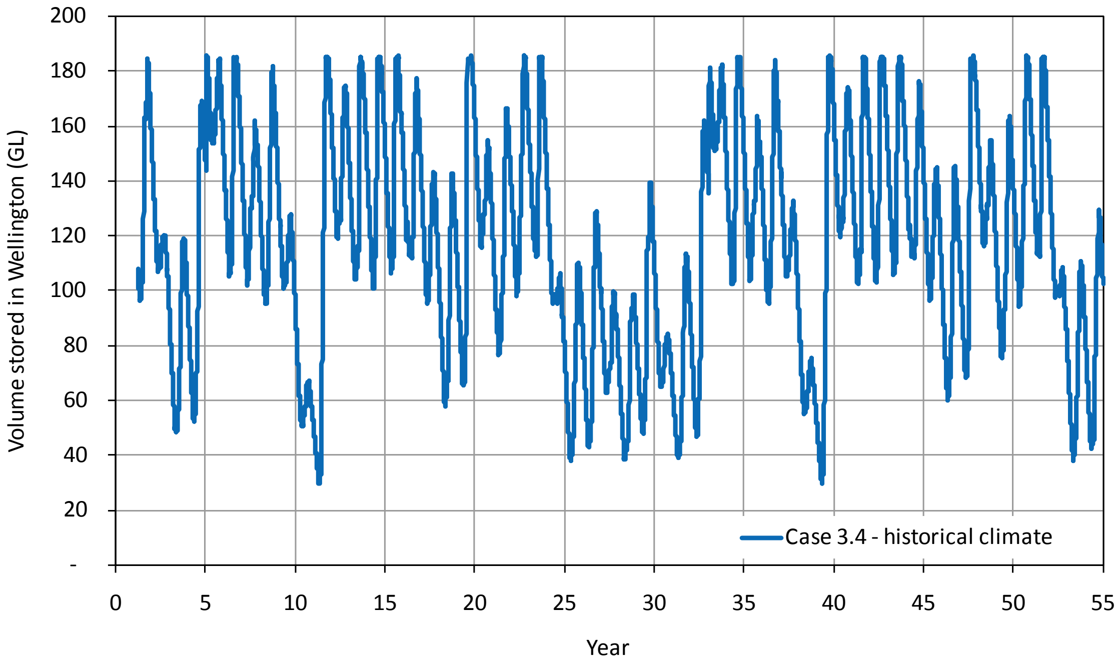

Figure 118 Annual volume stored in Wellington Reservoir for Case 3.4 – historical climate

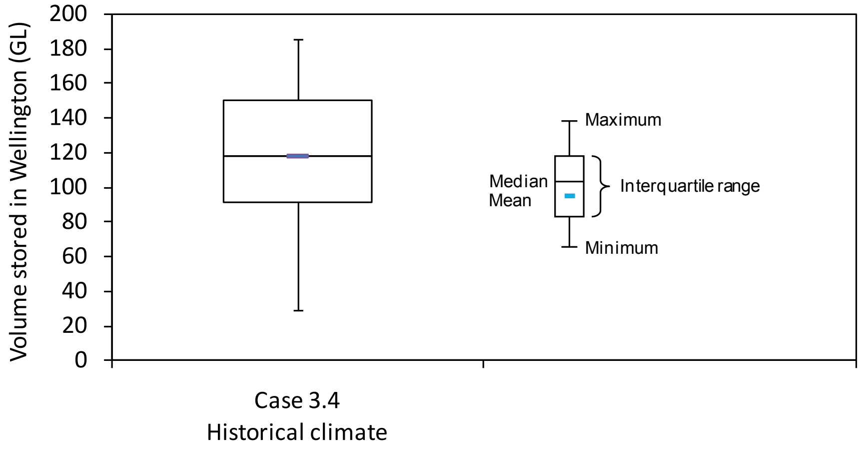

Figure 119 Distribution of annual volume stored in Wellington Reservoir for Case 3.4 – historical climate

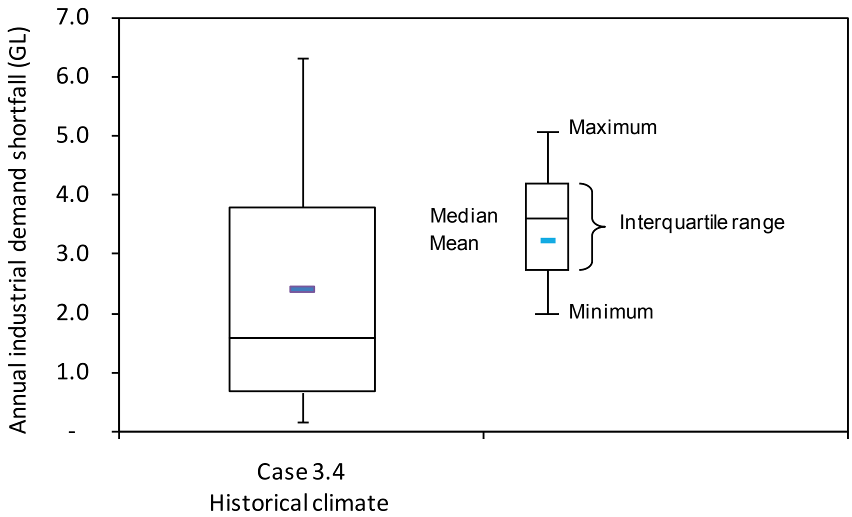

Figure 120 Range of industrial demand shortfalls for Case 3.4 – historical climate

Table 42 Annual industrial supply shortfalls for Case 3.4 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	6.32
Median of the annual shortfalls (GL)	1.59
Mean of the annual shortfalls (GL)	2.40

Case 3.4 – 2030 wet future climate

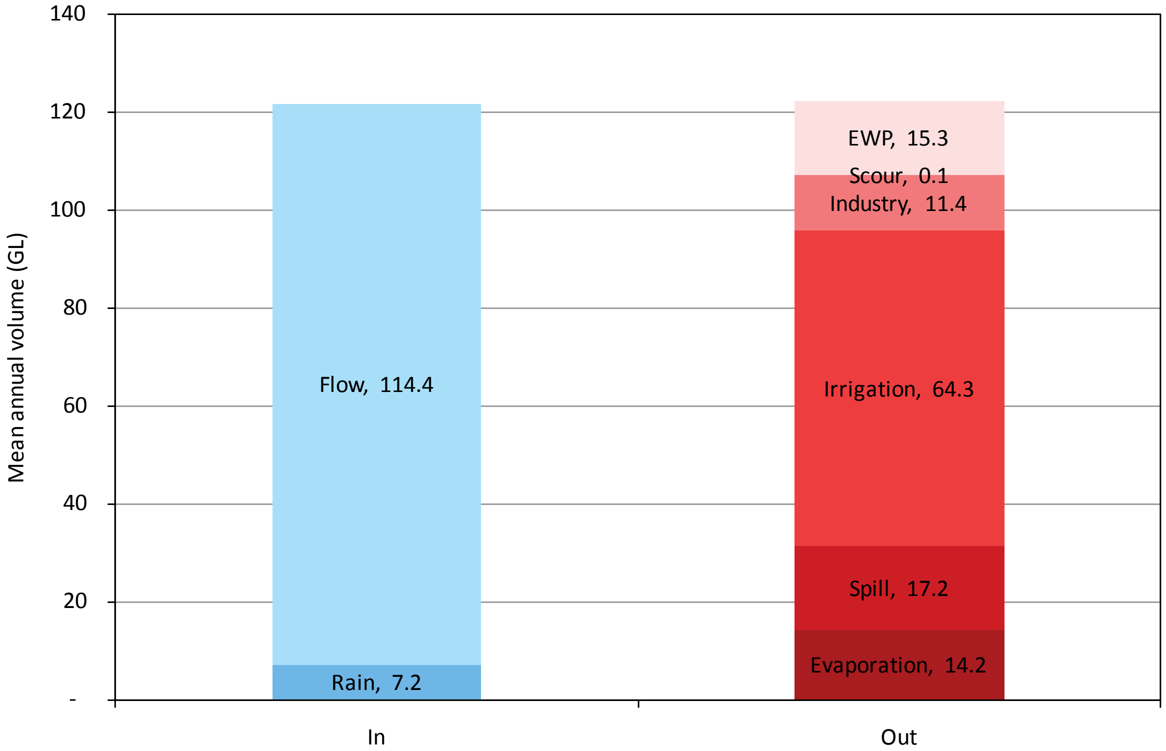

Figure 121 Mean annual water balance for Case 3.4 – 2030 wet future climate

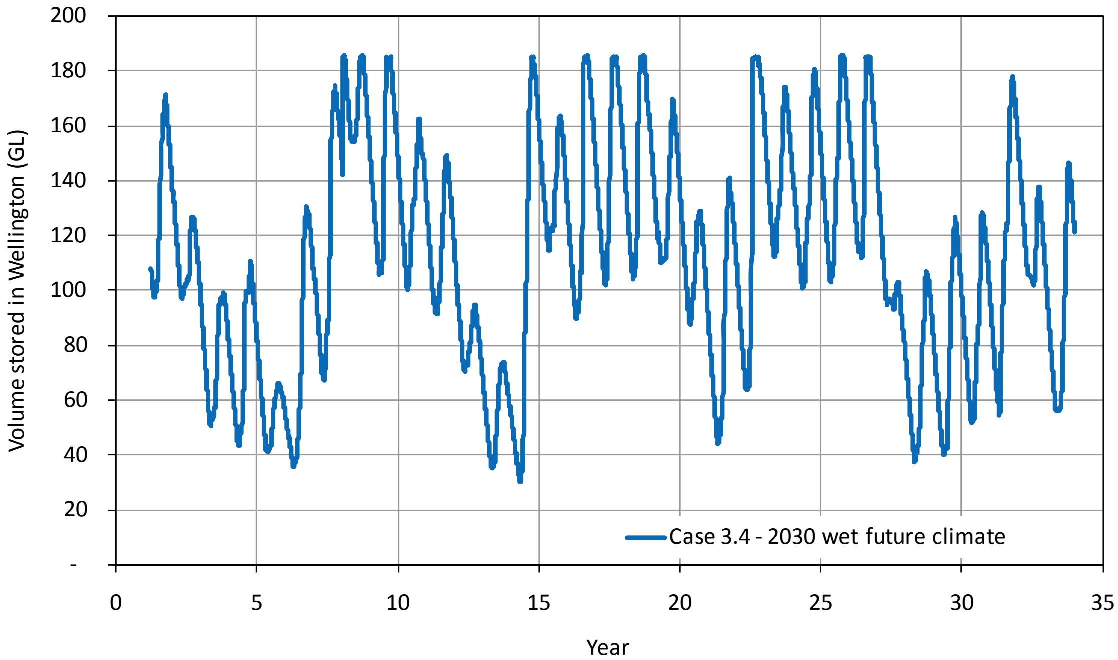

Figure 122 Annual volume stored in Wellington Reservoir for Case 3.4 – 2030 wet future climate

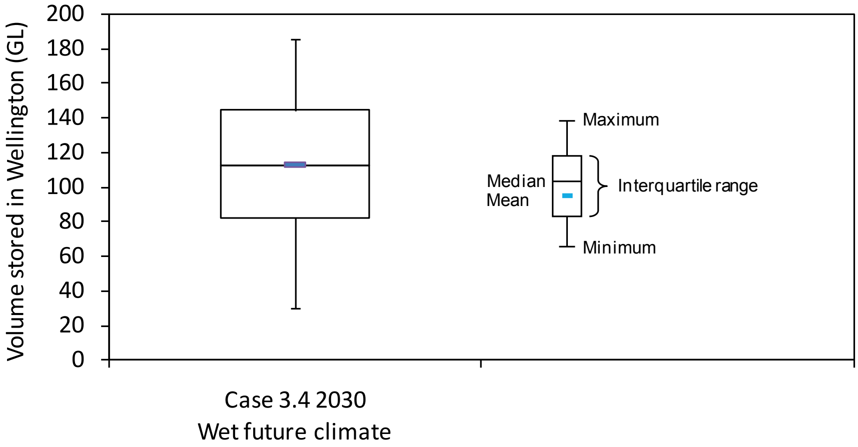

Figure 123 Distribution of annual volume stored in Wellington Reservoir for Case 3.4 – 2030 wet future climate

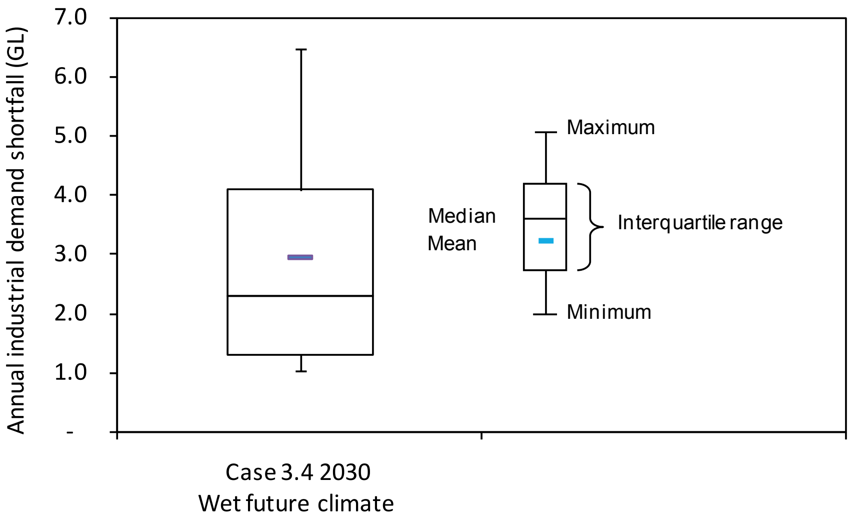

Figure 124 Range of industrial demand shortfalls for Case 3.4 – 2030 wet future climate

Table 43 Annual industrial supply shortfalls for Case 3.4 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.49
Median of the annual shortfalls (GL)	2.30
Mean of the annual shortfalls (GL)	2.95

Case 3.4 – 2030 median future climate

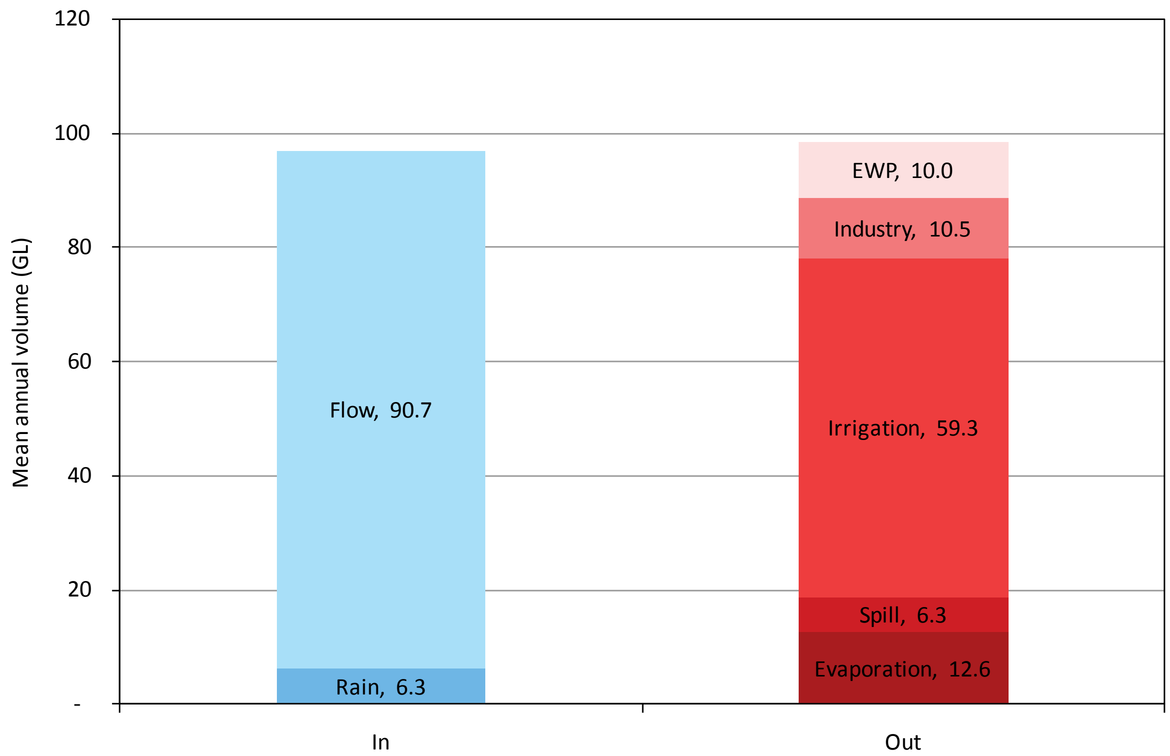

Figure 125 Mean annual water balance for Case 3.4 – 2030 median future climate

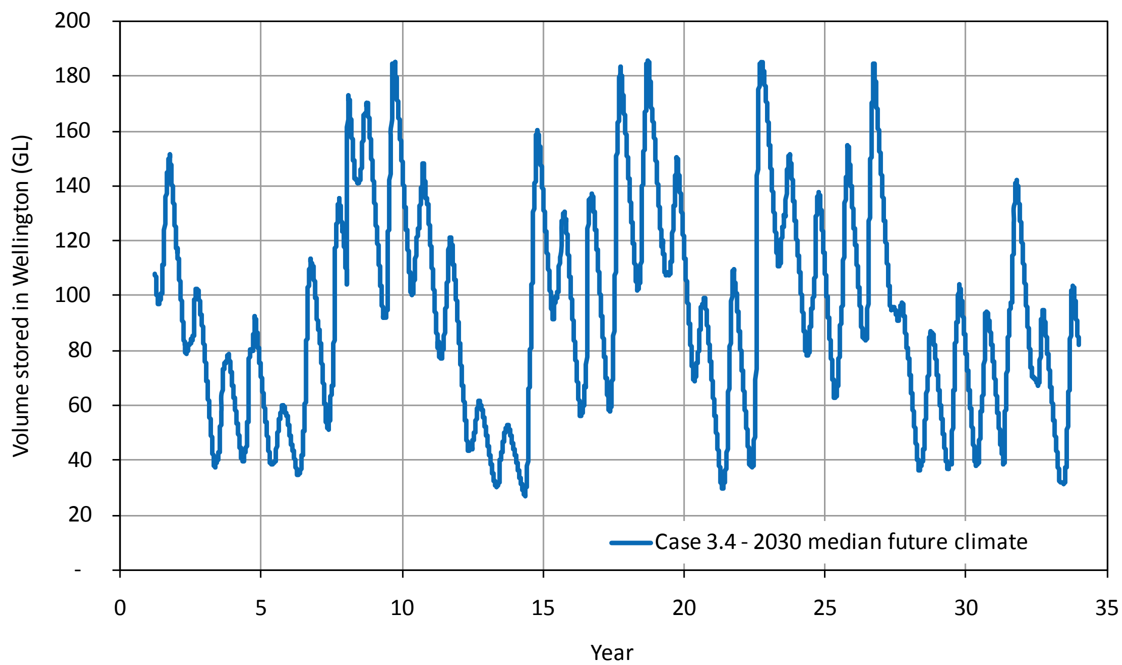

Figure 126 Annual volume stored in Wellington Reservoir for Case 3.4 – 2030 median future climate

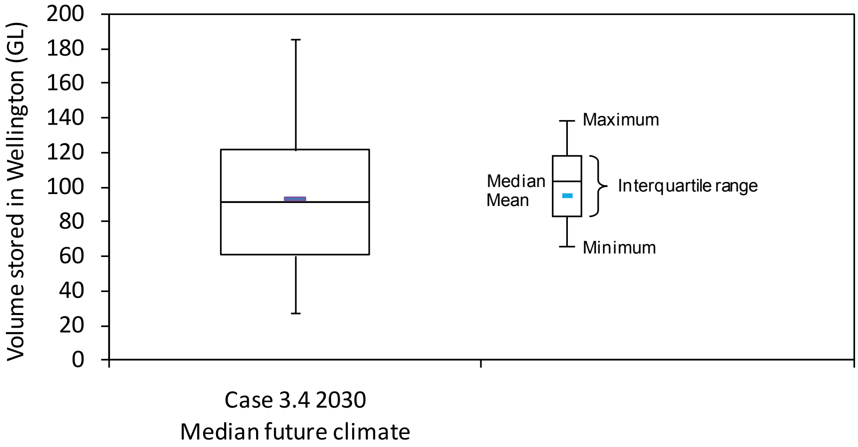

Figure 127 Distribution of annual volume stored in Wellington Reservoir for Case 3.4 – 2030 median future climate

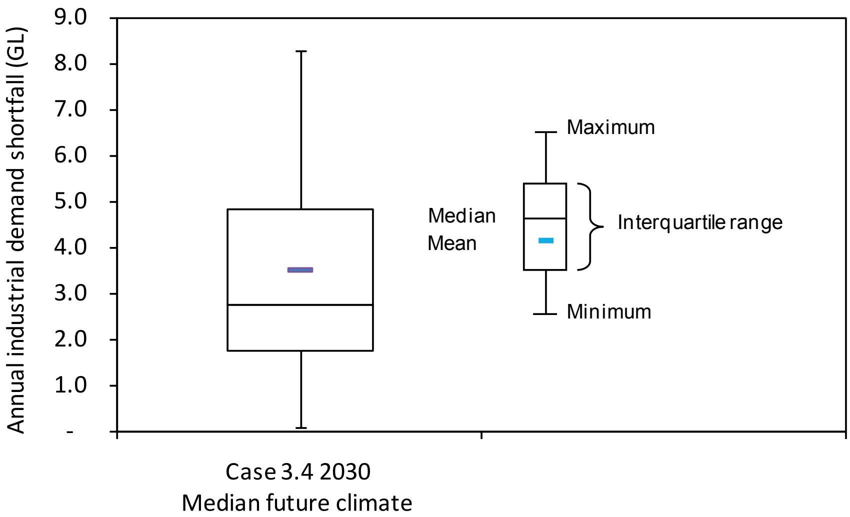

Figure 128 Range of industrial demand shortfalls for Case 3.4 – 2030 median future climate

Table 44 Annual industrial supply shortfalls for Case 3.4 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	44%
Maximum annual shortfall (GL)	8.29
Median of the annual shortfalls (GL)	2.75
Mean of the annual shortfalls (GL)	3.51

Case 3.4 – 2030 dry future climate

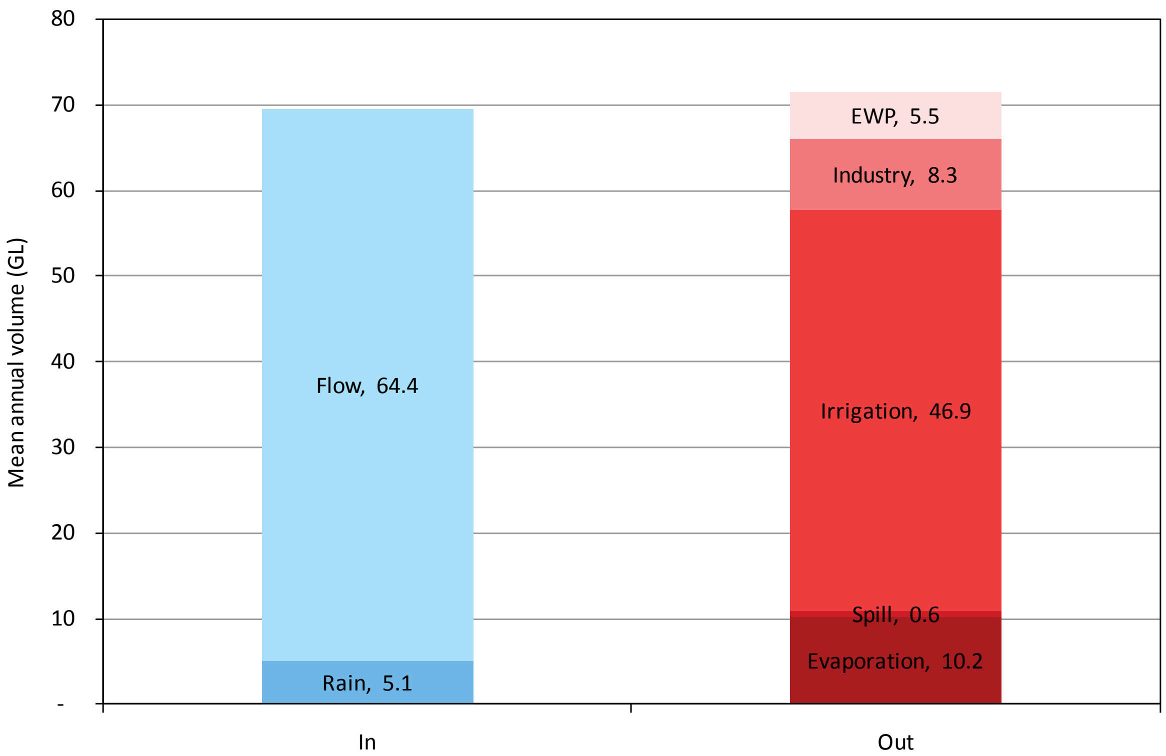

Figure 129 Mean annual water balance for Case 3.4 – 2030 dry future climate

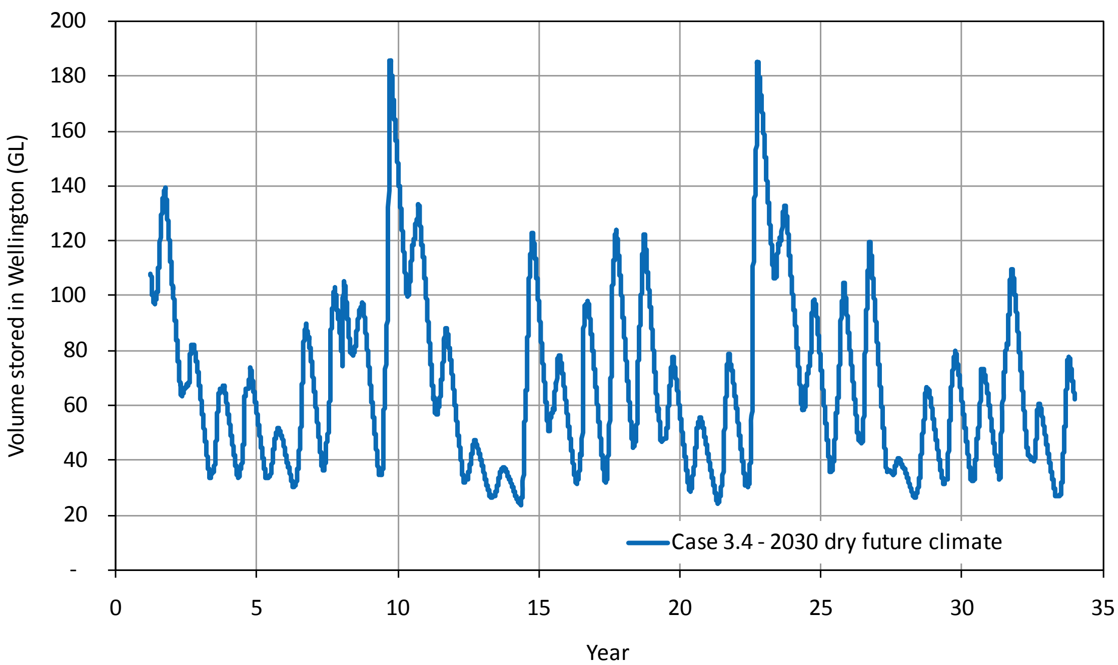

Figure 130 Annual volume stored in Wellington Reservoir for Case 3.4 – 2030 dry future climate

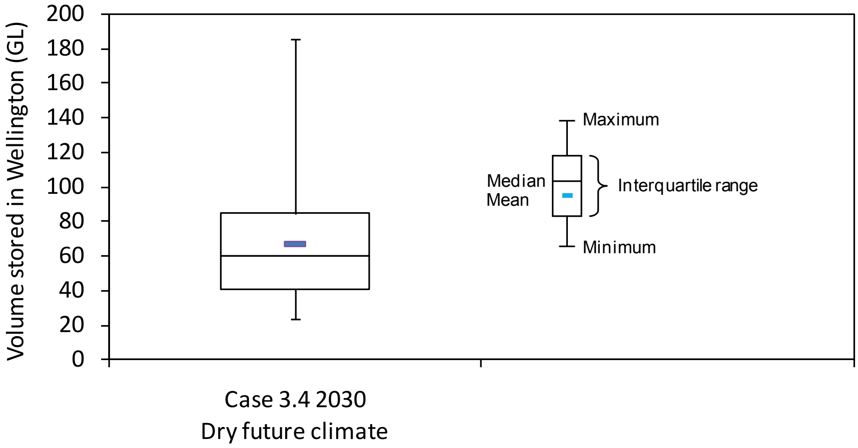

Figure 131 Distribution of annual volume stored in Wellington Reservoir for Case 3.4 – 2030 dry future climate

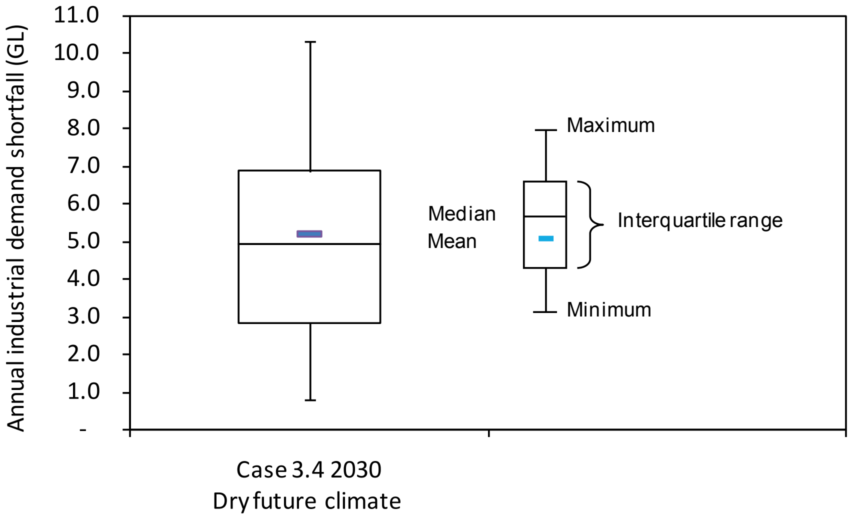

Figure 132 Range of industrial demand shortfalls for Case 3.4 – 2030 dry future climate

Table 45 Annual industrial supply shortfalls for Case 3.4 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	10.3
Median of the annual shortfalls (GL)	4.91
Mean of the annual shortfalls (GL)	5.19

Case 3.5 – historical climate

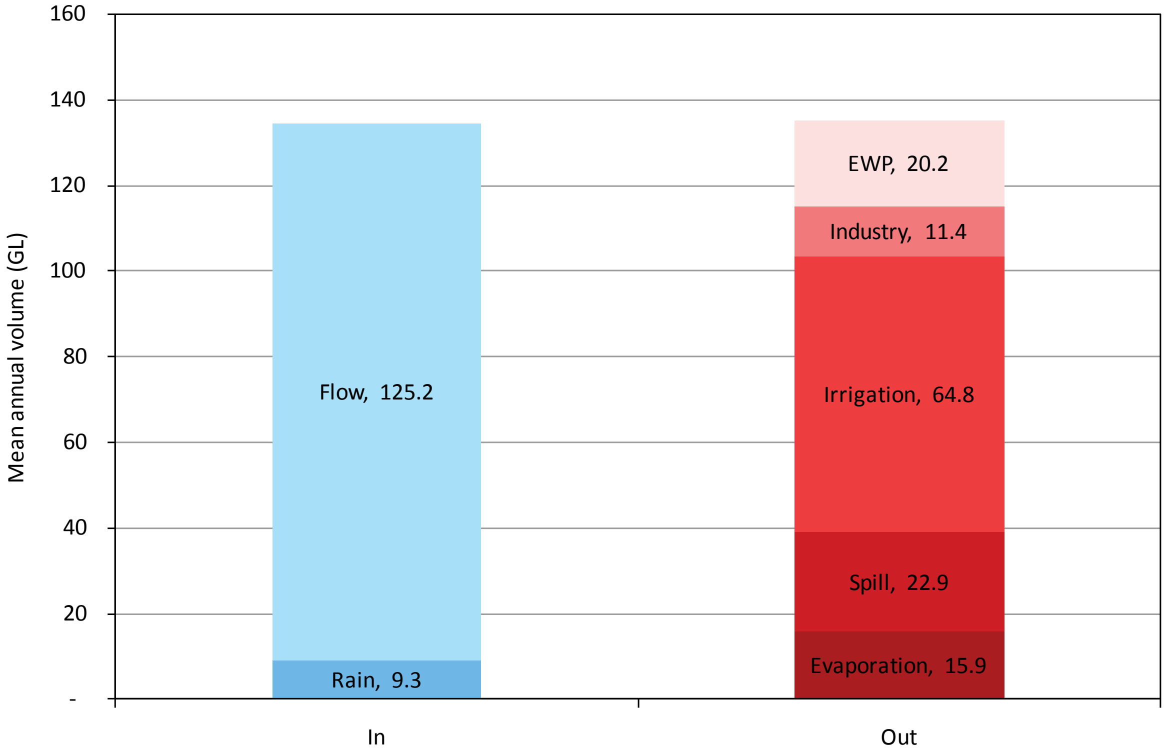

Figure 133 Mean annual water balance for Case 3.5 - historical climate

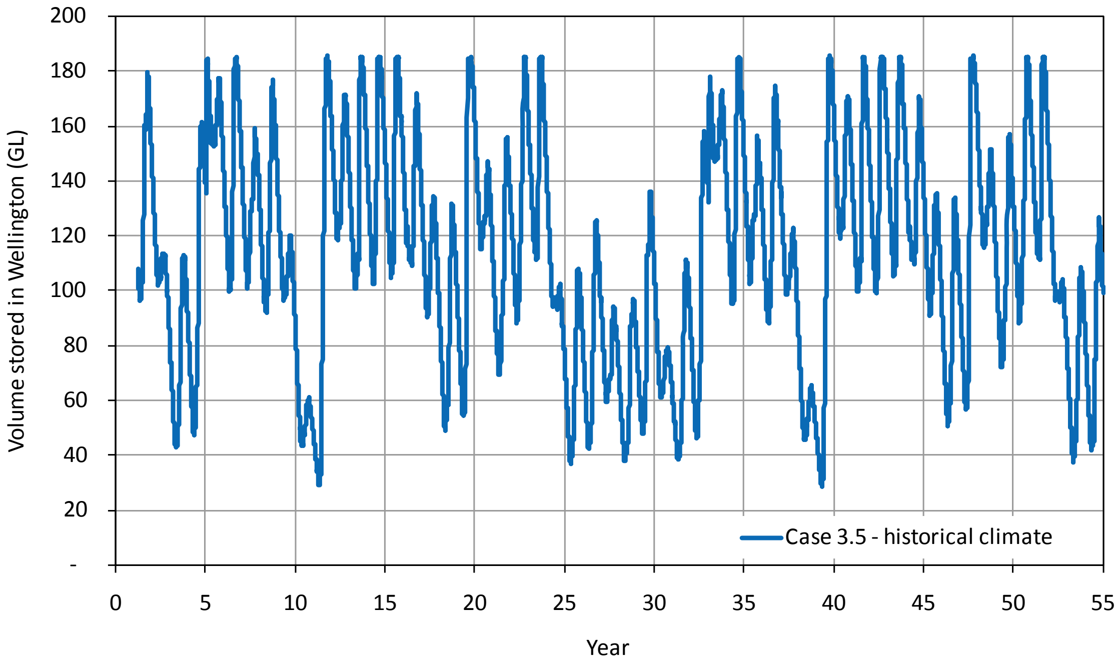

Figure 134 Annual volume stored in Wellington Reservoir for Case 3.5 – historical climate

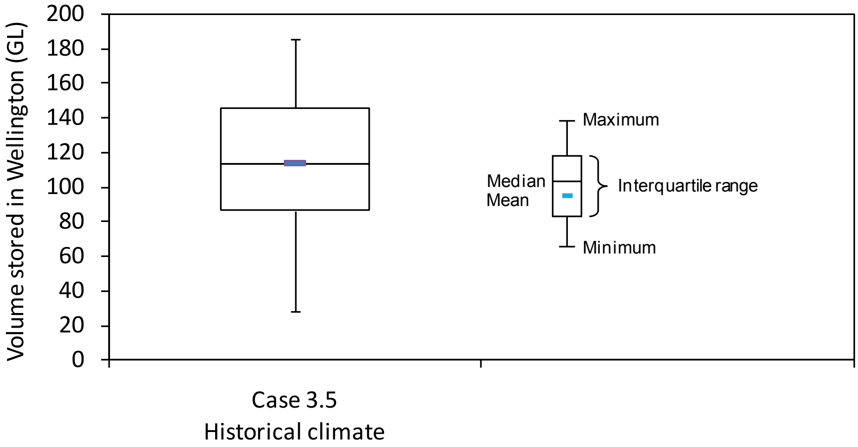

Figure 135 Distribution of annual volume stored in Wellington Reservoir for Case 3.5 – historical climate

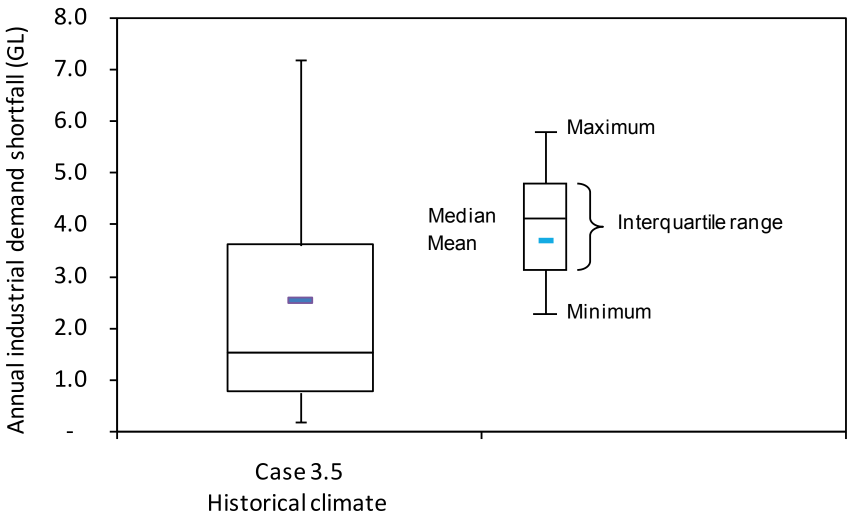

Figure 136 Range of industrial demand shortfalls for Case 3.5 – historical climate

Table 46 Annual industrial supply shortfalls for Case 3.5 – historical climate

	Historical climate
Years with a shortfall in supply	23%
Maximum annual shortfall (GL)	7.18
Median of the annual shortfalls (GL)	1.53
Mean of the annual shortfalls (GL)	2.53

Case 3.5 – 2030 wet future climate

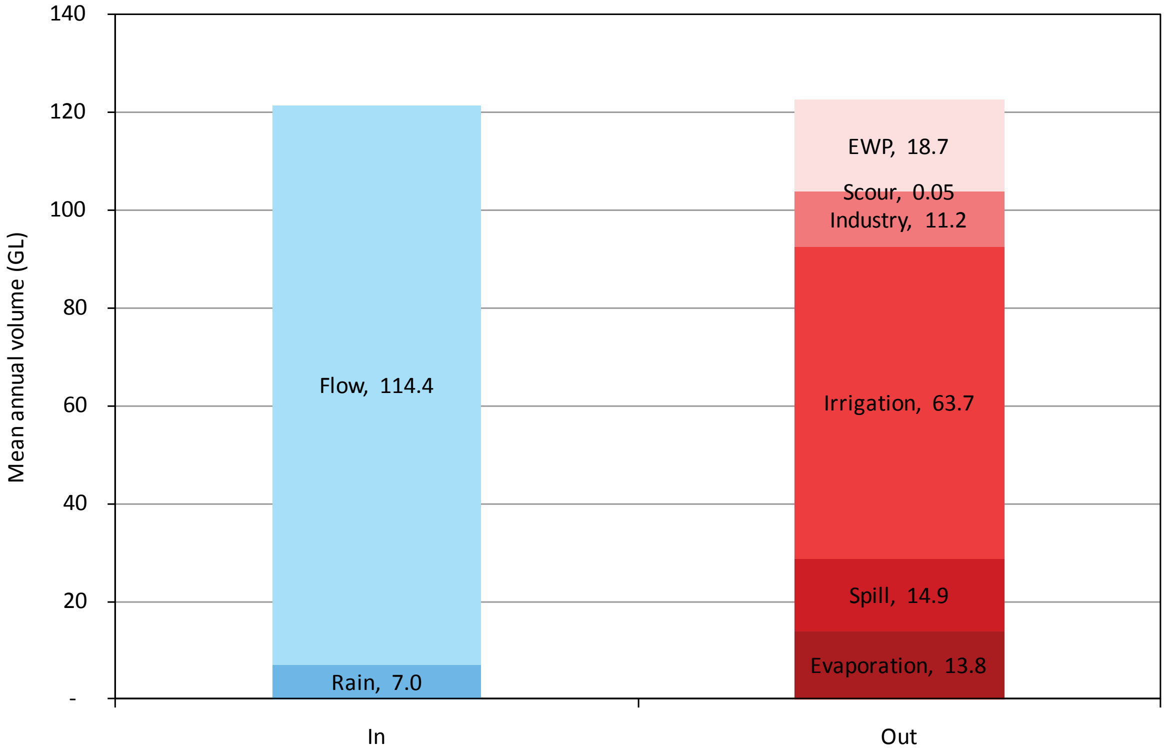

Figure 137 Mean annual water balance for Case 3.5 – 2030 wet future climate

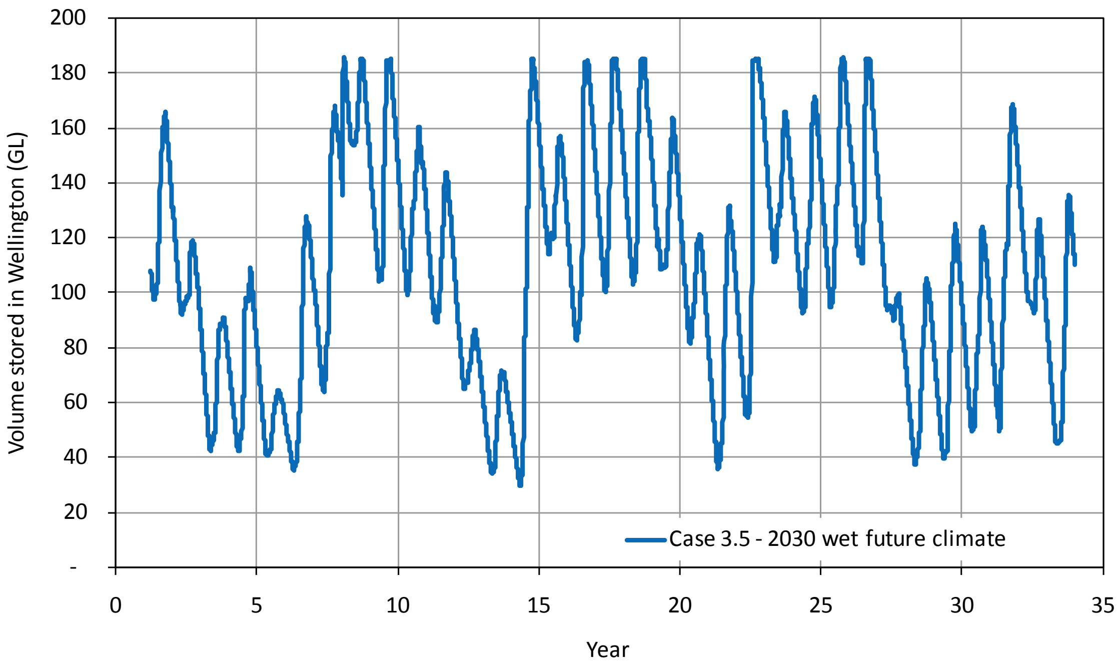

Figure 138 Annual volume stored in Wellington Reservoir for Case 3.5 – 2030 wet future climate

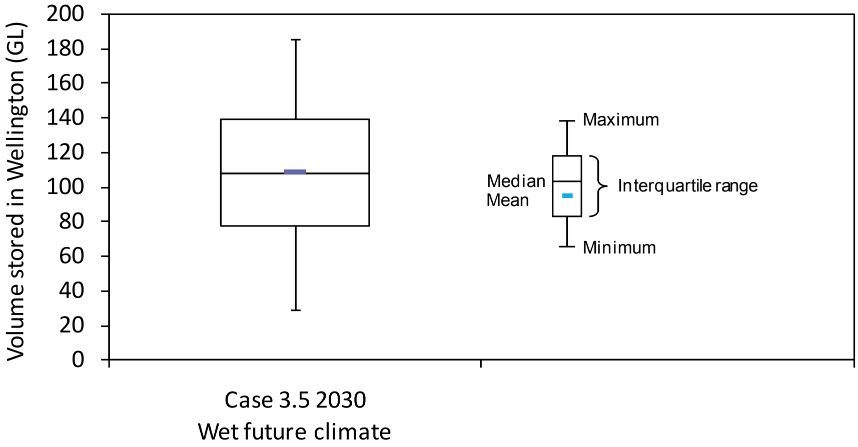

Figure 139 Distribution of annual volume stored in Wellington Reservoir for Case 3.5 – 2030 wet future climate

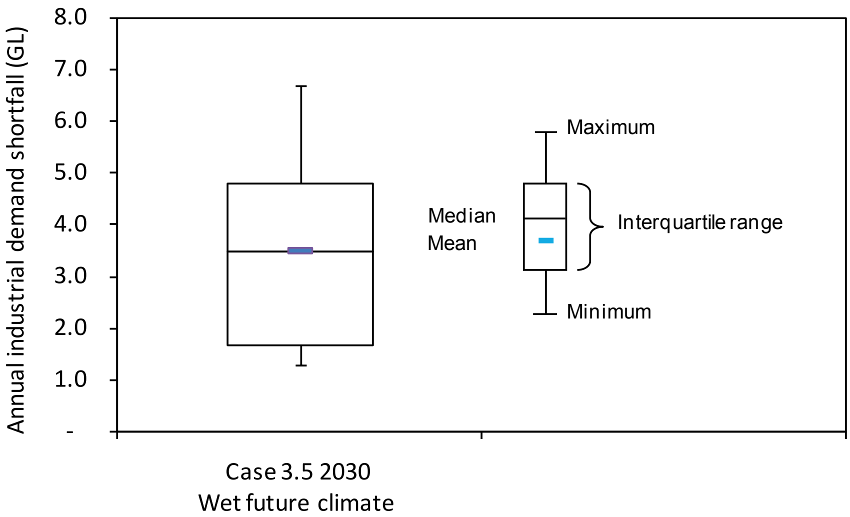

Figure 140 Range of industrial demand shortfalls for Case 3.5 – 2030 wet future climate

Table 47 Annual industrial supply shortfalls for Case 3.5 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.70
Median of the annual shortfalls (GL)	3.47
Mean of the annual shortfalls (GL)	3.49

Case 3.5 – 2030 median future climate

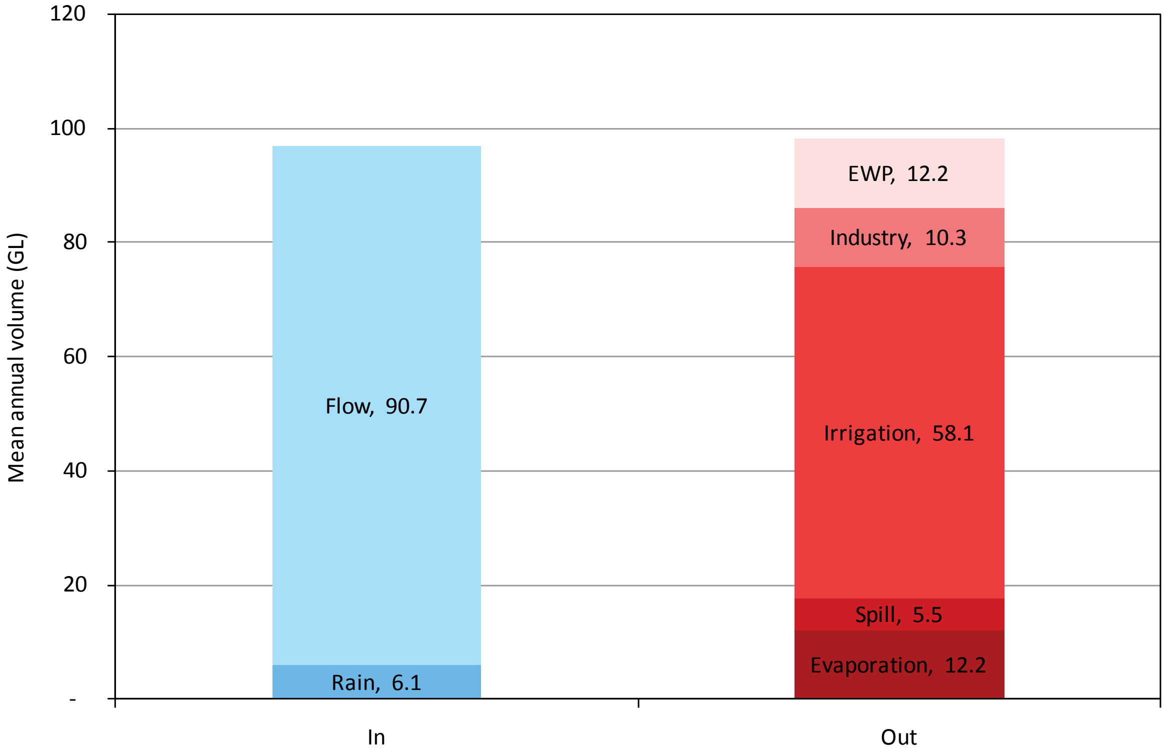

Figure 141 Mean annual water balance for Case 3.5 – 2030 median future climate

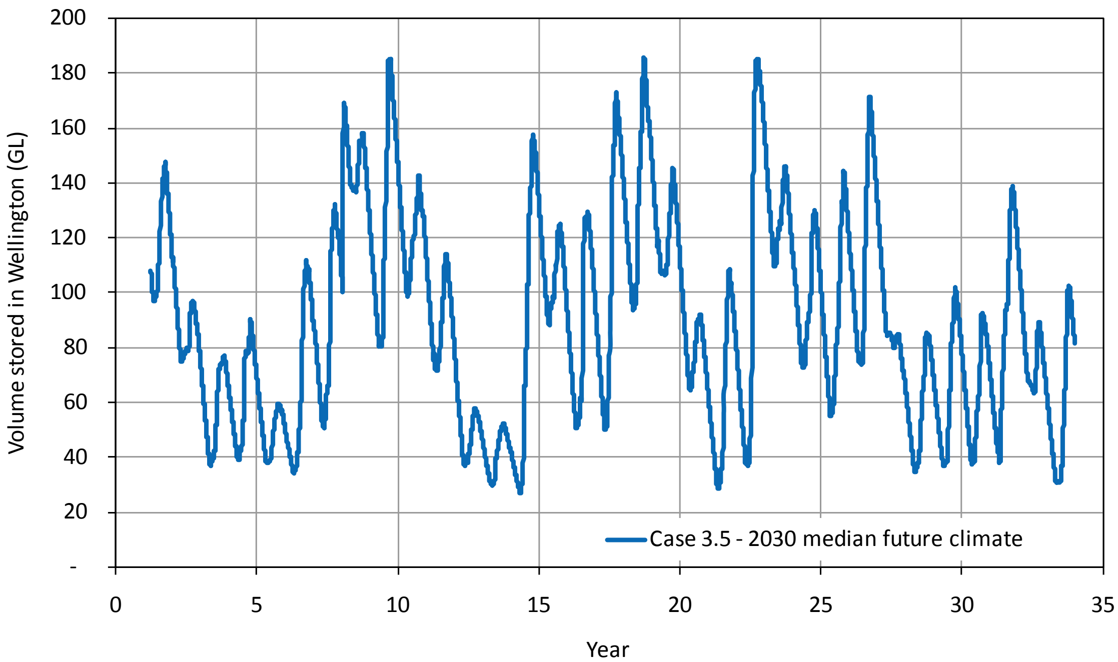

Figure 142 Annual volume stored in Wellington Reservoir for Case 3.5 – 2030 median future climate

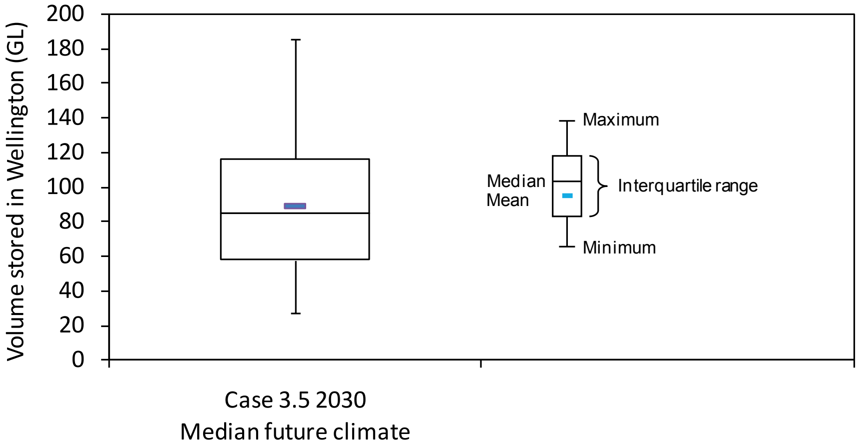

Figure 143 Distribution of annual volume stored in Wellington Reservoir for Case 3.5 – 2030 median future climate

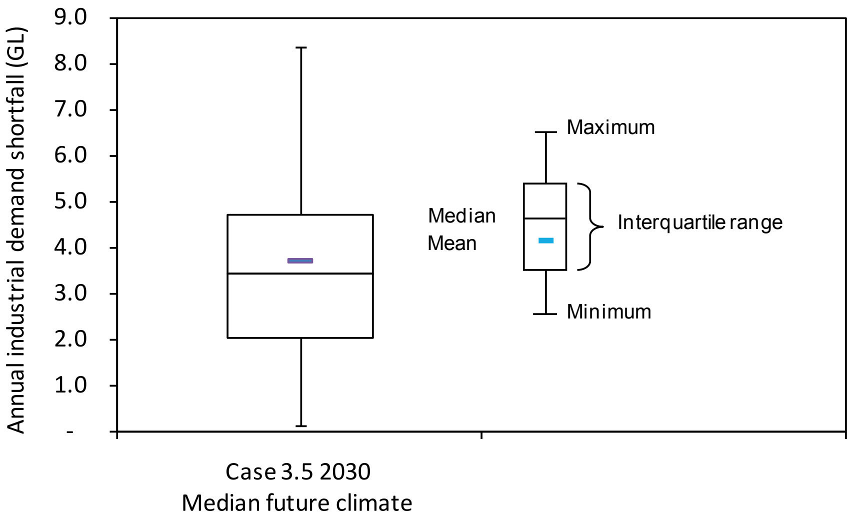

Figure 144 Range of industrial demand shortfalls for Case 3.5 – 2030 median future climate

Table 48 Annual industrial supply shortfalls for Case 3.5 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	47%
Maximum annual shortfall (GL)	8.36
Median of the annual shortfalls (GL)	3.46
Mean of the annual shortfalls (GL)	3.72

Case 3.5 – 2030 dry future climate

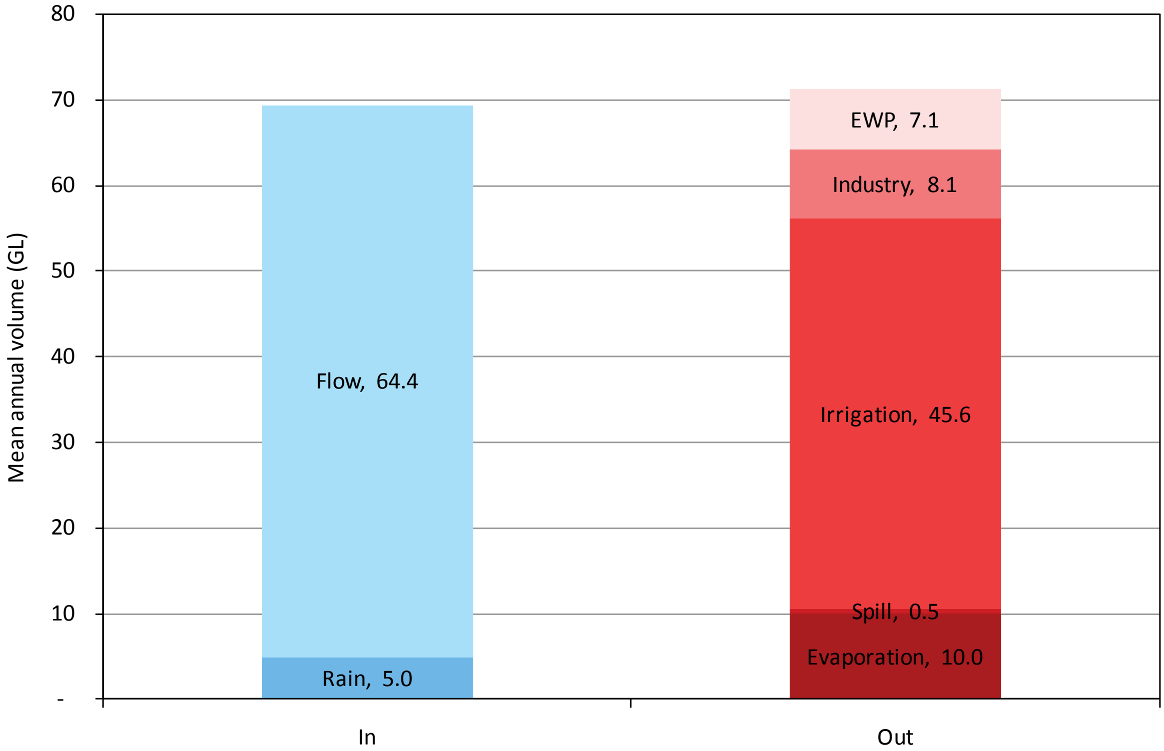

Figure 145 Mean annual water balance for Case 3.5 – 2030 dry future climate

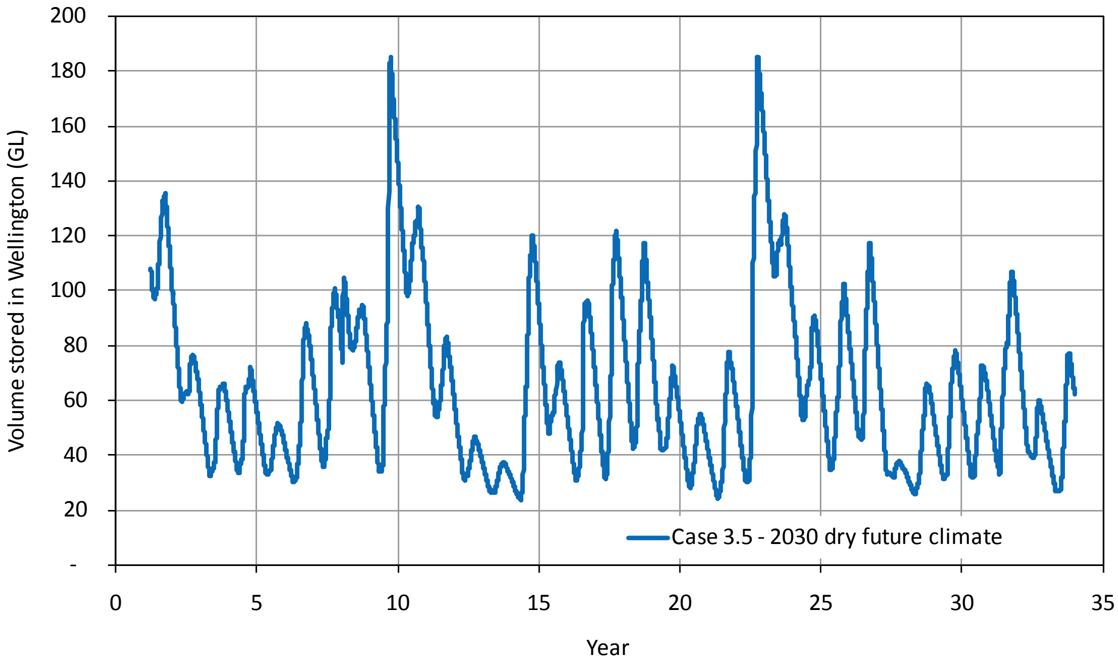

Figure 146 Annual volume stored in Wellington Reservoir for Case 3.5 – 2030 dry future climate

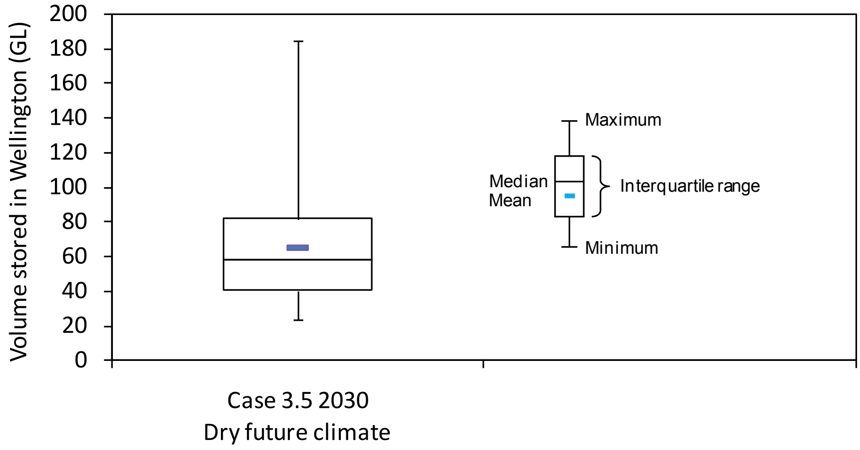

Figure 147 Distribution of annual volume stored in Wellington Reservoir for Case 3.5 – 2030 dry future climate

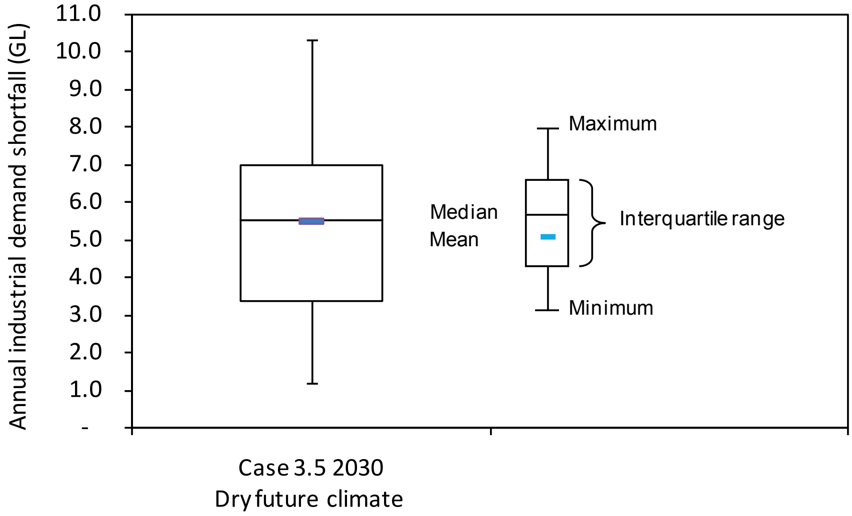

Figure 148 Range of industrial demand shortfalls for Case 3.5 – 2030 dry future climate

Table 49 Annual industrial supply shortfalls for Case 3.5 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	10.3
Median of the annual shortfalls (GL)	5.52
Mean of the annual shortfalls (GL)	5.50

Case 4.1 – historical climate

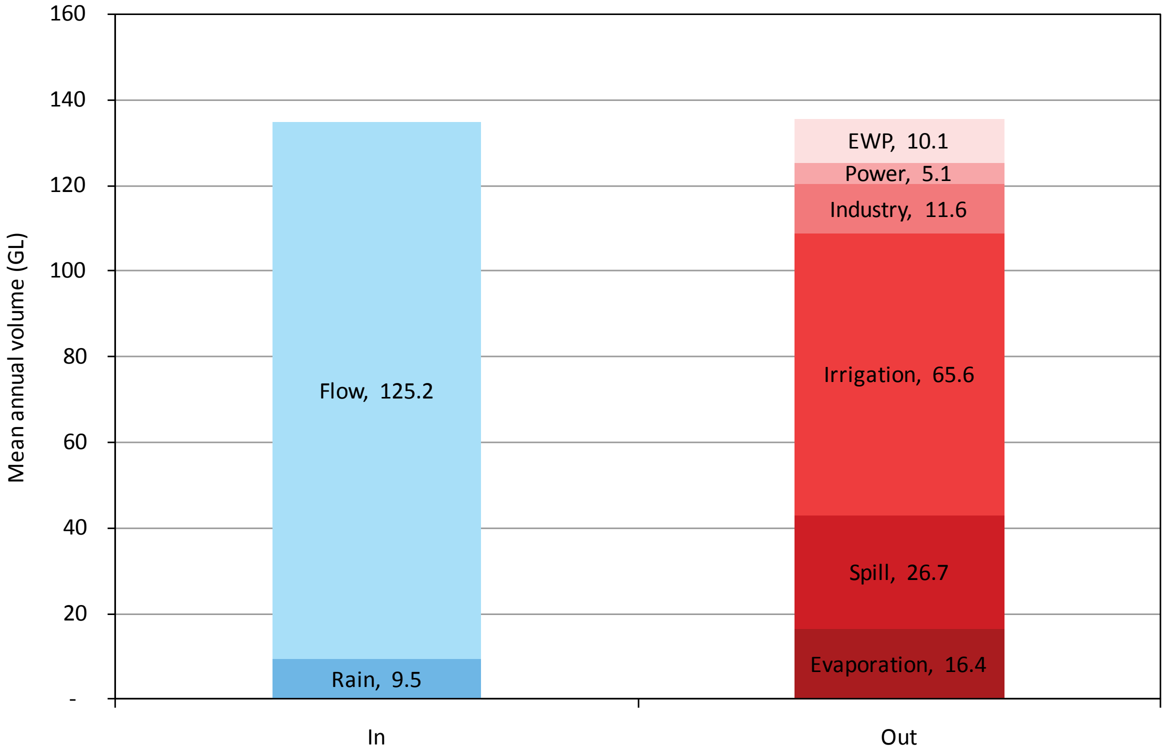

Figure 149 Mean annual water balance for Case 4.1 - historical climate

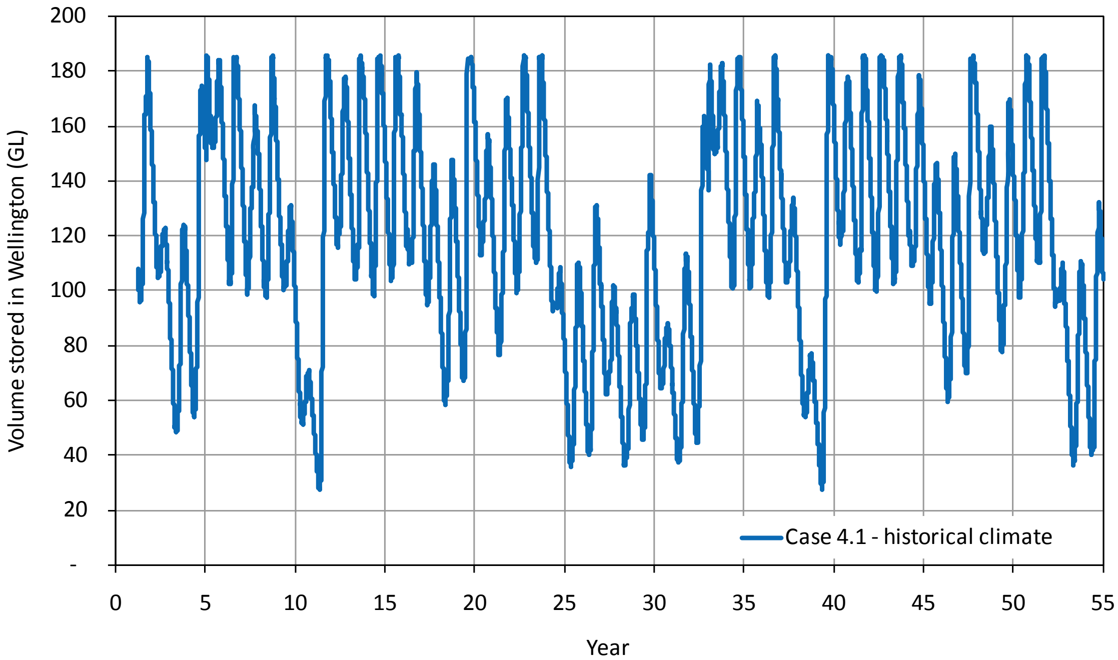

Figure 150 Annual volume stored in Wellington Reservoir for Case 4.1 – historical climate

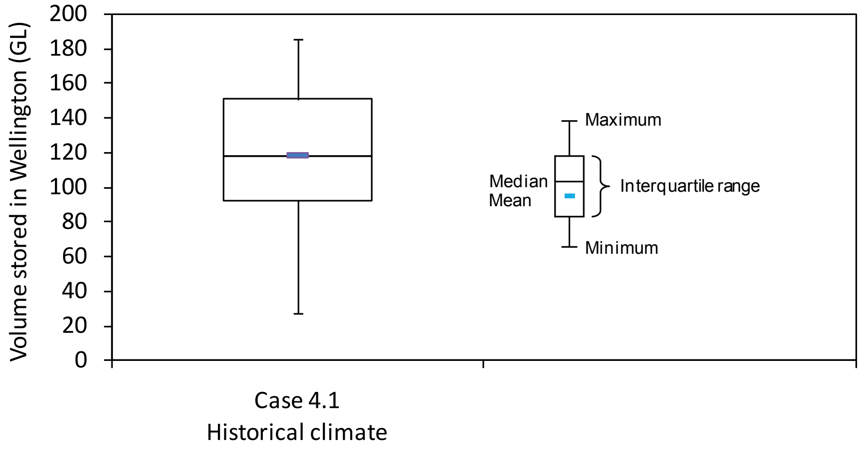

Figure 151 Distribution of annual volume stored in Wellington Reservoir for Case 4.1 – historical climate

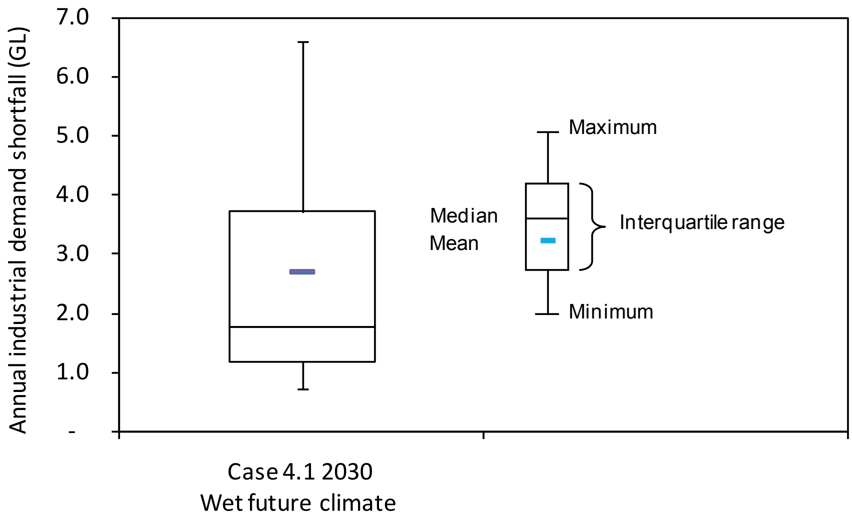

Figure 152 Range of industrial demand shortfalls for Case 4.1 – historical climate

Table 50 Annual industrial supply shortfalls for Case 4.1 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	5.81
Median of the annual shortfalls (GL)	1.30
Mean of the annual shortfalls (GL)	2.20

Case 4.1 – 2030 wet future climate

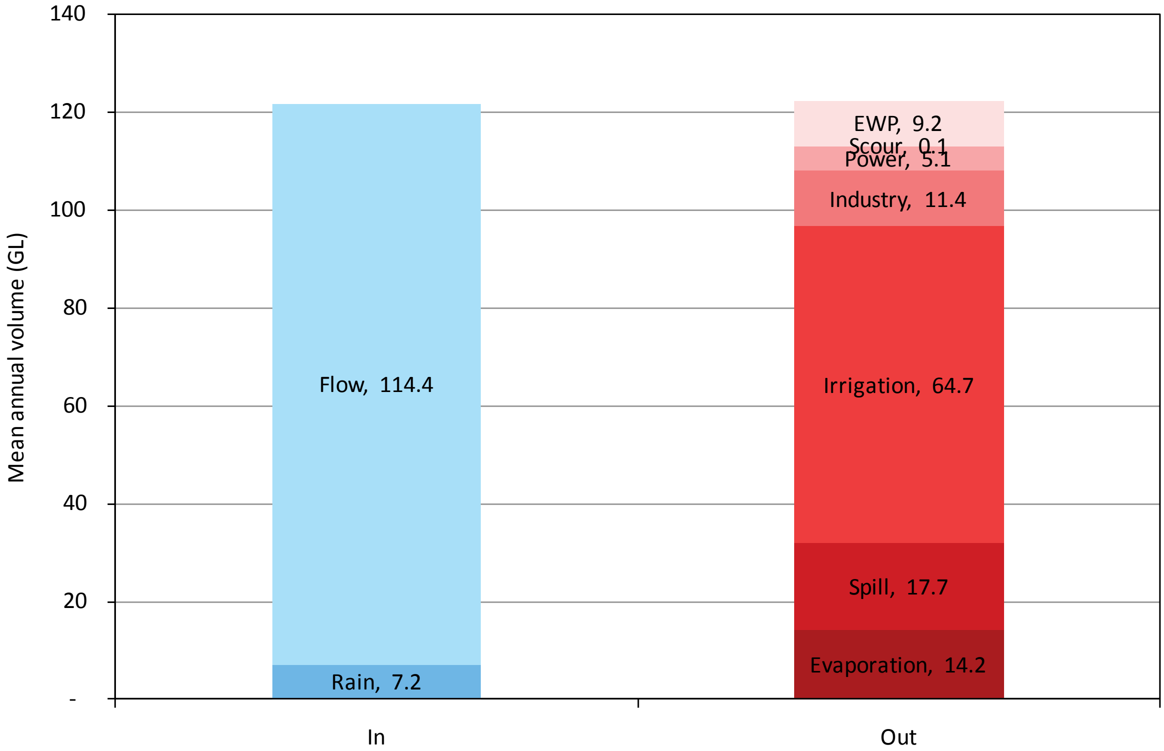

Figure 153 Mean annual water balance for Case 4.1 – 2030 wet future climate

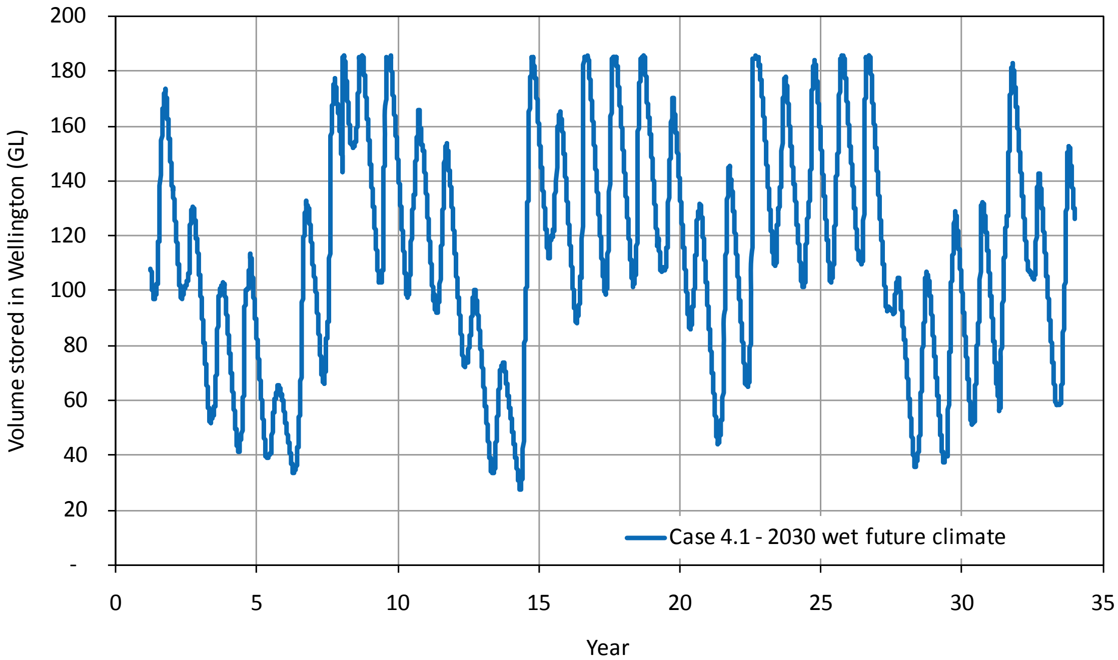

Figure 154 Annual volume stored in Wellington Reservoir for Case 4.1 – 2030 wet future climate

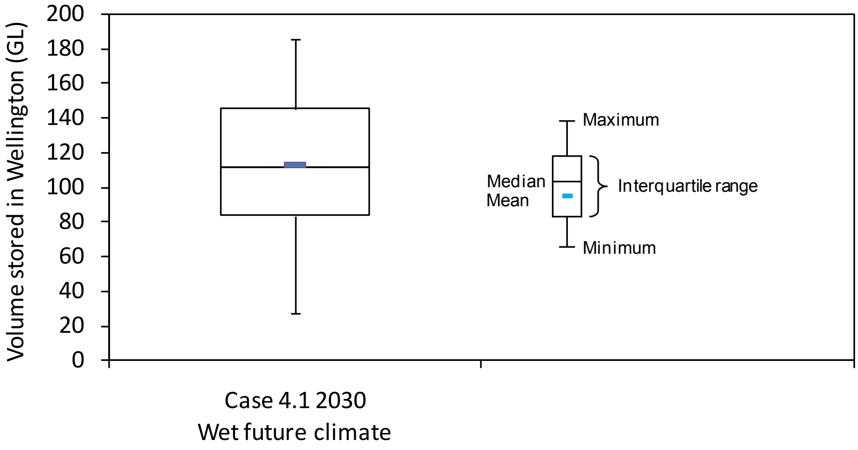

Figure 155 Distribution of annual volume stored in Wellington Reservoir for Case 4.1 – 2030 wet future climate

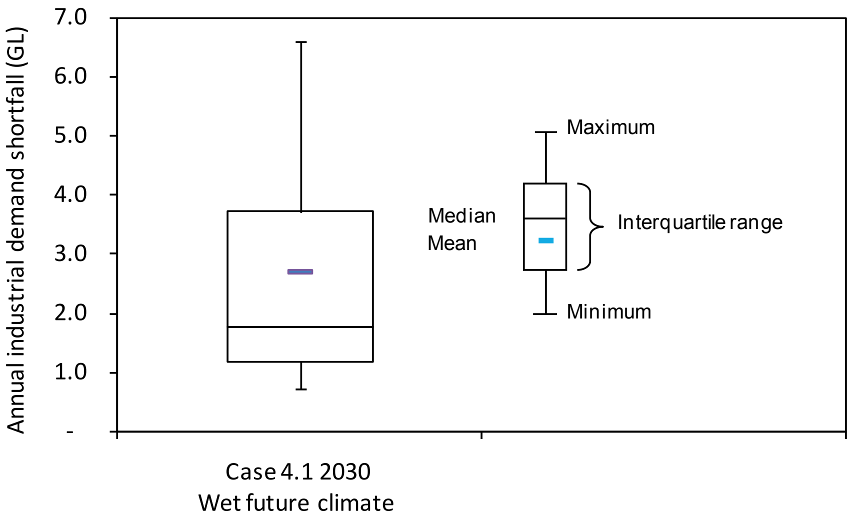

Figure 156 Range of industrial demand shortfalls for Case 4.1 – 2030 wet future climate

Table 51 Annual industrial supply shortfalls for Case 4.1 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.60
Median of the annual shortfalls (GL)	1.76
Mean of the annual shortfalls (GL)	2.70

Case 4.1 – 2030 median future climate

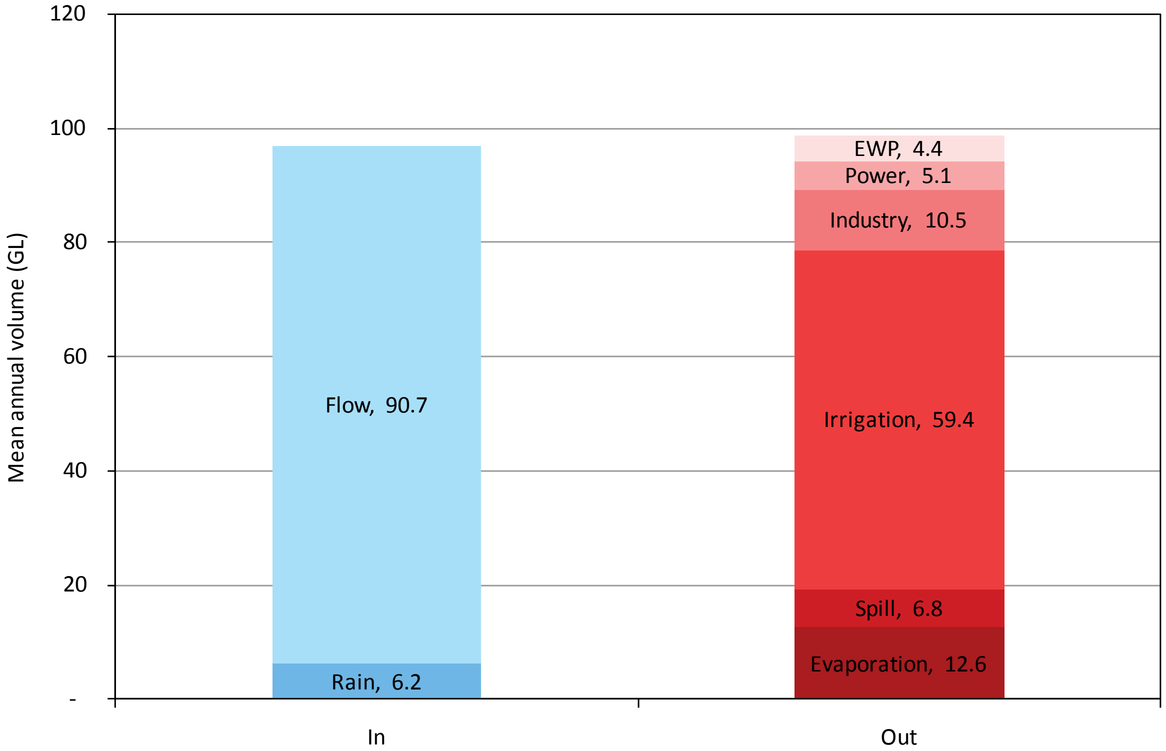

Figure 157 Mean annual water balance for Case 4.1 – 2030 median future climate

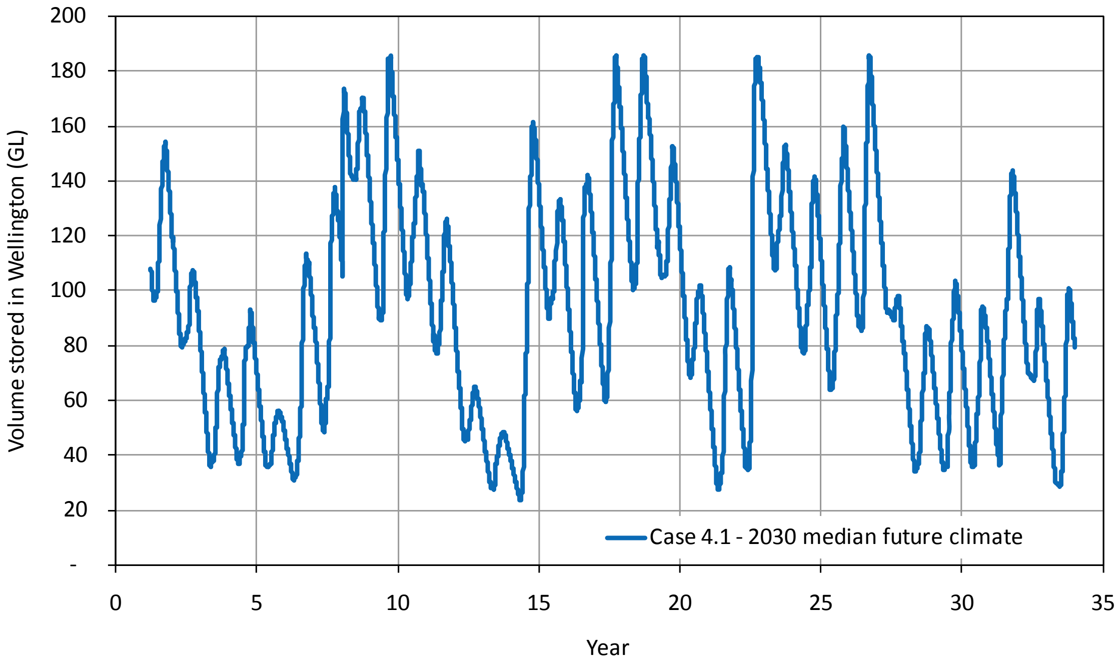

Figure 158 Annual volume stored in Wellington Reservoir for Case 4.1 – 2030 median future climate

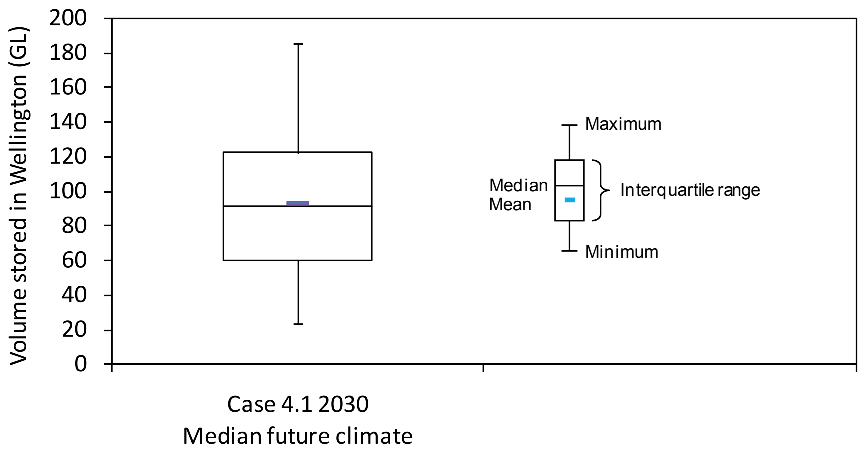

Figure 159 Distribution of annual volume stored in Wellington Reservoir for Case 4.1 – 2030 median future climate

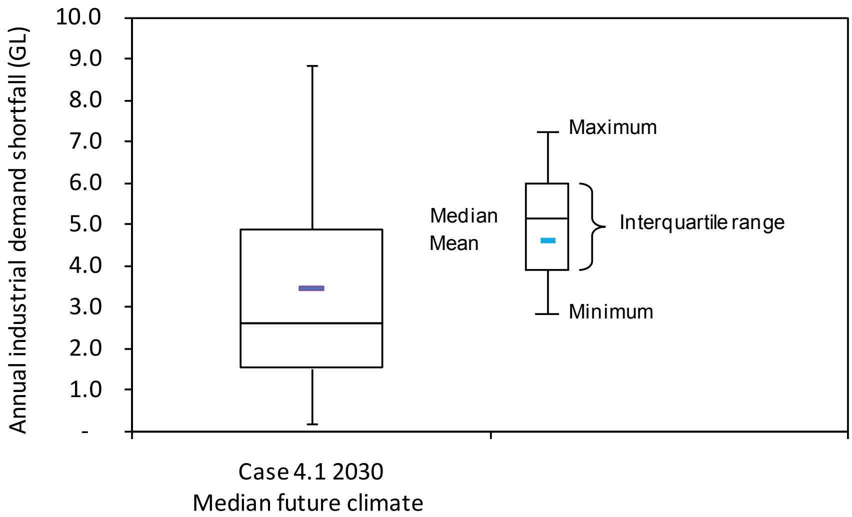

Figure 160 Range of industrial demand shortfalls for Case 4.1 – 2030 median future climate

Table 52 Annual industrial supply shortfalls for Case 4.1 – 2030 median future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	11.0
Median of the annual shortfalls (GL)	4.85
Mean of the annual shortfalls (GL)	5.33

Case 4.1 – 2030 dry future climate

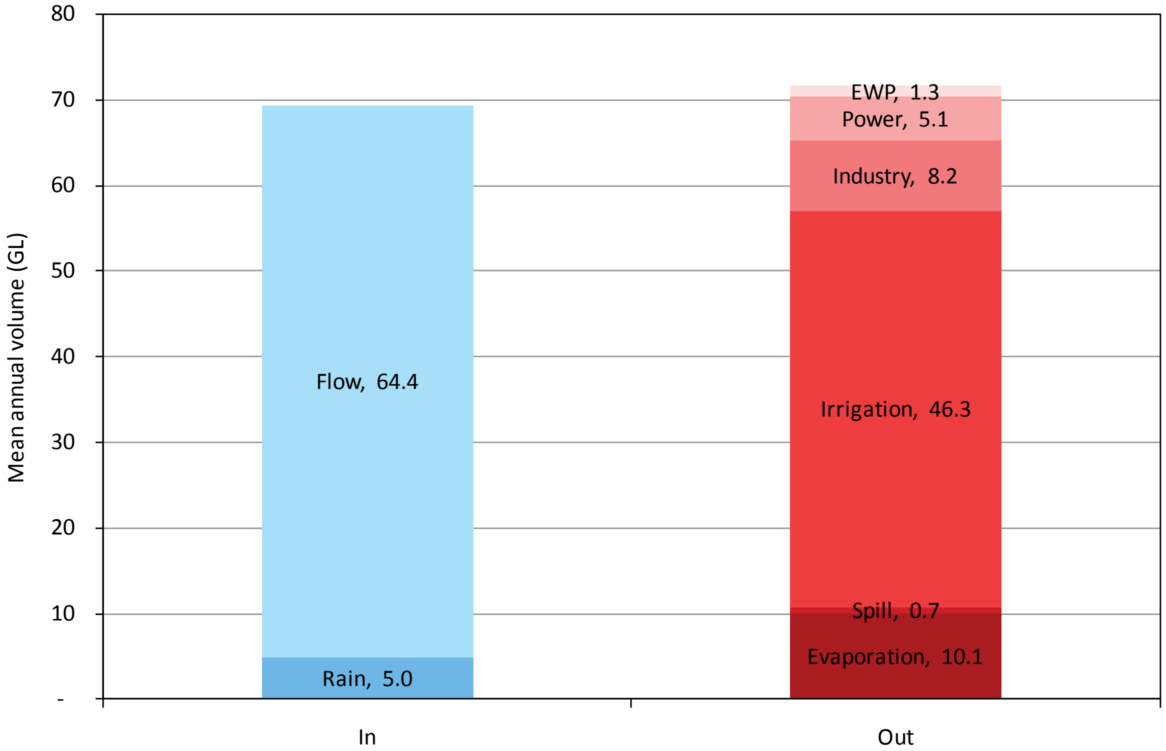

Figure 161 Mean annual water balance for Case 4.1 – 2030 dry future climate

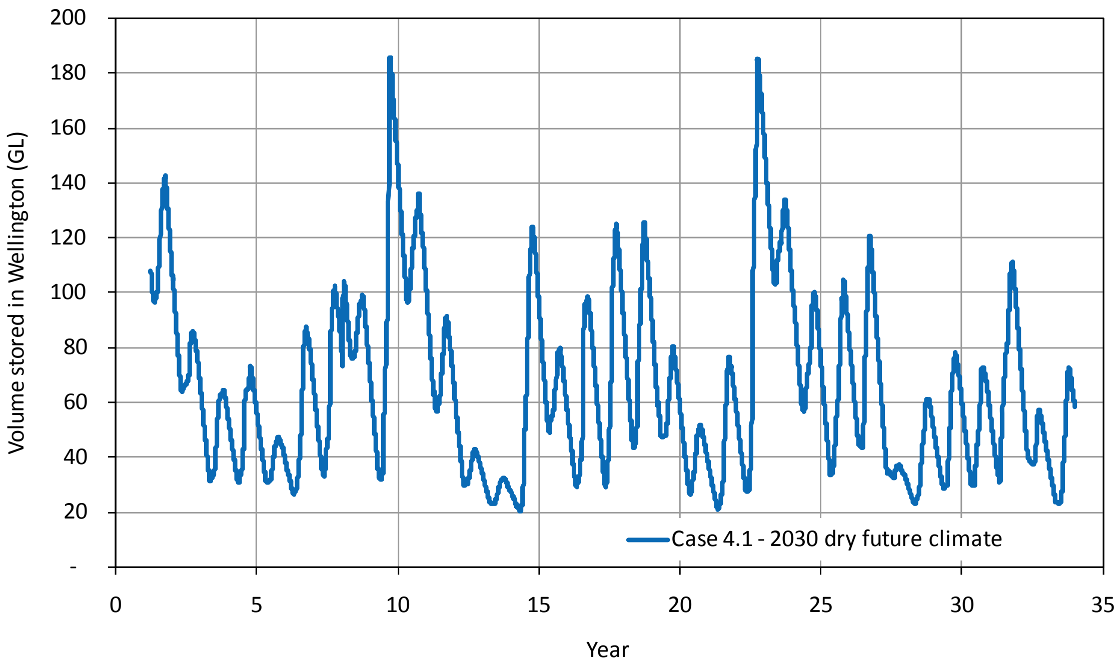

Figure 162 Annual volume stored in Wellington Reservoir for Case 4.1 – 2030 dry future climate

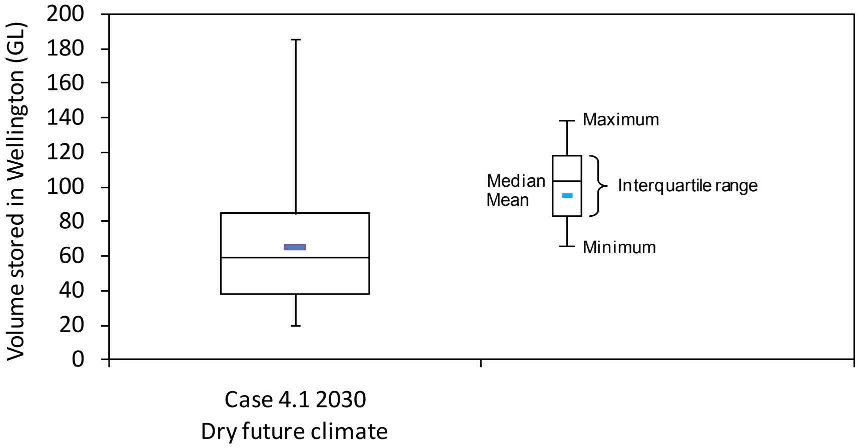

Figure 163 Distribution of annual volume stored in Wellington Reservoir for Case 4.1 – 2030 dry future climate

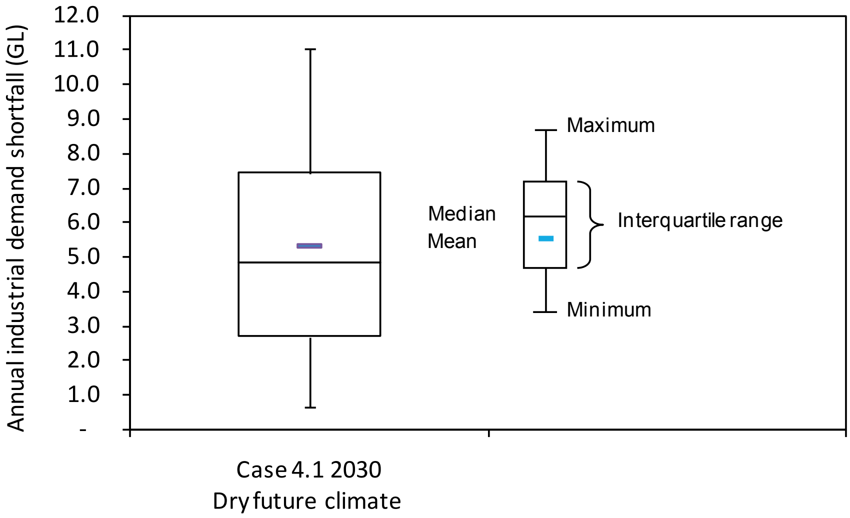

Figure 164 Range of industrial demand shortfalls for Case 4.1 – 2030 dry future climate

Table 53 Annual industrial supply shortfalls for Case 4.1 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	25%
Maximum annual shortfall (GL)	8.06
Median of the annual shortfalls (GL)	1.86
Mean of the annual shortfalls (GL)	3.02

Case 4.2 – historical climate

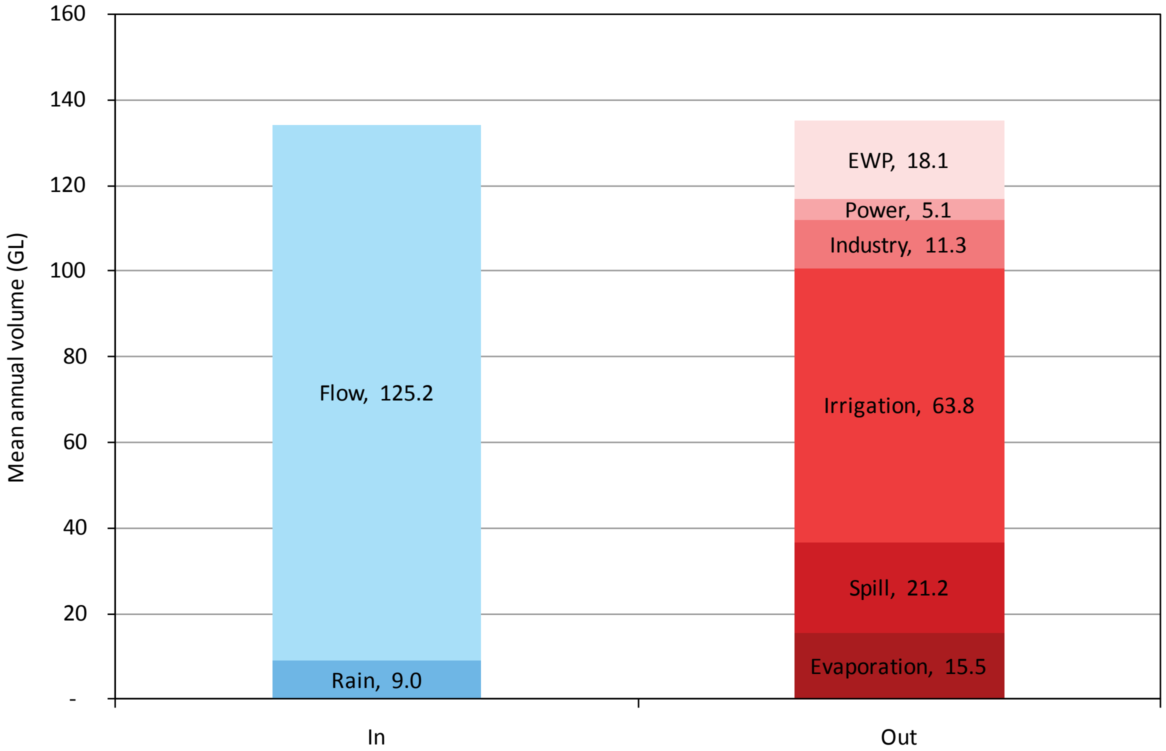

Figure 165 Mean annual water balance for Case 4.2 - historical climate

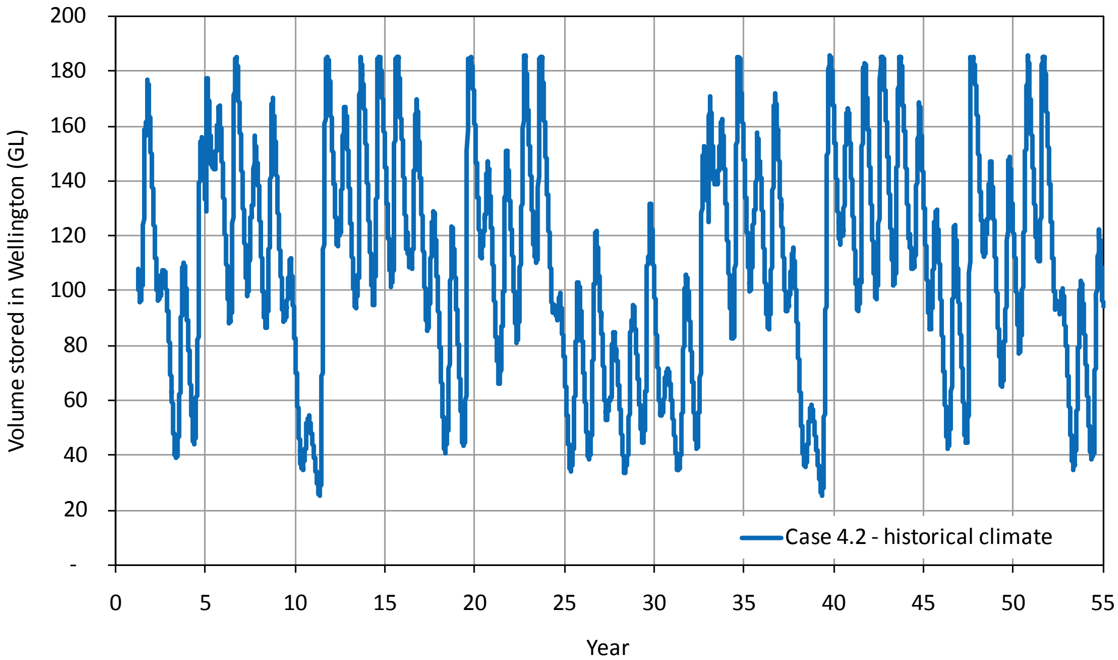

Figure 166 Annual volume stored in Wellington Reservoir for Case 4.2 – historical climate

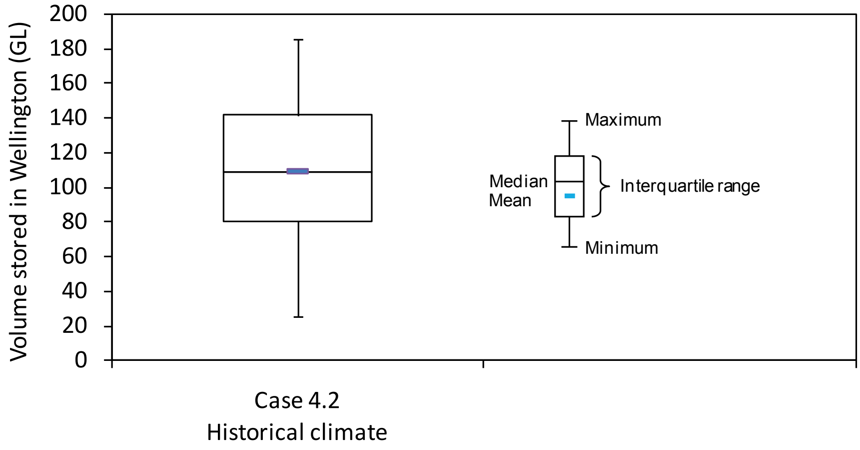

Figure 167 Distribution of annual volume stored in Wellington Reservoir for Case 4.2 – historical climate

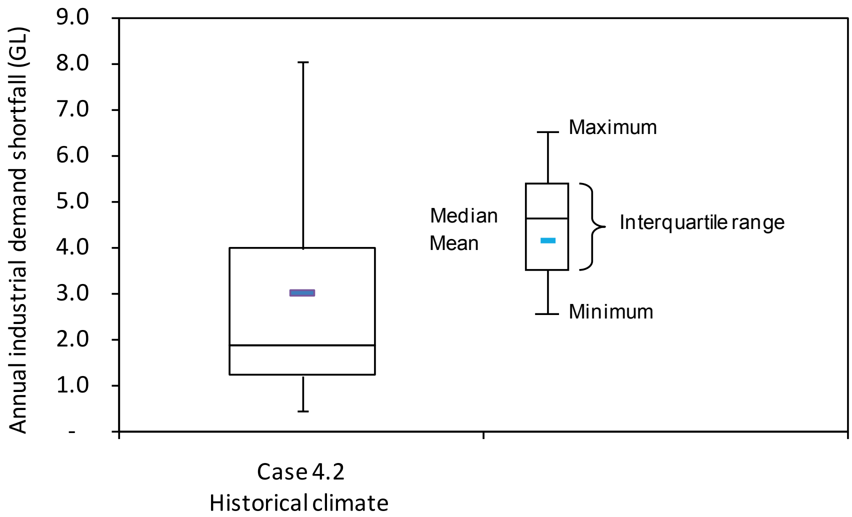

Figure 168 Range of industrial demand shortfalls for Case 4.2 – historical climate

Table 54 Annual industrial supply shortfalls for Case 4.2 – historical climate

	Historical climate
Years with a shortfall in supply	25%
Maximum annual shortfall (GL)	8.06
Median of the annual shortfalls (GL)	1.86
Mean of the annual shortfalls (GL)	3.02

Case 4.2 – 2030 wet future climate

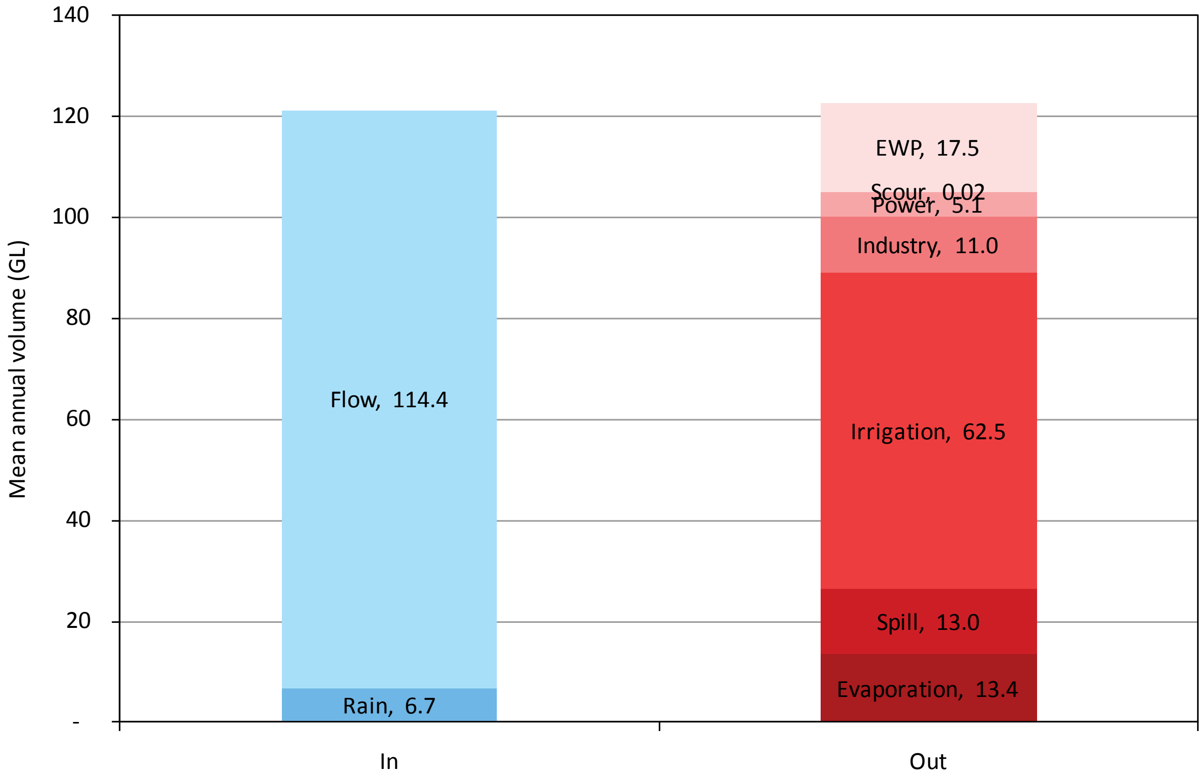

Figure 169 Mean annual water balance for Case 4.2 – 2030 wet future climate

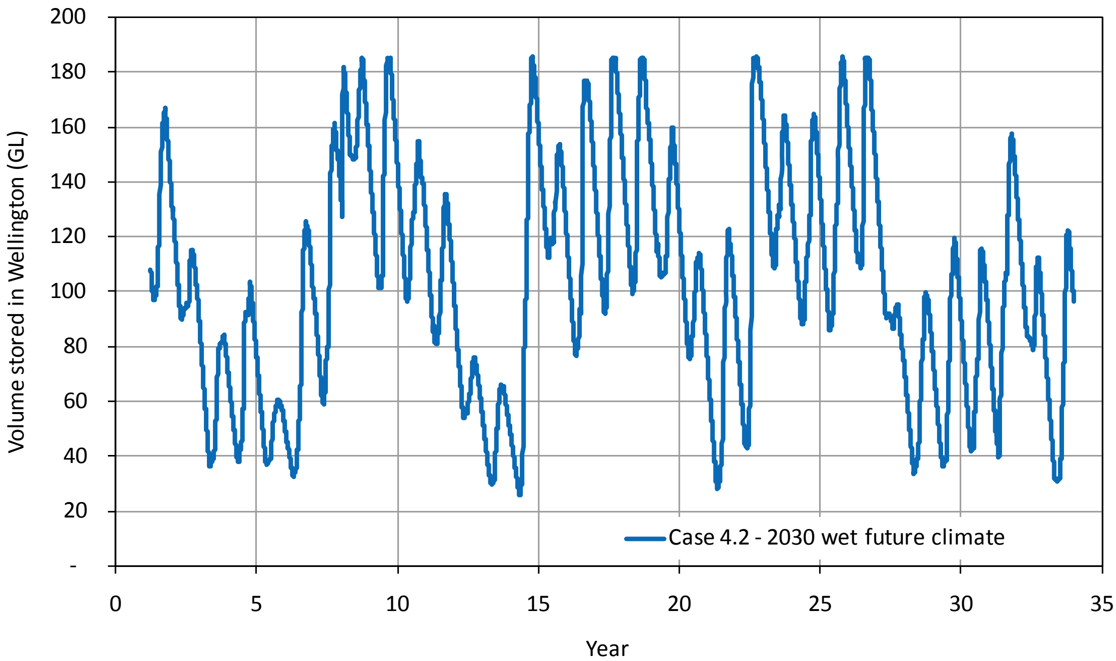

Figure 170 Annual volume stored in Wellington Reservoir for Case 4.2 – 2030 wet future climate

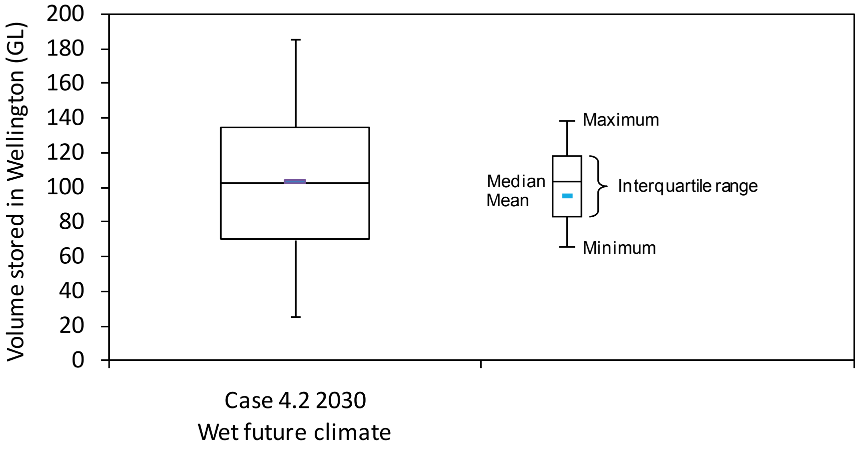

Figure 171 Distribution of annual volume stored in Wellington Reservoir for Case 4.2 – 2030 wet future climate

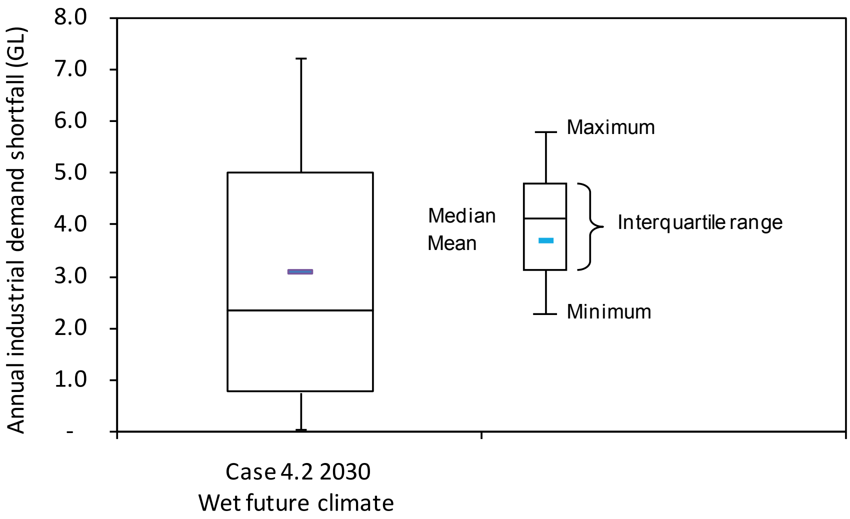

Figure 172 Range of industrial demand shortfalls for Case 4.2 – 2030 wet future climate

Table 55 Annual industrial supply shortfalls for Case 4.2 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	31%
Maximum annual shortfall (GL)	7.22
Median of the annual shortfalls (GL)	2.35
Mean of the annual shortfalls (GL)	3.09

Case 4.2 – 2030 median future climate

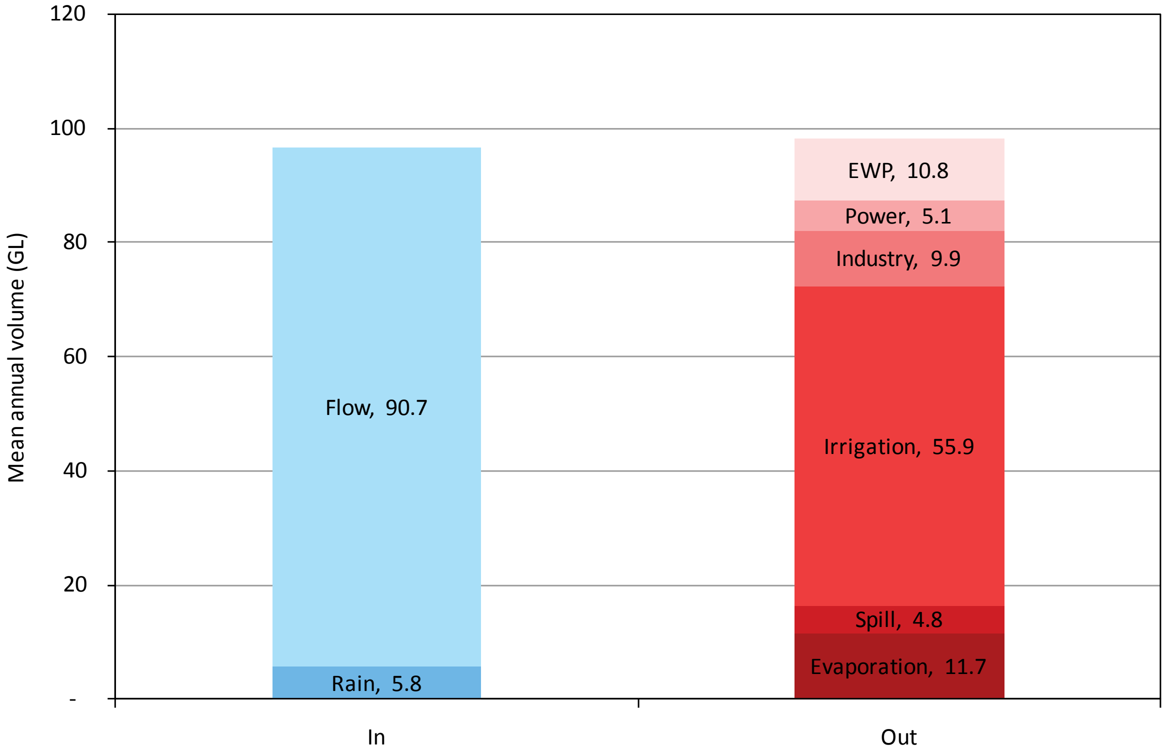

Figure 173 Mean annual water balance for Case 4.2 – 2030 median future climate

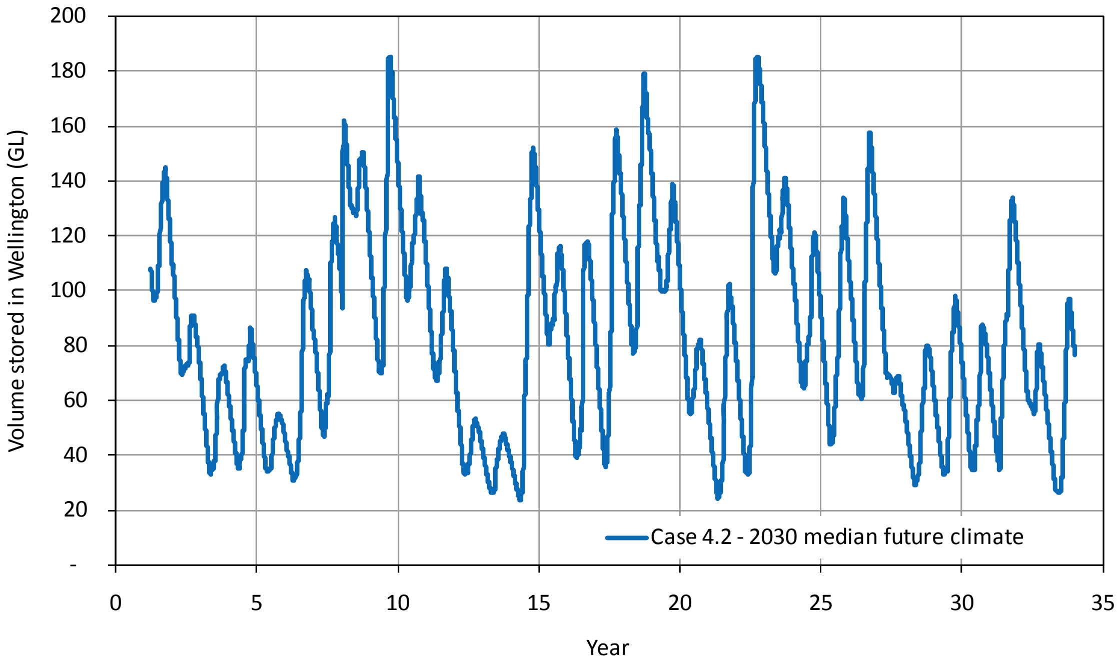

Figure 174 Annual volume stored in Wellington Reservoir for Case 4.2 – 2030 median future climate

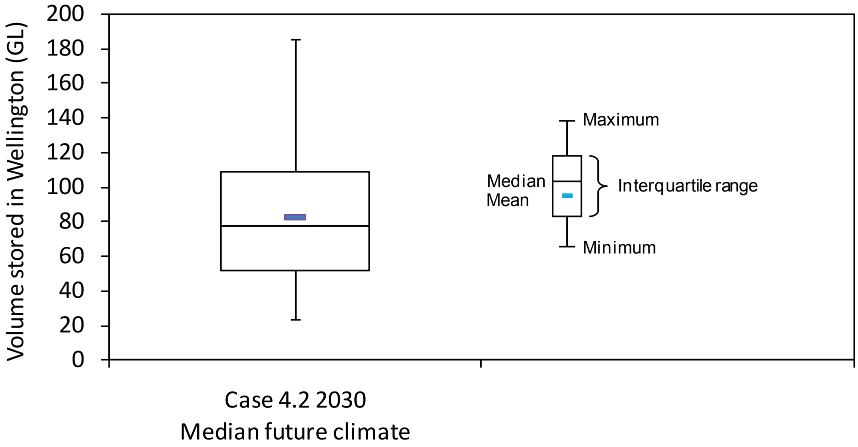

Figure 175 Distribution of annual volume stored in Wellington Reservoir for Case 4.2 – 2030 median future climate

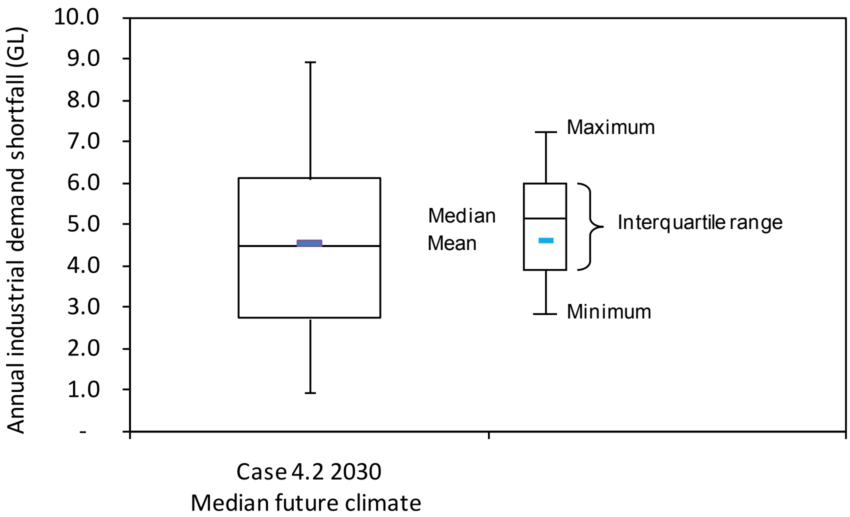

Figure 176 Range of industrial demand shortfalls for Case 4.2 – 2030 median future climate

Table 56 Annual industrial supply shortfalls for Case 4.2 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	47%
Maximum annual shortfall (GL)	8.97
Median of the annual shortfalls (GL)	4.49
Mean of the annual shortfalls (GL)	4.55

Case 4.2 – 2030 dry future climate

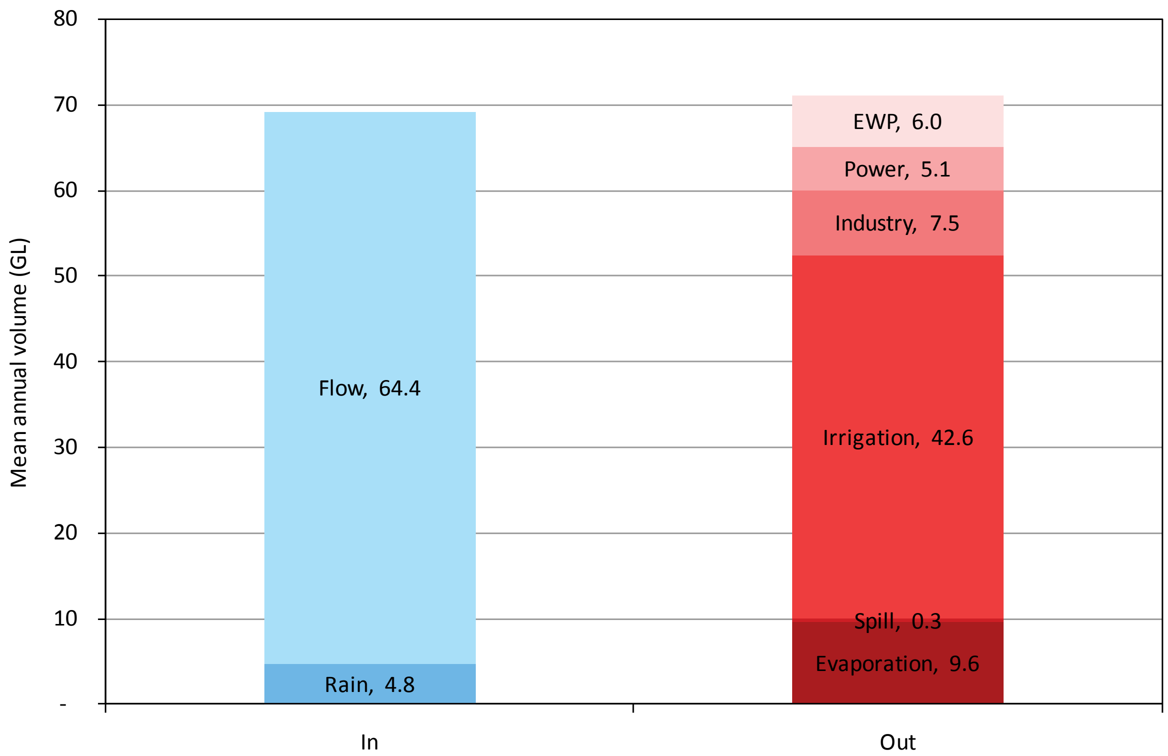

Figure 177 Mean annual water balance for Case 4.2 – 2030 dry future climate

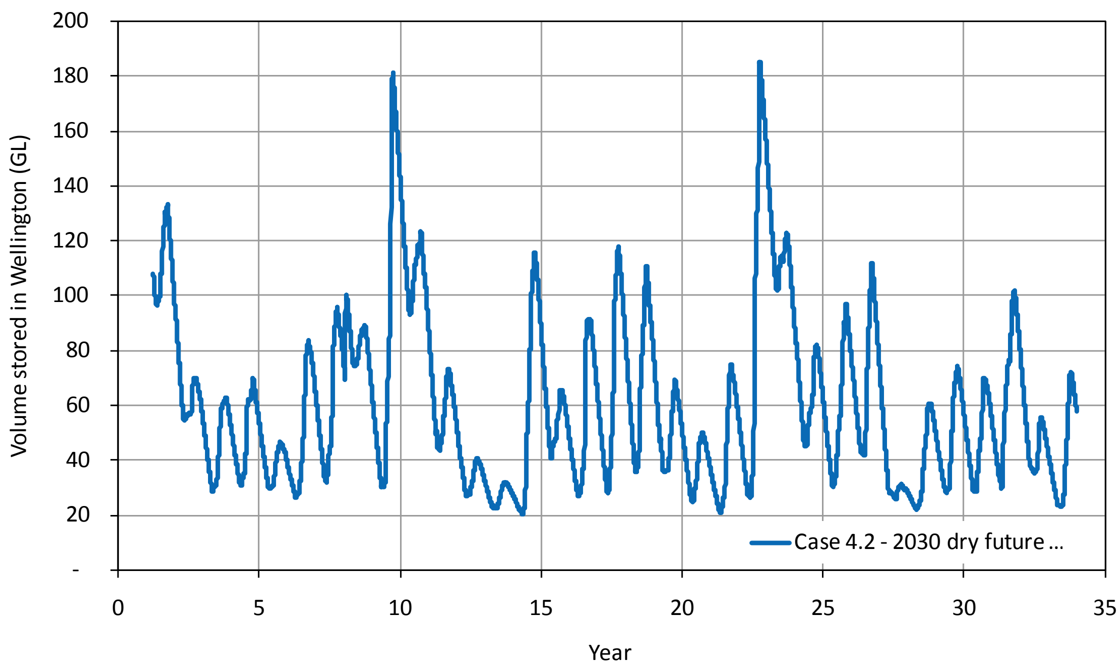

Figure 178 Annual volume stored in Wellington Reservoir for Case 4.2 – 2030 dry future climate

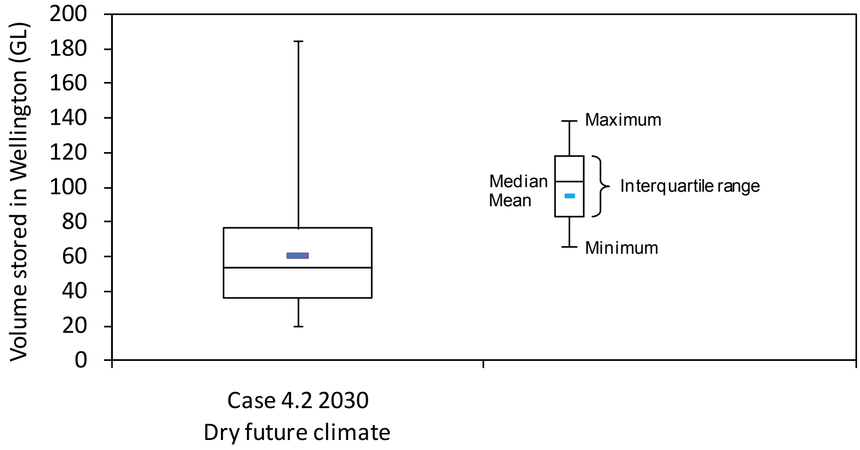

Figure 179 Distribution of annual volume stored in Wellington Reservoir for Case 4.2 – 2030 dry future climate

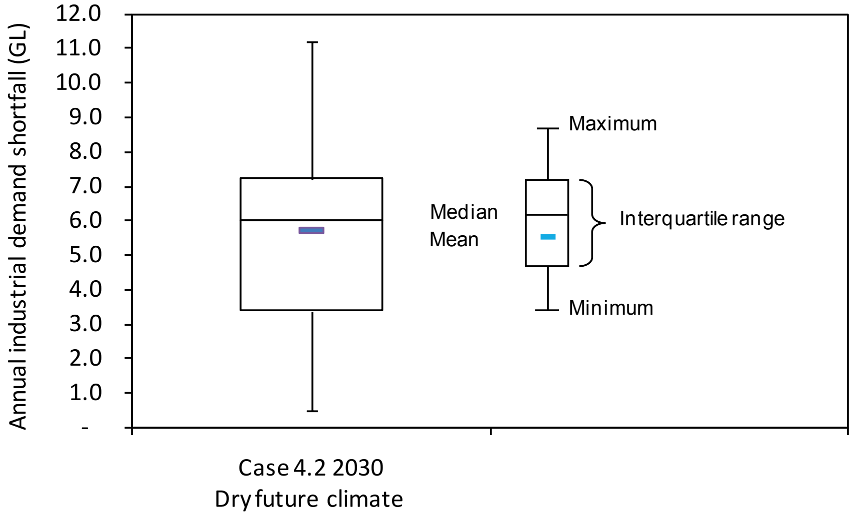

Figure 180 Range of industrial demand shortfalls for Case 4.2 – 2030 dry future climate

Table 57 Annual industrial supply shortfalls for Case 4.2 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	78%
Maximum annual shortfall (GL)	11.2
Median of the annual shortfalls (GL)	6.00
Mean of the annual shortfalls (GL)	5.74

Case 4.3 – historical climate

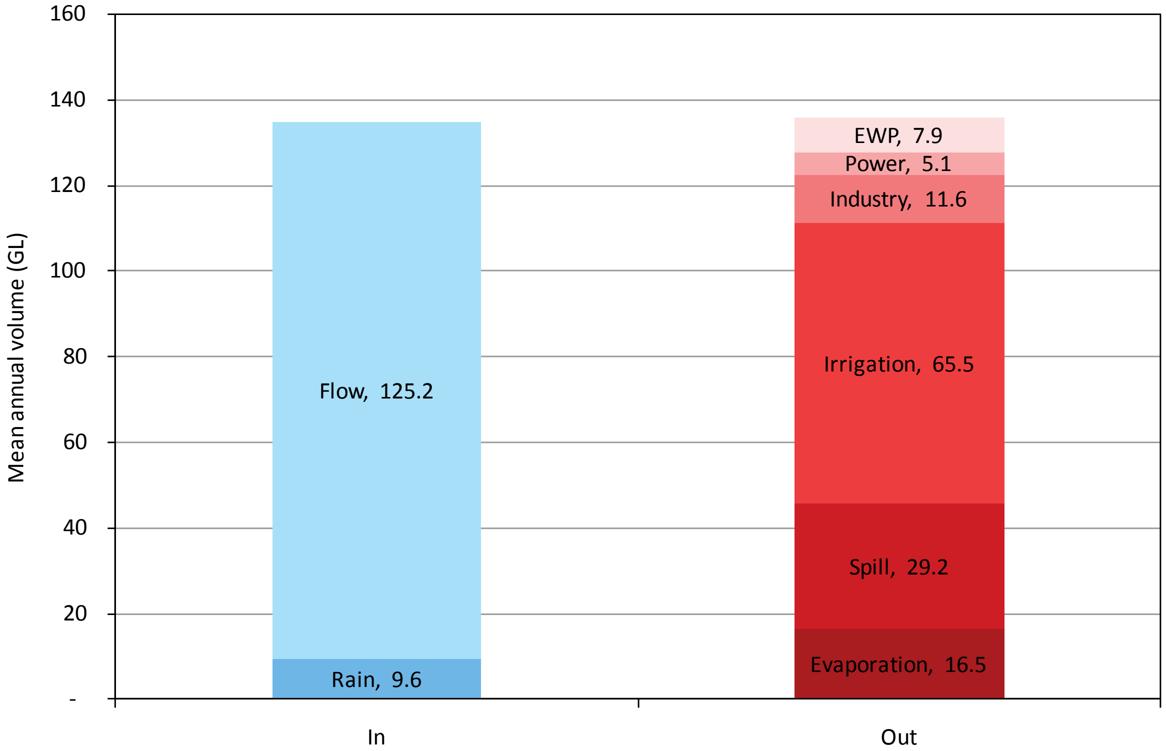

Figure 181 Mean annual water balance for Case 4.3 - historical climate

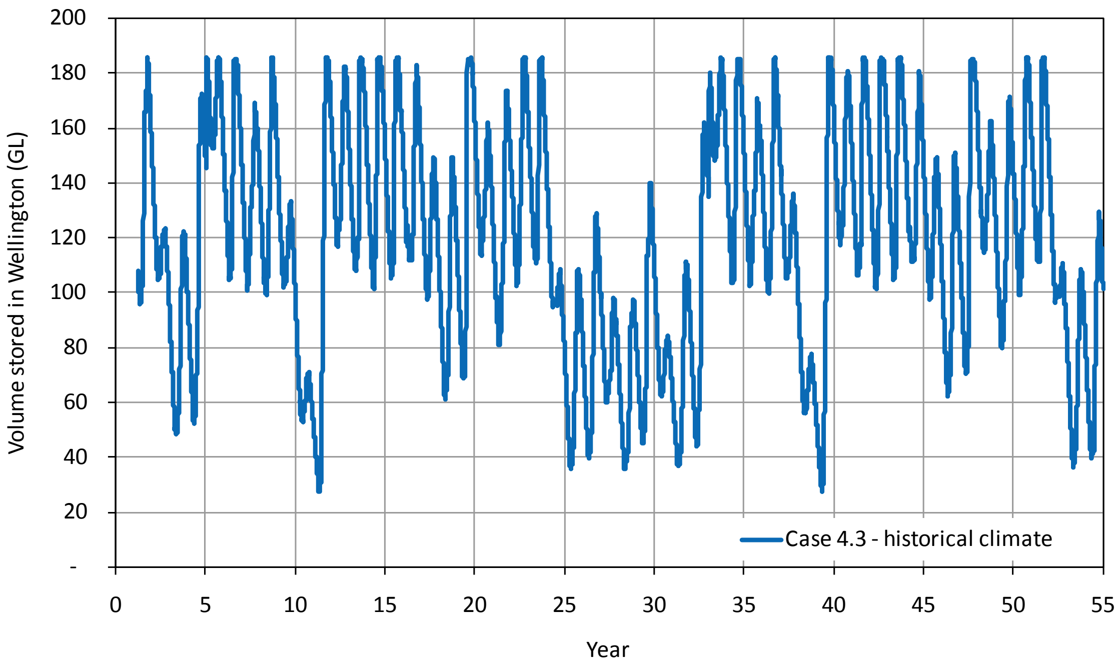

Figure 182 Annual volume stored in Wellington Reservoir for Case 4.3 – historical climate

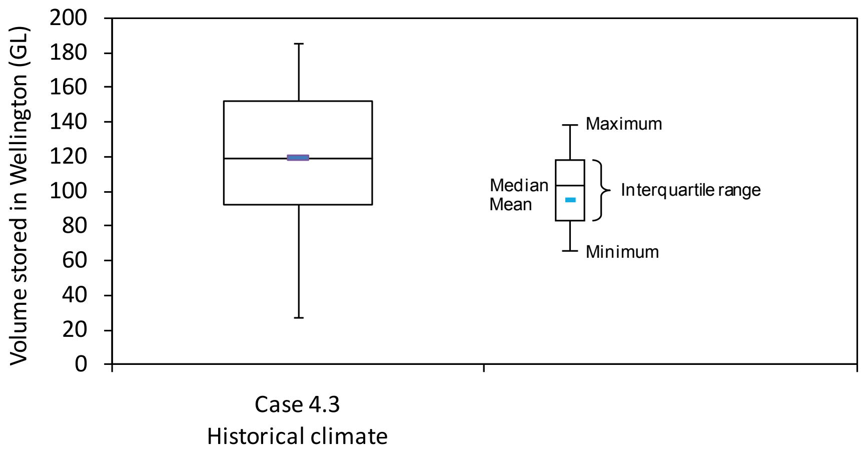

Figure 183 Distribution of annual volume stored in Wellington Reservoir for Case 4.3 – historical climate

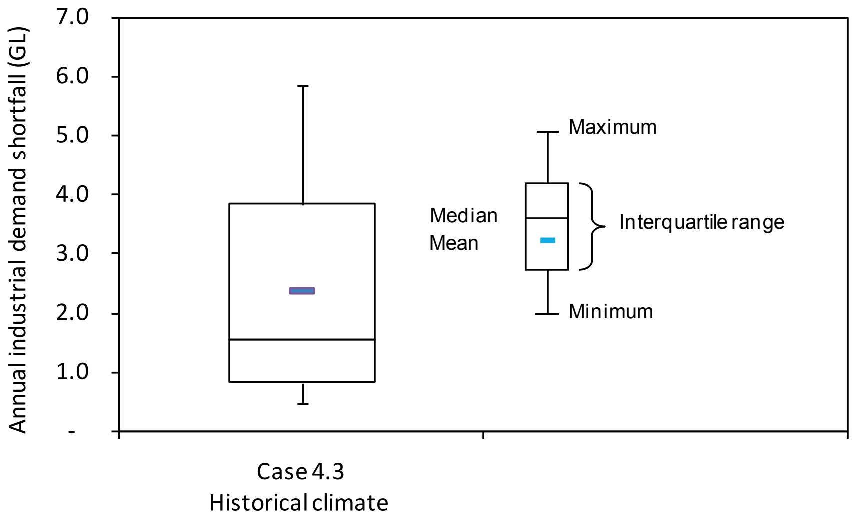

Figure 184 Range of industrial demand shortfalls for Case 4.3 – historical climate

Table 58 Annual industrial supply shortfalls for Case 4.3 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	5.84
Median of the annual shortfalls (GL)	1.56
Mean of the annual shortfalls (GL)	2.38

Case 4.3 – 2030 wet future climate

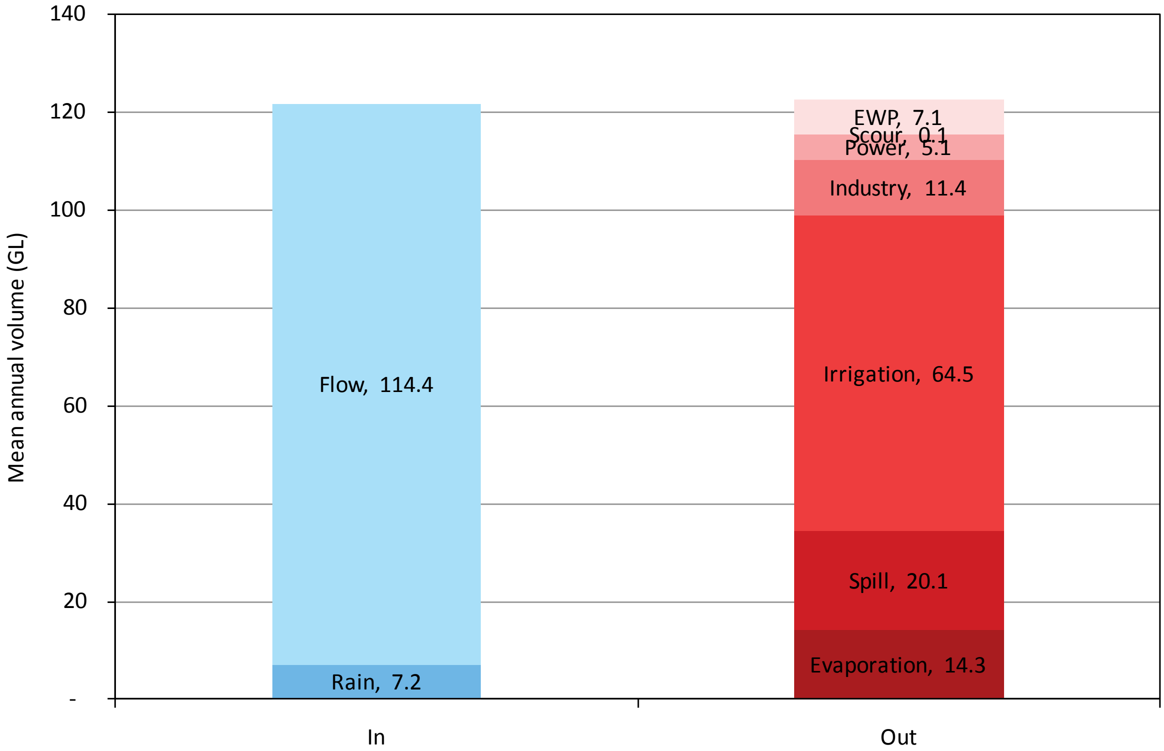

Figure 185 Mean annual water balance for Case 4.3 – 2030 wet future climate

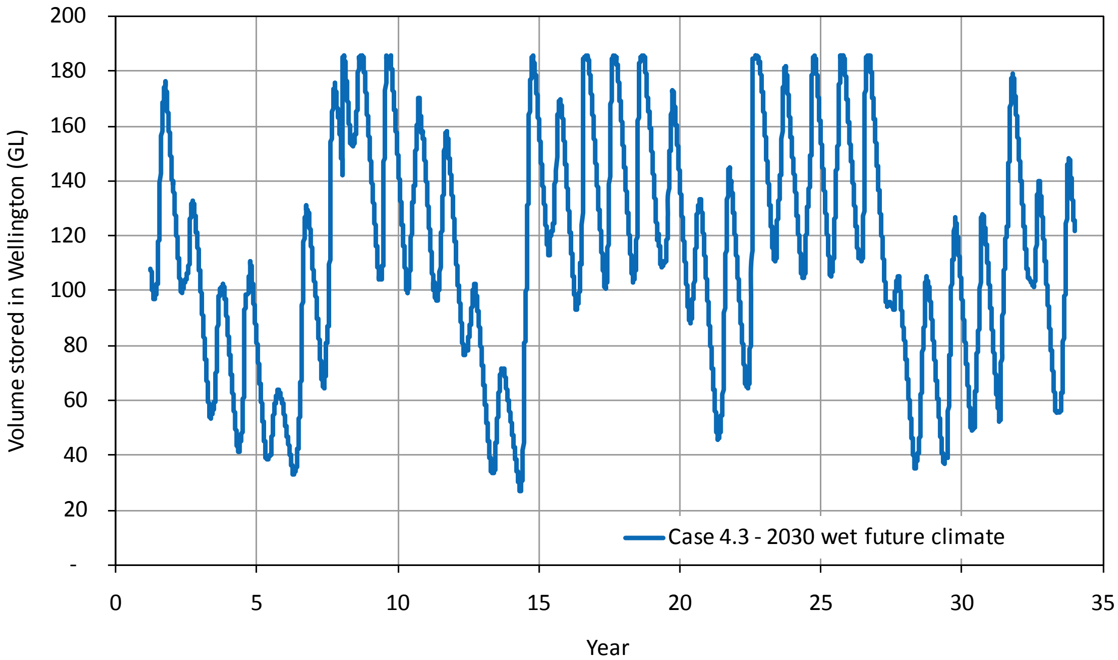

Figure 186 Annual volume stored in Wellington Reservoir for Case 4.3 – 2030 wet future climate

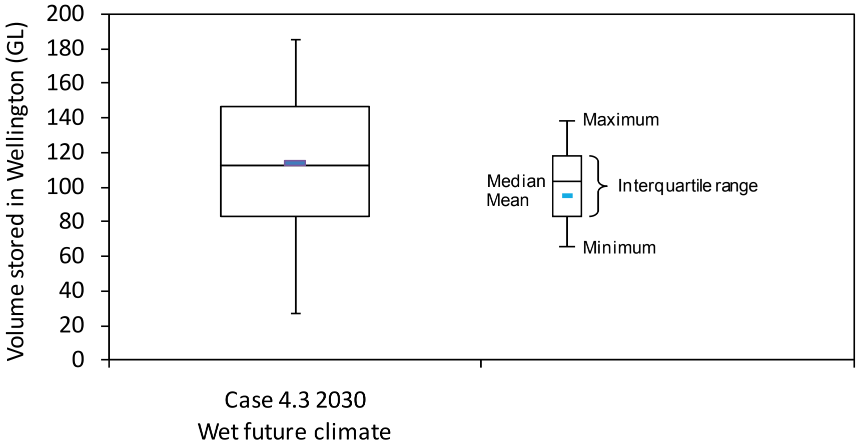

Figure 187 Distribution of annual volume stored in Wellington Reservoir for Case 4.3 – 2030 wet future climate

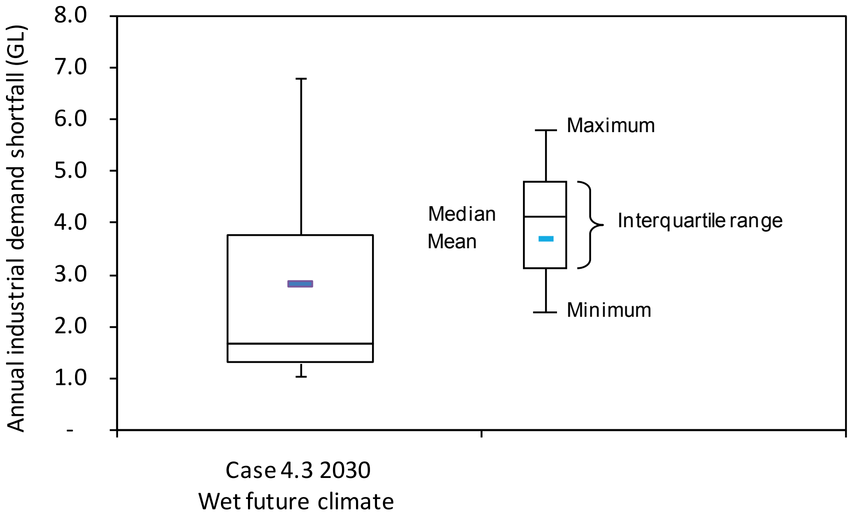

Figure 188 Range of industrial demand shortfalls for Case 4.3 – 2030 wet future climate

Table 59 Annual industrial supply shortfalls for Case 4.3 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	22%
Maximum annual shortfall (GL)	6.80
Median of the annual shortfalls (GL)	1.67
Mean of the annual shortfalls (GL)	2.81

Case 4.3 – 2030 median future climate

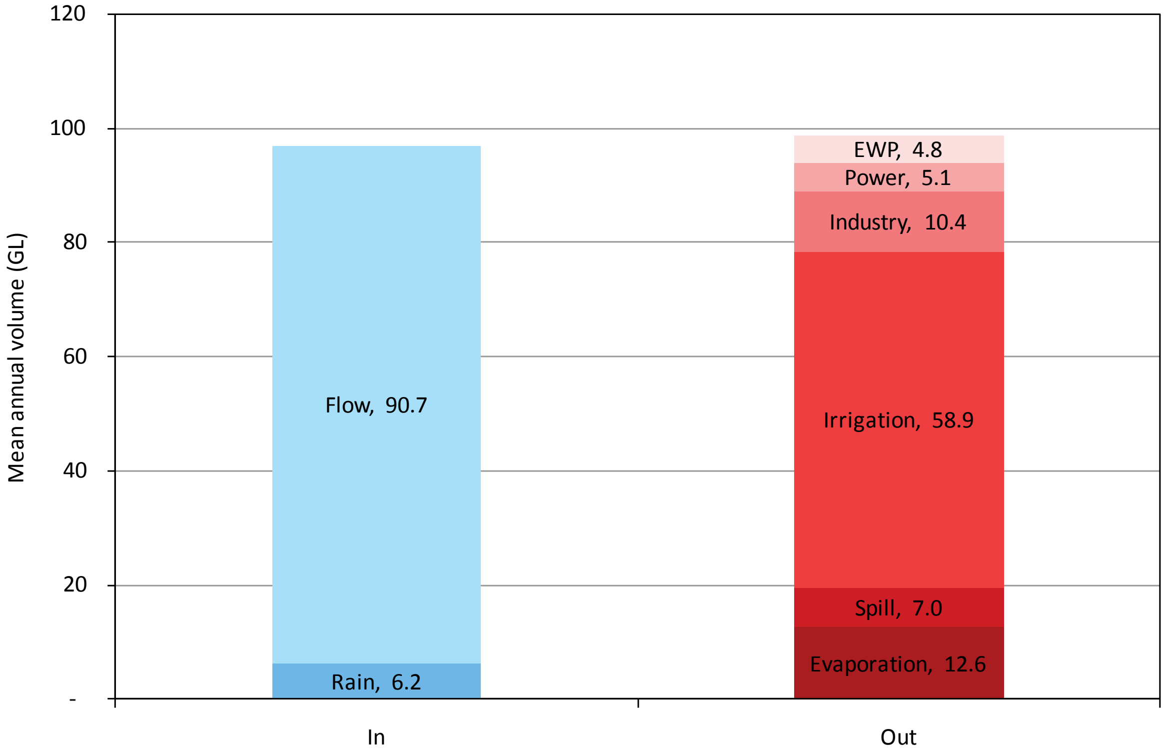

Figure 189 Mean annual water balance for Case 4.3 – 2030 median future climate

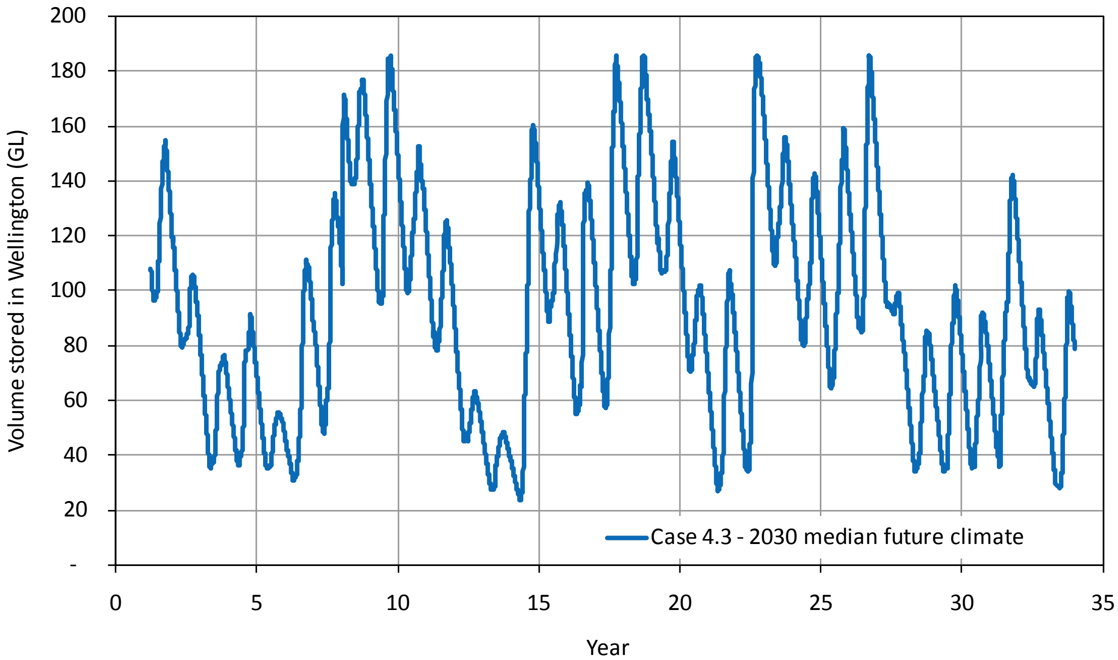

Figure 190 Annual volume stored in Wellington Reservoir for Case 4.3 – 2030 median future climate

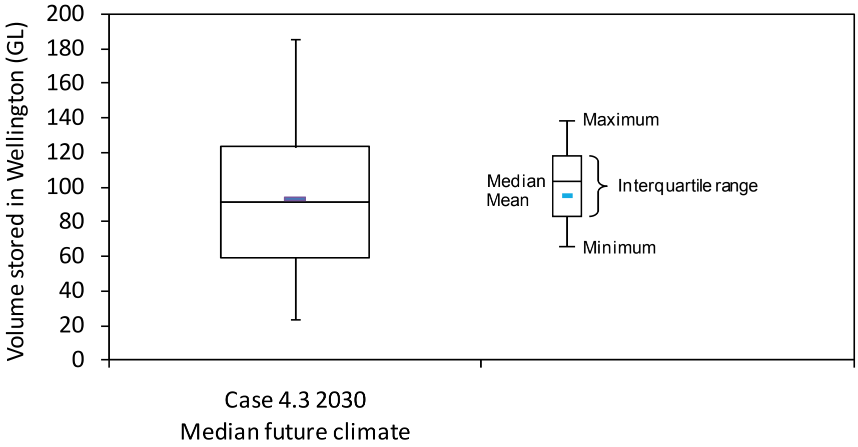

Figure 191 Distribution of annual volume stored in Wellington Reservoir for Case 4.3 – 2030 median future climate

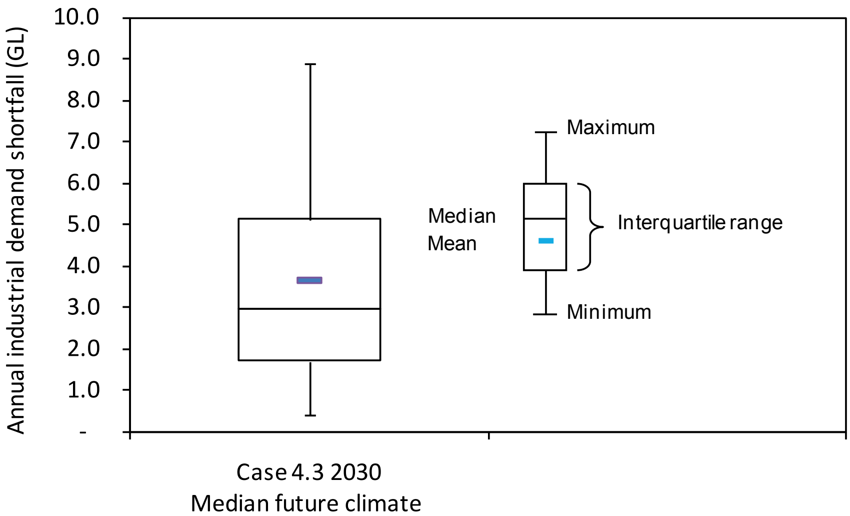

Figure 192 Range of industrial demand shortfalls for Case 4.3 – 2030 median future climate

Table 60 Annual industrial supply shortfalls for Case 4.3 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	44%
Maximum annual shortfall (GL)	8.89
Median of the annual shortfalls (GL)	2.98
Mean of the annual shortfalls (GL)	3.65

Case 4.3 – 2030 dry future climate

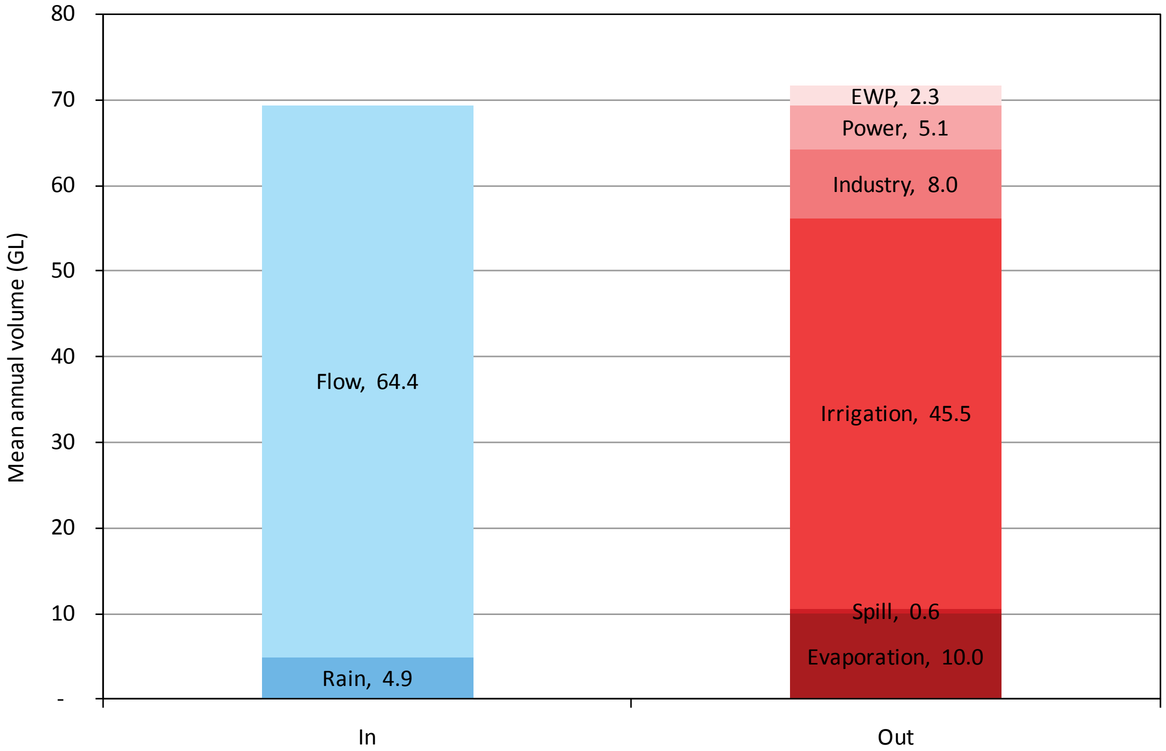

Figure 193 Mean annual water balance for Case 4.3 – 2030 dry future climate

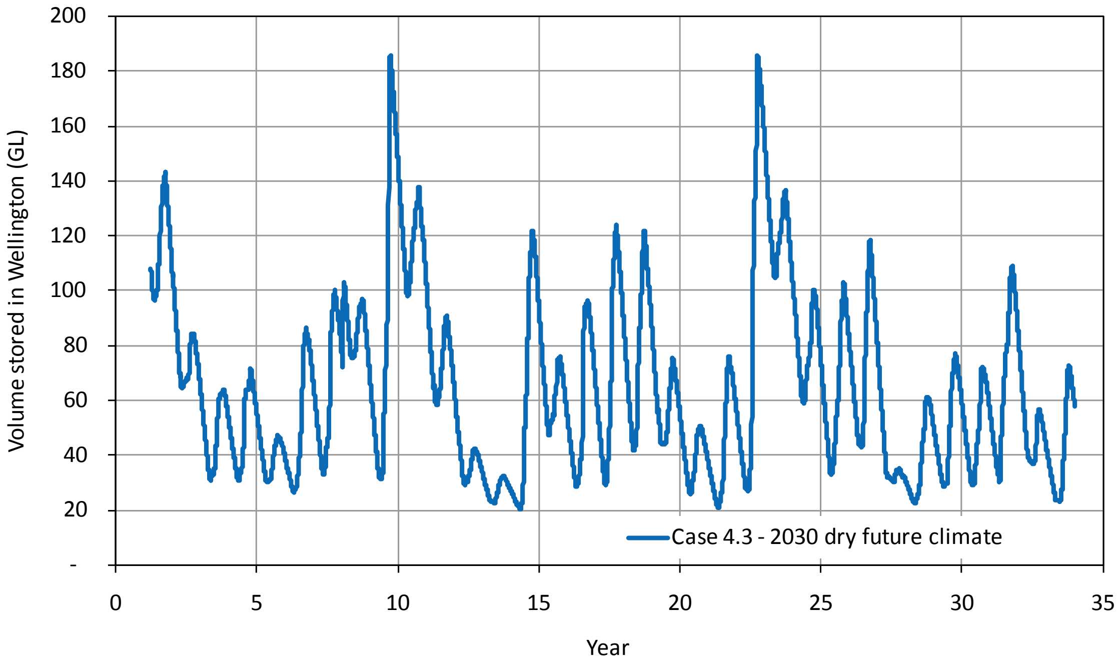

Figure 194 Annual volume stored in Wellington Reservoir for Case 4.3 – 2030 dry future climate

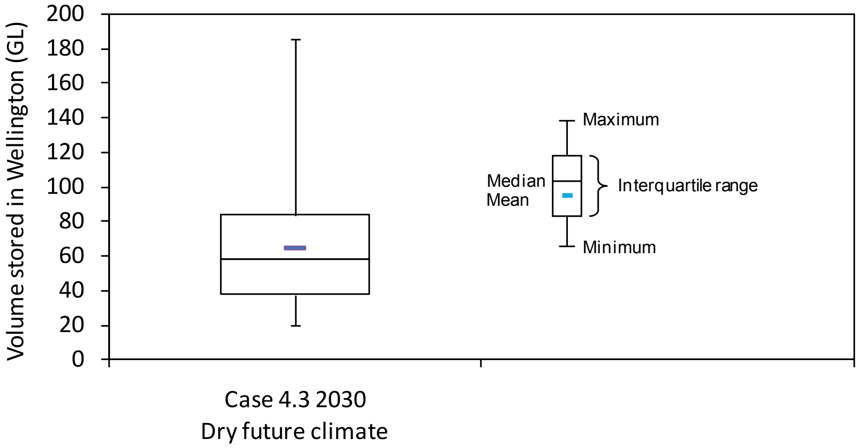

Figure 195 Distribution of annual volume stored in Wellington Reservoir for Case 4.3 – 2030 dry future climate

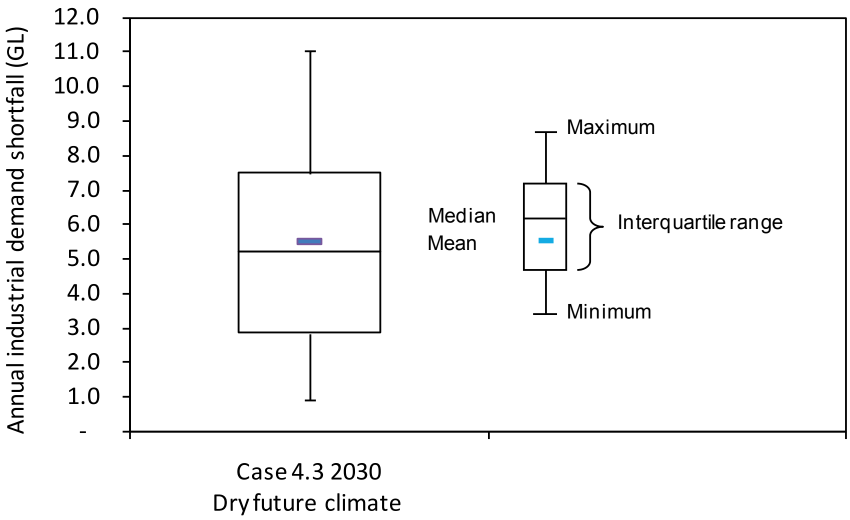

Figure 196 Range of industrial demand shortfalls for Case 4.3 – 2030 dry future climate

Table 61 Annual industrial supply shortfalls for Case 4.3 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	72%
Maximum annual shortfall (GL)	11.0
Median of the annual shortfalls (GL)	5.23
Mean of the annual shortfalls (GL)	5.51

Case 4.4 – historical climate

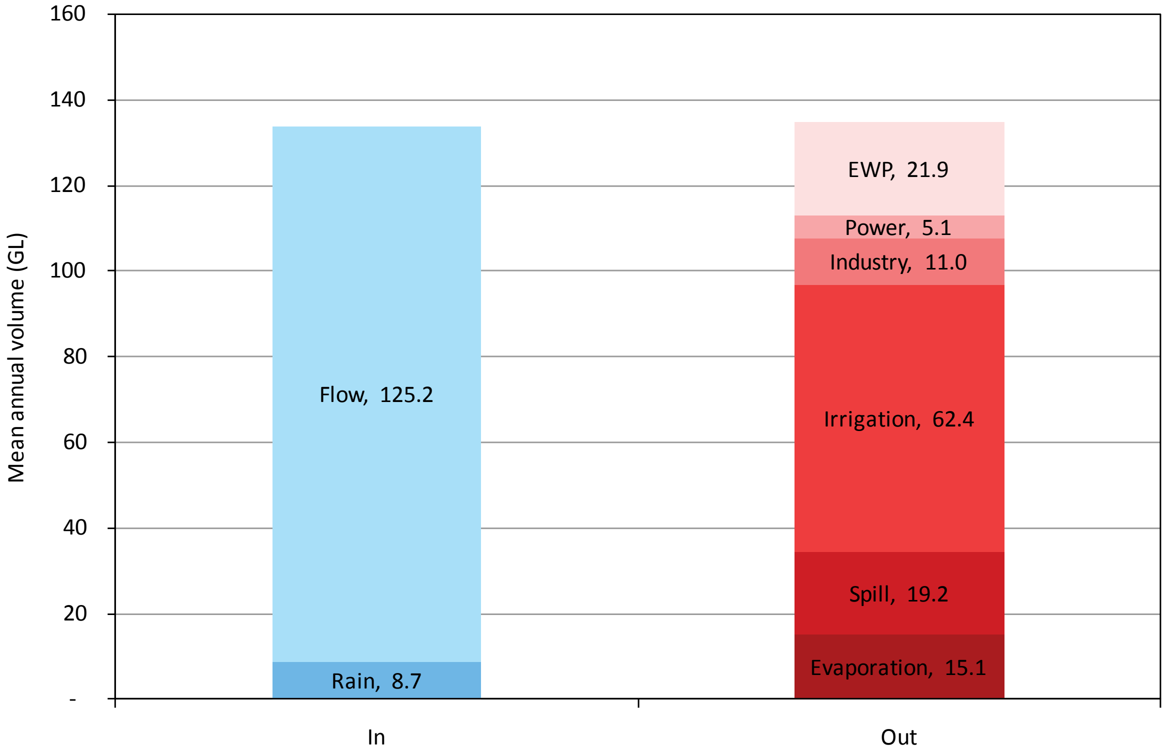

Figure 197 Mean annual water balance for Case 4.4 - historical climate

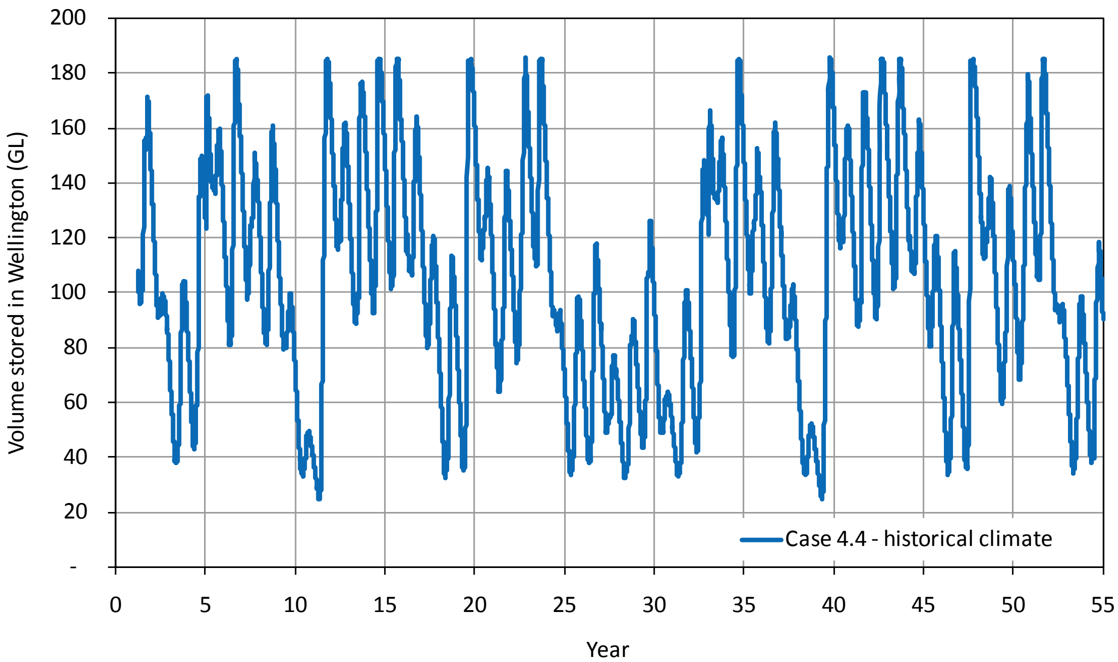

Figure 198 Annual volume stored in Wellington Reservoir for Case 4.4 – historical climate

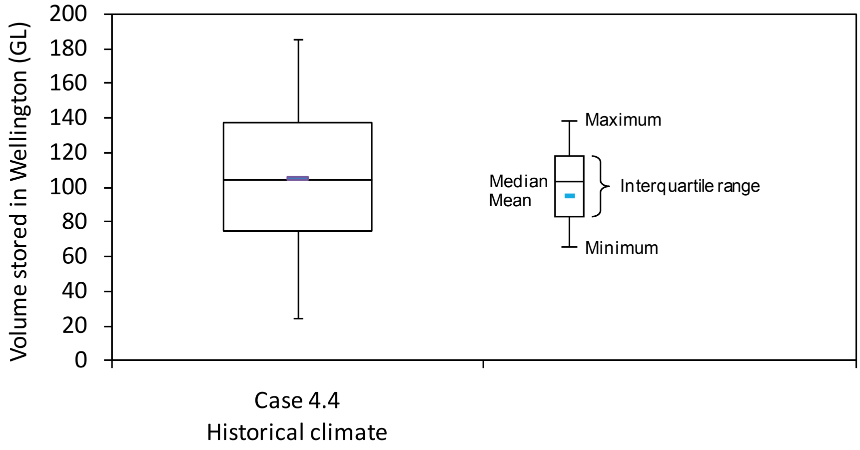

Figure 199 Distribution of annual volume stored in Wellington Reservoir for Case 4.4 – historical climate

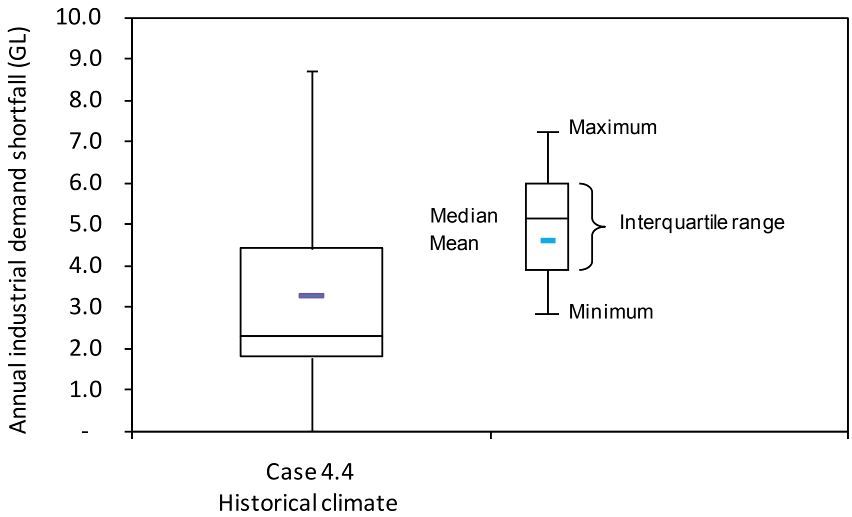

Figure 200 Range of industrial demand shortfalls for Case 4.4 – historical climate

Table 62 Annual industrial supply shortfalls for Case 4.4 – historical climate

	Historical climate
Years with a shortfall in supply	30%
Maximum annual shortfall (GL)	8.72
Median of the annual shortfalls (GL)	2.32
Mean of the annual shortfalls (GL)	3.28

Case 4.5 – historical climate

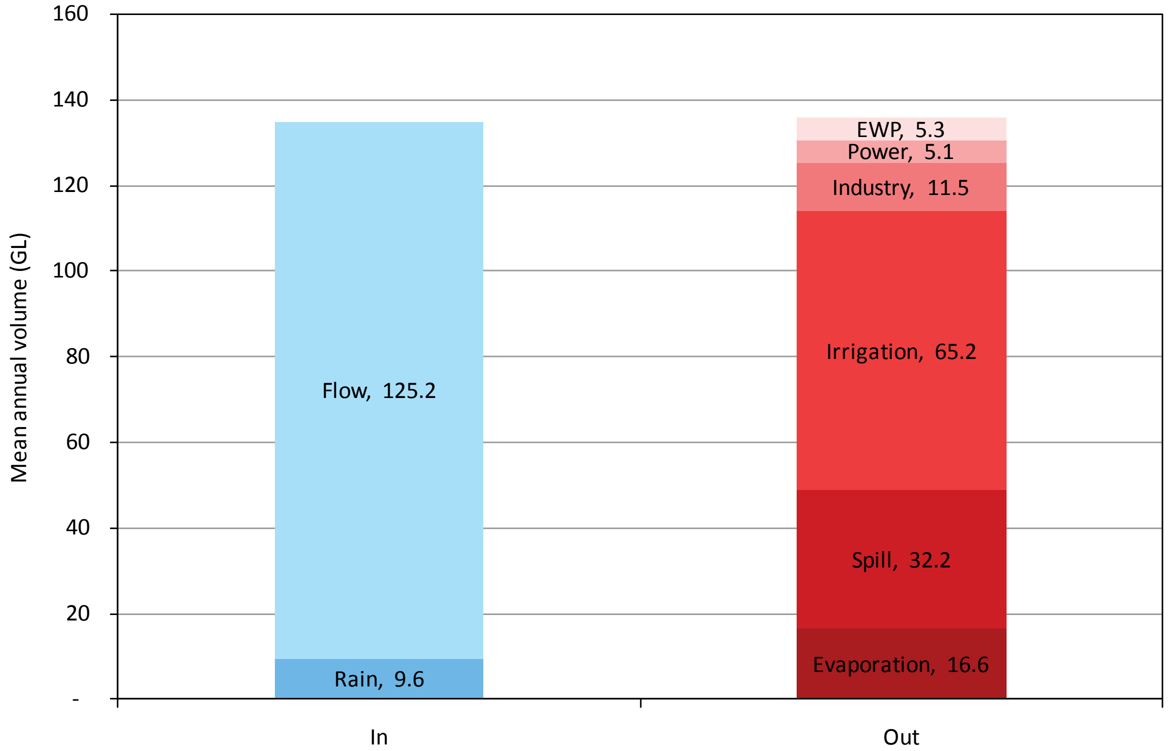

Figure 201 Mean annual water balance for Case 4.5 - historical climate

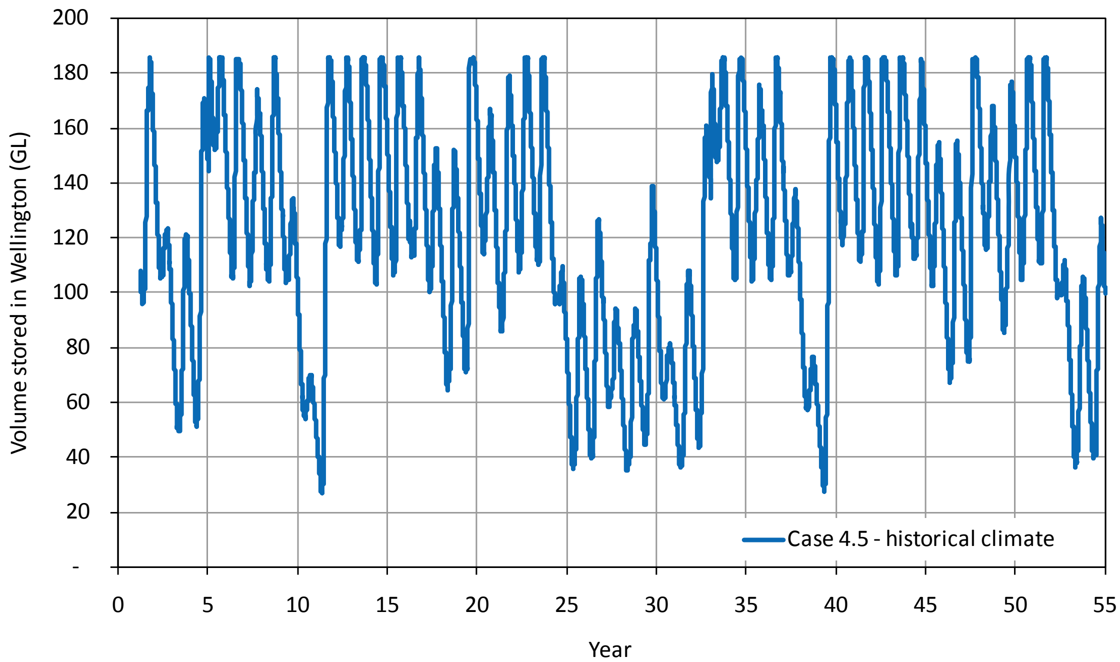

Figure 202 Annual volume stored in Wellington Reservoir for Case 4.5 – historical climate

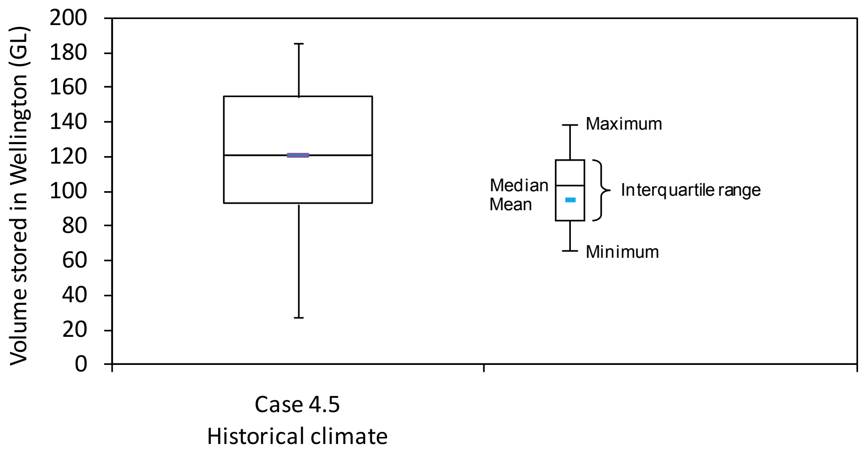

Figure 203 Distribution of annual volume stored in Wellington Reservoir for Case 4.5 – historical climate

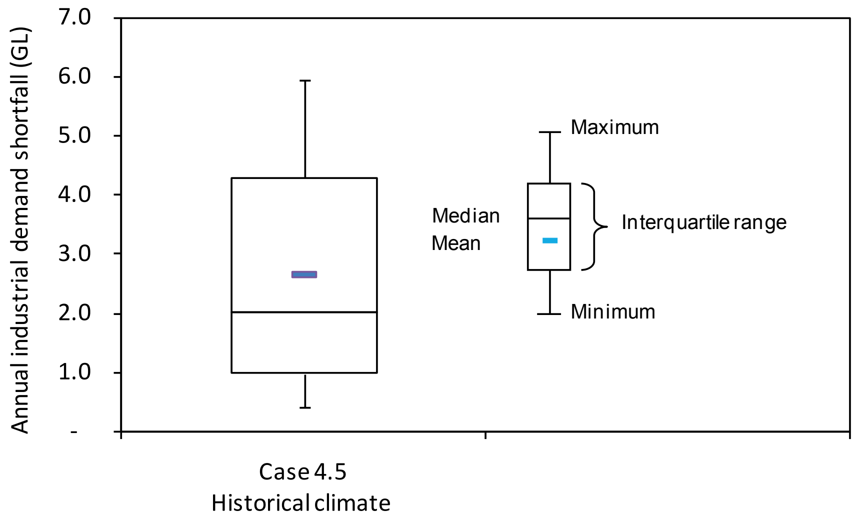

Figure 204 Range of industrial demand shortfalls for Case 4.5 – historical climate

Table 63 Annual industrial supply shortfalls for Case 4.5 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	5.96
Median of the annual shortfalls (GL)	2.01
Mean of the annual shortfalls (GL)	2.65

Case 4.6 – historical climate

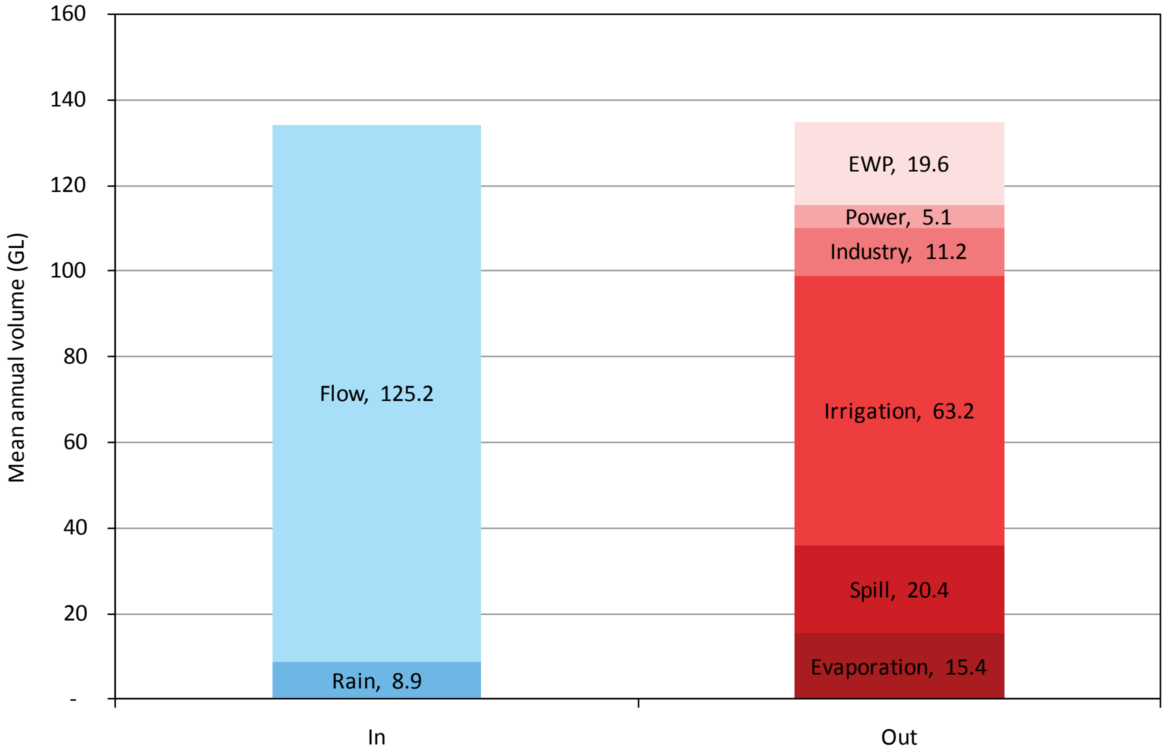

Figure 205 Mean annual water balance for Case 4.6 - historical climate

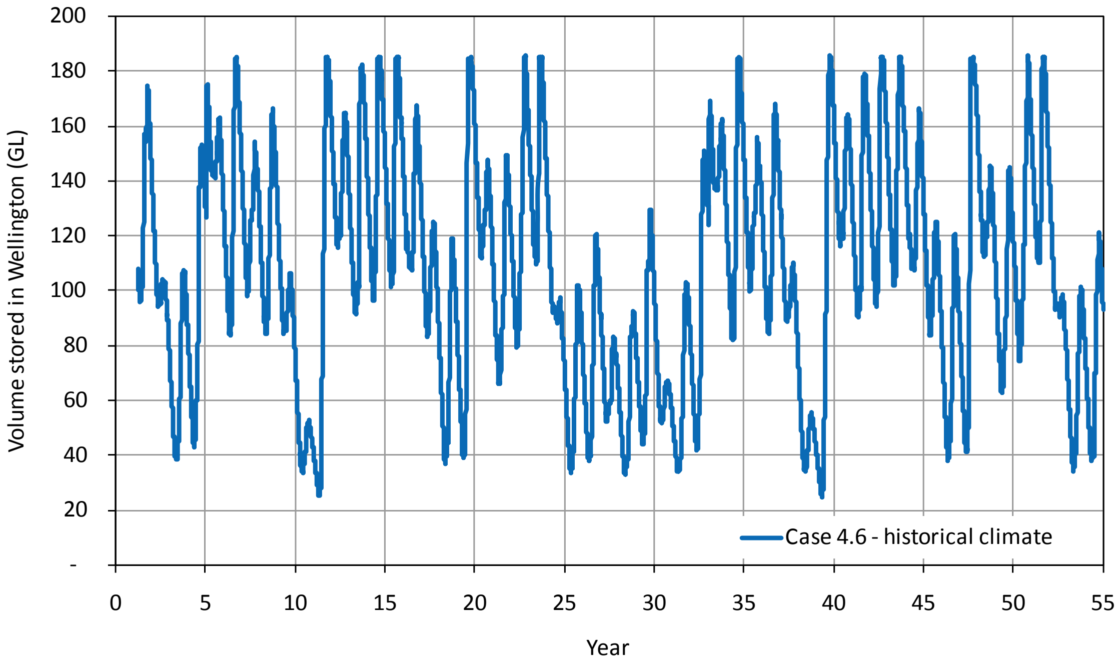

Figure 206 Annual volume stored in Wellington Reservoir for Case 4.6 – historical climate

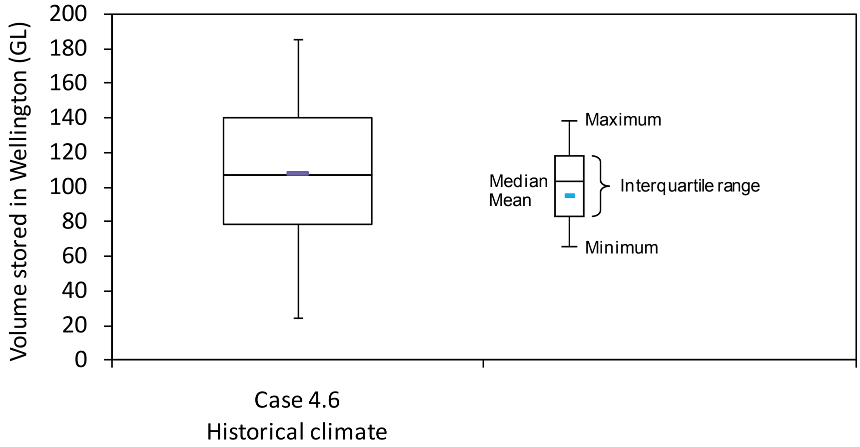

Figure 207 Distribution of annual volume stored in Wellington Reservoir for Case 4.6 – historical climate

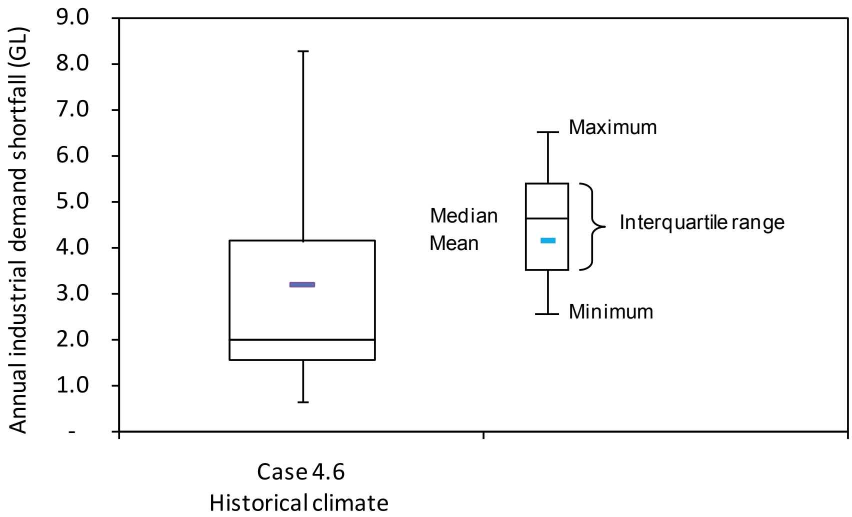

Figure 208 Range of industrial demand shortfalls for Case 4.6 – historical climate

Table 64 Annual industrial supply shortfalls for Case 4.6 – historical climate

	Historical climate
Years with a shortfall in supply	26%
Maximum annual shortfall (GL)	8.29
Median of the annual shortfalls (GL)	2.00
Mean of the annual shortfalls (GL)	3.19

Case 4.7 – historical climate

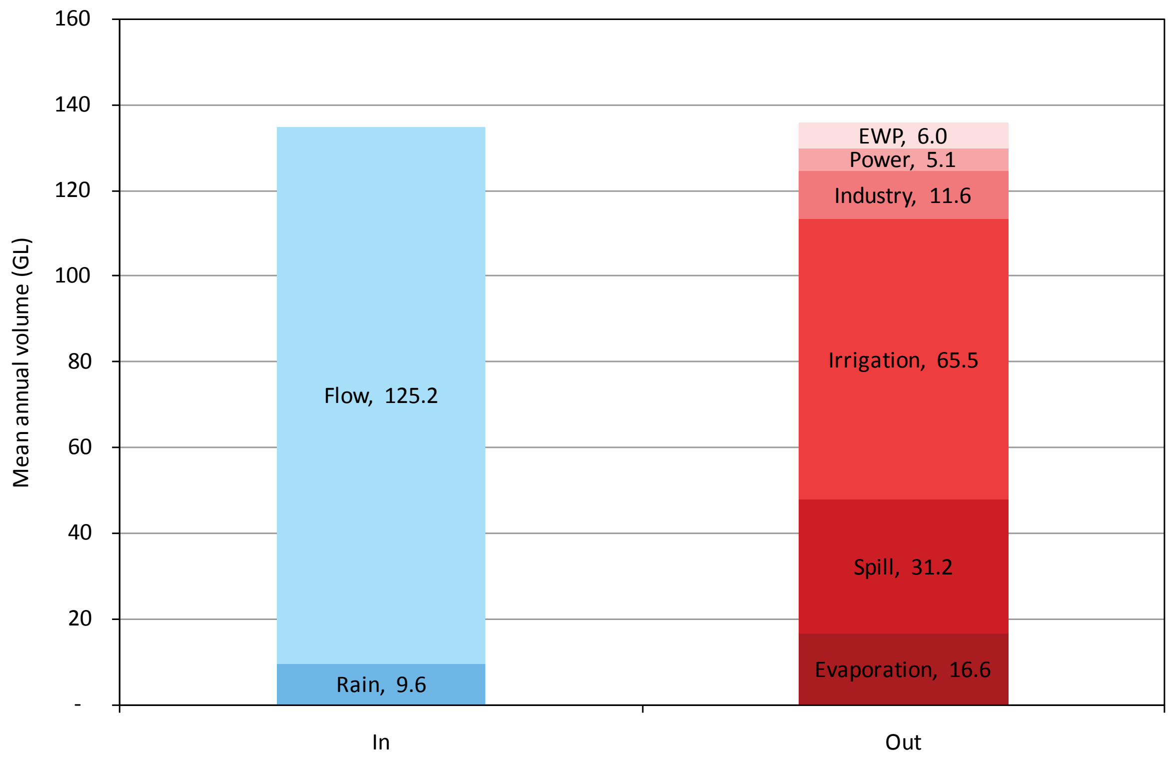

Figure 209 Mean annual water balance for Case 4.7 - historical climate

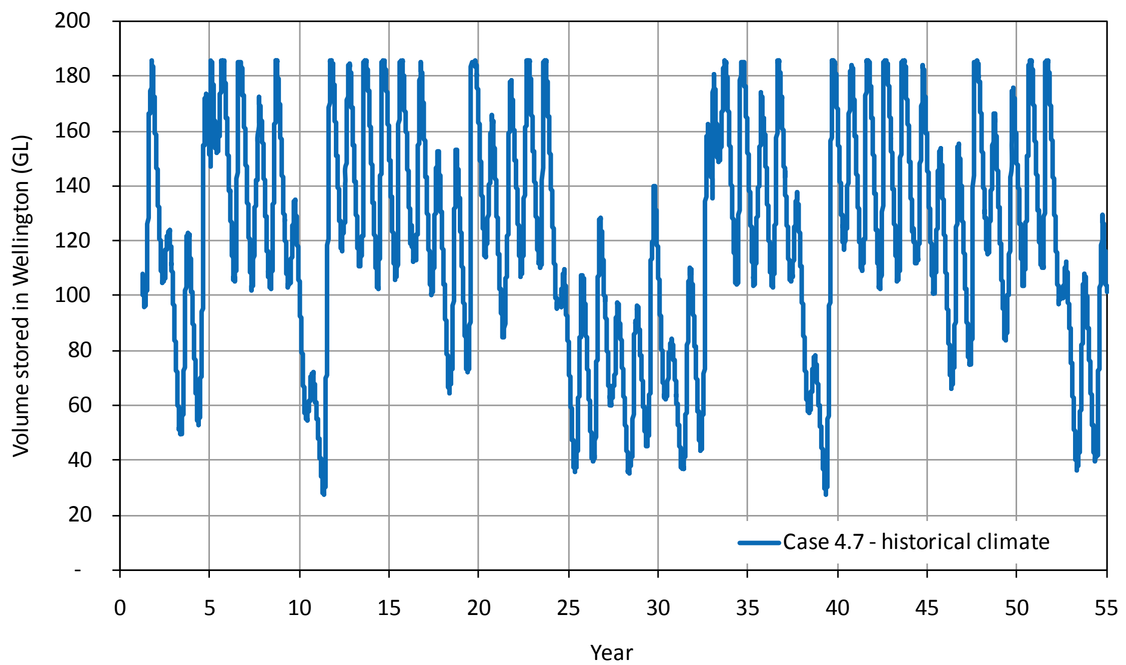

Figure 210 Annual volume stored in Wellington Reservoir for Case 4.7 – historical climate

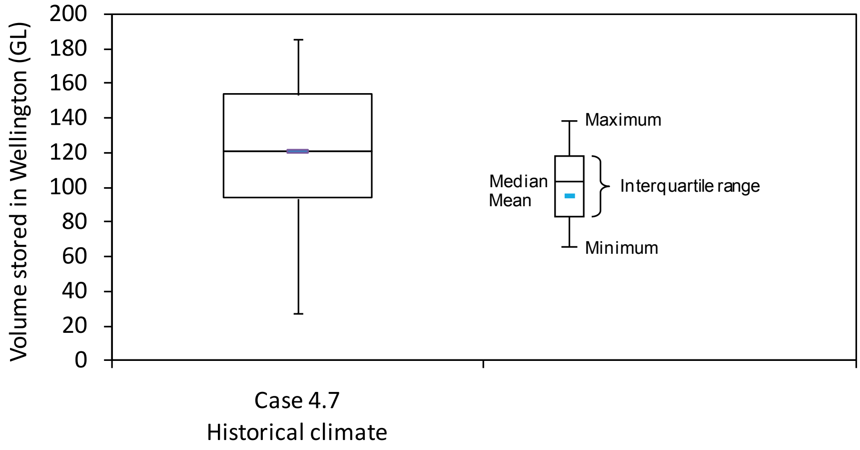

Figure 211 Distribution of annual volume stored in Wellington Reservoir for Case 4.7 – historical climate

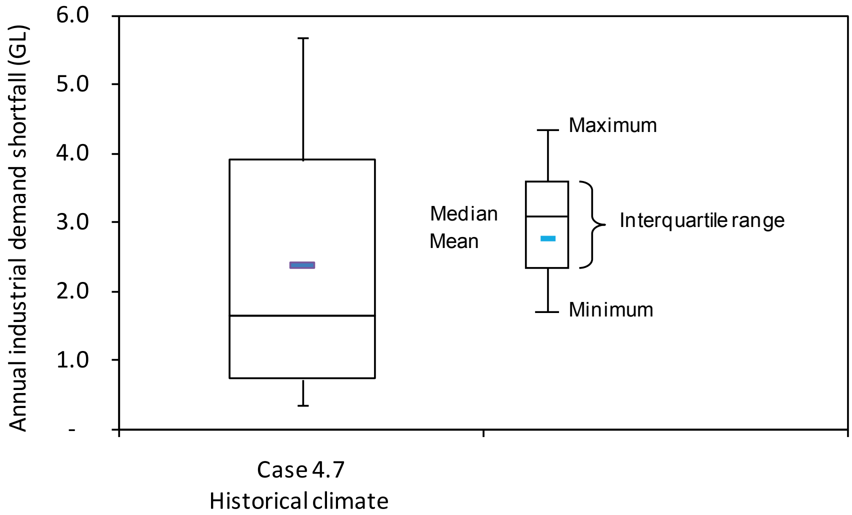

Figure 212 Range of industrial demand shortfalls for Case 4.7 – historical climate

Table 65 Annual industrial supply shortfalls for Case 4.7 – historical climate

	Historical climate
Years with a shortfall in supply	19%
Maximum annual shortfall (GL)	5.68
Median of the annual shortfalls (GL)	1.64
Mean of the annual shortfalls (GL)	2.38

Case 4.7 – 2030 median future climate

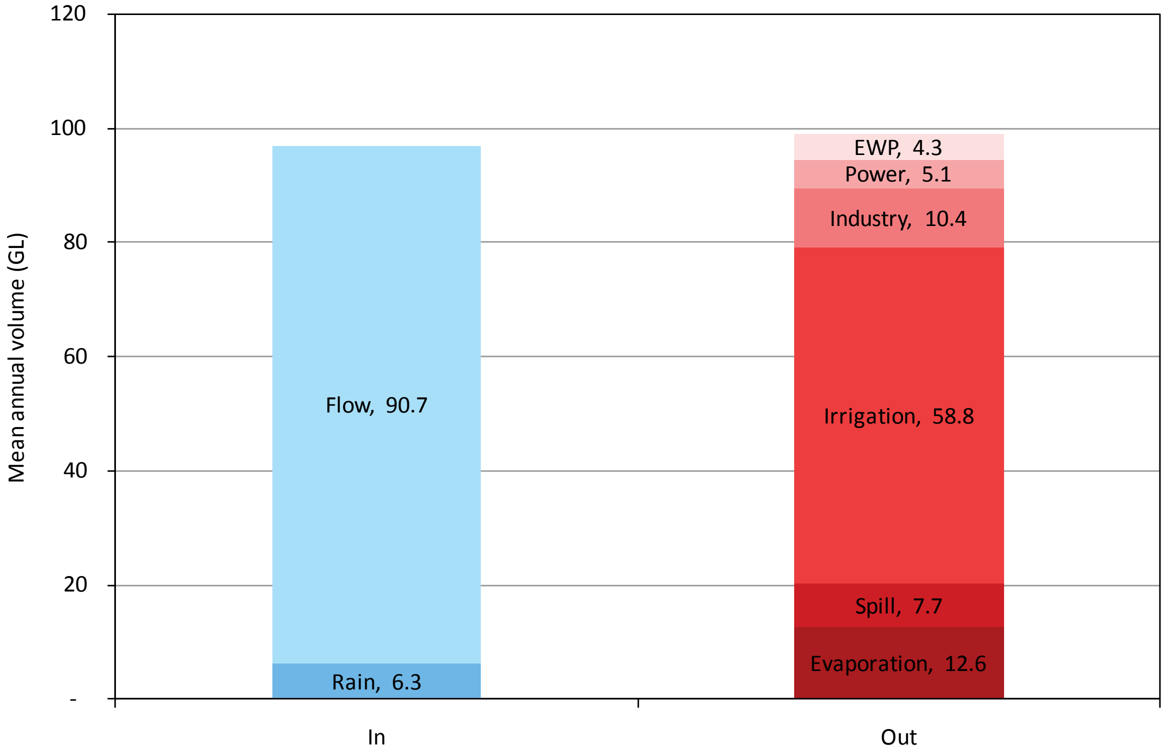

Figure 213 Mean annual water balance for Case 4.7 – 2030 median future climate

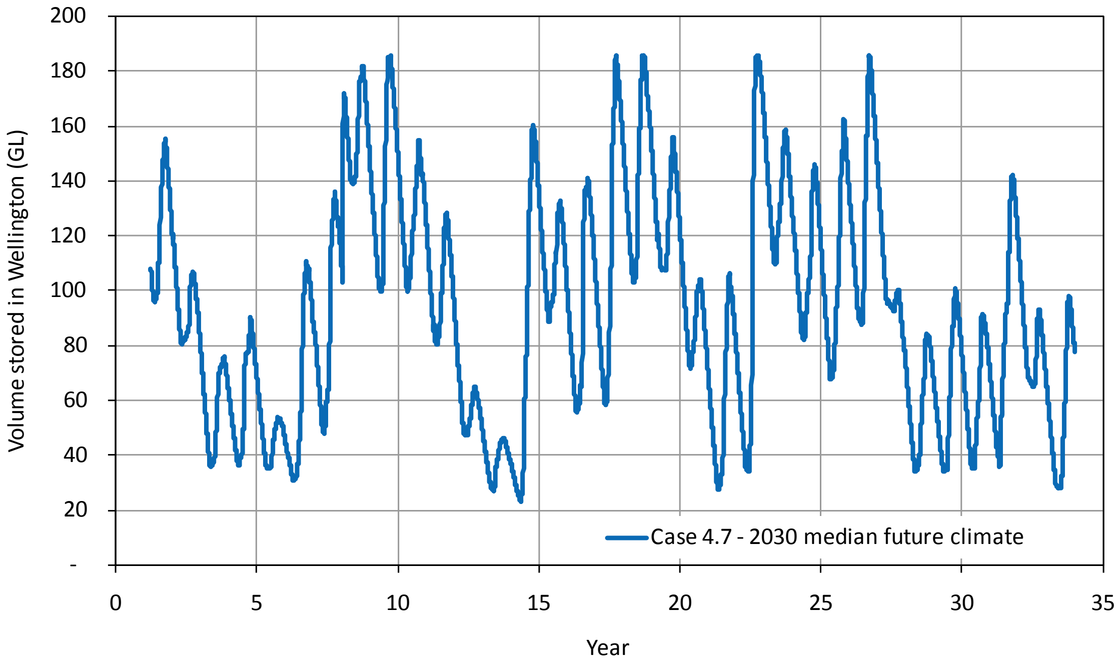

Figure 214 Annual volume stored in Wellington Reservoir for Case 4.7 – 2030 median future climate

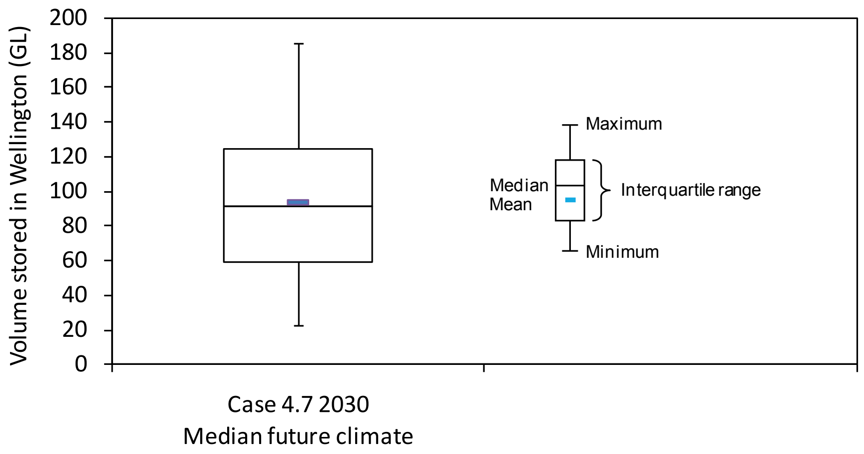

Figure 215 Distribution of annual volume stored in Wellington Reservoir for Case 4.7 – 2030 median future climate

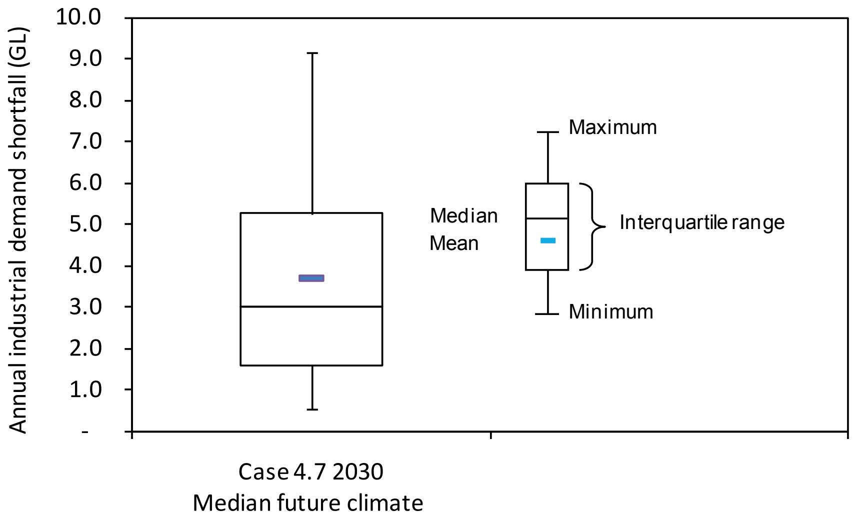

Figure 216 Range of industrial demand shortfalls for Case 4.7 – 2030 median future climate

Table 66 Annual industrial supply shortfalls for Case 4.7 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	44%
Maximum annual shortfall (GL)	9.15
Median of the annual shortfalls (GL)	3.04
Mean of the annual shortfalls (GL)	3.70

Case 4.8 – historical climate

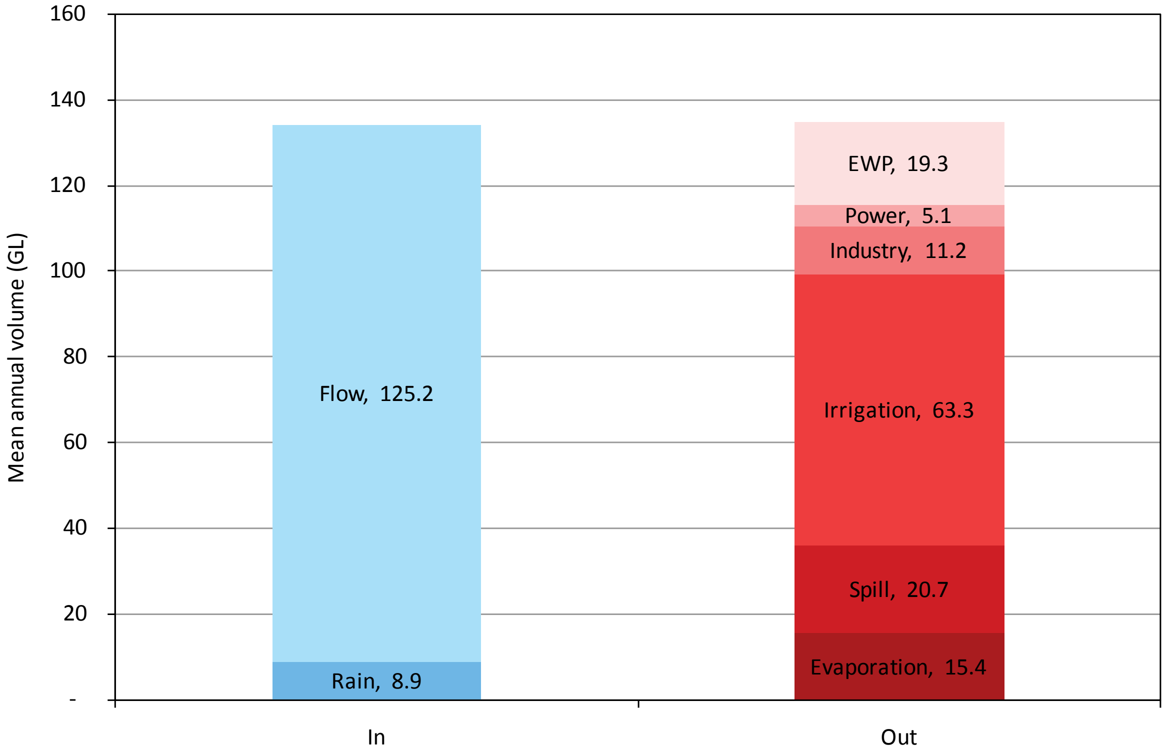

Figure 217 Mean annual water balance for Case 4.8 - historical climate

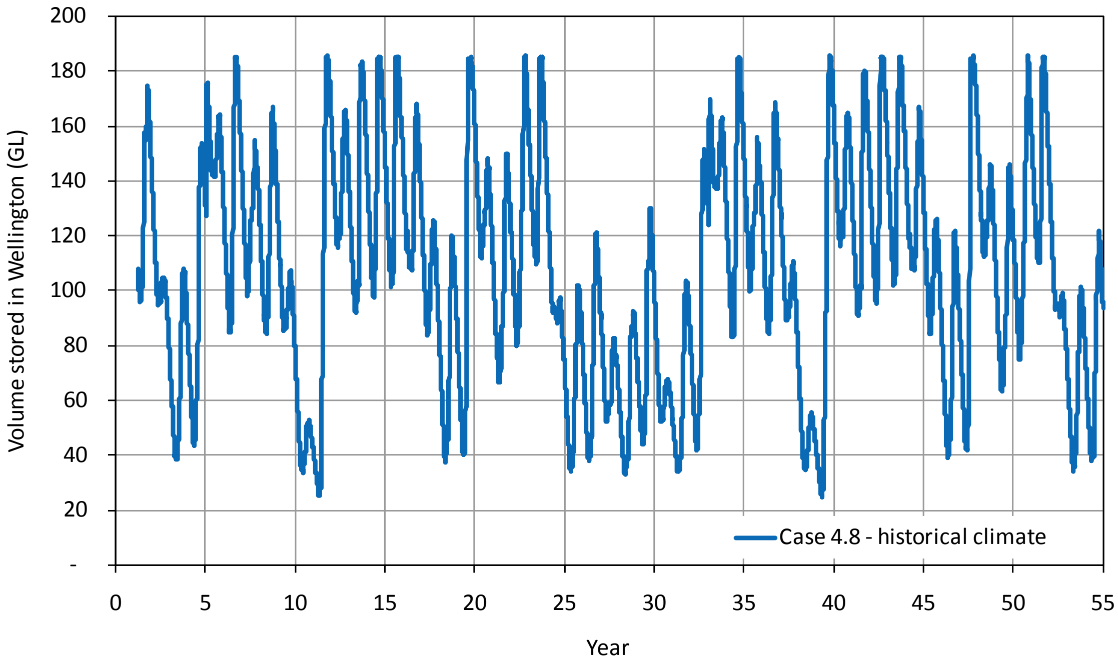

Figure 218 Annual volume stored in Wellington Reservoir for Case 4.8 – historical climate

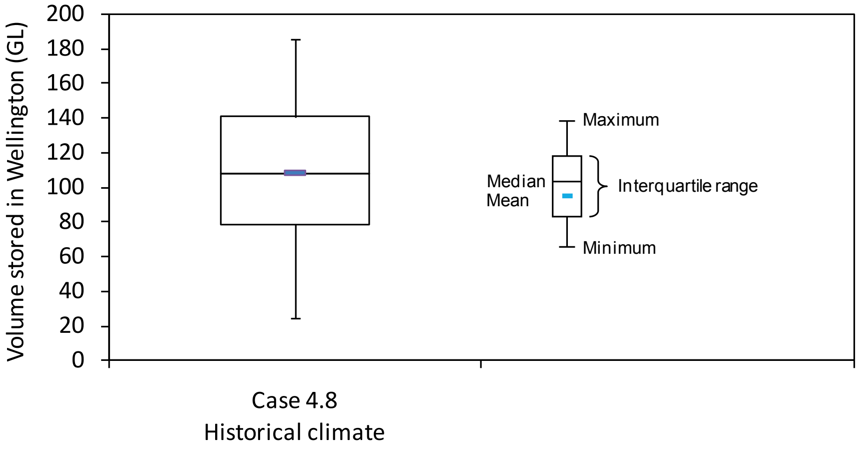

Figure 219 Distribution of annual volume stored in Wellington Reservoir for Case 4.8 – historical climate

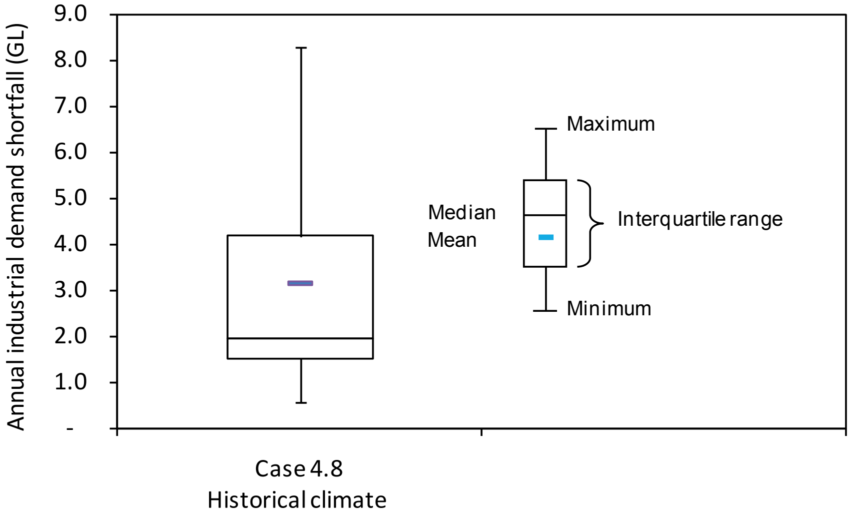

Figure 220 Range of industrial demand shortfalls for Case 4.8 – historical climate

Table 67 Annual industrial supply shortfalls for Case 4.8 – historical climate

	Historical climate
Years with a shortfall in supply	26%
Maximum annual shortfall (GL)	8.28
Median of the annual shortfalls (GL)	1.96
Mean of the annual shortfalls (GL)	3.16

Case 4.8 – 2030 median future climate

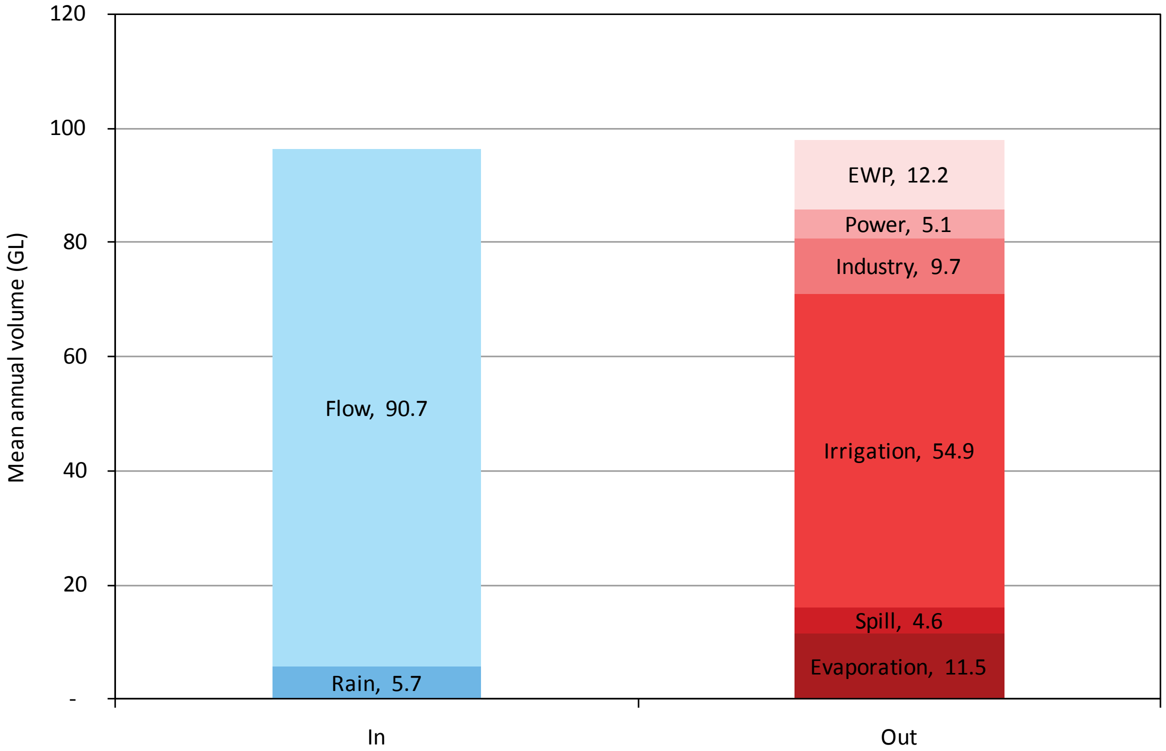

Figure 221 Mean annual water balance for Case 4.8 – 2030 median future climate

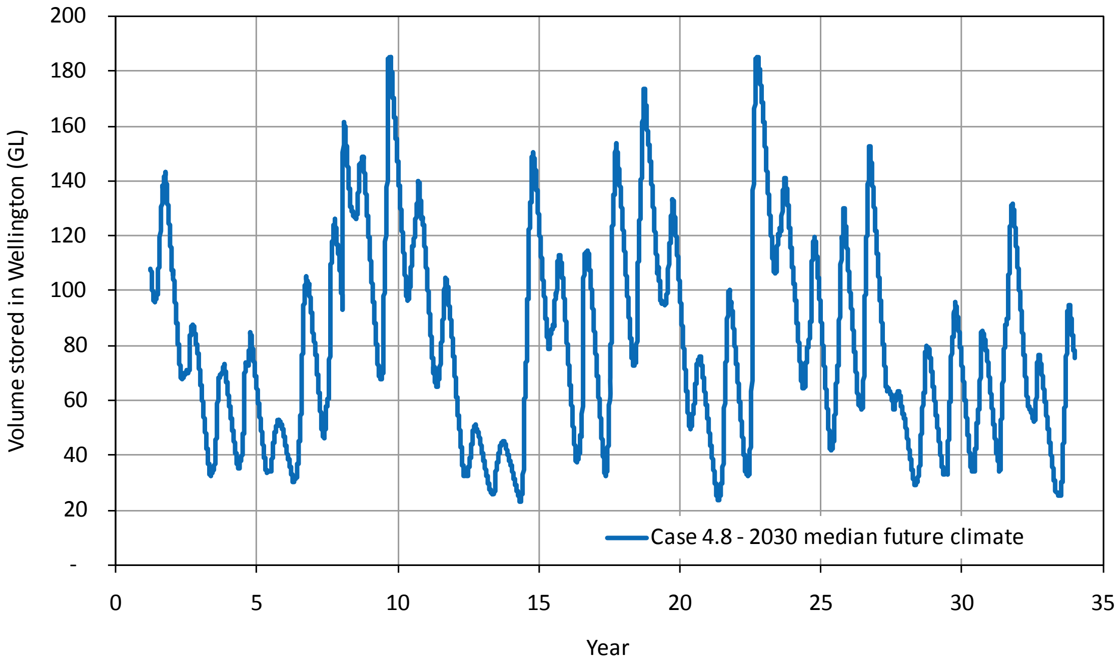

Figure 222 Annual volume stored in Wellington Reservoir for Case 4.8 – 2030 median future climate

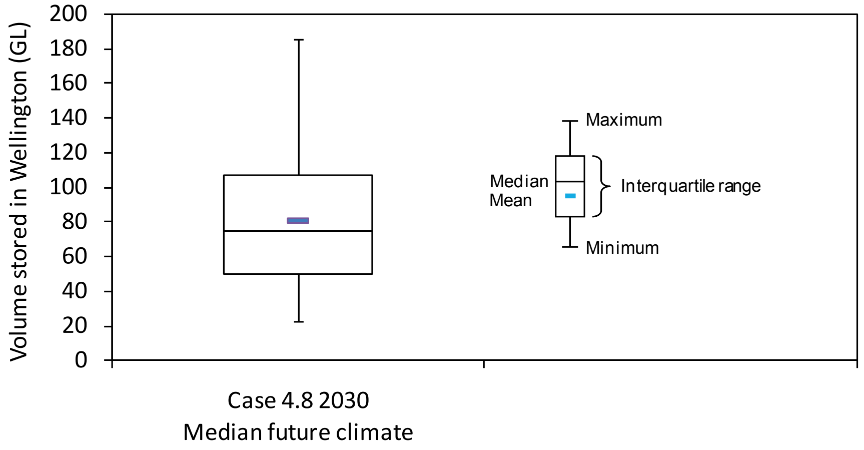

Figure 223 Distribution of annual volume stored in Wellington Reservoir for Case 4.8 – 2030 median future climate

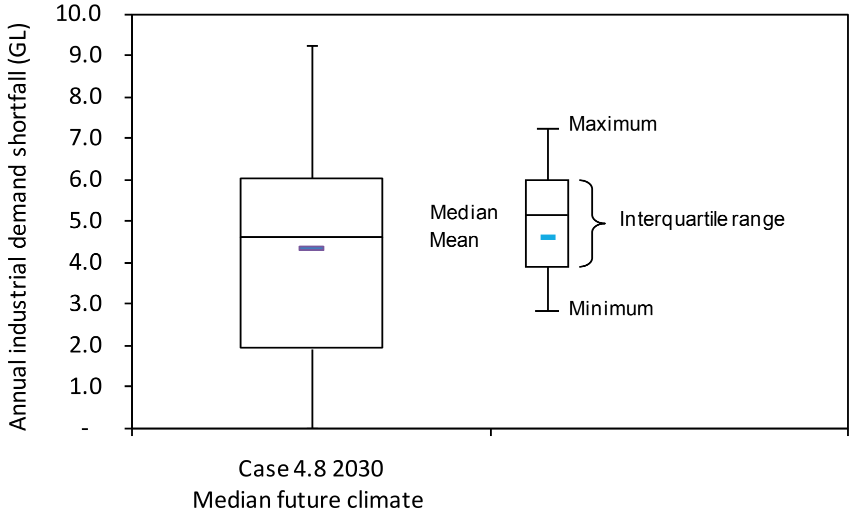

Figure 224 Range of industrial demand shortfalls for Case 4.8 – 2030 median future climate

Table 68 Annual industrial supply shortfalls for Case 4.8 –2030 median future climate

	2030 median future climate
Years with a shortfall in supply	53%
Maximum annual shortfall (GL)	9.27
Median of the annual shortfalls (GL)	4.64
Mean of the annual shortfalls (GL)	4.35

Case 7.1 – 2030 dry future climate

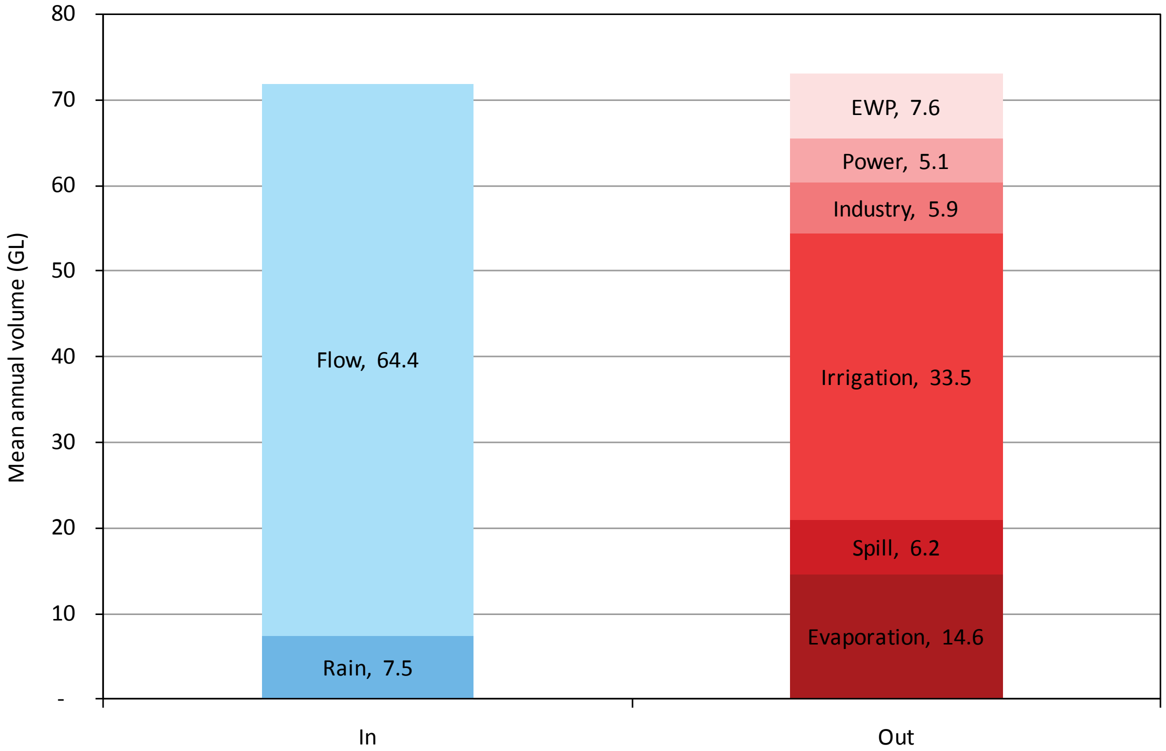

Figure 225 Mean annual water balance for Case 7.1 – 2030 dry future climate

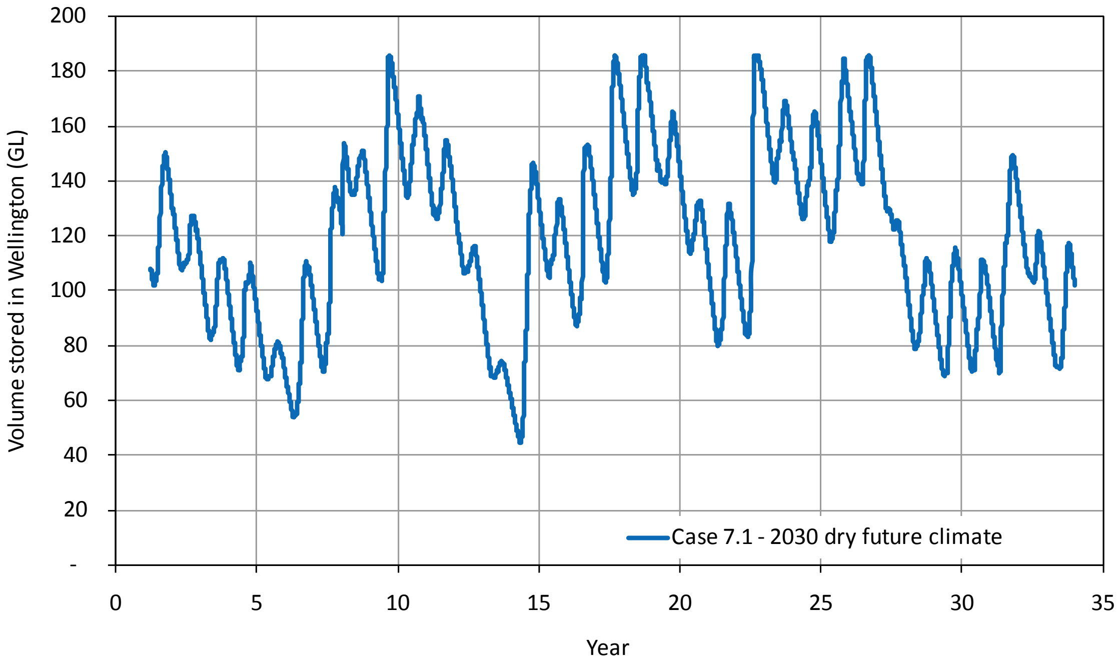

Figure 226 Annual volume stored in Wellington Reservoir for Case 7.1 – 2030 dry future climate

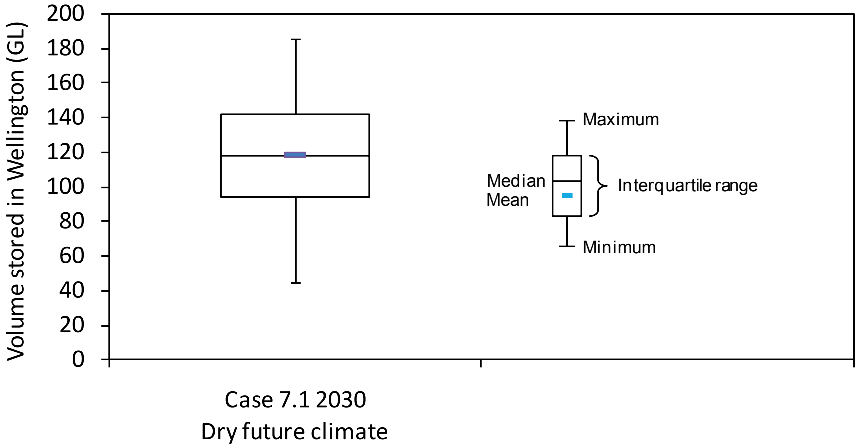

Figure 227 Distribution of annual volume stored in Wellington Reservoir for Case 7.1 – 2030 dry future climate

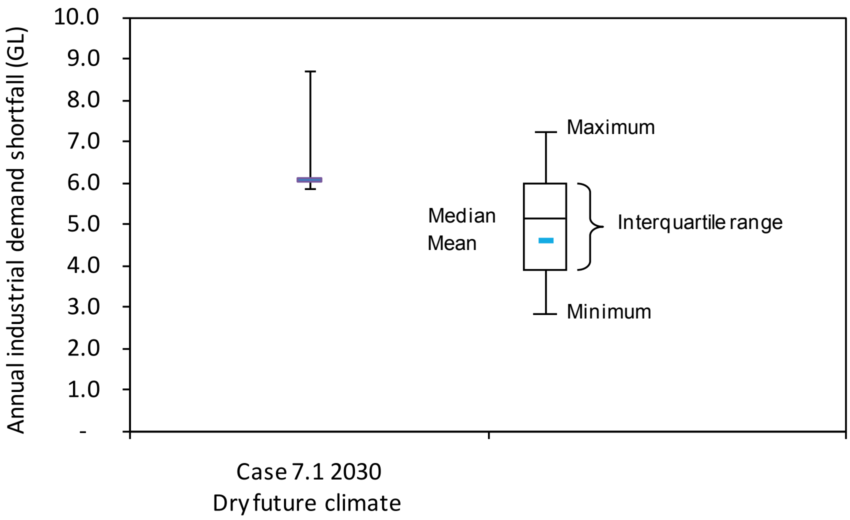

Figure 228 Range of industrial demand shortfalls for Case 7.1 – 2030 dry future climate

Table 69 Annual industrial supply shortfalls for Case 7.1 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	8.70
Median of the annual shortfalls (GL)	5.88
Mean of the annual shortfalls (GL)	6.09

Case 7.2 – 2030 median future climate

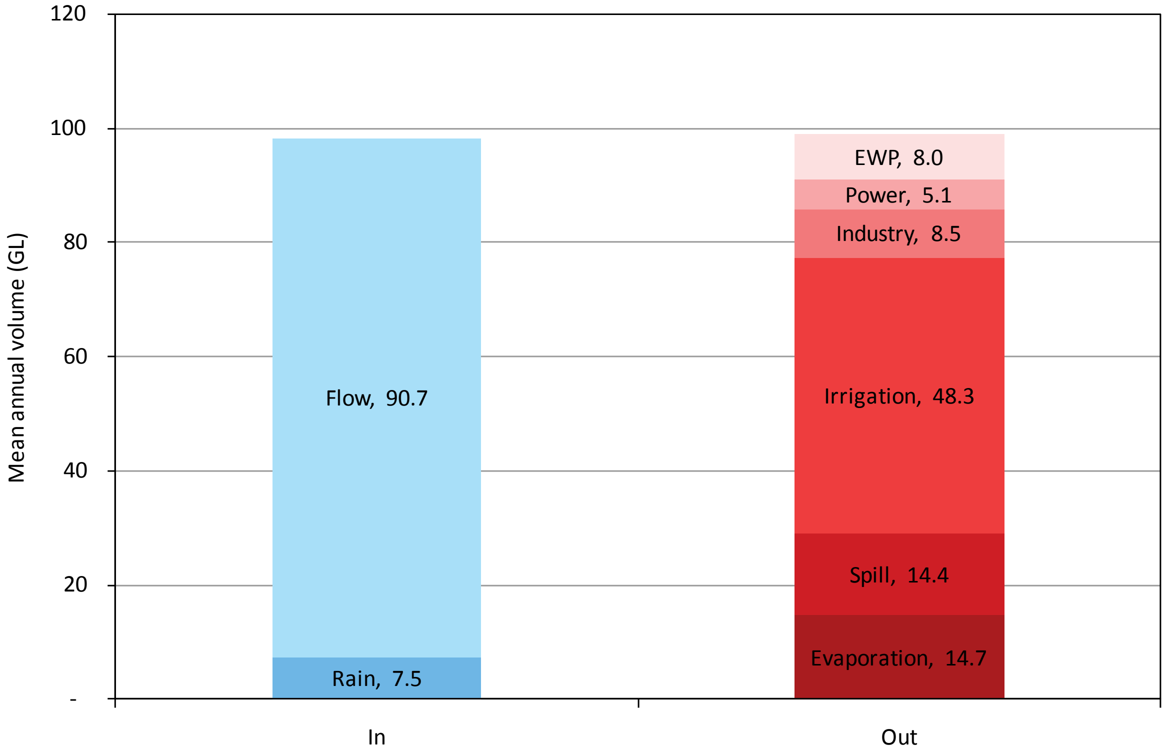

Figure 229 Mean annual water balance for Case 7.2 – 2030 median future climate

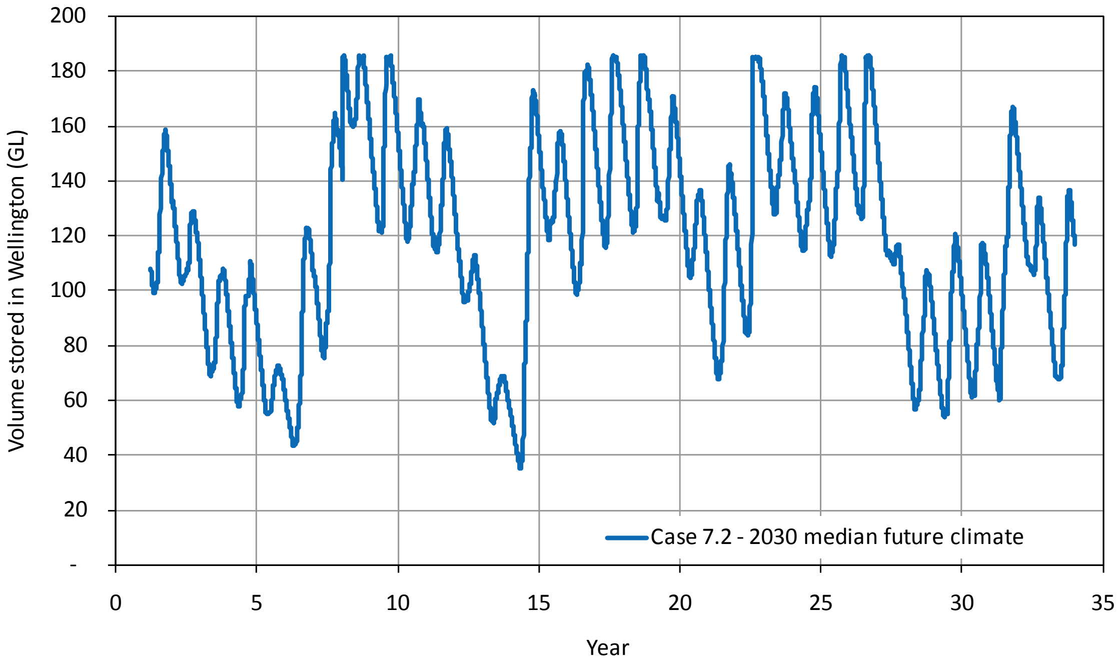

Figure 230 Annual volume stored in Wellington Reservoir for Case 7.2 – 2030 median future climate

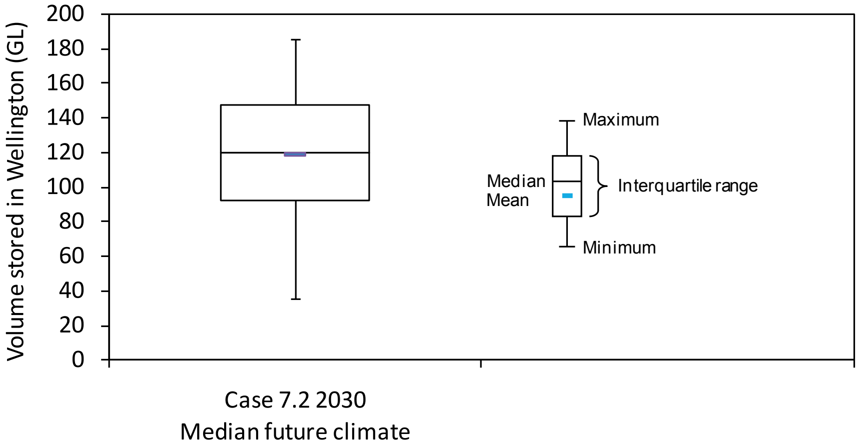

Figure 231 Distribution of annual volume stored in Wellington Reservoir for Case 7.2 – 2030 median future climate

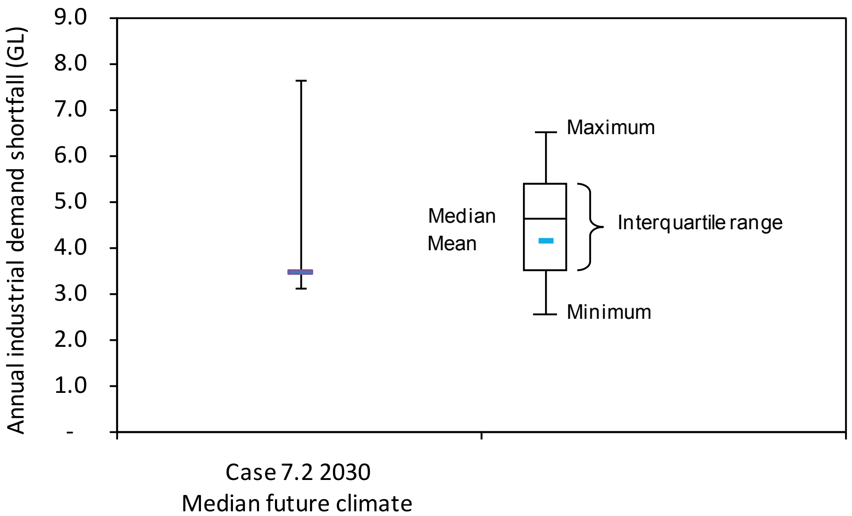

Figure 232 Range of industrial demand shortfalls for Case 7.2 – 2030 median future climate

Table 70 Annual industrial supply shortfalls for Case 7.2 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	7.67
Median of the annual shortfalls (GL)	3.12
Mean of the annual shortfalls (GL)	3.48

Case 7.3 – 2030 wet future climate

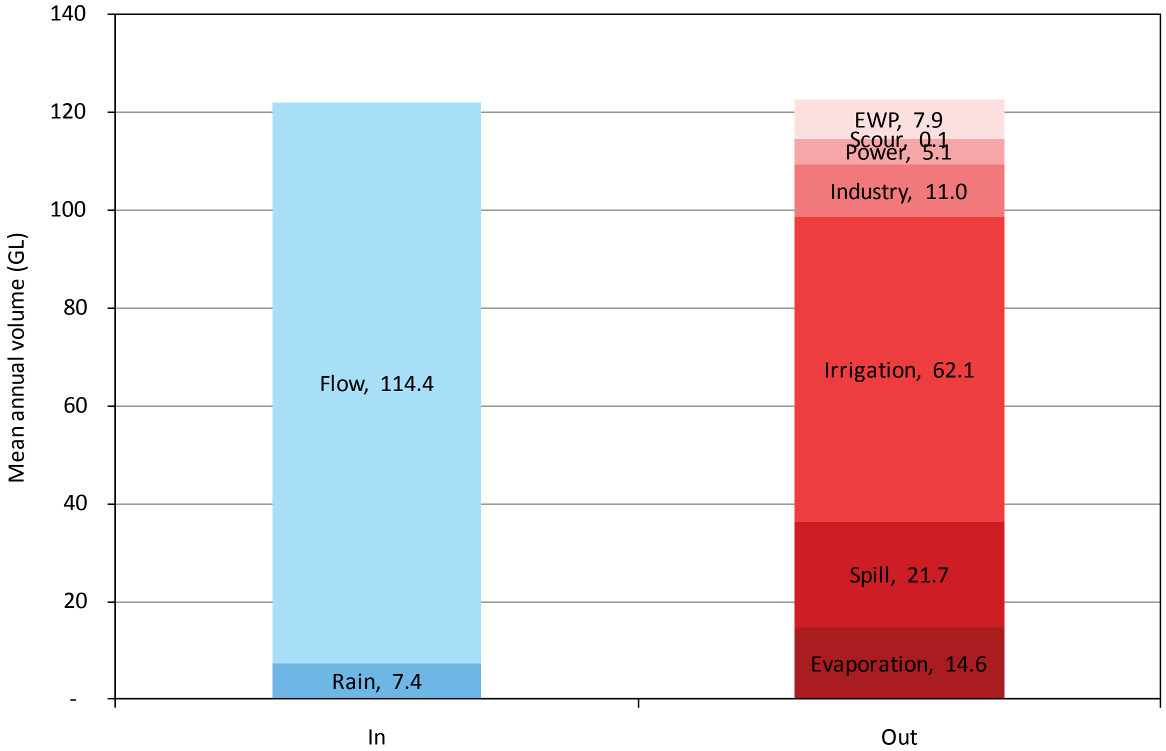

Figure 233 Mean annual water balance for Case 7.3 – 2030 wet future climate

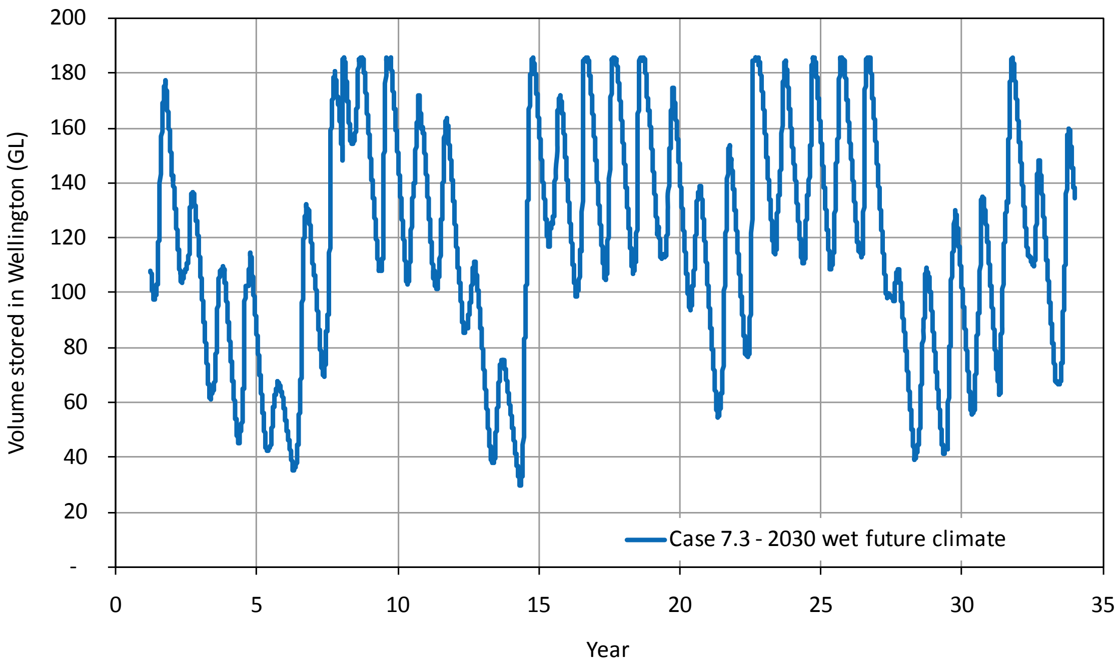

Figure 234 Annual volume stored in Wellington Reservoir for Case 7.3 – 2030 wet future climate

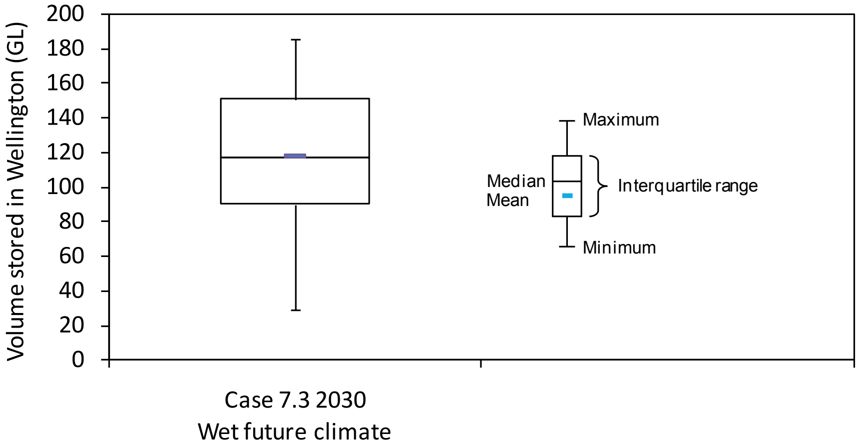

Figure 235 Distribution of annual volume stored in Wellington Reservoir for Case 7.3 – 2030 wet future climate

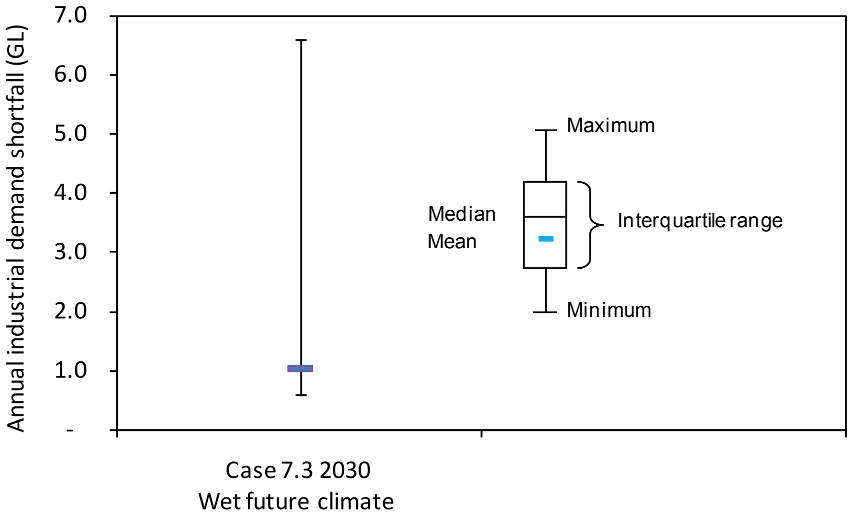

Figure 236 Range of industrial demand shortfalls for Case 7.3 – 2030 wet future climate

Table 71 Annual industrial supply shortfalls for Case 7.3 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	6.60
Median of the annual shortfalls (GL)	0.60
Mean of the annual shortfalls (GL)	1.05

Case 8.1 – 2030 wet future climate

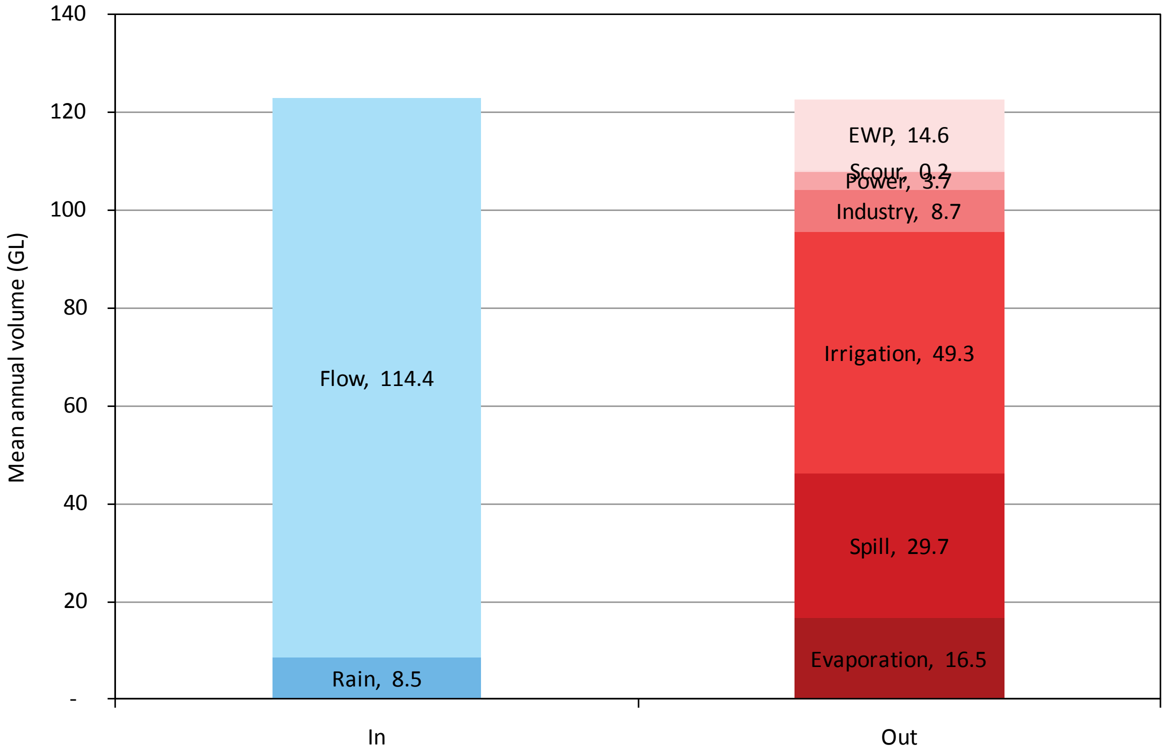

Figure 237 Mean annual water balance for Case 8.1 – 2030 wet future climate

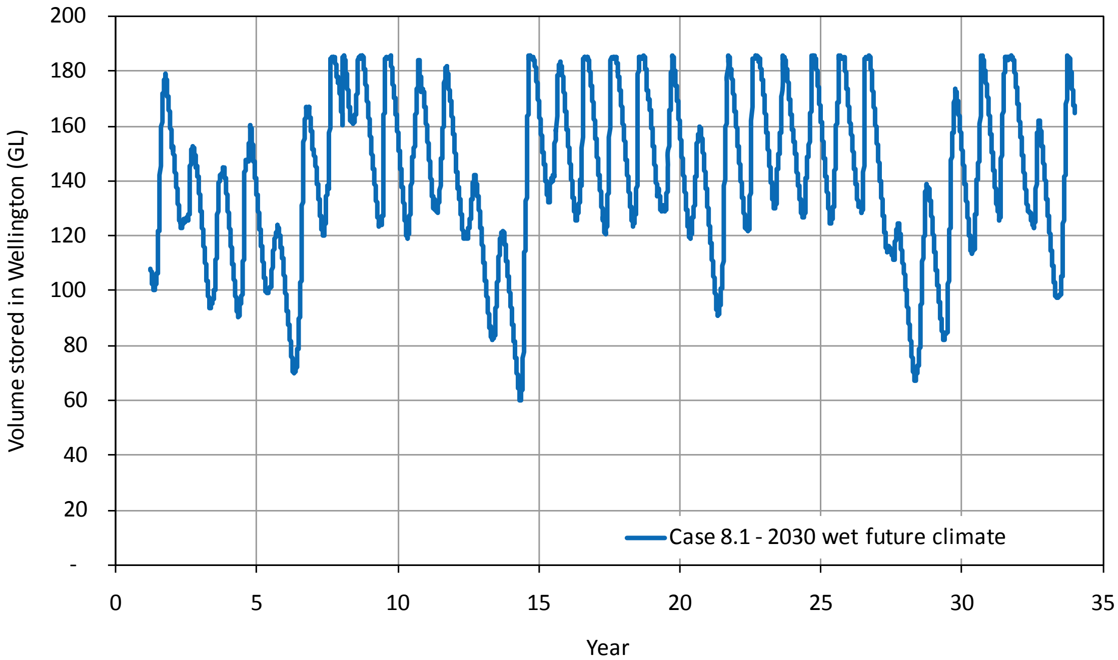

Figure 238 Annual volume stored in Wellington Reservoir for Case 8.1 – 2030 wet future climate

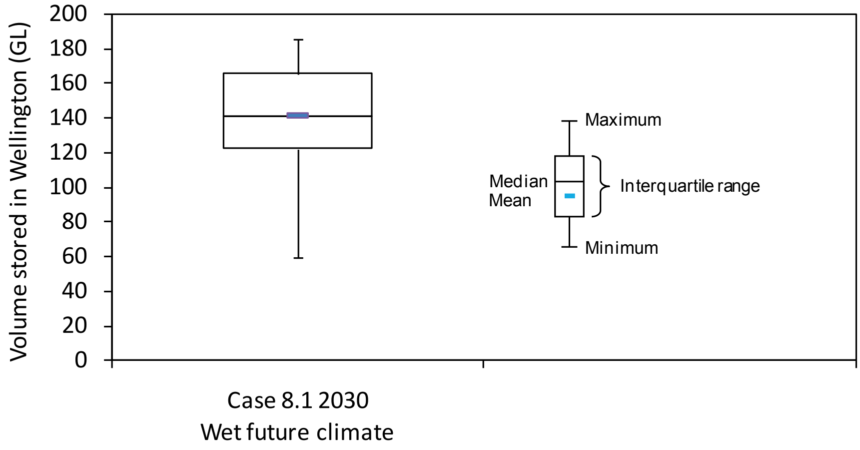

Figure 239 Distribution of annual volume stored in Wellington Reservoir for Case 8.1 – 2030 wet future climate

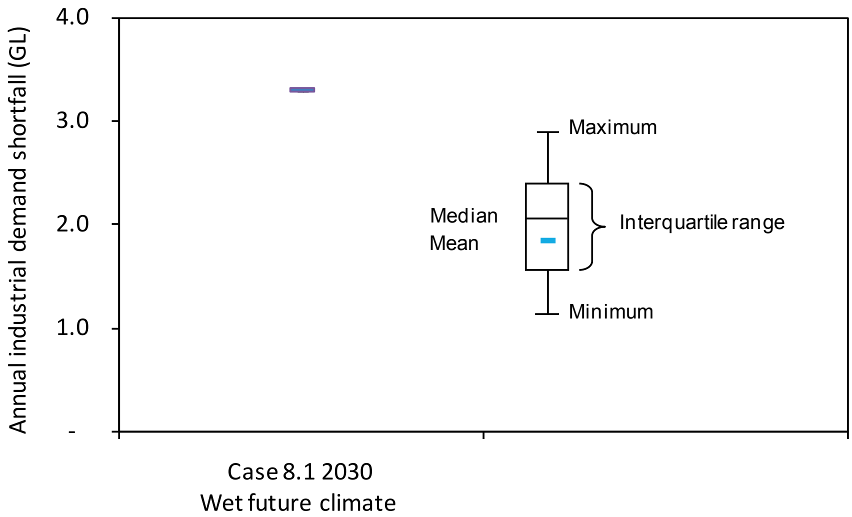

Figure 240 Range of industrial demand shortfalls for Case 8.1 – 2030 wet future climate

Table 72 Annual industrial supply shortfalls for Case 8.1 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	7.67
Median of the annual shortfalls (GL)	3.13
Mean of the annual shortfalls (GL)	3.48

Case 8.1 – 2030 median future climate

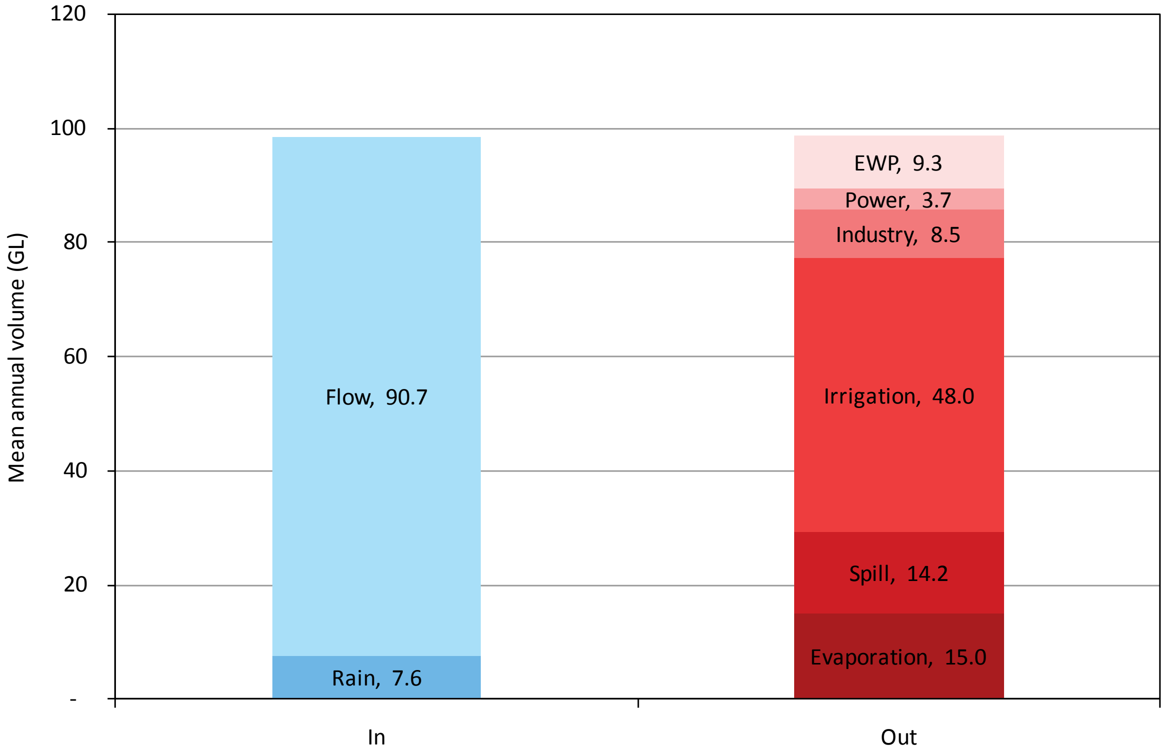

Figure 241 Mean annual water balance for Case 8.1 – 2030 median future climate

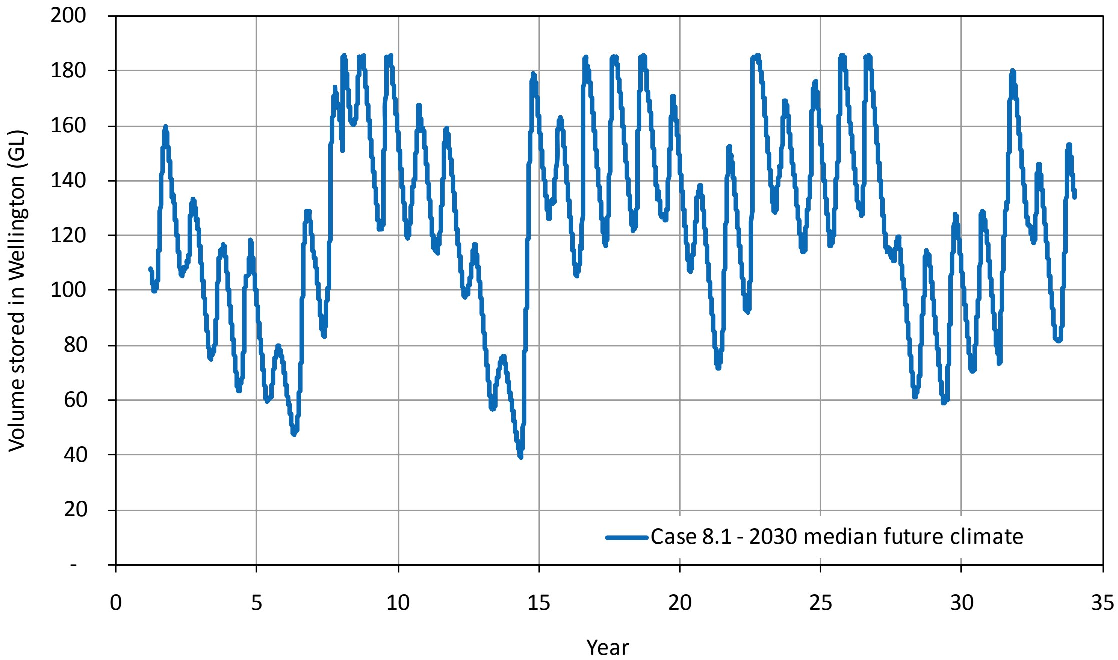

Figure 242 Annual volume stored in Wellington Reservoir for Case 8.1 – 2030 median future climate

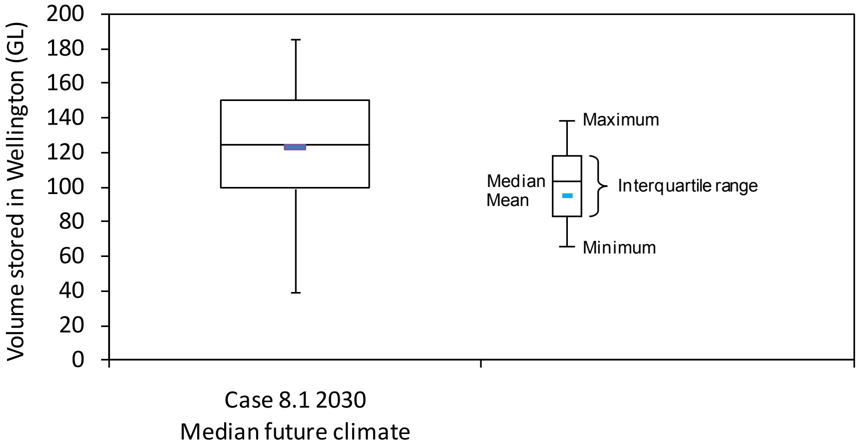

Figure 243 Distribution of annual volume stored in Wellington Reservoir for Case 8.1 – 2030 median future climate

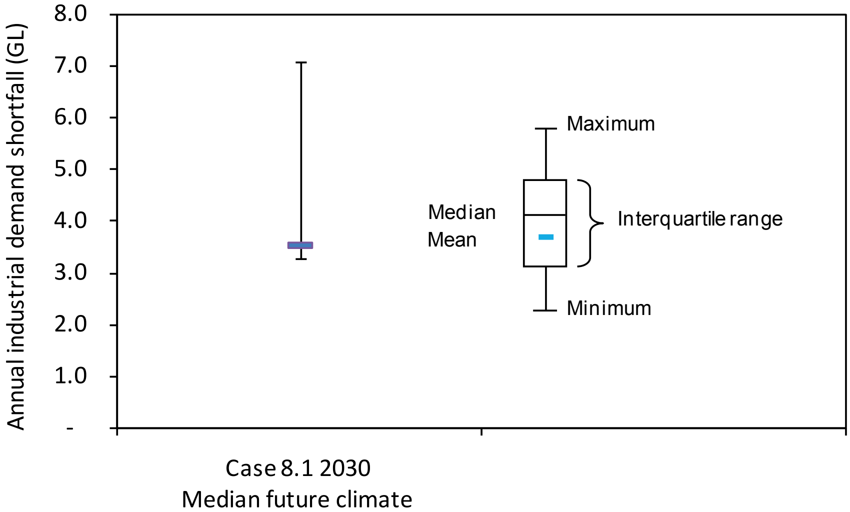

Figure 244 Range of industrial demand shortfalls for Case 8.1 – 2030 median future climate

Table 73 Annual industrial supply shortfalls for Case 8.1 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	7.08
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	3.53

Case 8.1 – 2030 dry future climate

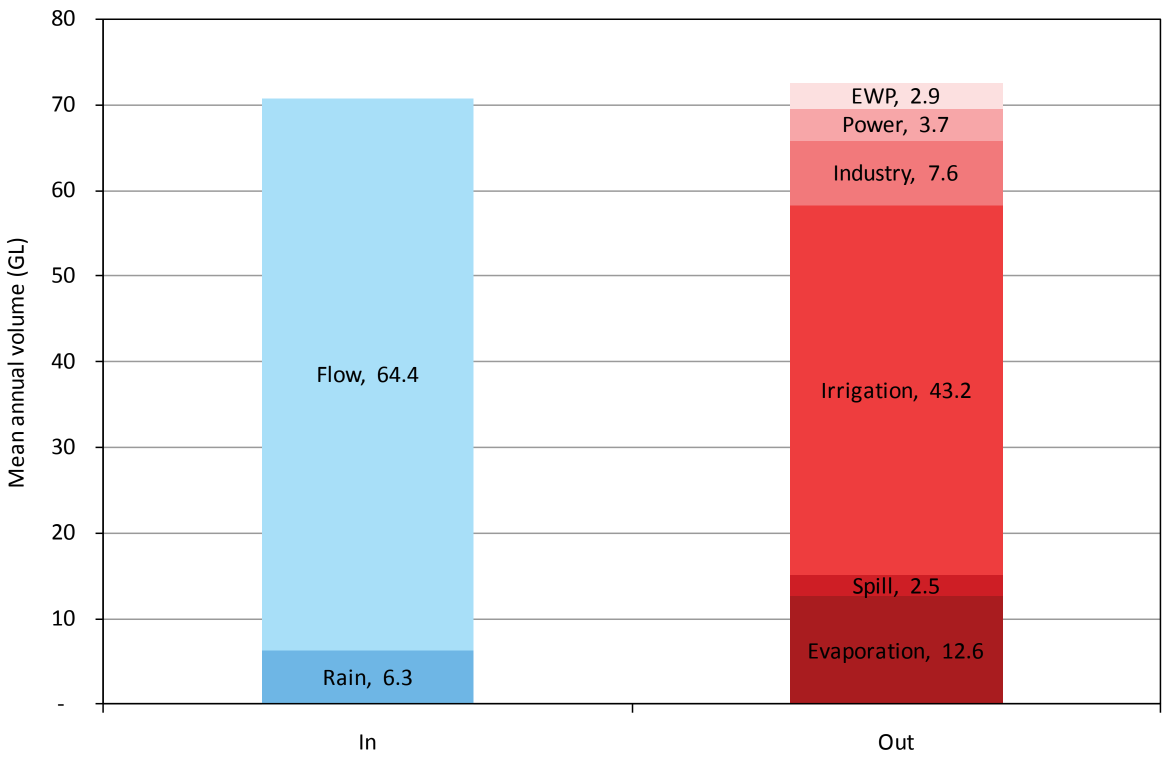

Figure 245 Mean annual water balance for Case 8.1 – 2030 dry future climate

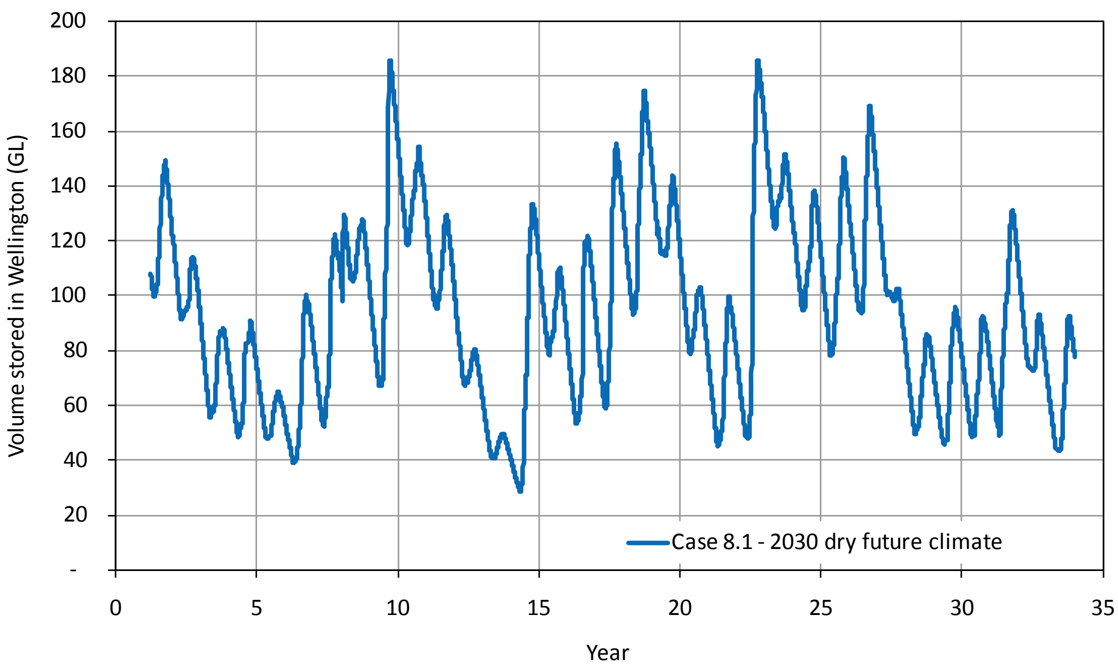

Figure 246 Annual volume stored in Wellington Reservoir for Case 8.1 – 2030 dry future climate

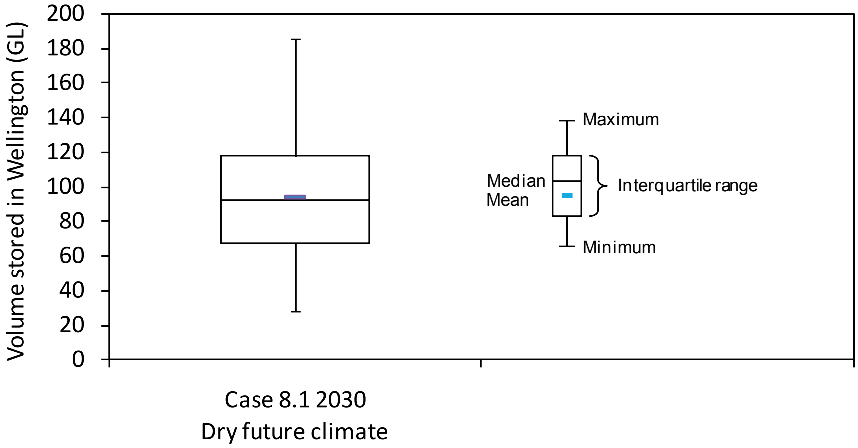

Figure 247 Distribution of annual volume stored in Wellington Reservoir for Case 8.1 – 2030 dry future climate

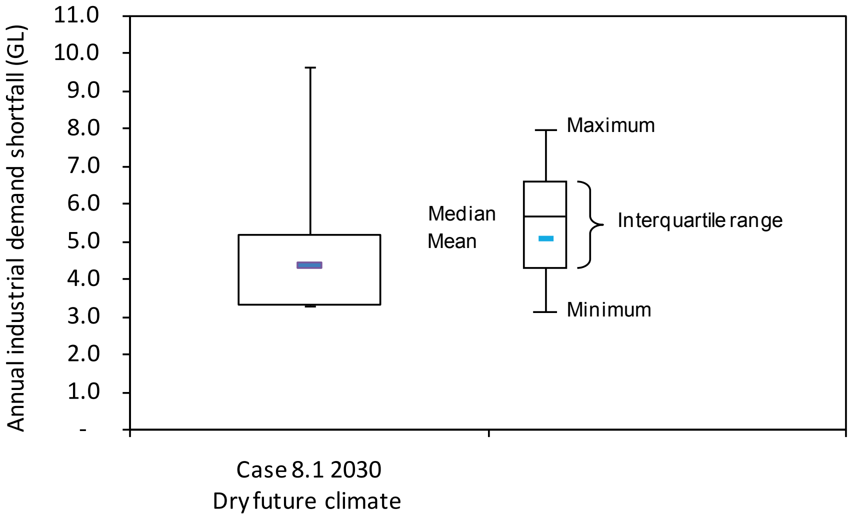

Figure 248 Range of industrial demand shortfalls for Case 8.1 – 2030 dry future climate

Table 74 Annual industrial supply shortfalls for Case 8.1 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	9.63
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	4.38

Case 8.2 – 2030 wet future climate

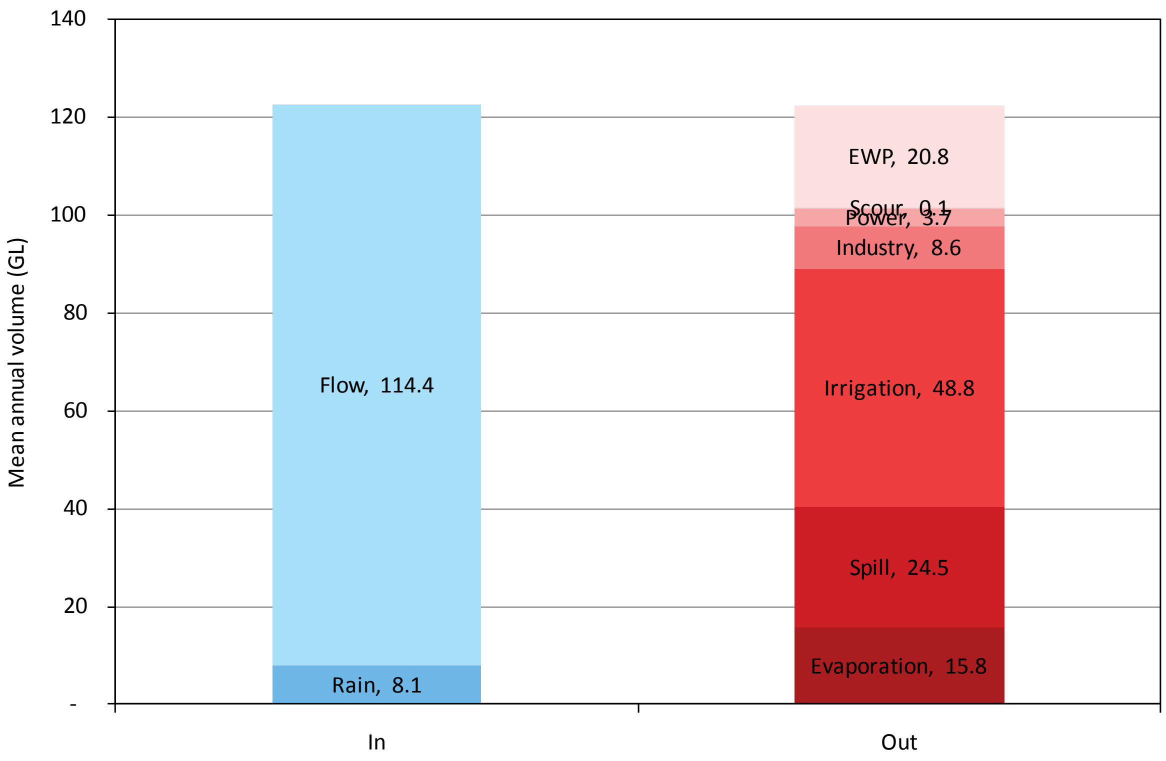

Figure 249 Mean annual water balance for Case 8.2 – 2030 wet future climate

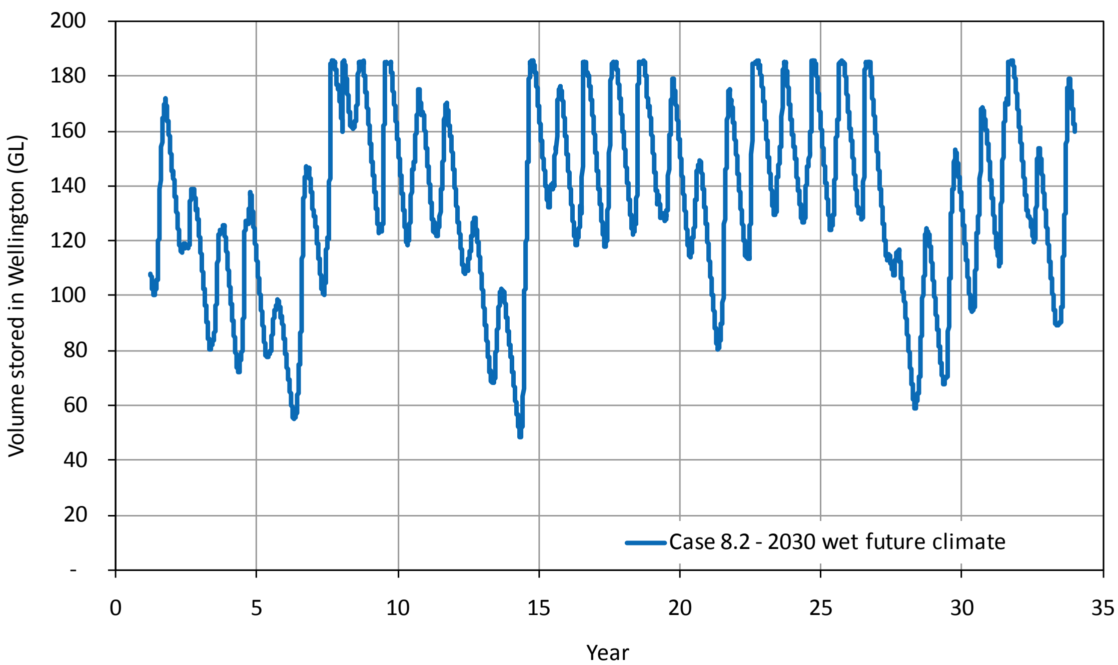

Figure 250 Annual volume stored in Wellington Reservoir for Case 8.2 – 2030 wet future climate

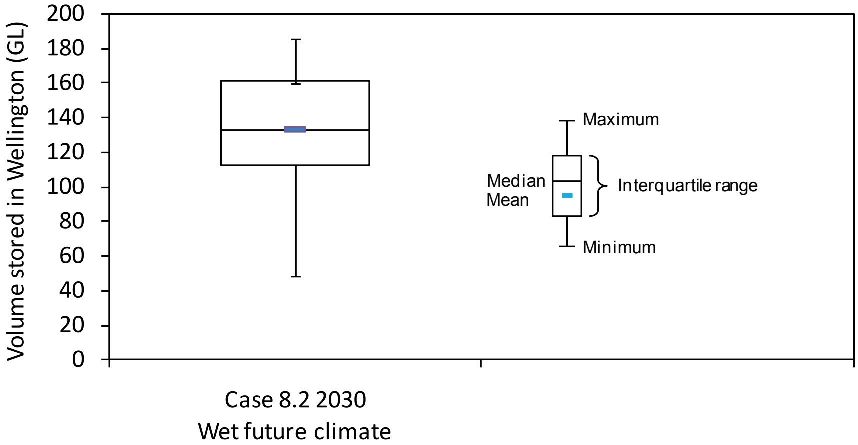

Figure 251 Distribution of annual volume stored in Wellington Reservoir for Case 8.2 – 2030 wet future climate

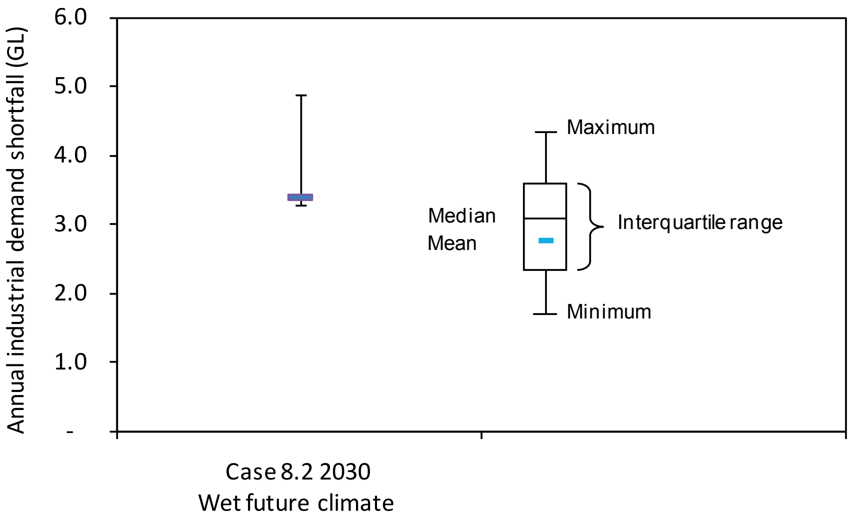

Figure 252 Range of industrial demand shortfalls for Case 8.2 – 2030 wet future climate

Table 75 Annual industrial supply shortfalls for Case 8.2 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	4.89
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	3.39

Case 8.2 – 2030 median future climate

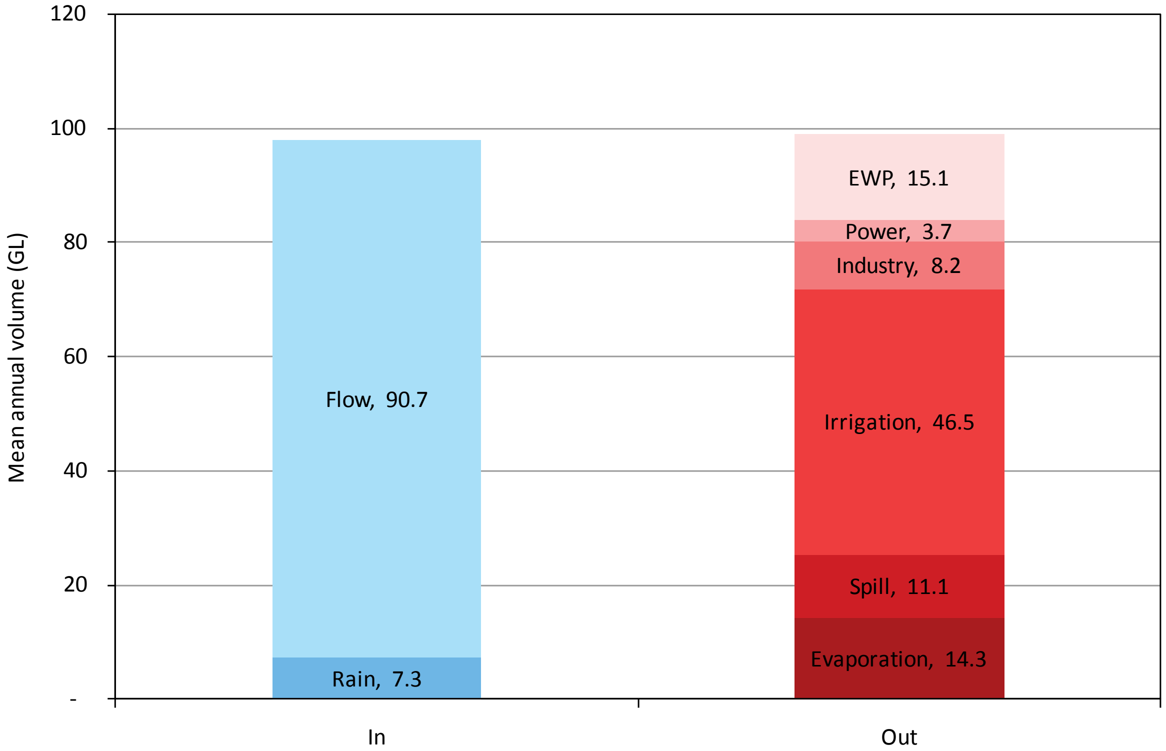

Figure 253 Mean annual water balance for Case 8.2 – 2030 median future climate

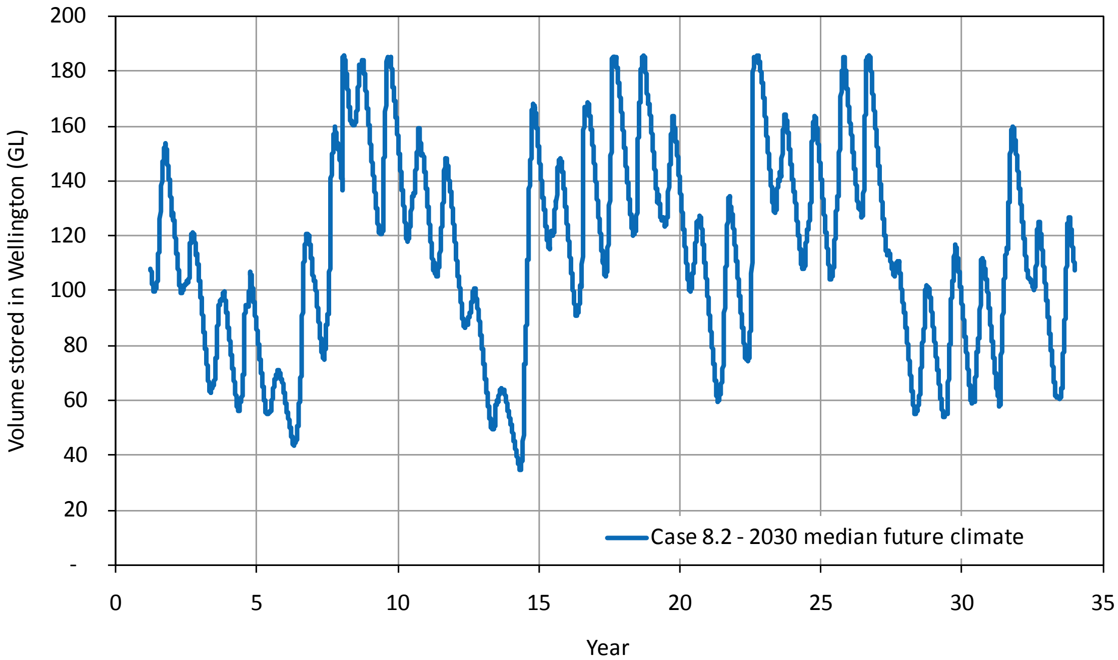

Figure 254 Annual volume stored in Wellington Reservoir for Case 8.2 – 2030 median future climate

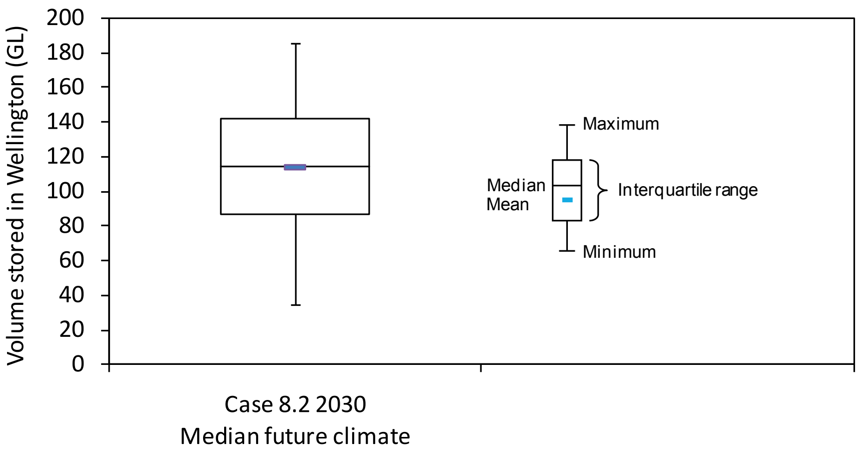

Figure 255 Distribution of annual volume stored in Wellington Reservoir for Case 8.2 – 2030 median future climate

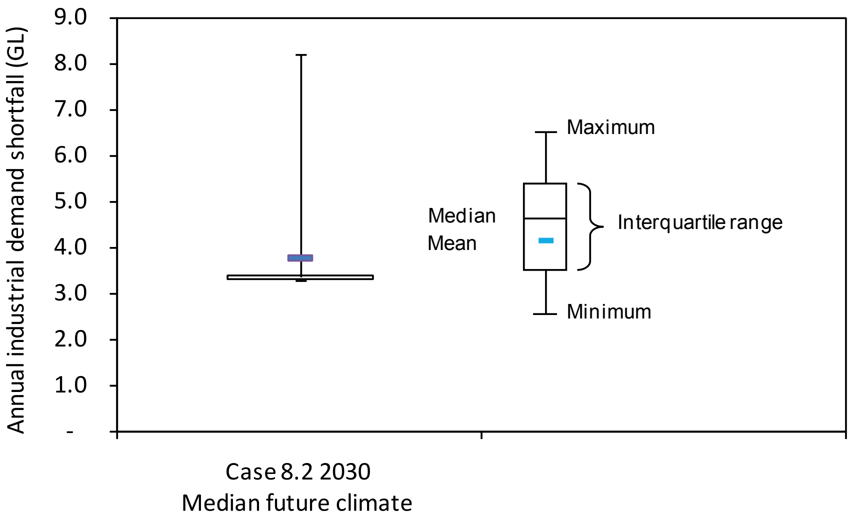

Figure 256 Range of industrial demand shortfalls for Case 8.2 – 2030 median future climate

Table 76 Annual industrial supply shortfalls for Case 8.2 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	8.21
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	3.79

Case 8.2 – 2030 dry future climate

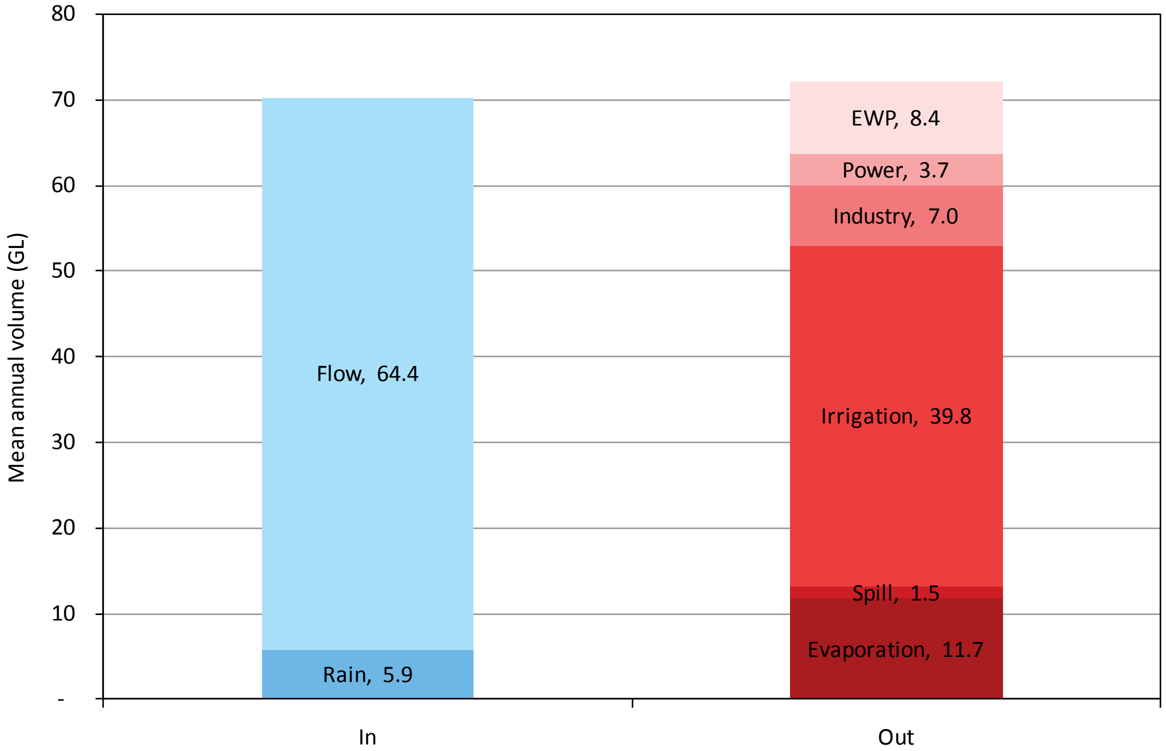

Figure 257 Mean annual water balance for Case 8.2 – 2030 dry future climate

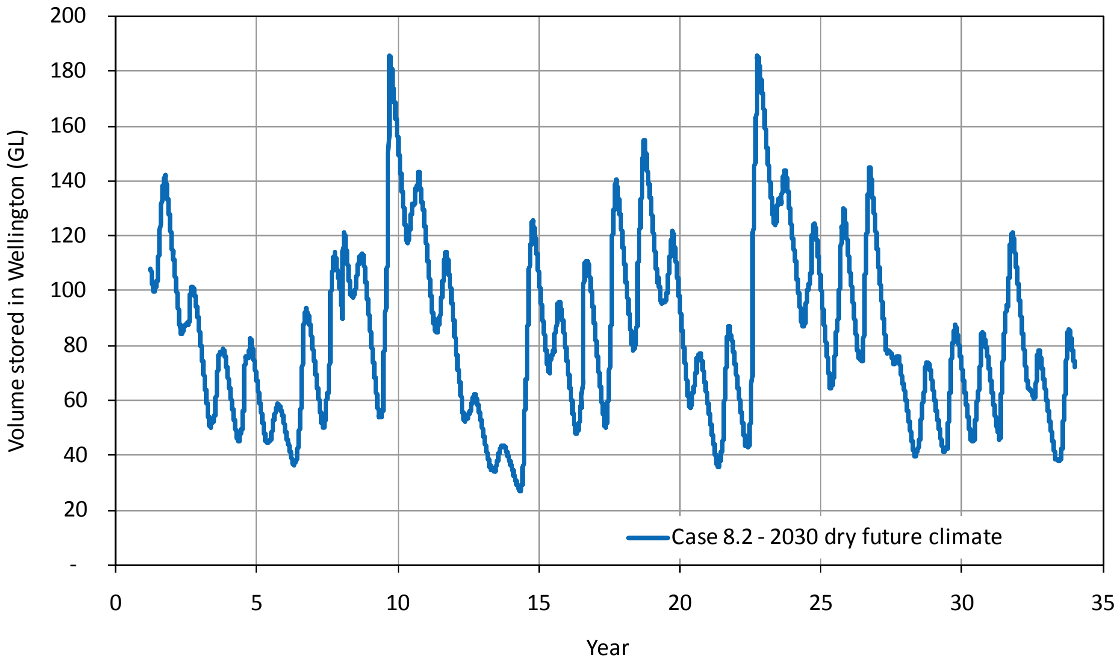

Figure 258 Annual volume stored in Wellington Reservoir for Case 8.2 – 2030 dry future climate

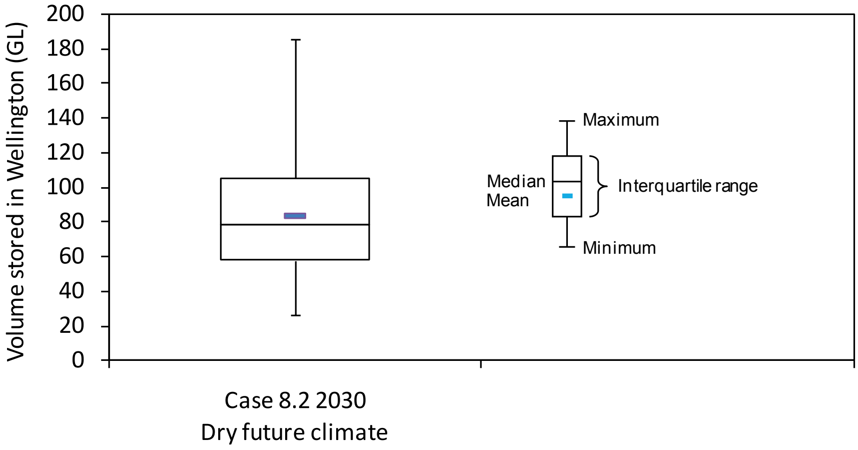

Figure 259 Distribution of annual volume stored in Wellington Reservoir for Case 8.2 – 2030 dry future climate

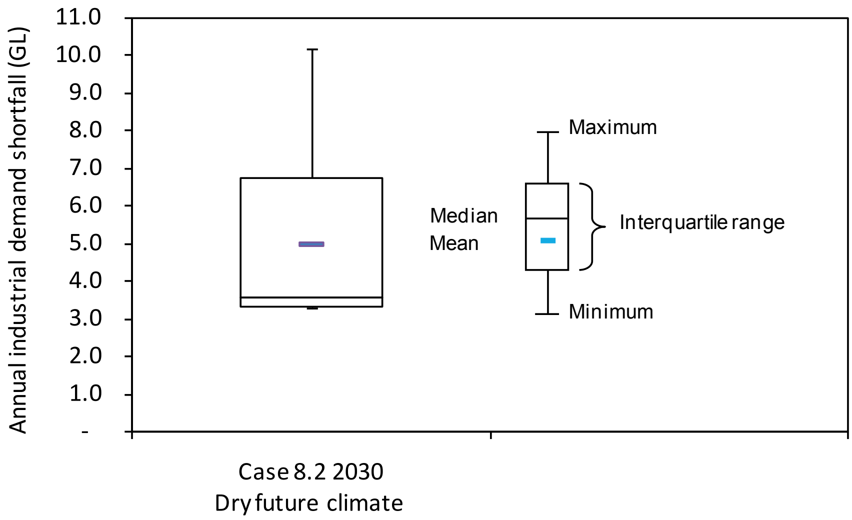

Figure 260 Range of industrial demand shortfalls for Case 8.2 – 2030 dry future climate

Table 77 Annual industrial supply shortfalls for Case 8.2 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	10.2
Median of the annual shortfalls (GL)	3.59
Mean of the annual shortfalls (GL)	4.98

Case 8.3 – 2030 wet future climate

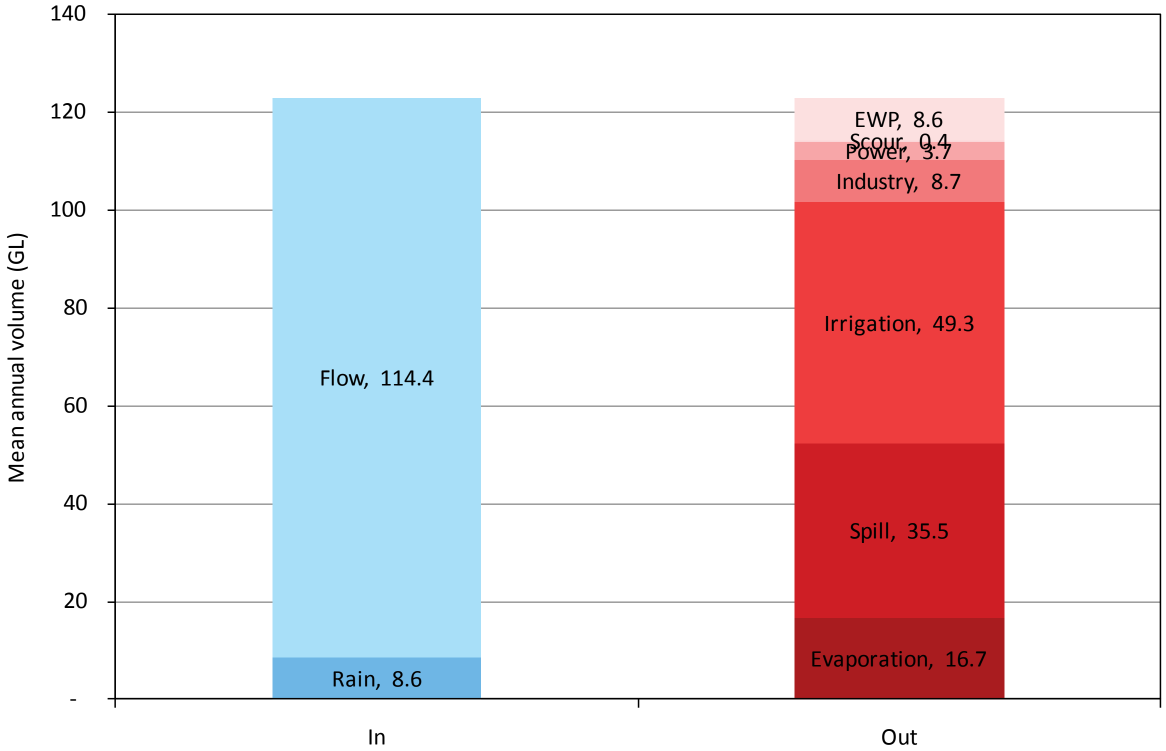

Figure 261 Mean annual water balance for Case 8.3 – 2030 wet future climate

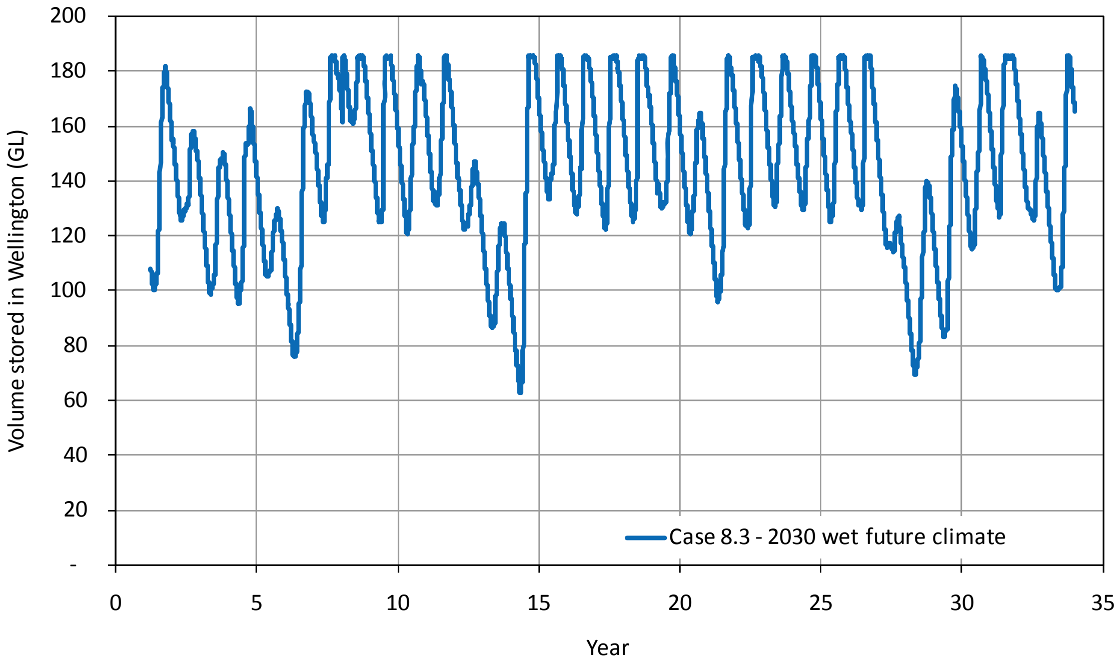

Figure 262 Annual volume stored in Wellington Reservoir for Case 8.3 – 2030 wet future climate

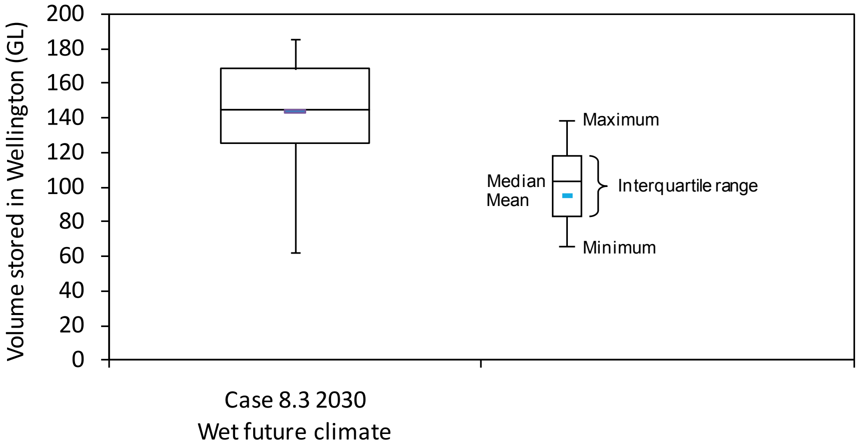

Figure 263 Distribution of annual volume stored in Wellington Reservoir for Case 8.3 – 2030 wet future climate

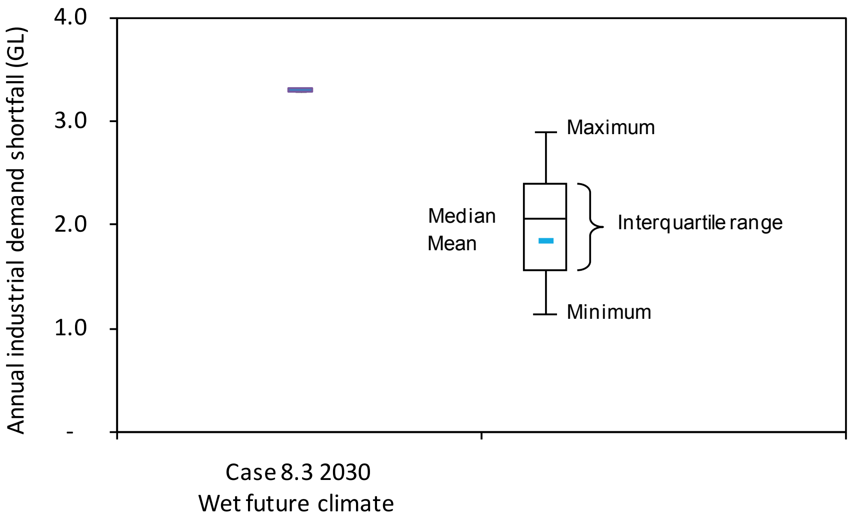

Figure 264 Range of industrial demand shortfalls for Case 8.3 – 2030 wet future climate

Table 78 Annual industrial supply shortfalls for Case 8.3 – 2030 wet future climate

	2030 wet future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	3.30
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	3.30

Case 8.3 – 2030 median future climate

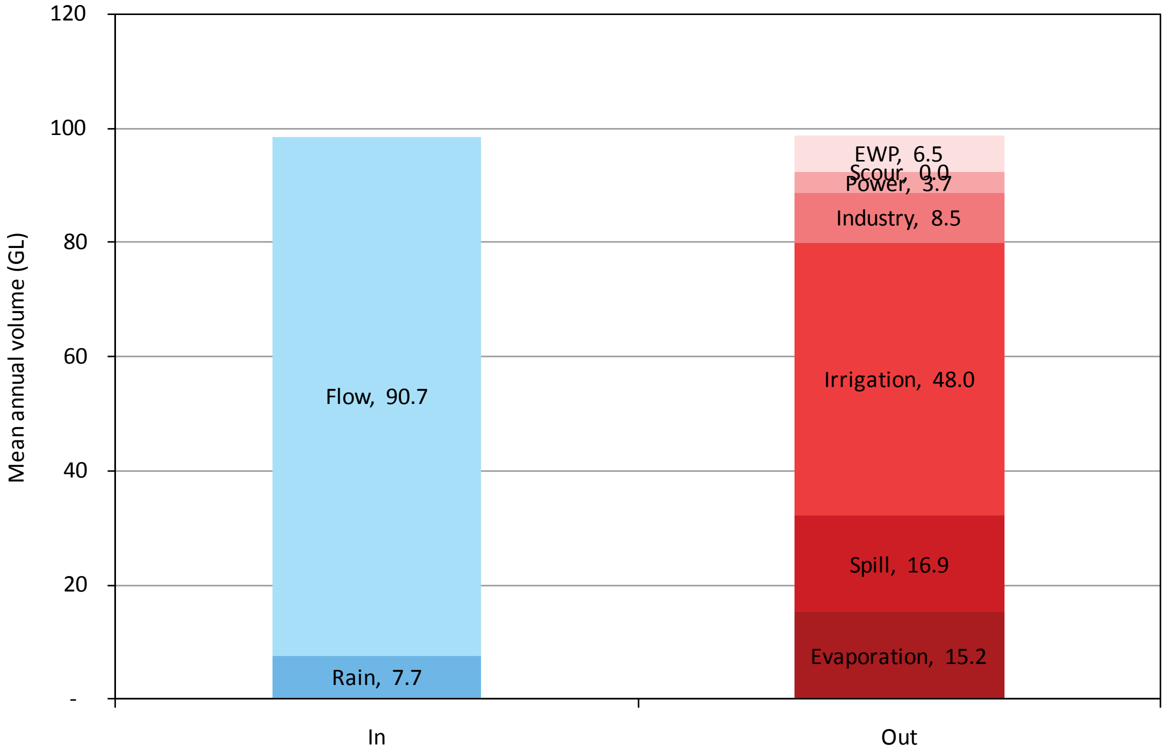

Figure 265 Mean annual water balance for Case 8.3 – 2030 median future climate

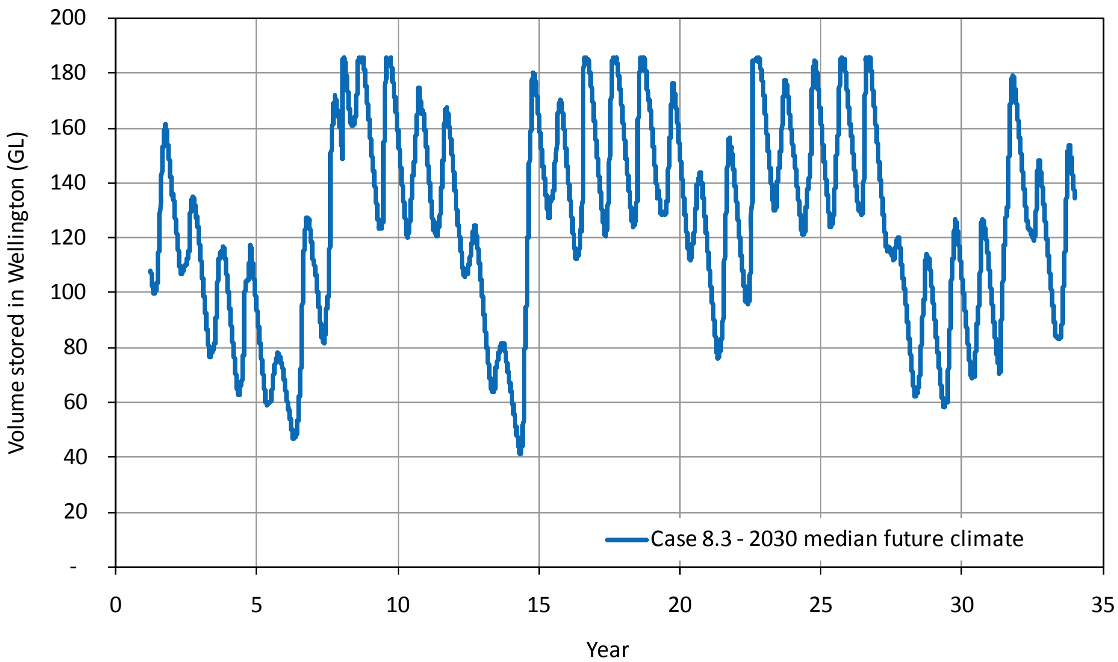

Figure 266 Annual volume stored in Wellington Reservoir for Case 8.3 – 2030 median future climate

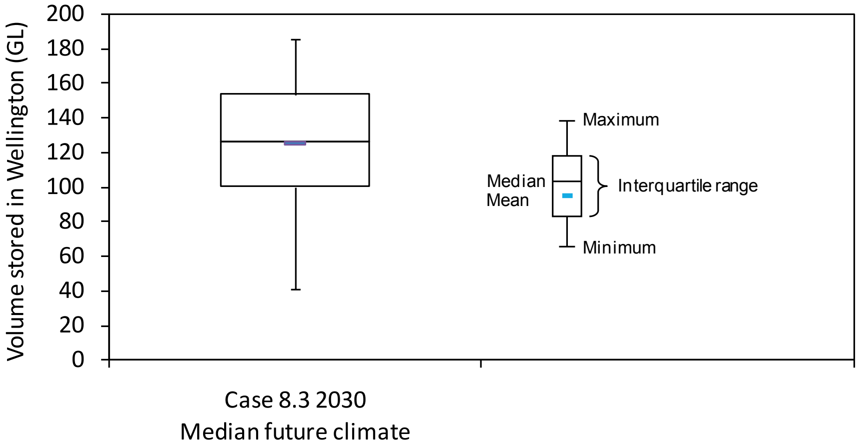

Figure 267 Distribution of annual volume stored in Wellington Reservoir for Case 8.3 – 2030 median future climate

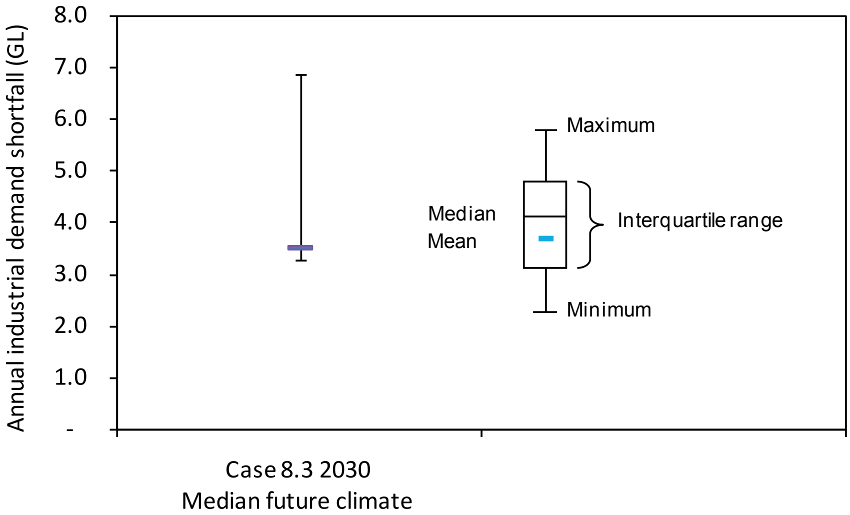

Figure 268 Range of industrial demand shortfalls for Case 8.3 – 2030 median future climate

Table 79 Annual industrial supply shortfalls for Case 8.3 – 2030 median future climate

	2030 median future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	6.86
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	3.52

Case 8.3 – 2030 dry future climate

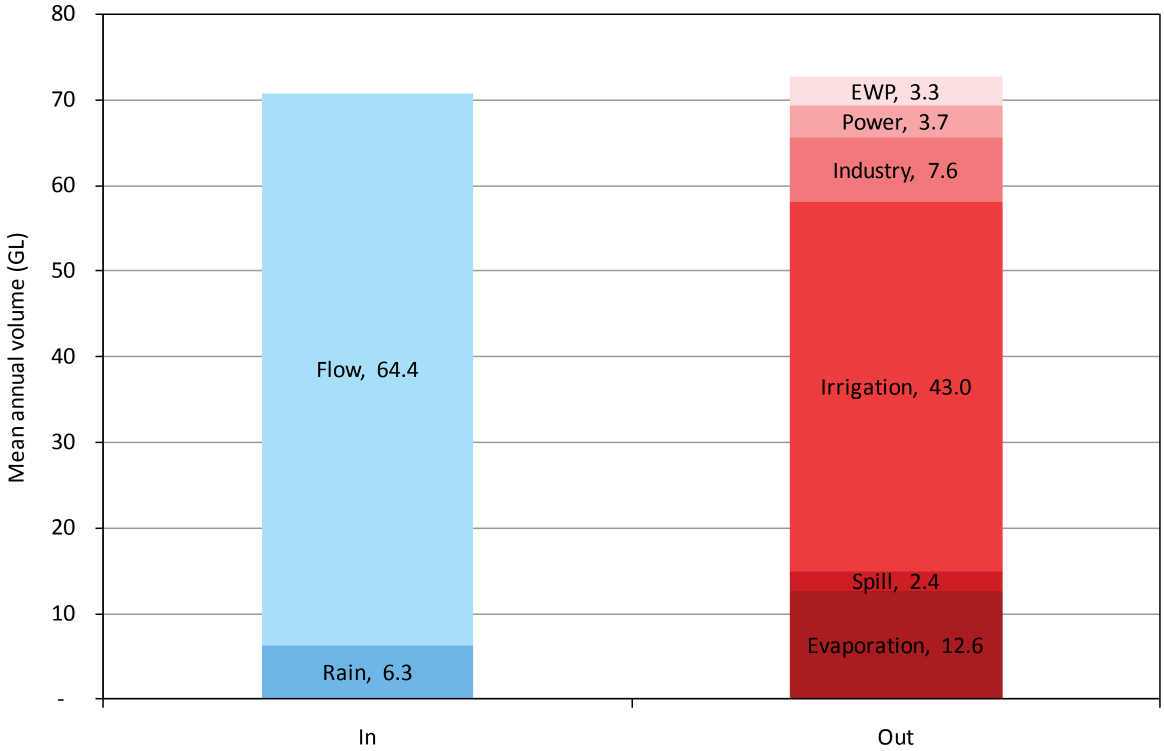

Figure 269 Mean annual water balance for Case 8.3 – 2030 dry future climate

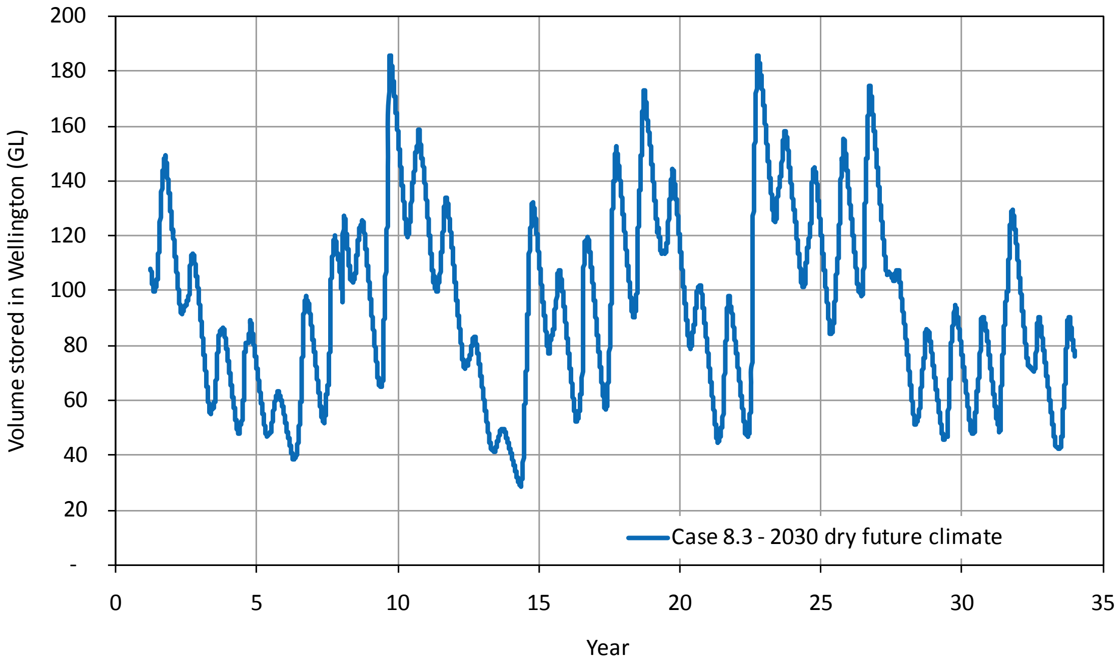

Figure 270 Annual volume stored in Wellington Reservoir for Case 8.3 – 2030 dry future climate

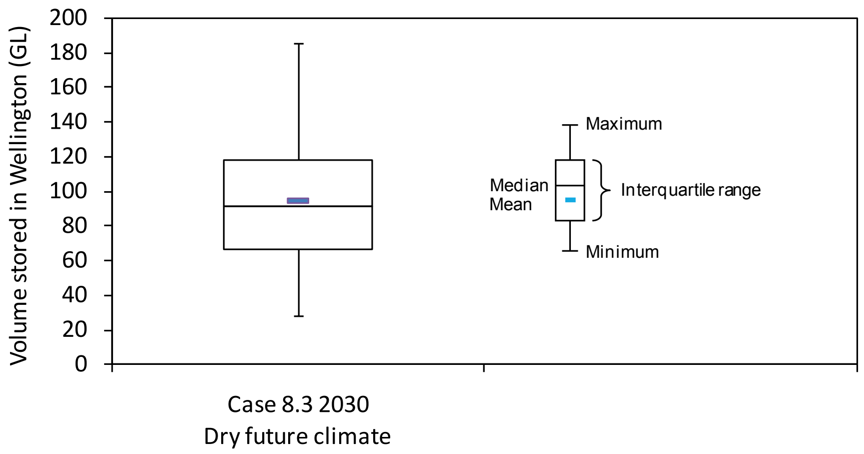

Figure 271 Distribution of annual volume stored in Wellington Reservoir for Case 8.3 – 2030 dry future climate

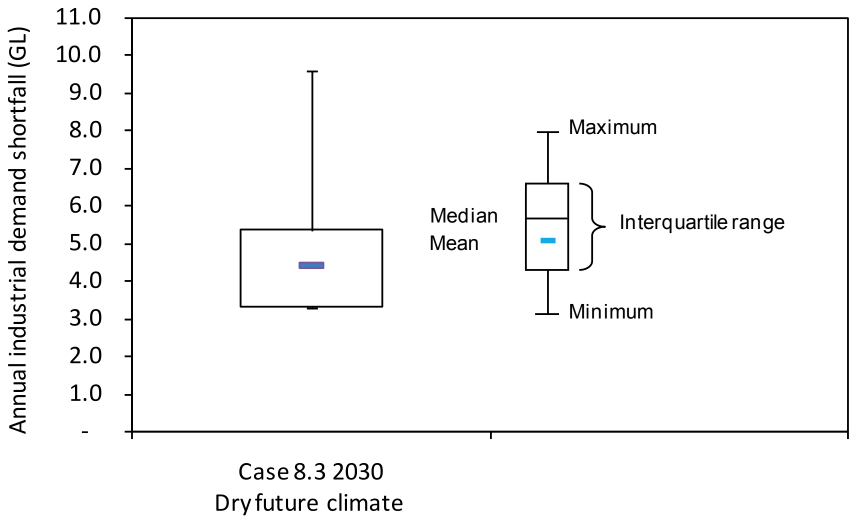

Figure 272 Range of industrial demand shortfalls for Case 8.3 – 2030 dry future climate

Table 80 Annual industrial supply shortfalls for Case 8.3 – 2030 dry future climate

	2030 dry future climate
Years with a shortfall in supply	100%
Maximum annual shortfall (GL)	9.60
Median of the annual shortfalls (GL)	3.30
Mean of the annual shortfalls (GL)	4.41

Shortened forms

EWP	Environmental water provision
EWR	Ecological water requirement
GSTWSS	Great Southern Towns Water Supply Scheme
LUCICAT	Land Use Change Incorporated Catchment

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
IL distribution	Monthly distribution of EWP releases based on the historical Wellington Reservoir winter scour regime.
KB distribution	Monthly distribution of EWP releases based on the distribution of the historical inflows to the Wellington Reservoir.
LUCICAT	The Land Use Change Incorporated Catchment (LUCICAT) model is a dynamic water-balance model that simulates daily streamflow and salt load for given rainfall, evaporation and land use.
Reliability	The frequency with which water allocated under a water access entitlement is able to be supplied in full. Referred to in some states as ‘high security’ and ‘general security’.

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