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

Lower Collie surface water allocation plan methods report

Background information and description of methods for the Lower Collie surface water allocation plan

Looking after all our water needs

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Department of Water

May 2011

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Summary

What is this document?

The Department of Water has prepared this document to explain how we developed the *Lower Collie surface water allocation plan* (DoW 2011a).

Why we produced the Lower Collie methods report

We prepared this document to make the process used in setting the lower Collie allocation limits transparent and publicly available. This document explains the approach we used to set the allocation limits and the licensing policies in the plan.

What the methods report includes

In this report we describe how we have used the hydrological, ecological, economic, social investigations completed in the plan area over the last 10 years to develop:

- objectives
- yield estimates and allocation limits
- environmental water provisions from the Worsley and Wellington Reservoirs.

We anticipate that the allocation limits and environmental water provisions will maximise the amount of time that people can take their full entitlements in a drier and warmer future (e.g. maximise reliability of supply) and will protect ecological, cultural and social values in the lower Collie for future generations.

The document is split into four sections:

Section	Content
1	Context and background
2	Current water use and future demand, hydrological, ecological, social and Indigenous cultural and yield estimate information
3	Our approach to developing plan objectives, selecting yield estimates and setting allocation limits
4	Our approach to develop management rules for the Wellington Reservoir

1 Background

1.1 The lower Collie water allocation plan

During 2010, the Department of Water prepared the *Lower Collie surface water allocation plan.* This method report explains how we developed the plan.

Plan area

The plan covers an area of approximately 800 km^2 and is located in the south-west of Western Australia around 200 km south of Perth. There are three subareas in the lower Collie plan area:

- the Wellesley subarea which covers 238 km^2 and includes the Wellesley River
- the Brunswick subarea which covers 286 km^2 and includes the Brunswick, Lunenburg and Augustus Rivers
- the lower Collie and tributaries subarea which covers 282 km^2 and includes the lower Collie River, Henty Brook, Flaherty Brook and Millers Creek.

Parts of the Collie River and Harvey irrigation districts are included within the plan boundary. However the Wellington and Harvey reservoirs, which deliver water to the irrigation districts, are outside the plan boundary.

The Wellington Reservoir allocation limit is set in the *Upper Collie allocation plan* (DoW 2009b) but we have set an environmental water provision for the reservoir as part of the lower Collie plan. The provision will be used in determining how water will be released from the reservoir in the future to maintain social and environmental values in the lower Collie River.

Proclaimed areas

Most of the lower Collie plan area is proclaimed under the *Rights in Water and Irrigation Act 1914* (Figure 1and Figure 2). A part of the Brunswick River is proclaimed as a drinking water supply catchment under the *Country Area Water Supply Act 1947*.

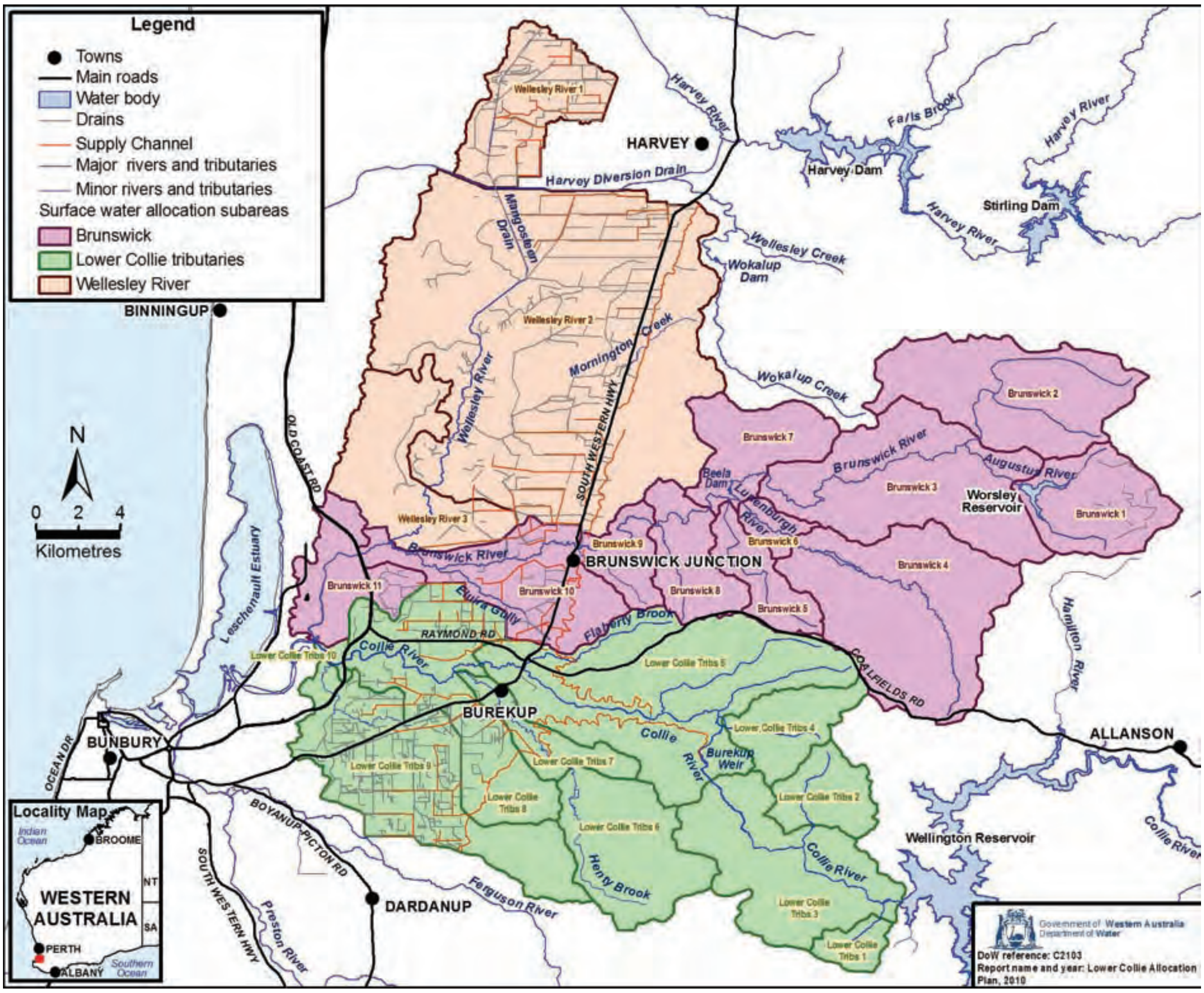


Figure 1 Lower Collie surface water allocation plan area

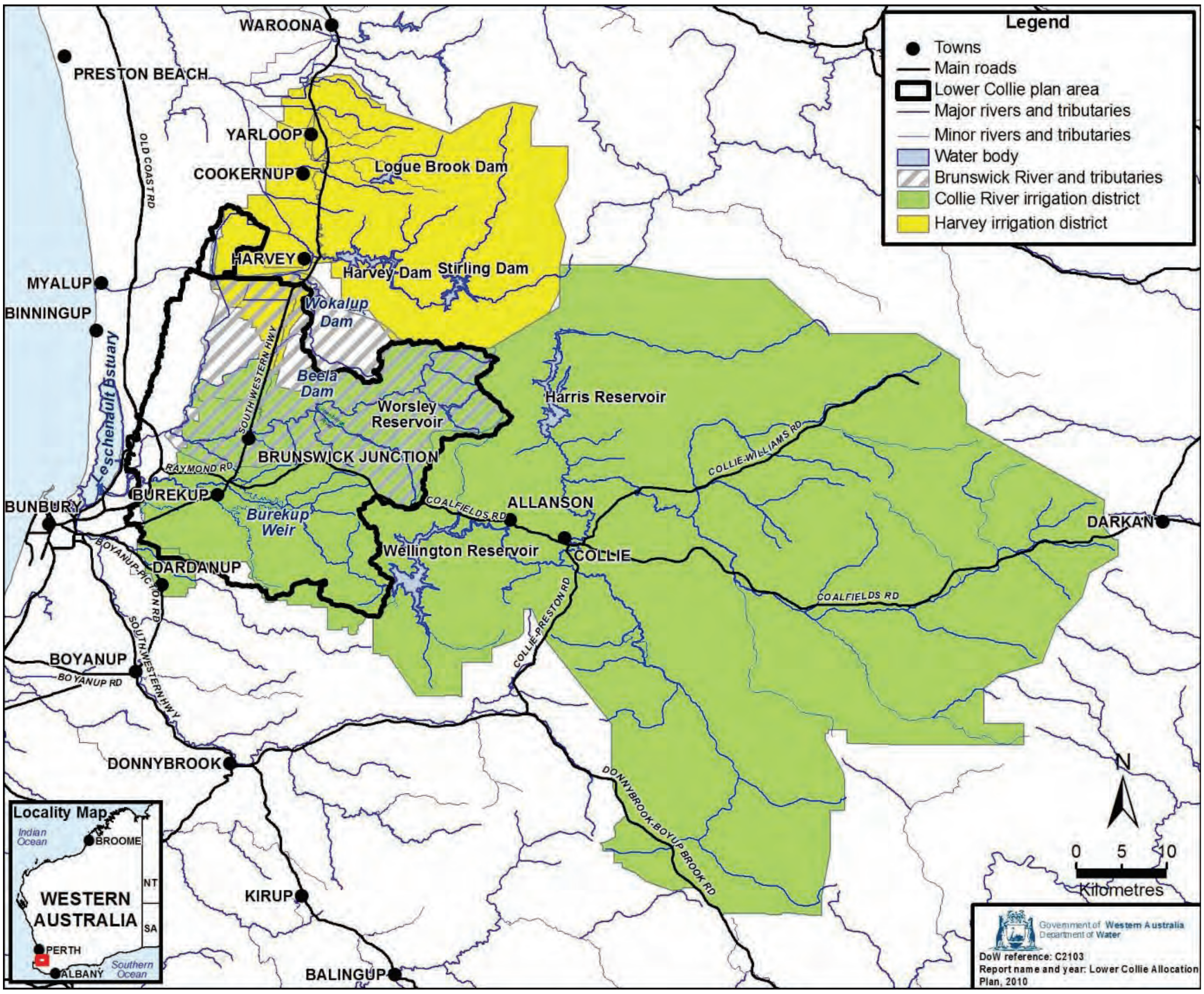


Figure 2 Proclaimed areas in the lower Collie surface water allocation plan area

1.2 Water resources managed under the plan

The plan includes the Wellesley, Brunswick, Lunenburg, Augustus and lower Collie rivers, Henty Brook and numerous tributaries and drains.

The resources in the plan are divided further into 24 surface water resource units. These are based on the hydrological catchment boundaries developed as part of the sustainable diversion limits project (SDL) undertaken for the south-west of Western Australia. Allocation limits have been developed for each of the 24 resources in the plan area (Figure 1).

1.3 The approach to setting allocation limits

Our previous licensing and allocation approach in the lower Collie area

The department has managed surface water use in the lower Collie allocation plan area through licences since the 1960s. Until now no formal allocation limits have been set.

As part of licensing we estimate the yield for a resource. Prior to 2008 this was done using mean annual flow with the regional models 6 and 75 (REG6 and REG75) – based on land clearing and rainfall data.

The REG6 model used the lesser of the 10th% annual flow and 60% of the mean annual flow. REG75 used 18% of the mean annual flow for the rainfall period 1975–2003. We ceased using mean annual flow to estimate yield in 2007 because we recognised that it did not consider variability between years.

Since 2008, the department has used yield estimates based on the sustainable diversion limits method in the South West. The SDL method is a regional model which estimates the divertible yield for rivers in the South West from Geraldton to Esperance.

For each licence application regional licensing officers assess yield information using SDL , catchment size, vegetation cover, rainfall, evaporation and the proposed method of water abstraction. This information is used to guide whether applicants get a licence, the volume of the licence, and what licence conditions are appropriate to manage water abstraction.

Current approach to licensing and allocation

Our new allocation planning process began in 2009 and is based on the department's standard allocation planning process which is outlined in Figure 3.

As part of the process we investigate and assess water resources, and use this information to set objectives, select a yield estimate and decide on allocation limits, and set rules on how to manage the storage and take of water.

The environmental flow regime is considered both as part of selecting the yield estimate and in developing rules for the storage and take of water (e.g. local licensing policies and the environmental water provision).

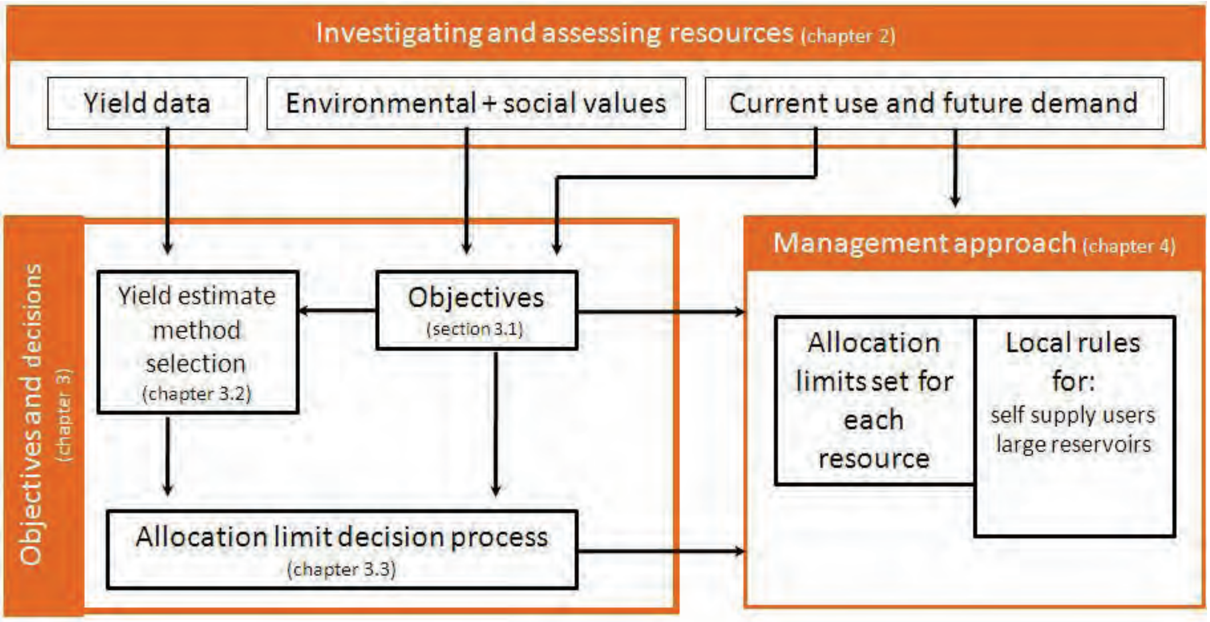


Figure 3 Allocation planning process for the lower Collie surface water allocation plan

Working with water users and other stakeholders

Involving the community throughout our planning process is an essential part of our work for any plan. In preparing the lower Collie allocation plan we consulted extensively to ensure we set the right management approach for the area. Particularly important was the need to ensure that the decisions made in the plan would effectively manage the system and would be supported by the community, representative organisations and other regulatory agencies.

We circulated a pamphlet to community and other stakeholders at the start of the planning process to introduce the plan and to explain what it would contain. We consulted with a range of people and organisations as part of developing the lower Collie allocation plan, including the:

- Brunswick River Restoration Action Group
- Department of Agriculture and Food
- Department of Environment and Conservation
- Harvey Water
- Harvey Shire Council
- Leschenault Catchment Council
- Nyungar elders and traditional owners
- WA Plantation Resources
- Worsley Alumina Pty Ltd.

A community information session was also held at the Brunswick hall on the 25 March 2010 to inform the community of the purpose and timeline for developing the lower Collie allocation plan. The project team held a follow up workshop with the Brunswick River Restoration Action Group to discuss streamflow gauging on the Brunswick River.

The department used information from these meetings combined with the detailed environmental, social and cultural studies that have been completed in the area over the last five years to develop objectives specific to each resource in the plan area.

In addition to the information gained during the consultation process, we will also consider and respond to the comments we receive following the public comment period for the plan. Submissions on the plan close on 29th August 2011

1.4 Definition of an allocation limit

An allocation limit is the annual volume of water set aside for consumptive use from a water resource. In lower Collie this includes two components:

- Licensable use – which includes existing licensed use as well as water that is available for new licences.
- Unlicensable use – which includes the water set aside for uses exempt from licensing, such as riparian rights.

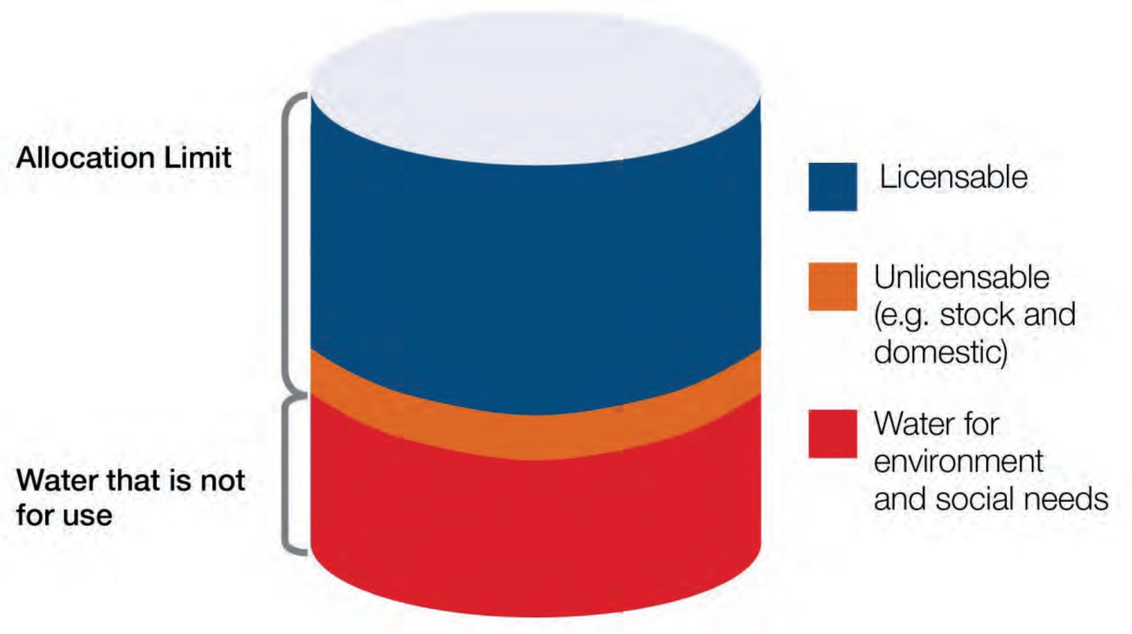


Figure 4 Components of the allocation limit [1]

[1]The tank diagram represents the average annual flow. Proportions represented are not to scale.

Figure 4 illustrates the components of the allocation limit in the lower Collie plan area. The diagram represents the mean annual flow in a river and how it is partitioned between environmental and social needs, and licensable and unlicensable use. The proportions represented in the diagram are not to scale.

There are no public water supply reserves in the lower Collie plan area, but the Brunswick River is proclaimed under the *Country Areas Water Supply Act 1947* as a drinking water catchment. The Water Corporation decommissioned the Beela Dam on the Brunswick River in 2004 and is not considering the Brunswick River as a drinking water source (Water Corporation 2010).

Managing variability

The flows in surface water systems in the south-west of Western Australia are highly variable. The department uses past observations and future climate predictions to project the average annual flow in the future – but ultimately the amount of water in rivers will vary from year to year depending on rainfall and runoff in the catchment.

In the lower Collie area we set allocation limits that are a fixed volume over a year and we use management rules (e.g. local and state licensing policies, environmental water provisions and take rules) to manage how water is taken and stored.

The allocation limits for the lower Collie area have been set considering the influence that the variability in streamflows has on the reliability of supply.

In self-supply areas where it is harder to predict the amount of water available for a coming year and to store and take water in a flexible manner, the allocation limits have been set with the expectation that they will be available in more than 80% of years, even in a median future climate at 2020.

In the Wellington Reservoir, where it is easier to predict water availability in the coming year and to alter releases accordingly, we expect that industrial and irrigation entitlements will have 53% reliability under a median future climate at 2030.

The management rules for the lower Collie plan area are designed to maximise the amount of water available while minimising the risk to environmental and social values in low-flow years.

2 Investigating and assessing resources

This section describes the information we use to inform our management decisions – Figure 5. It describes the:

- surface water resources now and in the future
- ecological, social and cultural Indigenous values ('in situ values')
- interaction between surface water and groundwater
- current use and future water demand in the plan area.

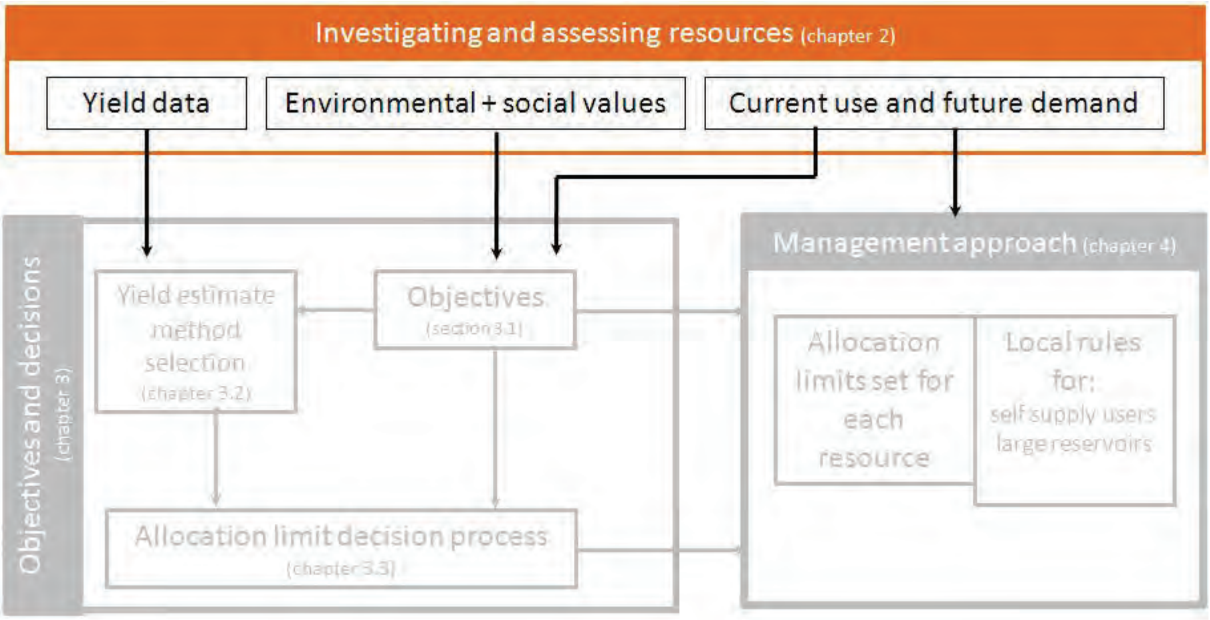


Figure 5 Allocation planning process for the lower Collie surface water allocation plan – investigating and assessing

Resource information

Hydrology

Information on the surface water hydrology of the lower Collie plan area is detailed in *Surface water hydrology of the lower Collie catchment* (DoW 2011b). A summary of the information used in the lower Collie surface water allocation plan is shown below.

Rainfall

The lower Collie catchment has a temperate climate, with warm dry summers and cool wet winters. Average annual rainfall ranges from 750 mm, increasing to 970 mm and then decreasing to 900 mm from west to east across the catchment (based on 1975–2003 rainfall isohyets).

The rainfall distribution is highly seasonal in the lower Collie catchment, with 79% of the annual rainfall occurring between May and September inclusive. October to April water is limited, when the mean monthly evaporation exceeds the rainfall. The long-term peak rainfall month is June but the recent rainfall record shows a shift to July as the peak rainfall month.

During the period post-1975 the south-west Western Australia region has experienced a decline in the May to July rainfall of 10 to 15% (from the 1900 to 1974 average) (Bates et al 2008). The rainfall decline has contributed to a severe reduction in runoff, with an average change in runoff of 2 to 3% for every 1% change in rainfall (Fu et al 2007).

Streamflow gauging

Streamflow records from the following gauges were used to assess water quantity and variability in the *lower Collie surface water allocation plan* (Figure 6):

- Wellesley River, Juegenup Wellesley (612039)
- Lunenburgh River, Silver Springs (612023)
- Brunswick River, Sandalwood (612022)
- Brunswick River, Cross Farm (612032)
- Falcon Brook, Falcon Road (612012)
- Stones Brook, Mast View (612005)
- Collie River, Rose Road (612043).

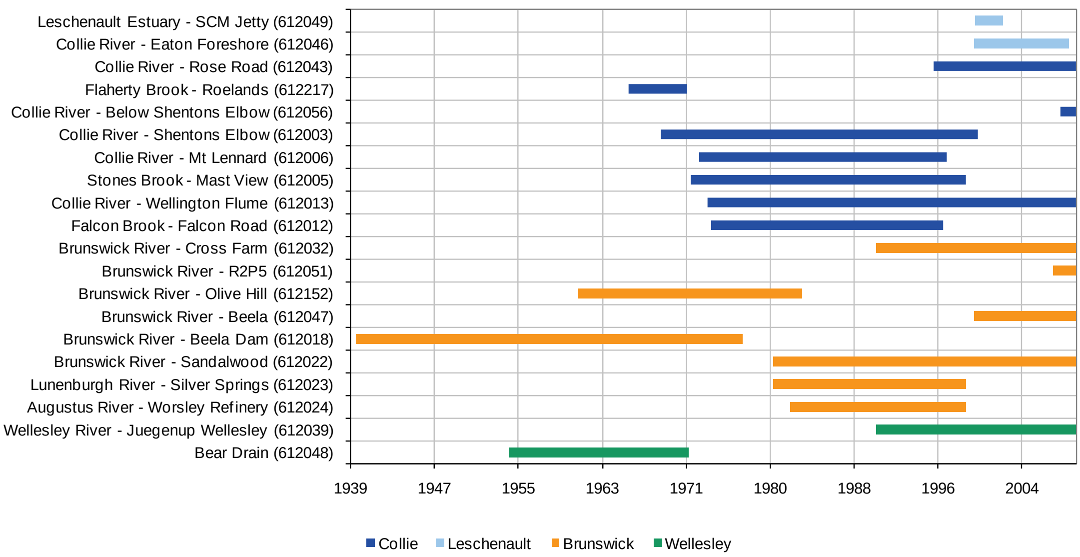


Figure 6 Period of record of streamflow gauging stations in the lower Collie catchment area

These gauges were selected because they have a record of at least 10 years, post-1975. Only post-1975 data was used as south-west Western Australia has experienced reduced rainfall, and subsequently reduced runoff, since this time.

Figure 7 shows all gauges in the plan area and highlights the ones that were used to develop the lower Collie allocation plan.

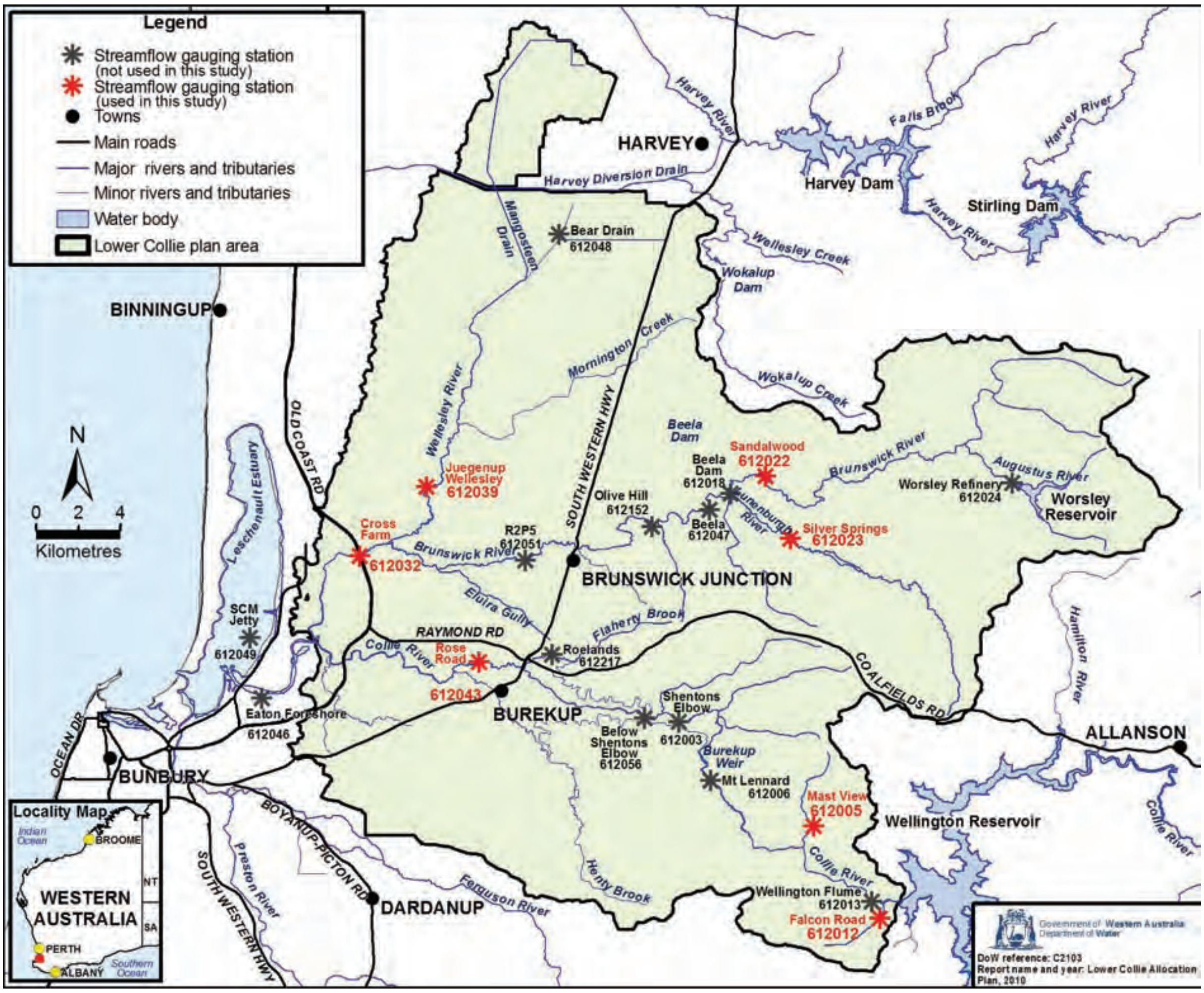


Figure 7 Location of streamflow gauging stations used in this study

Observed streamflow characteristics

Streamflow in the lower Collie surface water allocation plan area is highly seasonal and generally coincides with rainfall, with 75 to 89% of the annual flow occurring from June to September (inclusive) for the Brunswick and Wellesley subareas and 66% of the annual flow occurring for the Collie River subarea during this period.

In comparison to the other rivers in the plan area, higher summer flows are recorded in the Wellesley River, due to irrigation return flows from the Collie and Harvey irrigation districts, and in the lower Collie River, due to irrigation releases from Wellington Reservoir, and leakage and spill of irrigation water over Burekup Weir.

The peak flow month is typically July or August. There is a lag between the rainfall starting in May and the corresponding runoff response starting in June and also between the peak rainfall month (June) and the peak flow month. The majority of the Brunswick and Collie River tributaries are intermittent streams but the Brunswick and Collie rivers have water in them most of the time.

2.1 Future resource projections

Almost all global climate models used by the Intergovernmental Panel on Climate Change (IPCC) predict that south-west Western Australia will experience a drier and warmer future (CSIRO 2009). This means that water resource assessments in the lower Collie plan area cannot be based on what has occurred previously – even post-1975.

The lower Collie plan has therefore been developed using future projections of rainfall and runoff. The annual flow information for each resource in the lower Collie plan area - based on observed flows between 1975 and 2009 and modelled flows under a future climate centred on 2020 are summarised in Table 2 on page 13 and 14.

Application of future climate projections to the lower Collie

The Department of Water has used climate and runoff data from the CSIRO south-west Western Australia sustainable yields project (CSIR0 2009) for the lower Collie allocation plan.

Wet, median and dry future climate scenarios were compared to rainfall and runoff from 1975 to 2007. The relative reductions were then applied to observed streamflow statistics for each resource in the lower Collie plan area.

The average change across the lower Collie catchment for the mean annual rainfall and mean annual runoff from the 1975 to 2007 period is shown in Table 1.

It should be noted that wet, median and dry future scenarios all project a decline in mean annual rainfall. The 'wet' scenario isn't wetter than conditions between 1975 and 2007 but is wetter than the median scenario.

Table 1 Percentage change in mean annual rainfall and runoff from the historical baseline of 1975 to 2007 for the future climate scenarios centred on 2030, averaged across the plan area

Future climate scenarios	Projected reduction %	
	Mean annual rainfall	Mean annual runoff
Future – wet	−2	−6
Future – median	−9	−24

Future – dry	−15	−40

Annual streamflow

The mean annual flow and minimum annual flow statistics are also used as part of allocation planning as an indication of the quantity and variability of a stream in a catchment. Annual streamflow estimates have been calculated for all resources in the lower Collie area based on:

- gauged streamflows between 1975 and 2009
- modelled streamflows which reflect a future median climate centred on 2020.

Selecting a climate scenario to set allocation limits

We have chosen the future median climate scenario to estimate yield in the lower Collie surface water allocation plan area. We balanced a number of considerations including:

- comparison of recent climate trends to the wet, median and dry projections
- an assessment of the acceptable level of risk to supply, the water resource, and social and ecological systems
- the Department of Water’s licensing and planning approach.

The future evaluation and improvement of the lower Collie plan will allow for the ongoing development of future climate scenarios and for changes in hydrologic variability. This ensures that adjustments can be made into the future to account for uncertainties.

We will assess rainfall and runoff trends every five years to identify which future climate scenario streamflow and rainfall data most closely reflects. We may need to revise the allocation limits and release rules from reservoirs in the plan area if analysis shows that the climate is changing in a way different to that predicted by the future median climate projection (This is an action for implementing the allocation plan - Refer to Section 7 of the *Lower Collie surface water allocation plan*).

Time frame for assessment

The allocation plan is likely to be reviewed in 10 years and because of this we have used estimates of future water yields centred on 2020 to develop the plan. We have used estimates centred on 2030 to develop management rules for the Wellington reservoir.

The median future climate scenario is not a prediction of the climate over the next ten years, or a forecast of the climate at 2020. It is a scenario of observed data scaled by projected global temperature change between 1990 and 2020. For convenience, the statistics for this period are referred to as being ‘centred on 2020’.

The CSIRO's south-west Western Australia sustainable yields project (2009) gives no explicit projection for 2020. Because of this the department used a linear interpolation of the runoff between the historical baseline scenario and the wet, median and dry scenarios at 2030 to construct 2020 values. The interpolation is explained pictorially for mean annual runoff in Figure 8.

The report, *Surface water hydrology of the lower Collie catchment* (DoW 2011b) provides further details about our approach to estimating streamflow for a future climate in the lower Collie plan area.

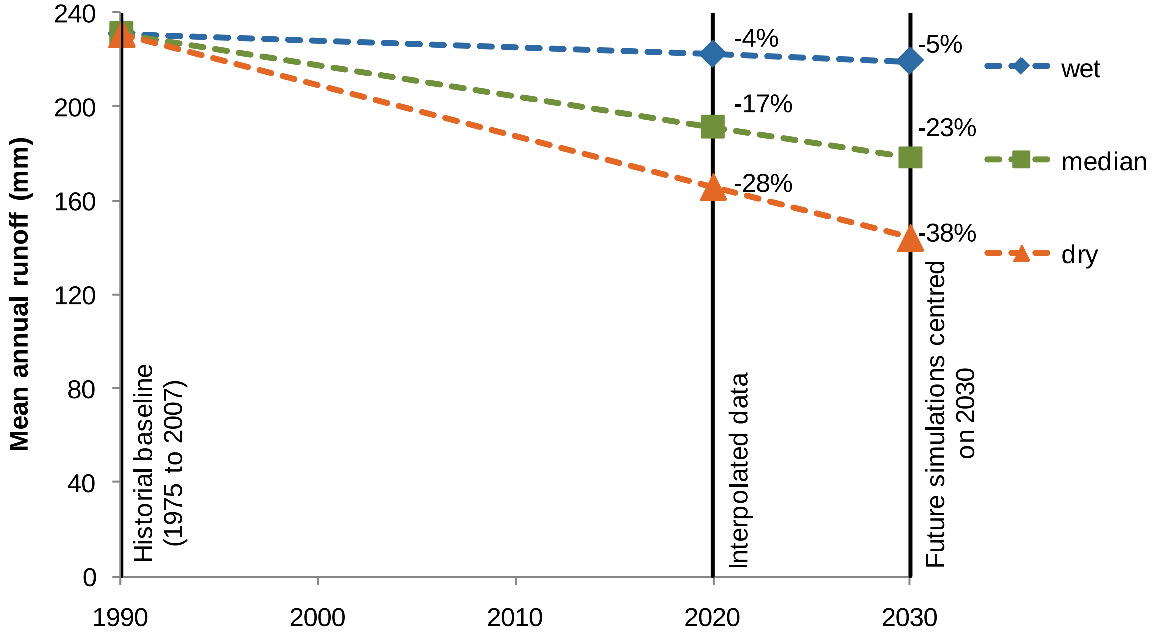


Figure 8 Interpolation between the historical baseline centred on 1990 and the future scenarios centred on 2030 to construct scenarios at 2020 (data is for Cross Farm, 612032)

Table 2 Annual flow information (including irrigation return flows) for resource areas in the lower Collie catchment

Resource	**Observed flows (1975- 2009)**		**Modelled flows under a median future climate at 2020**	
	Mean annual flow ML/yr	**Minimum annual flow ML/yr**	**Mean annual flow ML/yr**	**Minimum annual flow ML/yr**
Lower Collie tribs 1	602	92	466	51
Lower Collie tribs 2	1 541	229	1 192	128
Lower Collie tribs 3	3 055	1 474	2 586	1 202
Lower Collie tribs 4	4 851	516	3 825	294
Lower Collie tribs 5	16 819	8 263	14 244	6 747

Resource	Observed flows (1975- 2009)		Modelled flows under a median future climate at 2020	
	Mean annual flow ML/yr	Minimum annual flow ML/yr	Mean annual flow ML/yr	Minimum annual flow ML/yr
Lower Collie tribs 6	11 664	3 601	9 714	2 756
Lower Collie tribs 7	4 745	1 468	3 980	1 164
Lower Collie tribs 8	8 029	1 895	6 800	1 610
Lower Collie tribs 9	9 323	4 555	7 900	3 676
Lower Collie tribs 10	113	57	95	45
Brunswick 1	5 636	1 175	4 715	833
Brunswick 2	7 294	2 202	6 106	1 734
Brunswick 3	10 790	3 557	9 032	2 801
Brunswick 4	11 572	3 865	9 773	2 990
Brunswick 5	4 408	1 200	3 616	797
Brunswick 6	1 849	376	1 517	249
Brunswick 7	4 012	1 492	3 293	1101
Brunswick 8	3 794	1 762	3 114	1300
Brunswick 9	3 777	1 085	3 099	801
Brunswick 10	2 577	412	2 146	344
Brunswick 11	1 013	386	851	302
Wellesley River 1	7 067	3 629	6 026	2 891
Wellesley River 2	54 174	15 505	46 065	12721
Wellesley River 3	738	442	628	361

2.2 Yield estimate information

The yield estimate is the amount of water that can be abstracted while still meeting the environmental objectives for the resource. An environmental objective is a goal to maintain, protect, restore or improve an identified ecological asset, process or function.

We based our estimated yield for the resources in the lower Collie area on streamflow projected for a future median climate at 2020. This is, on average, 17% less than the streamflow recorded in the plan area between 1975 and 2007.

There were two methods available to estimate yield as part of the lower Collie allocation plan:

- the sustainable diversion limits method
- the environmental flow study and PADFLOW/RESYM method.

Using the sustainable diversion limits method to estimate yield

The ‘sustainable diversion limit’ (SDL) method identifies the acceptable limit of change to flow. It does this based on daily flow duration curves at gauging stations where post 1975 flow data is available. It has been used to develop estimates of sustainable yield for catchment areas from Geraldton to Esperance in Western Australia and is applicable in areas where there is low surface water use. The SDL method was developed by SKM in collaboration with the department and has been reviewed both by the department and by external ecologists and hydrologists.

The SDL method is not suitable for determining yield in resources that are affected by the Wellington and Worsley reservoirs. This is because the streamflow estimates used as part of the SDL method are based on observed flows for rivers that have a low level of water use. SKM (2008a, 2008b) provides further detail on the SDL approach.

Figure 17 on page 42 shows the process used to decide which yield estimating method was suitable for each resource in the plan area.

The SDL method incorporates some general ecological principles (e.g. a minimum flow threshold) but these thresholds are not site specific. The method is essentially a regional, hydrologic estimate of yield. Central to the method are four rules:

- a winter fill period over which abstractions can occur (15 June to 15 October)
- a minimum flow threshold above which diversions can occur
- a maximum daily extraction rate (for pumped extractions)
- an annual volume associated with an 80% reliability of supply (e.g. in 20% of years the full volume cannot be abstracted if the other rules are maintained).

The sustainable diversion limits derived by SKM (2008a, 2008b) are based on historical flow data. Maintaining these limits under a drier flow regime reduces the water available for use and therefore the amount of time that people will get their full entitlement.

Therefore, we have estimated potential future diversions based on the four rules, including maintaining the reliability of supply at 80% under the median 2020 climate scenario (DoW 2011b). The 80% reliability of supply target was chosen as part of the SDL study because it is assumed to be typical of the reliability associated with agricultural uses.

Estimates of the volume diverted in the minimum year under the future climate scenario were also made and are summarised in Table 3.

The sustainable diversion limit method and application of the future climate scenarios are outlined in more detail in SKM (2008a, 2008b) and *Surface water hydrology of the lower Collie catchment* (DoW 2011b).

Table 3 Yield estimate for resources in the lower Collie catchment under the median future climate scenario centred on 2020 using the SDL method

Resource	Yield estimate (volume diverted at an 80% reliability) ML/yr	Yield estimate (volume diverted in minimum year) ML/yr
Lower Collie tribs 1	59	8
Lower Collie tribs 2	211	30
Lower Collie tribs 3	371	204
Lower Collie tribs 4	243	41
Lower Collie tribs 5	1356	747
Lower Collie tribs 6	831	183
Lower Collie tribs 7	195	43
Lower Collie tribs 8	494	109
Lower Collie tribs 9	493	109
Lower Collie tribs 10	6	2
Brunswick 1	444	40
Brunswick 2	799	87
Brunswick 3	1024	111
Brunswick 4	981	303
Brunswick 5	406	7
Brunswick 6	95	2
Brunswick 7	262	6
Brunswick 8	286	6
Brunswick 9	145	3
Brunswick 10	184	10
Brunswick 11	52	13
Wellesley River 1	826	298
Wellesley River 2	5004	1806
Wellesley River 3	56	4

Using environmental flow studies to determine yield

The environmental requirements of a river can be met by:

a) setting an allocation limit and applying take rules based on a yield estimate
b) the release of water from a large reservoir
c) both (a) and (b).

In this section we describe our approach to estimate yield using an environmental flow study - (a). The development of environmental water provisions for the Wellington Reservoir is outlined in detail in Section 4 – (b).

We have previously called environmental flow studies completed in Western Australia ‘ecological water requirements’ studies. In this document, all studies that relate to the development of environmental flow regimes for an area are referred to as environmental flow studies.

Our preferred approach in preparing an allocation plan is to estimate yield using an environmental flow study. This is because it uses the most detailed and site specific information available on the link between flow and ecology for an area.

To estimate yield using an environmental flow study the department estimates the:

1. flow regime and volume of water needed to maintain current ecological values – the environmental flow regime
2. flow regime under a future climate and future demand scenario – the projected future flow regime
3. the degree to which flow in the rivers is affected by abstraction – historical use.

Yield – the amount of water that can be abstracted while still meeting the environmental objectives for the resource – is determined at the environmental flow study site using Formula 1:

$$\text{Yield estimate} = \left(\text{projected future flow regime} - \text{environmental flow}\right) + \text{historical use}$$

The yield estimate is presented as a fixed annual volume at an environmental study site.

To apportion the yield estimate at an environmental flow site between resources in the lower Collie area, we used an approach developed as part of the SDL project. The approach utilises an algorithm based on catchment characteristics such as clearing, soil type, slope, evaporation and elevation to apportion an SDL yield developed for a gauging station (SKM 2008a, 2008b).

We applied this apportioning method to the lower Collie area by developing a ratio of yield using environmental flow studies and the total SDL derived by SKM (2008a, 2008b), at the environmental study site. The resulting ratio was then applied to the SDL volume at each resource using Formula 2:

$$\text{Yield estimate at resource} = \frac{\text{total yield using environmental flow study}}{\text{total yield using SDL}} \times \text{SDL at resource}$$

How do we develop the environmental flow regime?

We developed a flow regime sufficient to maintain the current ecological values of river systems in the lower Collie area, consistent with the objectives of the environmental flow study – we call this the environmental flow regime. The environmental flow regime includes variation in annual, seasonal and daily flow and variation in the frequency and duration of ecologically important flow events.

An environmental flow regime is developed using relationships between flow and ecology developed at an environmental flow study site (Figure 9). Flow–ecology linkages describe the water depths and related flow rates for flow events that maintain:

- populations of fish and macro-invertebrates
- vegetation community structure and composition
- water quality
- channel geomorphology
- ecosystem processes.

The flow–ecological linkages developed as part of environmental flow studies in the lower Collie area are listed in Appendix B. The flow required to meet each flow–ecology linkage is estimated using topographic survey information and the relationship between streamflow and water depth.

The flow–ecology linkages are then used as an input to the river ecological sustainable yield model (RESYM) and proportional abstraction of daily flow (PADFLOW) approach. The method allows identification of the environmental flow regime and the proportion of different historic flow components that can be abstracted before the required ecological flows are compromised.

Environmental flow studies

There are several environmental flow studies for the lower Collie area that we did not use to develop yield estimates because they do not adequately capture the variability of natural flows from year to year and/or because some of the methods used to develop flow–ecology thresholds have been superseded. They include Streamtec 2000, Welker Environmental Consultancy & Streamtec 2002, Hardcastle et al 2003, Storey 2003, and WRM 2010.

The three environmental flow studies (Figure 9) we did use to estimate yield in lower Collie were:

- Brunswick River ecological water requirements, (Donohue et al 2009) – the yield estimate at Reach 1 was used to assess yield for all resources along the Wellesley and Brunswick rivers in the plan area.
- Environmental flow regime of the lower Collie River – Shenton’s Elbow reach (Bennett & Green 2011a in preparation) which was used to assess yield in the lower Collie and tributaries resources 4, 5, 8 and 10.
- Environmental flow regime of the lower Collie River – Wellington reach (Bennett & Green 2011a in preparation) which was used to assess yield in the lower Collie and tributaries resources 1, 2, and 3.

We used these studies because they are based on the PADFLOW and RESYM method described above.

There are no environmental flow studies, and therefore no yield estimates, using environmental flow studies for the lower Collie and tributaries resource 9.

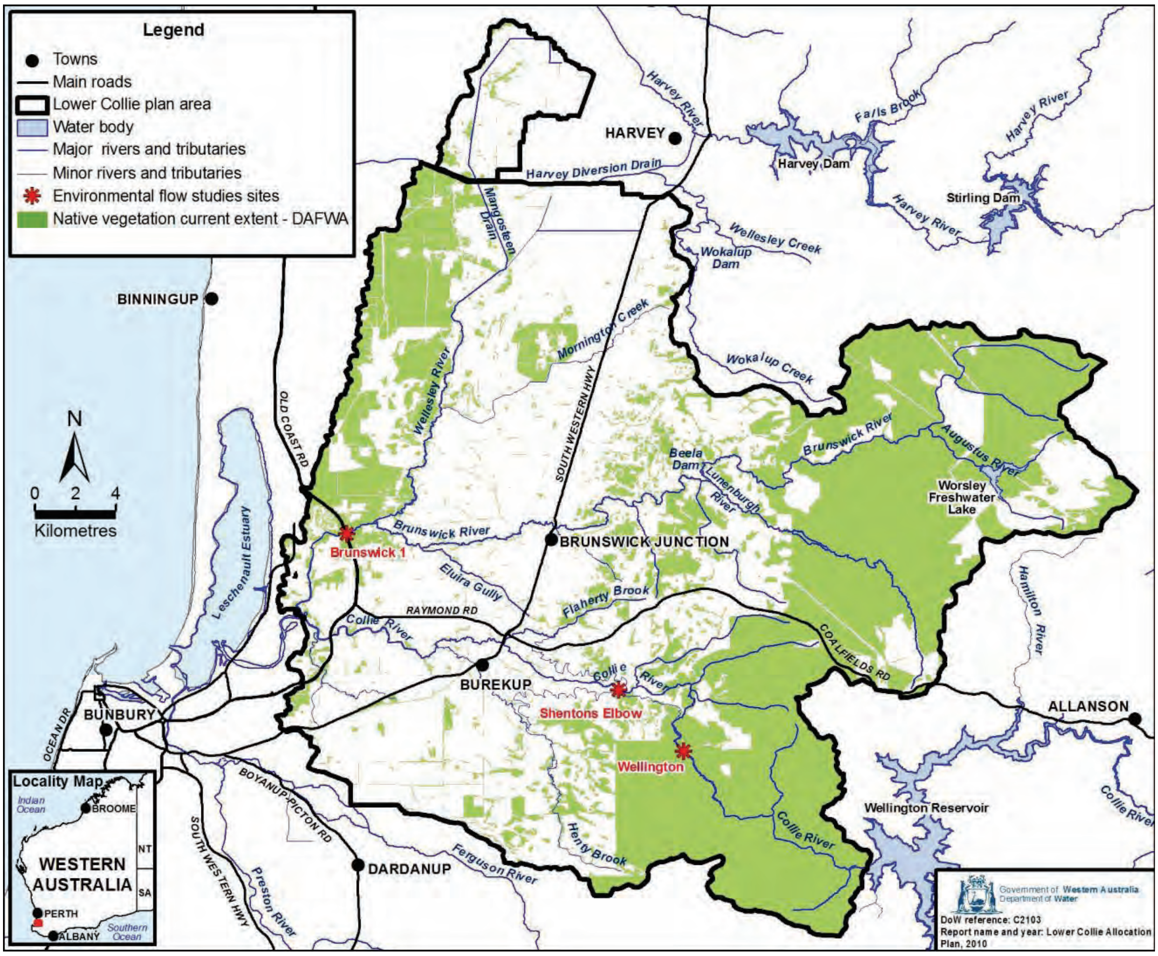


Figure 9 Environmental flow study sites

How did we develop the environmental and projected future flow regime at each study site?

The information used to develop an environmental flow regime and a projected future flow regime are summarised for each environmental flow study site in Table 4. These regimes were used to determine the yield at each environmental study site using Formula 1.

Table 4 Summary of information used to develop yield at each environmental study site (refer to Figure 9 for the study site locations)

Resource	**Environmental flow regime**	**Future flow regime**	**Historical use**
Brunswick 1,2,3,4,5,6,7,8,910,11 Wellesley River 1,2,3	Developed for the Brunswick 1 study site as part of the *Brunswick River ecological water requirements*, (Donohue et al 2009). It was developed using daily flows at the Brunswick River, Cross Farm (612032) measured between1975 and 2003.	Developed for Brunswick River, Cross Farm gauge using CSIRO (2009) future scenario modelling. We assumed that future self-supply demand in the Brunswick and Wellesley Rivers would be similar to historical use.	2.93 GL in 2001[1]
Lower Collie tribs 1, 2, 3,	Developed for the Wellington study site as part of the *Environmental flow regime of the lower Collie River – Wellington reach* (Bennett & Green 2011a in prep). The environmental flow regime is based on a proportion of daily inflow data for the Wellington Reservoir between 1975 and 2007[2]. We only assessed flows between May and September to avoid allocating summer irrigation releases from the Wellington Reservoir.	Developed using CSIRO predictions of inflow to Wellington Reservoir under a median future at 2020. The 0.3[3] future allocation scenario was used in conjunction with the Wellington Reservoir water balance model to predict the future flow regime for the Wellington reach. We only assessed flows between May and September to avoid allocating summer irrigation releases from the Wellington Reservoir. Refer to Section 4 and DoW 2011a in preparation for more information on the 0.3 allocation scenario.	4 ML/yr

[1] Yield at Brunswick reach 1 was estimated for the lowest flow year – 2001

[2] Excludes 2002 and 2003. Flow at the Wellington Flume (612013) gauging station, used to develop the historical flow at Mt Lennard gauging station site was not operational during 2002 and 2003, therefore 2002 and 2003 were excluded from the environmental flow regime for consistency

[3] Refer to DoW 2010d for a full explanation of the 0.3 future allocation scenario

Resource	Environmental flow regime	Future flow regime	Historical use
Lower Collie tribs 4, 5,8,10	Developed for the Shenton's Elbow study site as part of the *Environmental flow regime of the lower Collie River* – Shenton's Elbow reach (Bennett & Green 2011a in prep). We used daily flows at Shenton's Elbow study site between 1997 and 2007 developed from correlations between flow at the Collie River at Rose Road (612043) and a temporary water level probe inserted at Shenton's Elbow.	The outputs of the Wellington Reservoir water balance model, scenario 0.3, were used in conjunction with a water balance model for Burekup Weir to model spills and the diversion of water at Burekup Weir to predict the future flow regime for the Shenton's Elbow reach. Refer to Section 4 and DoW 2011a in preparation for more information on the 0.3 allocation scenario.	165 ML/yr
Lower Collie tribs 6,7, 9	No accepted environmental flow study exists for these resources.		

What were our yield estimate results at each environmental flow study site?

Brunswick environmental flow study site

There is yield available at the Brunswick environmental study site (Figure 10), which has been used to estimate yield in all resources in the Brunswick and Wellesley subareas.

Yield in these resources has been estimated for the lowest flow year, because the ability to vary the volume of abstraction between wet years and dry years is limited. We have used the lowest flow year to minimise risks to environmental and social values in dry years.

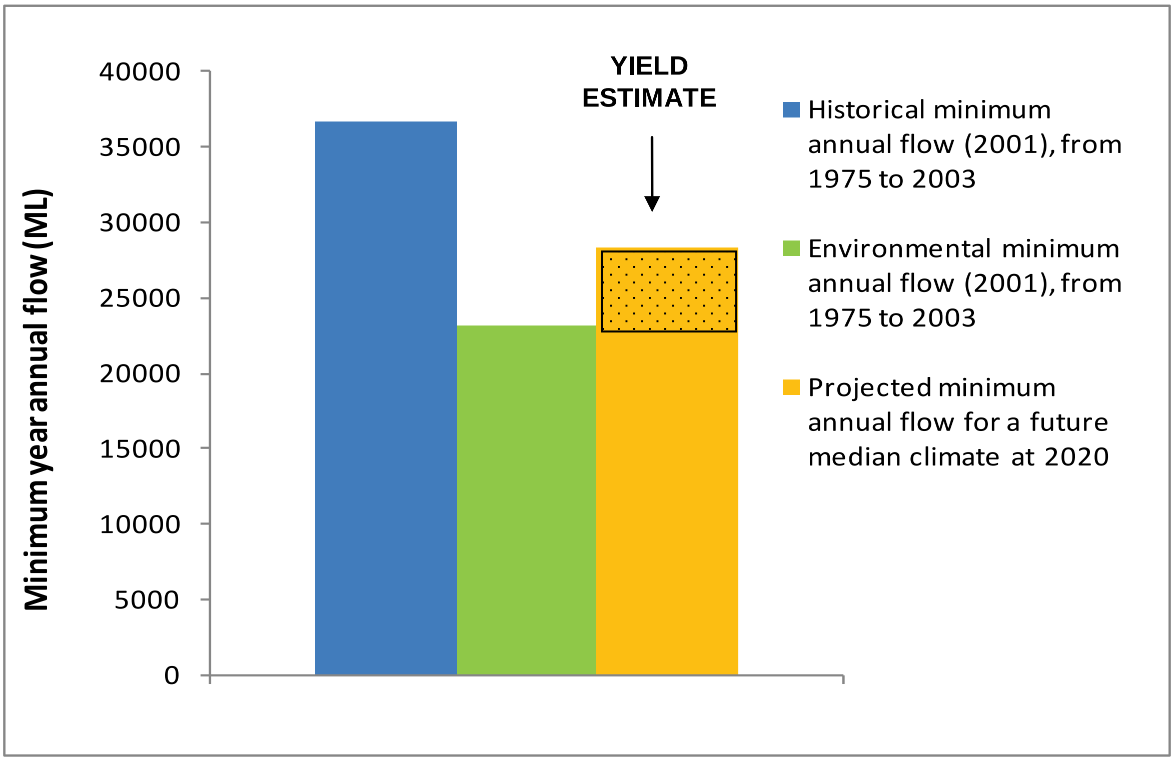


Figure 10 Historical, environmental and projected minimum annual flows at the Brunswick environmental study site Reach 1

Using Formula 1, yield at the Brunswick environmental flow study site is 8022 ML/yr. Using Formula 2, 8022ML/yr was apportioned to Brunswick and Wellesley resources (see Table 5).

Wellington and Shenton's elbow environmental flow study sites

At these study sites the average future flow regime was compared with the average environmental flow regime.

We did this because of difficulties associated with comparing the projected flow regime (developed using the CSIRO modelled streamflow sequence), with the environmental flow regime (developed using the observed streamflow sequence).

Figure 11 and Figure 12 show that there is no additional yield at the lower Collie, Wellington and Shenton's Elbow environmental flow study sites.

At the Shenton's Elbow site the average annual projected flow is 14.4 GL per year below the annual average environmental flow regime – 67% of the flow required to meet the environmental flow. The yield estimate at Shenton's Elbow was used to estimate yield in the lower Collie and Tributaries 4, 5, 8 and 10 using Formula 2.

At the Wellington site the average annual projected flow (from May to September) is 15.2 GL per year below the annual average environmental flow regime – 64% of the flow required to meet the environmental flow. The yield estimate at the Wellington site was used to estimate yield in lower Collie and tributaries 1, 2, 3 using Formula 2.

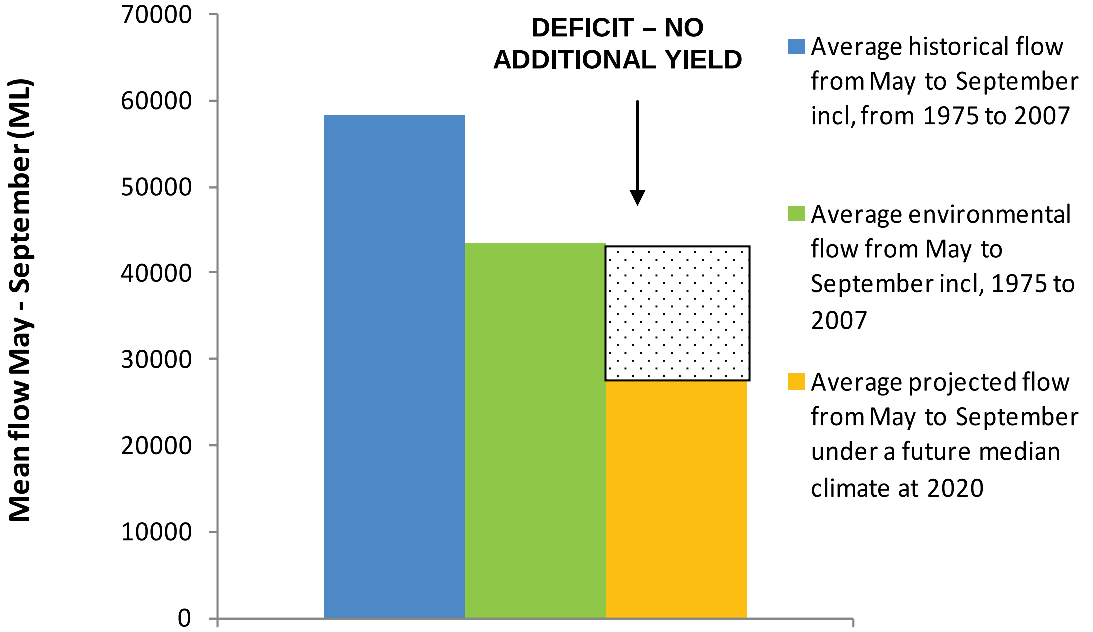


Figure 11 Average historical, environmental and projected flows from May to September inclusive, at the Mt Lennard gauging station site in the Wellington reach

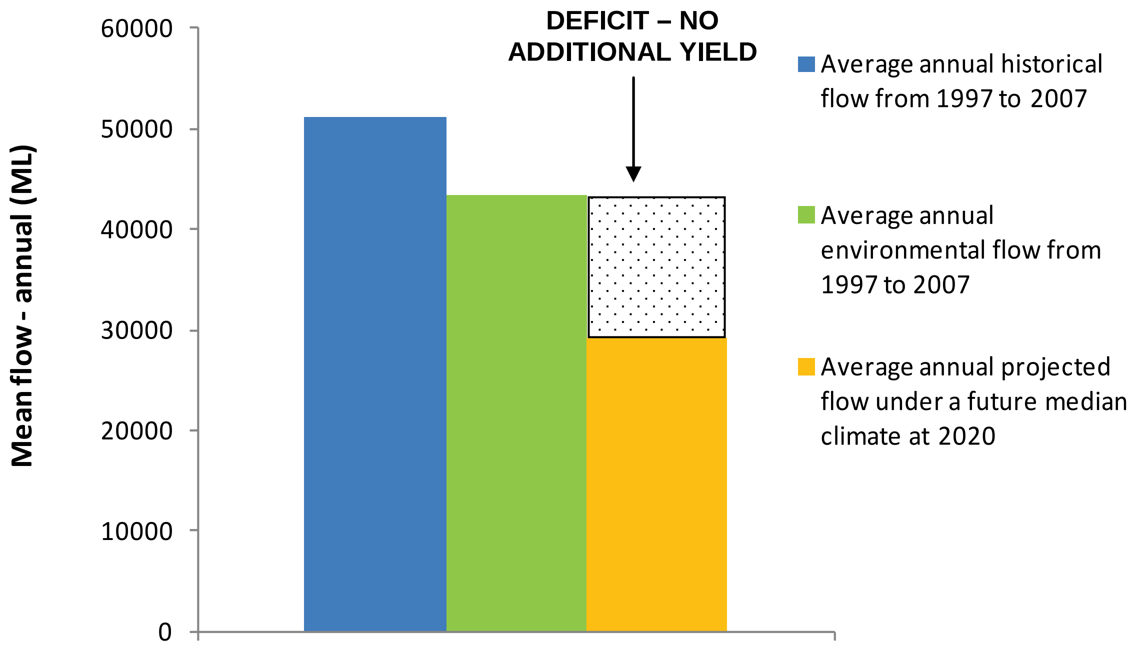


Figure 12 Average annual historical, environmental and projected flow at the Shenton's Elbow reach

What were our environmental yield estimate results at each resource?

Using Formula 2, yield at the environmental flow study sites was apportioned to applicable resources. The final yield estimates are summarised in Table 5. Because the yield at the Shenton's Elbow and Wellington environmental flow sites is negative, yield in lower Collie resources 1,2,3,4,5,8 and 10 has been estimated as zero and these are not shown in Table 5.

Table 5 Total environmental yield estimate for each resource in the Brunswick and Wellesley catchment area using environmental flow studies

Catchment	Resource	Apportioning ratio	SDL for resource ML/yr	Total environmental yield estimate for each resource ML/yr
Brunswick	1	0.65	540	349
	2	0.65	1 035	669
	3	0.65	1 327	857
	4	0.65	1 177	760

Catchment	Resource	Apportioning ratio	SDL for resource ML/yr	Total environmental yield estimate for each resource ML/yr
	5	0.65	490	317
	6	0.65	115	74
	7	0.65	337	218
	8	0.65	367	237
	9	0.65	186	120
	10	0.65	219	142
	11	0.65	61	40
Wellesley River	1	0.65	929	600
	2	0.65	5 631	3 638
	3	0.65	63	41

Management implications of the yield estimates

The yield estimates were used to develop the allocation limits set in the *lower Collie surface water allocation plan.*

We have also developed an environmental water provision for downstream of the Worsley and Wellington Reservoirs. The provisions have been designed to maintain key ecological functions like the maintenance of water quality and fish migration, given that the amount of water remaining in the system in future is unlikely to be enough to meet the environmental flow regime in the Brunswick 3 and lower Collie and tributaries 1, 2, 3, 4, 5, 8, and 10 resources.

Section 4 outlines the environmental water provision for the Wellington Reservoir in more detail.

2.3 Surface and groundwater interaction

There are depths to the watertable of less than 1 m around riparian zones in much of the plan area. The contribution of groundwater to streams increases from the Darling Scarp to the Swan Coastal Plain (SKM 2010 in preparation), and there is a connection between surface and groundwater.

Existing studies indicate that groundwater is likely to contribute a relatively small amount (< 5 %) to surface water flows in the plan area (SKM 2010 in preparation).

The plan area contains groundwater-dependent ecosystems such as Benger Swamp (SKM 2010 in preparation).

Groundwater use

Groundwater is used for stock and domestic, agricultural, horticultural and industrial purposes in the plan area. The resources with the highest amount of licensed groundwater use are Brunswick 11 (2.5 GL/yr) and Wellesley 3 (1.8 GL/yr). Groundwater used in the plan area is predominantly from confined aquifers.

2.4 Ecological and social values and requirements

Ecological values

Information about the water-dependent ecological values and the water required to maintain these values, was collated for the lower Collie plan area using various environmental flow studies. These included the:

- *Brunswick River ecological water requirements study* (Donohue et al 2009)
- *Environmental flow regime of the lower Collie River, Wellington reach* (Bennett & Green 2011a in preparation)
- *Environmental flow regime for the lower Collie River – Shenton's Elbow reach* (Bennett & Green 2011a in preparation)
- *Collie River ecological values assessment* (WRM 2009)
- *Ecological water requirements of Augustus River – intermediary assessment* (WRM 2005).

Information from these reports has been used to guide the setting of allocation limits and environmental water provisions for the Wellington and Worsley reservoirs. The provisions will be used to define how water is released from these reservoirs in the future.

A summary of ecological values and water requirements for the lower Collie plan area is included in Appendix A of this document. For more detailed information please refer to the documents listed above.

Social values

Social values relate to water found in its natural place, not water consumed for social benefit (Beckwith 2009a). The *Environmental water provisions policy for Western Australia* (WRC 2000) identifies the following as the social values that require consideration in planning:

- Aboriginal cultural values

- Australian heritage values
- recreational and tourism pursuits
- landscape and aesthetic aspects
- educational and scientific aspects.

Social water requirements are the elements of a flow regime such as the flow rate, water level and water quality needed to maintain water-dependent social values.

The Department of Water has identified places in the lower Collie where social values are linked to surface water. This was done using interviews with various community and stakeholder representatives and existing information from databases and literature.

This information was gathered as part of the *Lower Collie River social values study* (Beckwith 2008) and the *Nyungar values of the Collie River* (Beckwith 2009b). The social values of the lower Collie area identified as part of these investigations are summarised in Appendix A.

The Department of Water uses this information to guide the licensing and allocation decisions made in the allocation plan.

2.5 Water quality

Water quality parameters like nutrients, salinity and dissolved oxygen were important factors we took into account when setting allocation limits and management rules for the lower Collie plan area.

In the Collie, Brunswick and Wellesley rivers and their tributaries it is influenced by a number of factors including:

- land use
- tidal movements and saltwater intrusion in summer
- freshwater surface flows
- rainfall
- clearing in the Collie catchment
- the volume and timing of releases from the Wellington Reservoir.

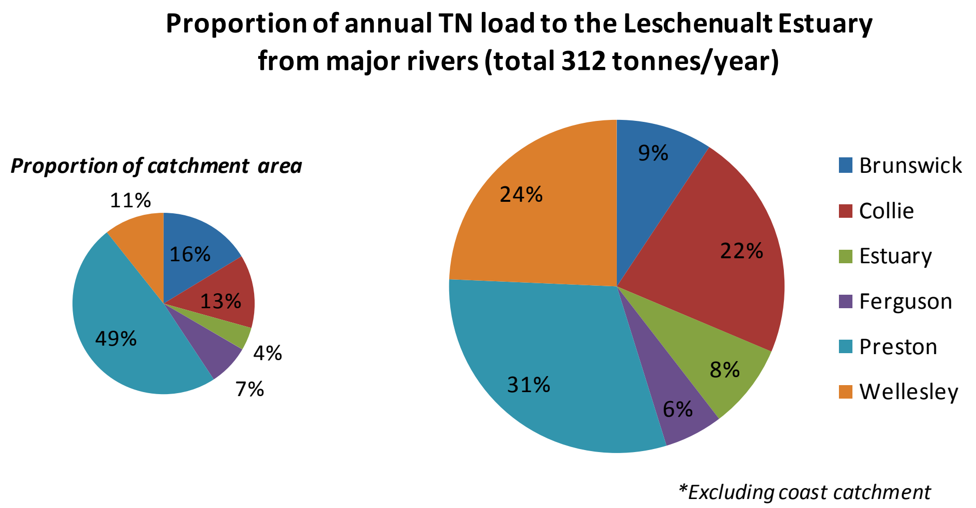
Phosphorus and nitrogen

There are high levels of total nitrogen and phosphorus in the lower Brunswick and Wellesley Rivers. These levels have contributed to algal blooms and fish kills in the lower Collie and Brunswick rivers (Kelsey and Hall 2009).

The lower Collie and Brunswick rivers and the Leschenault Estuary act as sinks for sediment and nutrients transported from the surface and soil profiles of the lower Collie area. This storage of nutrients, in conjunction with seasonal patterns of flow, determines how susceptible rivers in the plan area are to algal blooms and fish kill events (Kelsey and Hall 2009).

The charts below, taken from the Leschenault Water Quality Improvement Plan (DoW, 2011b in preparation), show the proportion of total annual nitrogen and total phosphorous load to the Leschenault Estuary from major rivers.

The charts show that the Wellesley River contributes the most total nitrogen and phosphorous to the Leschenault Estuary, despite it being around a fifth of the size of the catchment area of the Preston River. The Preston and Ferguson rivers are outside of the lower Collie surface water allocation plan area.



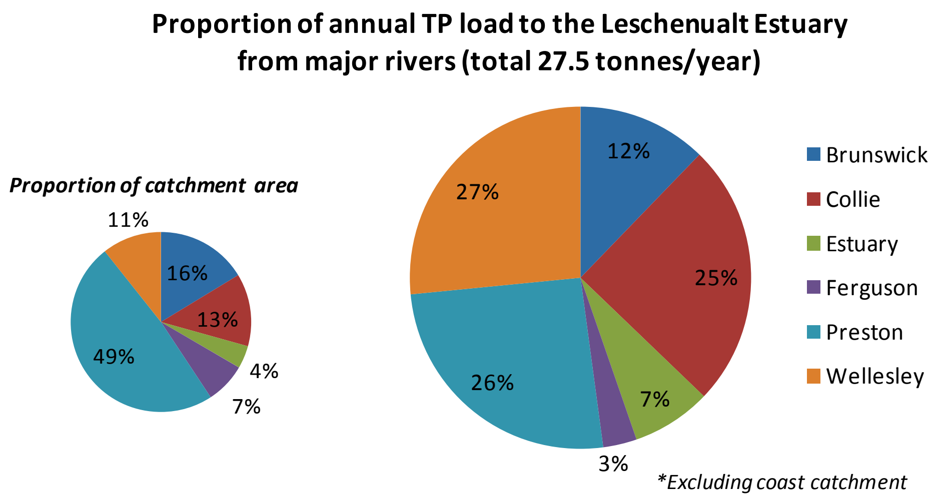


Figure 13 Relative contribution of nutrient loads to the Leschenault Estuary from rivers in the Leschenault catchment

Rainfall and runoff, and irrigation return flows from the Wellesley River mobilises nutrients and may increase nutrient loads in the lower parts of the catchment. However, it can also reduce the concentration of nutrients in rivers in the plan area, which can be critical to the survival of some aquatic biota.

We assessed the likely impact of the allocation limits on nitrogen and phosphorus (Kelsey 2010). The results of this work are summarised in Section 3.3.

Salinity

Clearing in the upper Collie catchment and wheat belt has led to salinisation of the Collie River East Branch in the catchment, and a subsequent increase in salinity in the Wellington Reservoir.

The Department of Water runs a salinity management program, which includes a program of works related to the management of salinity in the Collie basin. Information about this program can be found on the department's website if you go to Managing out water>Managing salinity.

The Department of Water and the Water Corporation actively manage salinity levels within the Wellington Reservoir by implementing the winter scour policy. The scour is aimed at discharging as quickly as possible the most saline early winter flows from the reservoir.

Water is released for scouring when the base salinity of the Wellington Reservoir is greater than 1100 mg/L and the difference between the surface and bottom salinity is greater than 400 mg/L (Water Corporation 2003). In winter scour only occurs when the volume of the reservoir is greater than 110 GL (Water Corporation 1999).

A snapshot study of salinity at the bottom of the Wellington Reservoir on 25 September from 2002 to 2008 showed a salinity range of 1000 mg/L to 1214 mg/L. This is higher than the accepted concentration for potable water in Western Australia (500 mg/L), is marginal for irrigated horticulture (grapes require < 640 mg/L) and is just acceptable for irrigated agriculture (kikuyu grass requires < 1280 mg/L).

A salinity of 1000 mg/L reportedly causes relatively little stress to freshwater ecology (Hart et al 1991, Horrigan et al 2005). However, 204 mg/L is the recommended level for freshwater lowland rivers in the south-west of Western Australia (ANZECC & ARMCANZ 2000).

Dissolved oxygen

Sampling from sites just below Wellington Reservoir indicates that reservoir releases are well oxygenated within a short distance downstream from the release point (Storey 2003). Storey 2003 states it is likely that releases from the reservoir will improve dissolved oxygen levels by preventing stratification in pools and oxygenating the released water.

A low-flow dissolved oxygen trial was undertaken in 2010 downstream of the Wellington Reservoir. The trial confirmed that ~3 ML/day of flow is required to maintain dissolved oxygen above 6 mg/L – which is the level considered acceptable for survival of aquatic biota – between the Wellington Reservoir and the Burekup Weir (WRM 2010).

2.6 Water use and management information

Land use

We determined the major land uses in the lower Collie plan area, using aerial photography flown in 2003 and in 2006 (for the urban areas). They are summarised in Table 6.

About two-thirds of the plan area is covered by native vegetation. The Wellesley subarea has the highest proportion of land used for pasture for dairy and beef cattle and the Brunswick subarea has the highest proportion of native remnant vegetation.

The land used for industrial purposes is relatively small (Refer Table 6 and Figure 14) but approximately 69 % of water that is licensed in the plan area is used for industry. This excludes water that is stored in the Wellington Reservoir and delivered to the Collie irrigation district.

Table 6 Percentage of current major land-use types in each subarea

Land use	**Wellesley River**		**Brunswick**		**Lower Collie tributaries**	
	Area ha	**% of subarea**	**Area ha**	**% of subarea**	**Area ha**	**% of subarea**
Cattle for beef	10 066	44	5 965	21	11 044	32
Cattle for dairy	4 353	19	1 065	4	1 842	5
Recreation / conservation	6 290	27	16 555	58	15 640	46
Tree plantation	333	1	1 527	5	644	2
Manufacturing / processing	14	< 1	774	3	27	0.08
Other*	2 003	9	2 740	10	4 792	15
Total	**23 058**	**100**	**28 625**	**100**	**33 988**	**100**

**Other – Refers to other land use types including utilities, viticulture, annual horticulture, pasture for hay, recreation- grass, perennial horticulture – trees, manufacturing / processing, urban residential, horses, water body, rural residential / bush block, quarry / extraction, unused – uncleared – tree/shrubs, transport / access, lifestyle block / hobby farm, wetland, unused – cleared – grass, commercial, community facility – non education, wetland.*

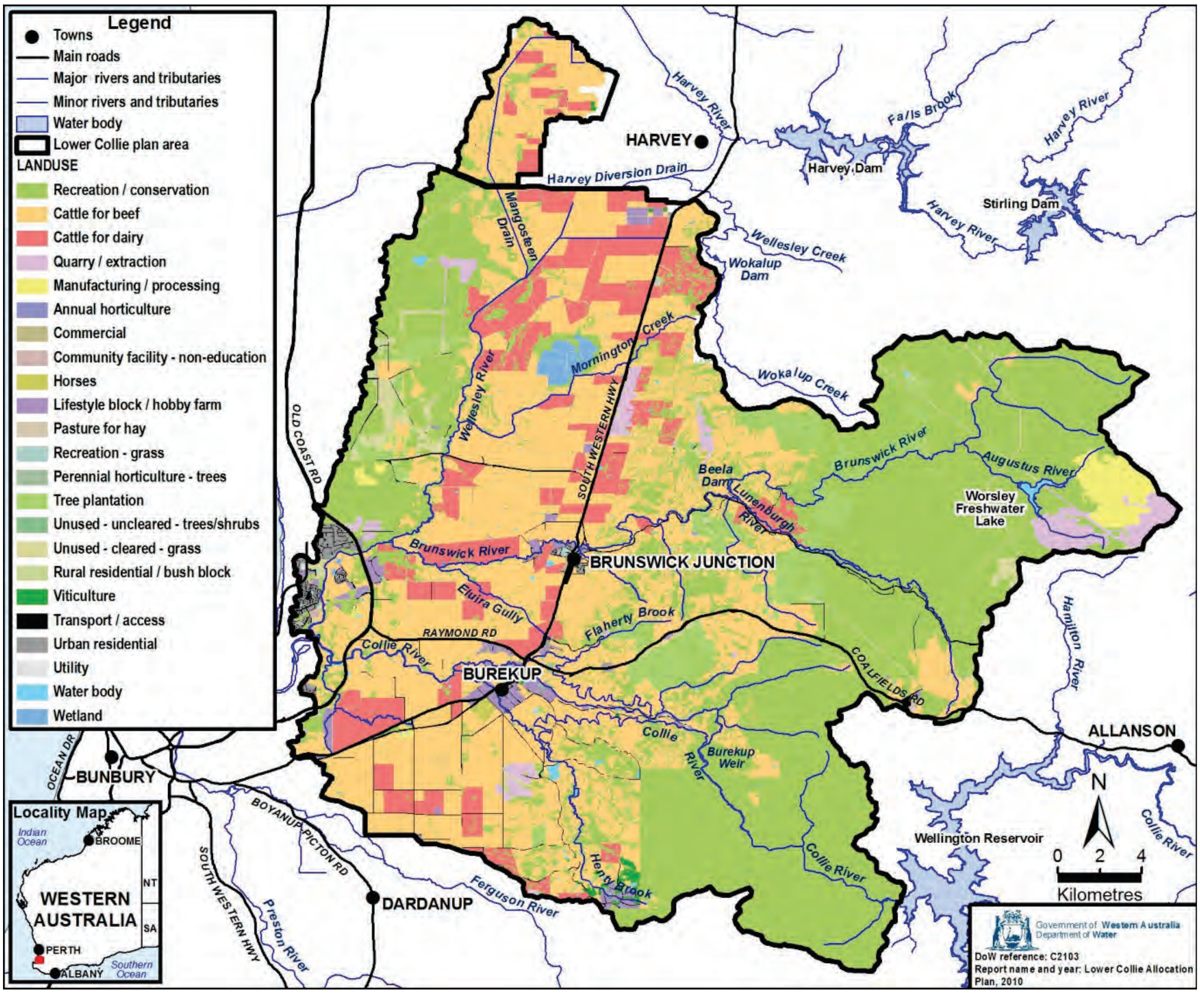


Figure 14 Land-use mapping in the lower Collie area (DAFWA 2003)

How water is abstracted and used in the area

Self-supply

Surface water is stored and distributed by individual users, called self-supply users, in the plan area by using:

- on-stream dams
- off-stream dams
- direct pumping from the river.

There are 16 self-supply licensees in the plan area. These are licensed to use 3.7 GL. 69% of licensed self supply is used by industry (mostly Worsley Pty Ltd) and around 7% is used for pasture.

Irrigation water supply

The majority of water used in the plan area is delivered from the Wellington Reservoir to the Collie irrigation district. Water from the Harvey Reservoir is also delivered to the Harvey irrigation district in the northern part of the Wellesley subarea.

Harvey Water is the major water service provider in the area, delivering non-potable water for irrigation and industry. Harvey Water holds a licensed entitlement for water that is stored and released from the Wellington Reservoir.

The Water Corporation maintains and operates the Wellington Reservoir and charge Harvey Water a fee for storing and releasing water from the reservoir, which Harvey Water passes on to their customers.

Water is released by the Water Corporation from the Wellington Reservoir into the Collie River. Around 12 km downstream of the reservoir, it is diverted by Harvey Water from the Burekup Weir and distributed to the Collie irrigation district via irrigation channels.

The diversions from the Burekup weir are managed by Harvey Water. Harvey Water has diverted an average of 47 GL of water per year from the Burekup Weir to the Collie irrigation district over the last thirteen years. The water has primarily been used for farmers to irrigate pasture for dairy and beef cattle (Harvey Water 2010).

Current water abstraction

We defined the licensable abstraction and estimated the unlicensable abstraction in the plan area.

The Department of Water requires licensees with entitlements greater than 50 ML to meter their water abstraction. Without metering information, we use other available datasets to estimate water use – such as land-use and farm dam mapping information – and verify them with water-use surveys.

The method used to define water use for self-supply use in the lower Collie plan area is outlined below. The water-use estimates for each resource is shown in Table 7.

Licensable water abstraction

Licensed abstractions

We used our licensing system to collate the surface water licences in the lower Collie area as at February 2011. The amount of water licensed for abstraction is 3.67 GL. Licensed use in each resource in the plan area is summarised in Table 7.

Unauthorised use

We estimate that approximately 550 ML of water abstraction in the plan area is unauthorised. We will carry out property surveys and where unauthorised use is identified we will undertake appropriate enforcement action. Item 5 in Table 6 of the *Lower Collie surface water allocation plan* (DoW 2011a) states that the department should prioritise self supply licence compliance in the lower Collie tributaries 5, 8, and Brunswick 2, 4, 7 and 8.

Unlicensable water use

Some uses of water are exempt from licensing under the *Rights in Water and Irrigation Act 1914*. This includes water abstracted:

- under a riparian or other right
- from springs and wetlands wholly within a property – if springs or wetlands are excavated then a groundwater licence will be required
- from streams arising on a property
- in unproclaimed areas.

We estimate that unlicensable water use is approximately 18% of total water use in the lower Collie area.

Riparian rights

Landowners who have legal access to a surface water resource may abstract water for stock and domestic use without a licence (referred to as a riparian right).

We estimate the maximum annual demand of water in the plan area for riparian rights is 13% of the total water use estimate for the plan area.

This estimate is based on existing cadastre, and using the following geographical information system datasets:

- Bunbury orthomosaic – Landgate 2004
- Bunbury orthomosaic – Landgate 2006
- Land-use mapping information from the Department of Agriculture and Food and the Department of Water based on 2003 and 2006 aerial imagery
- Hydrography, linear – Department of Water 2007
- Regional schemes – Department for Planning and Infrastructure 2010
- Spatial cadastral database – Department of Land Information 2009
- Town planning scheme zones– Department for Planning and Infrastructure 2009

- Dam mapping undertaken using the aerial photography (Bunbury Orthomosaic – Landgate 2006

Within a dataset we selected all privately owned properties adjacent to a watercourse in the plan area. We removed properties with at least one farm dam, because some of the water stored in farm dams is already accounted for as part of the storage component of surface water licences.

This means that the unlicensable component of these farm dams (or farm dams with a capacity of less than 8 ML) is not counted. We estimate this amount to be very small in comparison to total abstraction in the plan area.

We then assigned each property a total potential riparian right of 1500 kL, and calculated the total possible riparian right for the plan area (refer Table 7).

Interception from plantations

The total area covered by plantations in the lower Collie plan area is estimated to be approximately 25 km^2 (3% of the plan area). The largest proportion of plantations is within the upper parts of the Brunswick subarea (Brunswick 1, Brunswick 2 and Brunswick 3 resources) and is mostly bluegum (*Eucalyptus globulus*), with pine (*Pinus radiata)* interspersed.

Analysis for the report *Surface water hydrology of the lower Collie catchment* (DoW 2011b) showed that the current level of plantations do not have a significant impact on surface water resources in the plan area, so we have not considered plantation water use in our plan.

Table 7 Current water use estimates for self-supply for each resource in the lower Collie area (estimate does not include water from the Wellington and Harvey reservoirs and used in the plan area)

Resources	Licensed use ML	Use that requires a licence ML	Unlicensable use ML	Total water use estimate ML
Lower Collie tribs 1	0	0	0	0
Lower Collie tribs 2	0	0	0	0
Lower Collie tribs 3	0	0	3.6	3.6
Lower Collie tribs 4	0	0	42.5	42.5
Lower Collie tribs 5	0	47	122.4	169.4
Lower Collie tribs 6	593	43	105.3	741.3
Lower Collie tribs 7	340	0	33.6	373.6
Lower Collie tribs 8	0	12	34.8	46.8
Lower Collie tribs 9	0	22	92.9	114.9
Lower Collie tribs 10	0	0	9.6	9.6

Resources	Licensed use ML	Use that requires a licence ML	Unlicensable use ML	Total water use estimate ML
Total	**933**	**124**	**444.7**	**1501.7**
Brunswick 1	2600	0	0	2600
Brunswick 2	2	185	14.4	201.4
Brunswick 3	0	0	27.6	27.6
Brunswick 4	0	53	44	97
Brunswick 5	0	55	36.7	91.7
Brunswick 6	0	9	24	33
Brunswick 7	0	44	51.6	95.6
Brunswick 8	121	75	40.6	236.6
Brunswick 9	20	0	30	50
Brunswick 10	0	0	102	102
Brunswick 11	0	0	30	30
Total	**2743**	**421**	**400.9**	**3564.9**
Wellesley River 1	0	0	22.8	22.8
Wellesley River 2	0	0	72	72
Wellesley River 3	0	0	12	12
Total	**0**	**0**	**106.8**	**106.8**
Total use in plan area	**3676**	**545**	**952.4**	**5173.4**

2.7 Future demand

We have assessed the likely future demand for water in the lower Collie based on:

- the number of licence applications received over recent years in each resource
- information from *Water futures for Western Australia* (Thomas 2008)
- water demand projections from the south-west Western Australia sustainable yields project (CSIRO 2009).

Industry

Industry in the Collie catchment is expanding and requires water. Industrial companies and the department are currently investigating a range of water supply options.

Most of the industrial demand is for relatively large volumes, to come from the Wellington Reservoir. We have considered different future industrial demand scenarios as part of the Wellington Reservoir simulations (Refer to Section 4).

Agriculture

We expect agricultural water demand to remain similar to current levels until 2020. We base this on the:

- decline of the dairy industry in the Harvey area resulting from deregulation in 2000
- limitations of using relatively high salinity from the Wellington Reservoir. This could change if salinity from the reservoir improves.
- increasing industrial demand and competition for water in the region
- the potential expansion of post-production agriculture in the area.

Horticulture

There has been some expansion and diversification of horticulture in the plan area but it has been limited by the relatively high salinity of water that is supplied from the Wellington Reservoir.

We expect the amount of water used for horticulture to remain similar to past use over the next five years. This could change by 2020 if the salinity of the reservoir decreases, which is dependent on a number of proposed projects in the Collie catchment.

Riparian rights

We anticipate a small increase in the water used for stock and domestic purposes as part of a riparian right by 2020. This is in line with projections for steady population growth in the South West (Thomas 2008). There has also been an increase in smaller lifestyle properties around the townships of Bunbury and Burekup (DoW & GHD 2011 in preparation). However, most of this water demand is likely to be met by using groundwater.

3 Objectives and decisions

3.1 Objectives

We develop objectives as part of the objectives and decisions part of the allocation planning process described in Figure 15 below.

The department sets water resource and water management objectives for allocation plans to guide decisions on allocation limits and management rules.

Resource objectives relate to maintaining, increasing, improving, restoring, reducing or decreasing surface water flow, groundwater levels or water quality.

Management objectives relate to what we want our management to achieve and what we need to do to achieve the resource objectives. They will usually relate to the implementation of an allocation limit, how water is used and the rules of taking water to avoid ecological and or social harm.

Overall, in the lower Collie plan area we want to maximise the economic benefits of water while maintaining ecological, social and cultural water-dependent values.

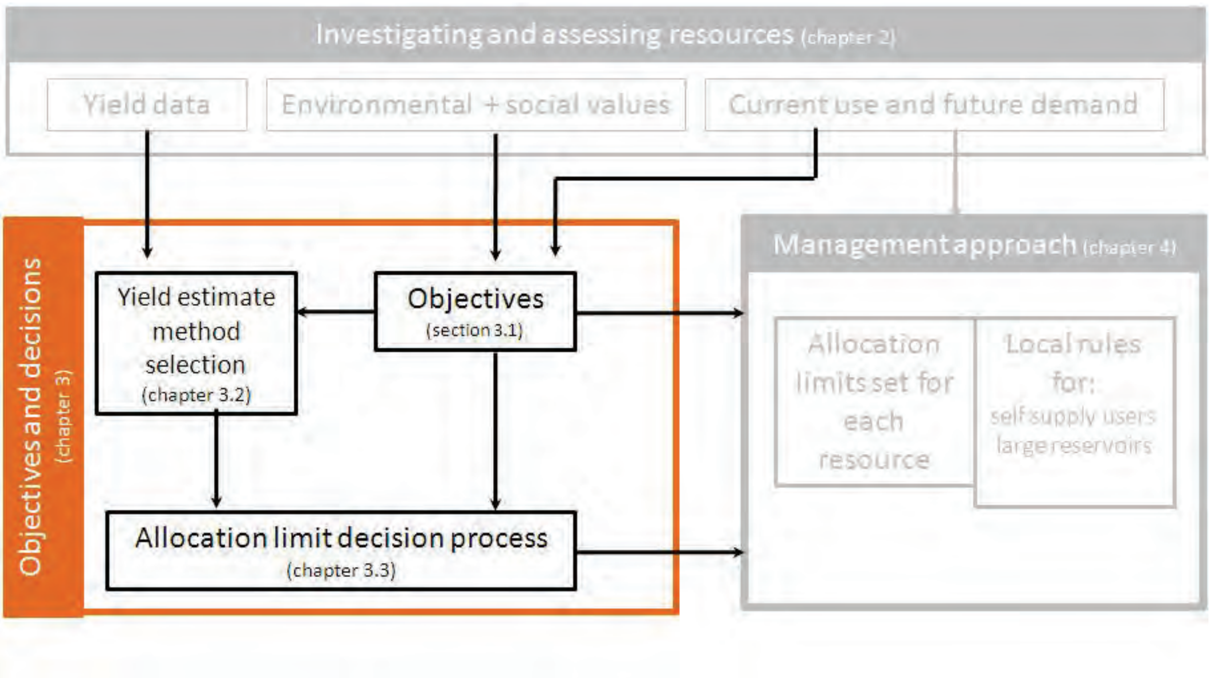


Figure 15 Allocation planning process for the lower Collie surface water allocation plan – objectives and decisions

How were the objectives developed?

To develop the water resource and management objectives for the lower Collie area we first set high, moderate and low rating categories for ecological and social value and quantity of current water (Table 8). These enabled us to rate and compare each of the 24 resources in the lower Collie area according to their ecological and social value and current water use (Table 9).

Cultural value was not included as a category because we understand that the spirit that the Nyungar people associate with water is present in all water, regardless of the land use or the condition of the stream. We note that flowing water is of particular importance to the Nyungar people, and this was considered as part of developing allocation limits and environmental water provisions for the lower Collie area.

Future demand was also not included as a category, because it was too indefinite to rate, but we did consider it as part of setting allocation limits.

Table 8 Justification of ratings for each parameter relative to the south-west of Western Australia

Parameter	**Rating**		
	High	**Moderate**	**Low**
Ecological	High proportion of intact native vegetation. High endemic aquatic in-stream biodiversity for the plan area.	Some remnant native vegetation, with poor cover and or quality of understorey. Moderate endemic aquatic in-stream biodiversity for the plan area.	Limited remnant native vegetation. Mostly cleared native vegetation which has been replaced with pasture. Lowest endemic aquatic in-stream biodiversity in the plan area.
Social	High number of recreational, scientific or educational sites.	Medium number of recreational, scientific or educational sites.	Small number of recreational, scientific or educational sites.
Level of current water use*	High level of current use (> 500 ML/yr).	Moderate level of current use < 500 ML/yr > 100 ML/yr.	Low level of current use < 100 ML/yr.

**includes use supplied directly from a river or delivered to an area from the Wellington Reservoir*

Table 9 Value and use ratings for each resource in the lower Collie surface water allocation plan area

Subarea	Resource	Values		Level of current water use
		Social	**Ecological**	
Lower Collie tributaries	1	Moderate	High	Low
	2	Moderate	High	Low
	3	High	High	Low
	4	Moderate	High	Low
	5	Low	Low	Moderate/low from Wellington Reservoir
	6	Low	Moderate	High
	7	Low	Low	Moderate /low from Wellington Reservoir
	8	Moderate	Low	Low /low from Wellington Reservoir
	9	Moderate	Low	Moderate /low from Wellington Reservoir
	10	Low	Low	Low
Brunswick	1	Moderate	Moderate	High
	2	Moderate	High	Moderate
	3	Moderate	High	Low
	4	Moderate	Moderate	Low
	5	Moderate	Moderate	Low
	6	Moderate	Moderate	Low
	7	Moderate	Moderate	Low
	8	Moderate	Moderate	Moderate
	9	Moderate	Moderate	Low
	10	Moderate	Moderate	Moderate/low from Wellington Reservoir
	11	Moderate	Moderate	Low
Wellesley River	1	Low	Low	Low /high from Harvey Reservoir
	2	Low	Low	Low /high from Harvey and Wellington reservoirs
	3	Low	Moderate	Moderate/high from Wellington Reservoir

Using the results from Table 9 we then grouped resources with similar ecological and social value and current water-use ‘rating levels’ into four objective groups. The four objectives groupings are summarised in Table 10 and Figure 16. Generally they are presented on a sliding scale from low ecological and social value (Group 1) to high ecological and social value (Group 4).

Table 10 Objectives categories based on value and use or demand information

Objective group	Social value	Ecological value	Current water use		Resources within lower Collie area with this rating
			Self-supply	From reservoirs	
1	Low	Low	Low	High from Wellington and Harvey reservoirs	Wellesley 1, 2,
	Low	Low	Moderate	Low from Wellington Reservoir	Lower Collie tributaries 5, 7
	Low	Low	Low	Low from Wellington Reservoir	Lower Collie tributary 10
2	Moderate	Low	Low	Low from Wellington Reservoir	Lower Collie tributaries 8, 9
	Moderate	Moderate	Low	NA	Brunswick 4,5,6,7,9
	Moderate	Moderate	Moderate	Low from Wellington Reservoir	Brunswick 8, 10, 11
	Low	Moderate	Moderate	High from Wellington Reservoir	Wellesley 3
	Low	Moderate	High	NA	Lower Collie tributary 6
3	Moderate	High	Moderate	NA	Brunswick 2
	Moderate	High	Low	NA	Brunswick 3
	Moderate	High	Low	NA	Lower Collie tributaries 1, 2 and 4
	High	High	Low	NA (only acts as a conduit)	Lower Collie tributary 3
4	Moderate	Moderate	High	NA	Brunswick 1

We then developed water resource and water management objectives for each of the objective groups.

The objectives developed for each of the four groups are presented in Table 11. They have been used to set allocation limits and management rules for the *Lower Collie allocation surface water plan.*

Table 11 Water resource and water management objectives relating to each objective group

Objective group	Water resource objective	Water management objective
1	Maintain a flow regime that supplies existing authorised use most of the time and meets the 'minimum'* ecological and social requirements in the lower Collie tributaries 5 (downstream of Burekup Weir), 6, 7, 8, 9, 10 resources.	Make as much water available as possible for consumptive use within the limits of the resource objectives. Release water from the Wellington Reservoir in a way that meets the 'key' ecological and social downstream requirements.
2	Maintain a flow regime that supplies authorised use in most years and meets 'key'* ecological and social requirements in lower Collie tributaries 3 and 5 (upstream of Burekup Weir) and the Brunswick 5, 6, 7, 8, 9, 10, 11 resources.	Make as much water available as possible for consumptive use within the limits of the resource objectives Release water from the Wellington Reservoir in a way that meets the 'key' ecological and social downstream requirements.
3	Maintain a flow regime that reflects catchment rainfall and runoff in the Brunswick 1, 2, 3, 4 and lower Collie tributaries 1, 2, 4 resources[1].	Make as much water available as possible for consumptive use within the limits of the resource objective.
4	Maintain a flow regime that reflects catchment rainfall and runoff in the Brunswick 1, 2, 3, 4 and lower Collie tributaries 1, 2, 4 resources.	Make as much water available as possible for consumptive use within the limits of the resource objectives. Release water from the Worsley Reservoir in a way that meets the 'key' downstream ecological, and social requirements.

** the 'minimum' and 'key' ecological objectives are defined in Appendix B. Refer to Figure 1 to match the resource and management objectives to the resources in the lower Collie plan area.*

[1]The lower Collie tributaries 3 was not included in objective (a) – even though it is part of group 3. This is because water is released into the resource from the Wellington Reservoir, so flow in that resource does not solely reflect catchment rainfall and runoff. Instead, lower Collie tributaries 3 has been included in objectives (b) and (f) for objective group 2.

3.2 Selection of yield estimate method

The yield estimate is the amount of water that can be abstracted while still meeting the environmental objectives for the resource.

As outlined in Section 2.2, there were two methods available to estimate yield as part of the lower Collie allocation plan. They were the sustainable diversion limits method and a method which utilises environmental flow studies and PADFLOW/RESYM. We used the decision making process outlined in Figure 17 to select the preferred method for each resource in the lower Collie area.

The SDL method was selected as the most appropriate method in the lower Collie tributaries resources 6, 7, and 9. The environmental flow study method was selected as the most appropriate method for the lower Collie tributaries resources 1, 2, 3, 4, 5, 8 and 10 and all of the Brunswick and Wellesley resources.

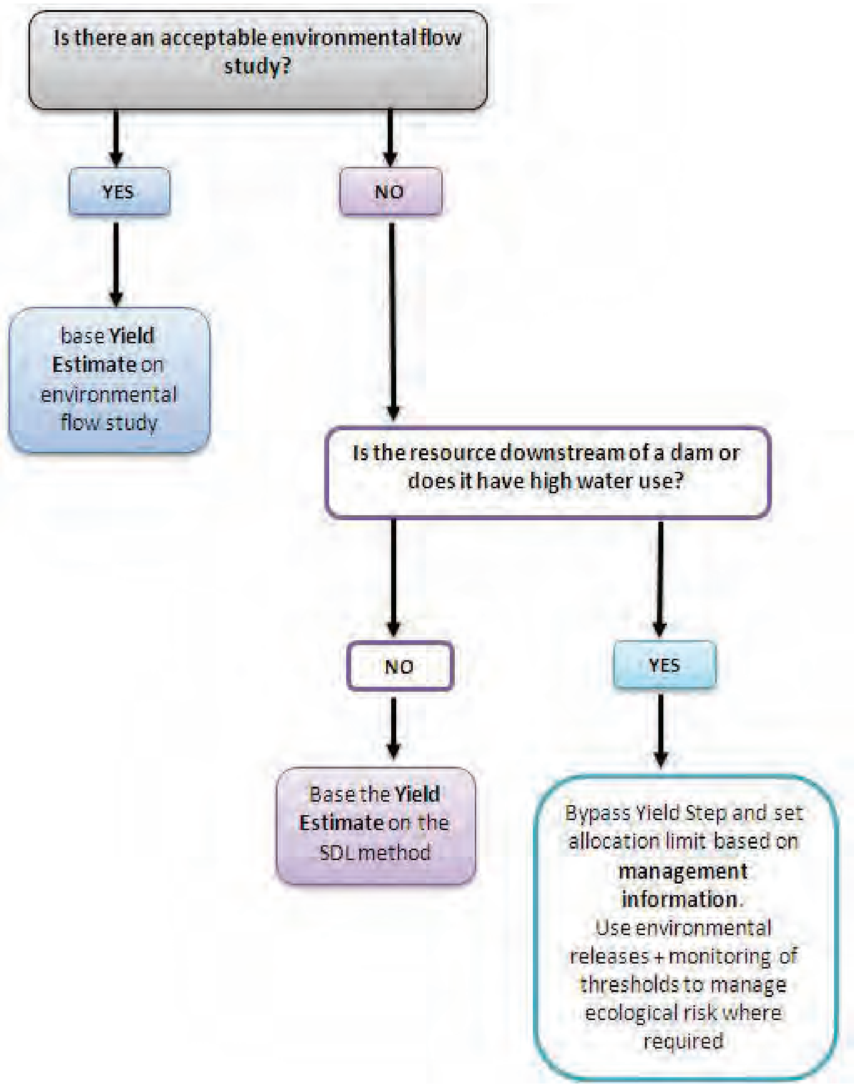


Figure 16 Method for selecting yield estimate method

3.3 Process for setting allocation limits

The allocation limit may be lower, equal to or higher than the yield estimate depending on the resource and management objectives, and on our ability to manage the risk of water use in a resource.

We considered the following when we set allocation limits for lower Collie:

a) Is there high use or high future demand in the resource that the state wants to support for economic development? Can we manage the impact this use may have on ecological and social values in the area?

b) Is there high ecological, social or cultural value within or downstream of a resource? Is the risk to these values adequately managed by allocating water within the limits defined by the yield estimate? If not what else can we do to manage this risk?

c) How much water is needed to manage the impact of nutrients and or salinity on in situ and or downstream values associated with the river?

Table 12 summarises the yield estimate and allocation decision for each resource in the lower Collie. More detailed information on (c) is provided below because water quality was raised by stakeholders as an important issue for the lower Collie area.

Investigating the impact of water allocations on water quality

We have done additional modelling to examine the likely impact of the water allocations of this plan on the Leschenault Estuary to address consideration (c) above.

The department has undertaken monthly water balance and nutrient modelling for major rivers in the Leschenault catchment including rivers in the lower Collie surface water allocation plan area as well as the catchments of the Ferguson and Preston rivers (Marillier 2009). This work was done as part of the water quality improvement plan for the Leschenault Estuary (DoW 2011b in preparation).

The downstream impact on streamflow, total nitrogen and total phosphorus concentrations of abstracting water up to the allocation limit was tested using the model developed for the water quality improvement plan. The scenario assumed the abstraction was taken uniformly over the wet season from June to October inclusive.

The modelling showed no impact on nutrient concentrations in the upper reaches of the catchments. A minor reduction in nutrient concentration in the lower reaches of the Brunswick and Collie rivers could occur if future abstraction reduces flow in the Wellesley River, which currently contributes the highest proportion of nutrients to the Leschenault Estuary.

Marillier (2009) noted that while nutrient loads reduce under lower flow conditions, nutrient concentrations are likely to increase, which will increase the likelihood of the occurrence of algal blooms. This suggests that a drier and warmer future climate may have a larger impact on nutrient concentrations than abstraction of the defined allocation limit volumes.

Table 12 Summary of yield estimate and allocation decision for each resource

Resource	Step 1: Select yield estimate		Step 2: Set allocation limit **Allocation Options**	Final allocation limit ML/yr
	Yield estimate method	**Yield estimate ML/yr**	**Is the allocation limit < yield estimate?** **Is the allocation limit = yield estimate?** **Is the allocation limit > yield estimate?**	
Brunswick 1	Environmental flow study	349	Allocation limit is > yield estimate Licensed water use in this resource is higher than the yield estimate. Release rules for the Worsley Reservoir have been set to maintain ecological values downstream.	2 600
Brunswick 2	Environmental flow study	669	Allocation limit is < yield estimate Most of the flow in these resources is protected to maintain environmental values within these resource and to maximise the amount of flow in Brunswick 5, 6, 7, 8, 9, and 10.	201
Brunswick 3	Environmental flow study	857		28
Brunswick 4	Environmental flow study	760		97
Brunswick 5	Environmental flow study	317	Allocation limit = yield estimate Additional water is available for abstraction in these resources within limits which minimise: • increases in nitrogen and phosphorus concentrations • the risk to ecological values in and downstream of these resources.	317
Brunswick 6	Environmental flow study	74		74
Brunswick 7	Environmental flow study	218		218
Brunswick 8	Environmental flow study	247		247
Brunswick 9	Environmental flow study	120		120

Resource	Step 1: Select yield estimate		Step 2: Set allocation limit **Allocation Options**	Final allocation limit ML/yr
	Yield estimate method	**Yield estimate ML/yr**	**Is the allocation limit < yield estimate?** **Is the allocation limit = yield estimate?** **Is the allocation limit > yield estimate?**	
Brunswick 10	Environmental flow study	142		142
Brunswick 11	Environmental flow study	40		40
Lower Collie tributary 1	Sustainable diversion limit	59	Allocation limit < yield estimate Most of the flow in these resources is protected to maintain environmental values within these resources and to maximise the amount of flow for lower Collie tributaries 3, 5, 8, 9, 10	0
Lower Collie tributary 2	Sustainable diversion limit	211		0
Lower Collie tributary 4	Sustainable diversion limit	243		43
Lower Collie tributary 3	Environmental flow study	0	Allocation limit > yield estimate The allocation limit is set at the current level of self-supply use (4 ML) to: • maintain supply for existing self-supply use within lower Collie tributary 2 • maximise the flow available for abstraction in lower Collie tributaries 5, 8, 9, 10 • maintain 'key' ecological, cultural and social values within the resource.	4

<table>
<tr><th rowspan="2">Resource</th><th colspan="2">Step 1: Select yield estimate</th><th>Step 2: Set allocation limit
<u>Allocation Options</u></th><th rowspan="2">Final allocation limit ML/yr</th></tr>
<tr><th>Yield estimate method</th><th>Yield estimate ML/yr</th><th>Is the allocation limit < yield estimate?
Is the allocation limit = yield estimate?
Is the allocation limit > yield estimate?</th></tr>
<tr><td>Lower Collie tributary 5</td><td>Environmental flow study</td><td>0</td><td rowspan="3">Allocation limit > yield estimate
The allocation limit has been set at the current level of self-supply use to:
• maximise the amount of time that water is available for existing users in lower Collie tributaries 5, 8, and 10
• minimise risks to social and environmental values.
An environmental water provision for the Wellington Reservoir has been defined to minimise the risk that reduced flows from the reservoir pose to ecological and social values in lower Collie tributaries 5, 8 and 10.</td><td>169</td></tr>
<tr><td>Lower Collie tributary 8</td><td>Environmental flow study</td><td>0</td><td>47</td></tr>
<tr><td>Lower Collie tributary 10</td><td>Environmental flow study</td><td>0</td><td>10</td></tr>
<tr><td>Lower Collie tributary 6</td><td>Environmental flow study</td><td>831</td><td>Allocation limit < yield estimate
The allocation limit is set at current use to maximise the amount of time that existing users get their entitlement. Streamflow gauging of this resource is required to assess whether additional water can be made available in future.</td><td>741</td></tr>
<tr><td>Lower Collie tributary 7</td><td>Environmental flow study</td><td>195</td><td>Allocation limit > yield estimate
The allocation limit is set at current use to maximise the amount of time that existing users get their entitlement.
Management rules (e.g. licence conditions) will continue to be used in these resources to manage how water is abstracted from the lower Collie River in summer, given that use is higher than the yield estimate in this resource.</td><td>374</td></tr>
<tr><td>Lower Collie tributary 9</td><td>Environmental flow study</td><td>493</td><td>Allocation limit = yield estimate
Additional water is available for abstraction within limits which minimise social and ecological risks within the resource.</td><td>493</td></tr>
</table>

Resource	Step 1: Select yield estimate		Step 2: Set allocation limit Allocation Options	Final allocation limit ML/yr
	Yield estimate method	Yield estimate ML/yr	Is the allocation limit < yield estimate? Is the allocation limit = yield estimate? Is the allocation limit > yield estimate?	
Wellesley 1	Environmental flow study	600	Allocation limit = yield estimate Additional water is available for abstraction in these resources within limits which minimise: • increases of nitrogen and phosphorus concentrations • risk to ecological values in and downstream of these resource.	601
Wellesley 2	Environmental flow study	3 638		3 638
Wellesley 3	Environmental flow study	41	Allocation limit = yield estimate Additional water is available for abstraction in these resources within limits which minimise: • increases of nitrogen and phosphorus concentrations • risk to ecological values in and downstream of these resource.	41
Total		**10 104**		**10 245**

Objective Group	Resource	Allocation limit decision
1	Lower Collie tributary 5, 8, 10	Allocation limit > Yield Estimate
	Lower Collie tributary 7	Allocation limit > Yield Estimate
	Wellesley 1, 2, 3	Allocation limit = Yield Estimate
2	Lower Collie tributary 3	Allocation limit > Yield Estimate
	Brunswick 5, 6, 7, 8, 9, 10, 11	Allocation Limit = Yield Estimate
	Lower Collie tributary 6	Allocation Limit = Yield Estimate
	Lower Collie tributary 9	Allocation Limit = Yield Estimate
3	Lower Collie tributary 1, 2, 4	Allocation limit < Yield Estimate
	Brunswick 2, 3, 4	
4	Brunswick 1	Allocation limit > Yield Estimate

4 Management approach

The purpose of the *Lower Collie surface water allocation plan* (DoW 2011a) is to set the allocation limits and the local water management rules which define the management approach for water use in the lower Collie plan area.

This section summarises the management approach part of the allocation planning process in lower Collie - Figure 17. It presents the allocation limits and provides an explanation of how the local rules for the Wellington Reservoir were developed for the plan.

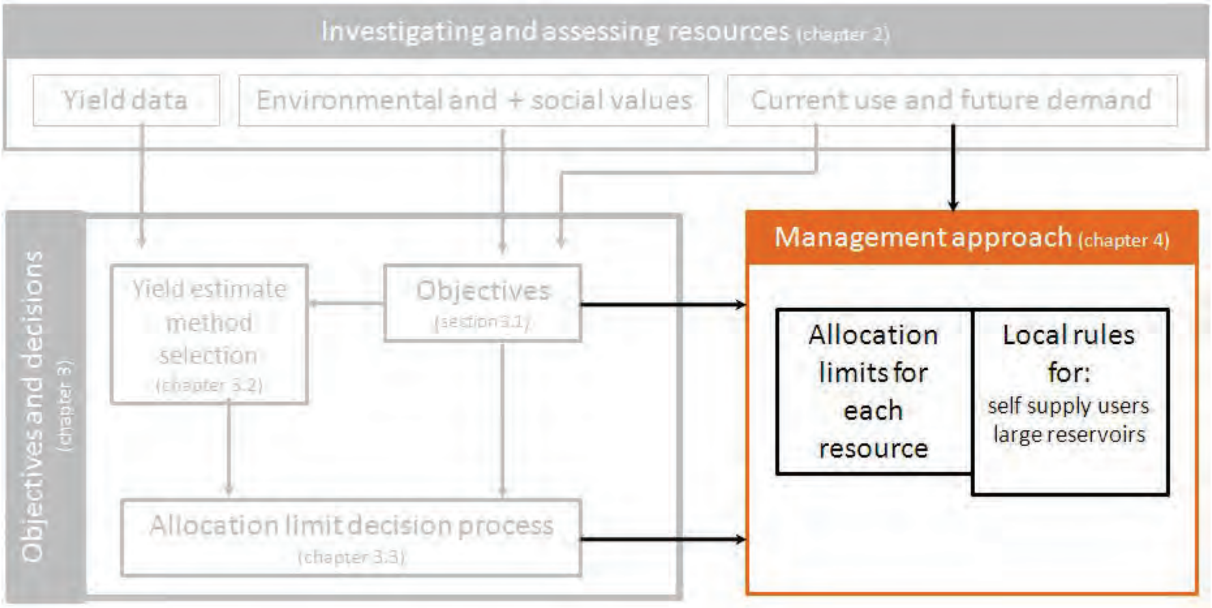


Figure 17 Allocation planning process for the lower Collie surface water allocation plan – management approach

4.1 The allocation limits

At 1 February 2011, 5633 ML was available for licensing in the lower Collie area. This includes 502 ML in the lower Collie subarea, 958 ML in the Brunswick subarea and 4173 ML in the Wellesley subarea. Table 13 shows how the allocation limits for each resource are made up of licensed and unlicensable components.

Table 13 Components of the allocation limit in the lower Collie area

Resource	Allocation limit	Allocation limit components ML/yr		Is new water available? (as at February 2010)	Existing use (as of February 2011)
		Licensable	Unlicensable use		
Lower Collie tributary 1	0	0	0	No	0
Lower Collie tributary 2	0	0	0	No	0
Lower Collie tributary 3	4	0	4	No	4
Lower Collie tributary 4	43	0	43	No	43
Lower Collie tributary 5	169	47*	122	Limited	169
Lower Collie tributary 6	741	636*	105	Limited	741
Lower Collie tributary 7	374	340	34	No	374
Lower Collie tributary 8	47	12*	35	Limited	47
Lower Collie tributary 9	493	400	93	Yes	115
Lower Collie tributary 10	10	0	10	No	10
Brunswick 1	2600	2600	0	No	2600
Brunswick 2	201	187*	14	Yes	201
Brunswick 3	28	0	28	No	28
Brunswick 4	97	53*	44	Yes	97
Brunswick 5	317	280	37	Yes	92
Brunswick 6	74	50	24	Yes	33
Brunswick 7	218	166	52	Yes	96
Brunswick 8	247	206	41	Yes	237
Brunswick 9	120	90	30	Yes	50
Brunswick 10	142	40	102	Limited	102
Brunswick 11	40	10	30	Limited	30
Wellesley River 1	601	578	23	Yes	23
Wellesley River 2	3638	3566	72	Yes	72
Wellesley River 3	41	29	12	Yes	12

[1] Available water is 'Limited' if current use is greater than 70 % of the allocation limit. No water available means that use has reached the allocation limit.

** The licensable estimate includes current licensed use + illegal use + any left over water that is available for licensing.*

Where water is limited or available but use is the same as the allocation limit it may be because there is unauthorised use. We include unauthorised use as part of the total water use estimate and also as water that is available for licensing.

4.2 Local rules

The lower Collie surface water allocation plan sets the following rules to manage the storage and take of water:

- state and local licensing policies for self-supply
- an environmental water provision that has been used to set release rules for Worsley Reservoir
- an environmental water provision that will be released from the Wellington Reservoir from 2011
- restriction rules for take from the Wellington Reservoir.

The state and local licensing policies for self-supply and the environmental water provision for the Worsley Reservoir are explained in the *Lower Collie surface water allocation plan* (DoW 2011a).

The following section provides background information on the environmental water provision and restriction rules developed for the Wellington Reservoir.

Current and future demands from the Wellington Reservoir

Since the 1970s the Water Corporation have released water from the Wellington Reservoir in summer for irrigation, and in winter to manage salinity levels in the reservoir (scour releases).

Since 1996, the irrigation releases have been diverted at Burekup Weir by Harvey Water to supply customers in the Collie irrigation district, and the irrigation demands from the reservoir have been met in all years. This is because 17.1 GL of the 85.1 GL reservoir allocation limit for the Wellington Reservoir has been unallocated, and because Harvey Water's 68 GL irrigation entitlement has not been fully used.

With the exception of the unusually long irrigation season and 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 1998–99. Accounting for transmission losses between the Burekup Weir and Wellington Reservoir, this equates to the release of approximately 59 GL of water from the Wellington Reservoir (DoW 2011a in preparation).

The total use from the reservoir has been low compared to the inflow and frequent spills have occurred when water levels in the reservoir exceed the full supply level (Figure 18).

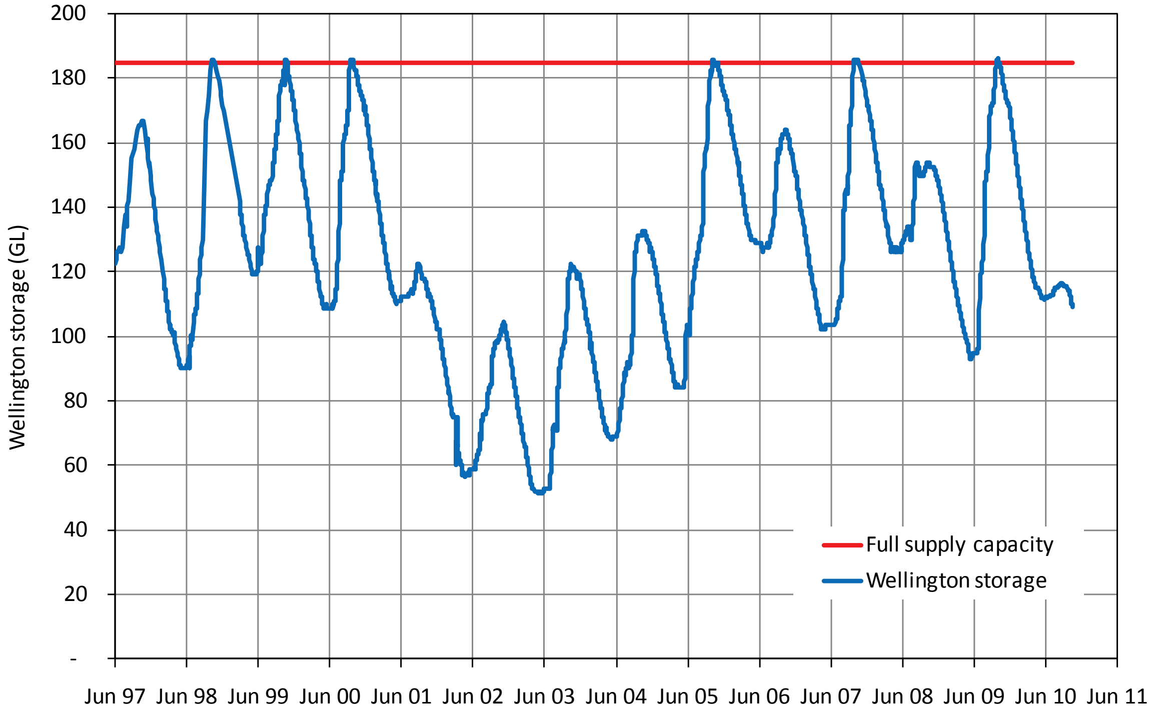


Figure 18 Stored volume in Wellington Reservoir since 1997 (DoW 2011a in preparation)

Industrial demand for water from Wellington Reservoir is increasing, with new entitlements for industrial cooling water (5.1 GL) and other industry (12 GL) expected to come into effect over the next five years. This increase in demand coincides with a decrease in annual inflows to the reservoir (Figure 21).

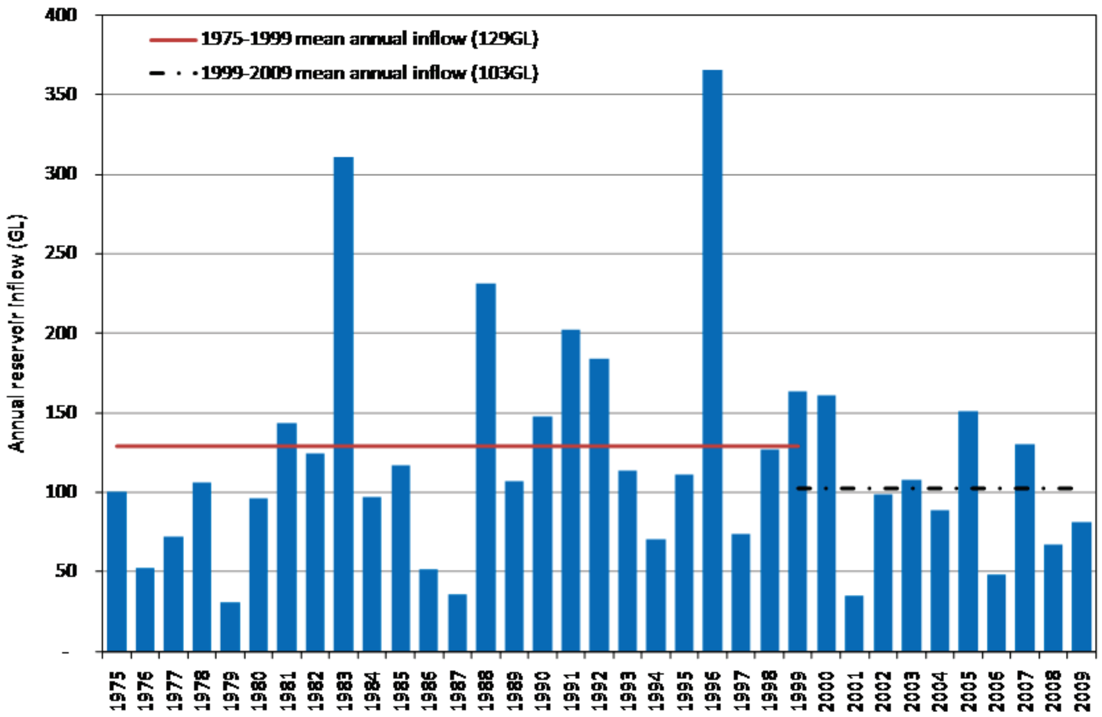


Figure 19 Annual inflow into the Wellington Reservoir between 1975 and 2009

To accommodate the additional demand for water from the Wellington Reservoir in a drier future:

- the volume of water released from the reservoir in winter is likely to reduce and the timing of the releases will change
- new industrial (excluding power station cooling) and existing irrigation entitlements from the Wellington Reservoir will be restricted when dam storage levels fall below 115 GL. Effectively, when the storage is greater than 115 GL on 1 October 100% of irrigation and industry entitlements will be available. However, as the storage level on 1 October reduces below 115 GL the level of restrictions increase, at a linear rate, until 0% of entitlements are available when the volume stored on 1 October reaches 25 GL (DoW 2011a in preparation) (Figure 20).

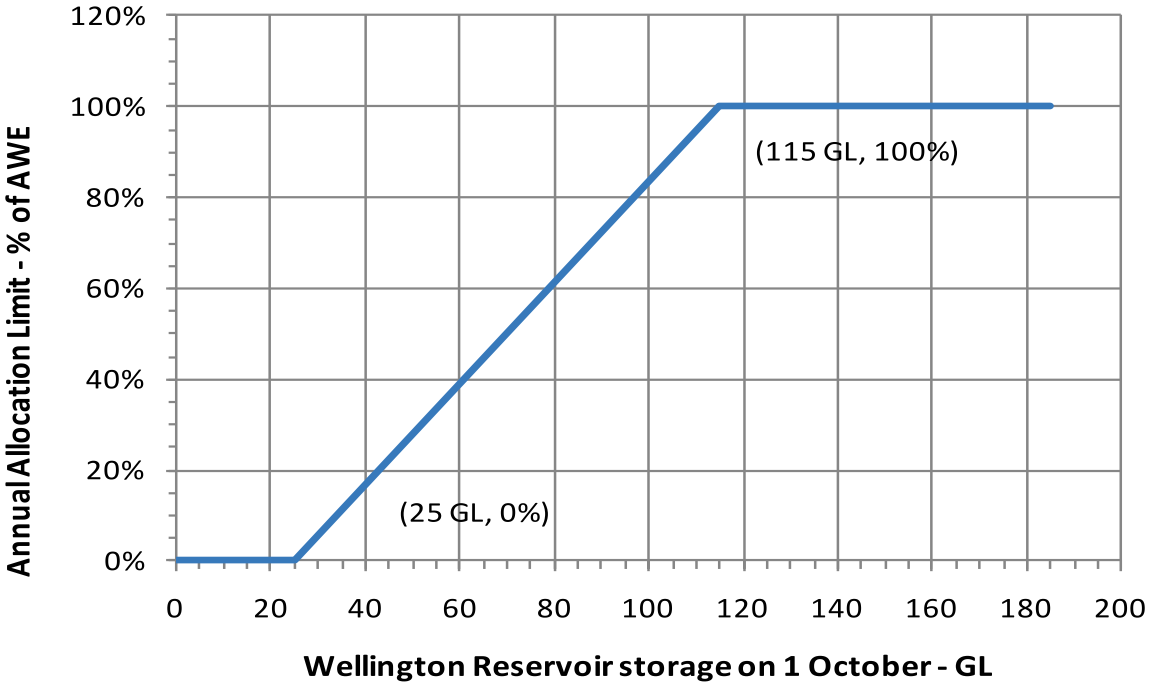


Figure 20 Annual allocation limit available as a percentage of annual water entitlements, as it relates to Wellington storage on 1 October (DoW 2011)

Wellington Reservoir simulations

The Department of Water has undertaken reservoir simulations of the Wellington Reservoir to investigate different options to balance the competing demands for water from the Wellington Reservoir (DoW 2011a in preparation).

The simulations were iterative and included a range of industrial, irrigation and power demand scenarios. This enabled an estimation of the reliability of meeting the different consumptive demands and the environmental water provision, based on:

- inflows to the reservoir recorded from 1976 to 2003
- future projections of inflows based on a median future climate at 2030 (Table 15).

The scenarios have been selected from a range of reservoir simulations undertaken as part of the studies for the report *Wellington Reservoir water balance simulations, a summary of the TwoRes modelling scenarios* (DoW 2011a in preparation). A brief explanation of the demand scenarios in Table 15 are presented below.

The demand scenarios presented in Table 14 and Table 15 are designed to reflect entitlements and releases from the reservoir that have occurred in the past (Scenario α), those which may occur in the next five years (Scenario 3.4), and those which are likely to occur by 2030 (Scenarios 0.3, 3.4, 4.7 and 4.8).

Table 14 Explanation of reservoir simulation scenarios presented in Table 15

Scenario*	Volume and reliability of supplying demand	Environmental Water	Climate sequence
α	Assumes that the only demand from the reservoir is for irrigation water. Sets the demand at the current licensed entitlement of 68 GL. The reliability of supply is 95%.	Assumes no environmental water provision, but implementation of the scour regime with the minimum stored volume for scouring trigger set at 100 GL. This is the only scenario that explicitly models a winter scour regime. This scenario was only simulated under the historical climate sequence (DoW 2011a in preparation).	Historical (base case)
0.3	Assumes that there is 59 GL of irrigation demand – the maximum annual use of irrigation water in the last thirteen years – an annual demand for industry of 12 GL at 85% reliability of supply under the historical climate and an annual demand of 5.1 GL for power cooling at 100% reliability of supply.	Assumes a fixed environmental water provision of 2.1 GL. For the variable component of the environmental water provision rules for how much is released at each dam storage level were adjusted to achieve 85% reliability under the historical climate. These release rules were then applied to future climate scenario. The mean annual variable environmental water provision volume is less under a median future climate because, on average, the dam storage volumes reduce.	Historical and median future at 2030
3.4	Assumes that the annual irrigation demand is the current licensed entitlement of 68 GL, with a 12 GL industrial demand at 85% reliability of supply under the historical climate and no demand for power cooling water.	This scenario assumes a fixed environmental water provision of 2.1 GL. For the variable component of the environmental water provision rules for how much is released at each dam storage level were adjusted to achieve 85% reliability under the historical climate. These release rules were then applied to future climate scenario. The mean annual variable environmental water provision volume is less under a median future climate because, on average, the dam storage volumes reduce.	Historical and median future at 2030

Scenario*	Volume and reliability of supplying demand	Environmental Water	Climate sequence
4.7	This scenario assumes a 68 GL annual irrigation demand, a 12 GL industrial demand at 85% reliability of supply under the historical climate and a 5.1 GL power station cooling water demand at 100% reliability of supply.	This scenario assumes a fixed environmental water provision of 2.1GL. For the variable component of the environmental water provision rules for how much is released at each dam storage level were adjusted to achieve 85% reliability under the historical climate. These release rules were then applied to future climate scenario. The mean annual variable environmental water provision volume is less under a median future climate because, on average, the dam storage volumes reduce.	Historical and median future at 2030
4.8	This scenario assumes identical demands as Scenario 4.7, but with a target annual reliability for the irrigation and industrial demands of 75% instead of 85%.	The scenario assumes a fixed environmental water provision. For the variable component of the environmental water provision rules for how much is released at each dam storage level were adjusted to achieve 75% reliability under the historical climate. These release rules were then applied to future climate scenario. The mean annual variable environmental water provision volume is less under a median future climate because, on average, the dam storage volumes reduce.	Historical and median future at 2030

* *the numbers used for each scenario are the same as those used in* Wellington Reservoir water balance simulations, a summary of the TwoRes model *(DoW 2011a in preparation).*

Environmental water provision

The department has defined a winter environmental water provision for the lower Collie River. This is the flow regime needed to maintain key ecological and social values downstream of the reservoir in winter. The key ecological values for the lower Collie River, Wellington reach, are summarised in Appendix B.

The environmental water provision will replace the existing scour releases when the operating strategy for the reservoir is updated in 2011. The winter environmental water provision includes a:

- fixed minimum component
- variable component.

The fixed minimum component of 2.1 GL/yr from May to September for river function is based on maintaining water quality in pools downstream of the reservoir and maintaining some riffle inundation for macroinvertebrates to provide food for native fish (WRM 2010).

The variable component provides additional winter flow events where possible. In months where dam storage levels are high it provides more water for fish spawning and migration and for inundation of fringing vegetation. In months where storage levels are low the variable component is less so that water is available for consumptive use.

Based on storage levels recorded from 1976 to 2003 the mean volume of the variable component would be between 3.8 GL and 18.2 GL. The mean volume for the variable component of the environmental water provision will depend on demand from the reservoir (Table 15).

The volume of the environmental water provision and spill from the reservoir would, on average, be less than the combined volume of scour and spill that has been recorded from the reservoir from 1976 to 2003. However, under the new release regime (to be implemented in 2011), the minimum release from the reservoir will not fall below the 2.1 GL fixed minimum component.

Table 15 shows the variable component of the environmental water provision for a range of demand scenarios based on reservoir storage between 1976 to 2003 and simulated storage in the reservoir under a median future climate at 2030.

How often will restrictions occur?

The reservoir simulations highlight that the irrigation and industrial entitlements from the Wellington Reservoir are unlikely to be met with high reliability in the future (Table 15).

To manage how water is shared between consumptive users and the environment, especially in dry years, the department has set restrictions for irrigation and industrial entitlements when dam storage on 1 October of each year falls below 115 GL. Full restrictions to industrial and irrigation entitlements would occur when reservoir storage on 1 October drops to 25 GL.

The number of years when there is likely to be a shortfall in industrial supply, and the maximum, median and mean annual volumes of shortfalls, are summarised for each scenario in the *Wellington Reservoir water balance simulations, a summary of the TwoRes modelling scenarios* (DoW 2011a in preparation).

Table 15 Potential future demand options for the Wellington Reservoir

Scenario number*	Climate scenario based on inflows to the reservoir from 1975–2003 (historical) and a median future climate at 2030 (future)	Primary allocation options: Irrigation demand GL/yr	Industry demand GL/yr	Reliability of supply for irrigation and industry %	Power generation demand GL/yr @ 100% reliability of supply	Environmental water provision GL/yr – May to September: Fixed @ 100% reliability of supply	Mean variable	Total	Spill from the reservoir GL/year
α	Historical	68	0	100	0	scour releases – minimum stored volume for scouring trigger set at 100GL. Average scour volume was 7.5GL/yr (May –September) from 1976 to 2003			42.4
0.3	Historical	59	12	85	5.1	2.1	18.3	20.4	25.8
3.4	Historical	68	12	85	0	2.1	14.6	16.7	25.5
4.7	Historical	68	12	85	5.1	2.1	3.9	6.0	31.2
4.8	Historical	68	12	76	5.1	2.1	17.2	19.3	20.7
0.3	Future	59	12	56	5.1	2.1	11	13.1	6.2
3.4	Future	68	12	59	0	2.1	7.9	10	6.3
4.7	Future	68	12	59	5.1	2.1	2.2	4.3	7.7
4.8	Future	68	12	53	5.1	2.1	10.1	12.2	4.6

** the numbers used for each scenario are the same as those used in* Wellington Reservoir water balance simulations, a summary of the TwoRes modelling scenarios *(DoW 2011a in preparation).*

The mean annual water balance of the Wellington Reservoir for Scenario α and for the four future demand scenarios (Scenarios 0.3, 3.4, 4.7 and 4.8) are presented below in Figure 23 to Figure 27 for both a historical and future climate.

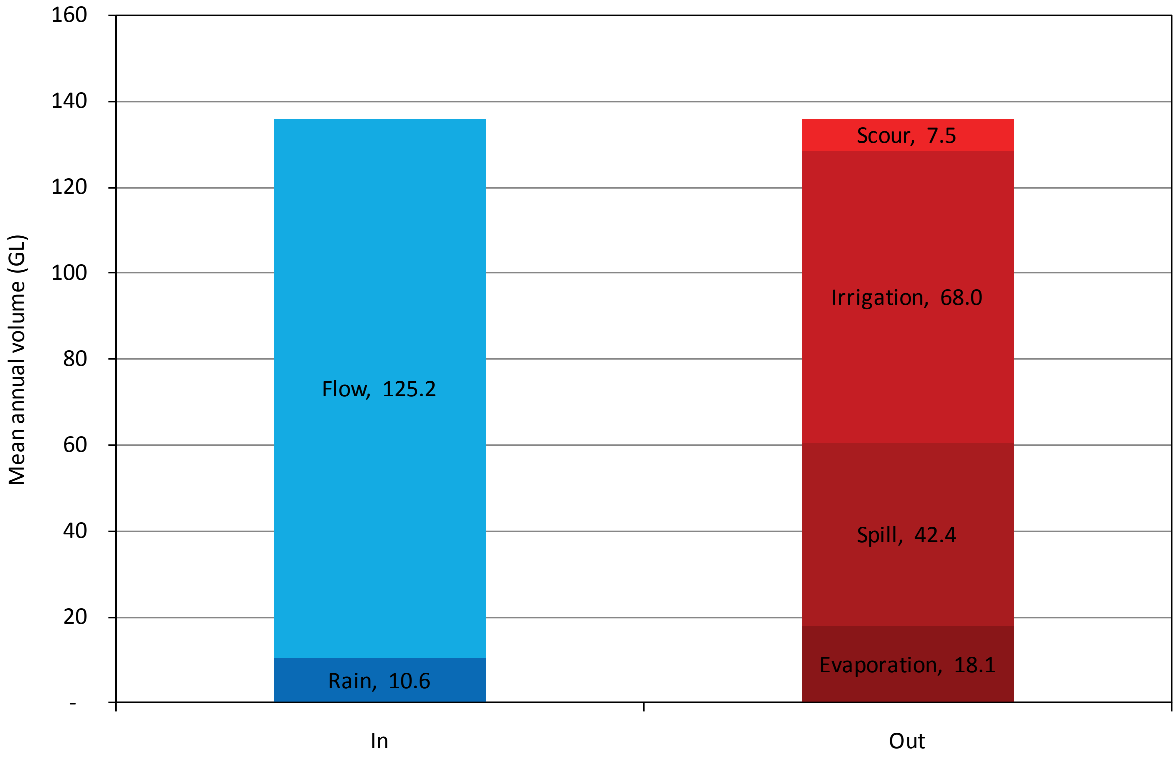


Figure 21 Mean annual water balance for Scenario α

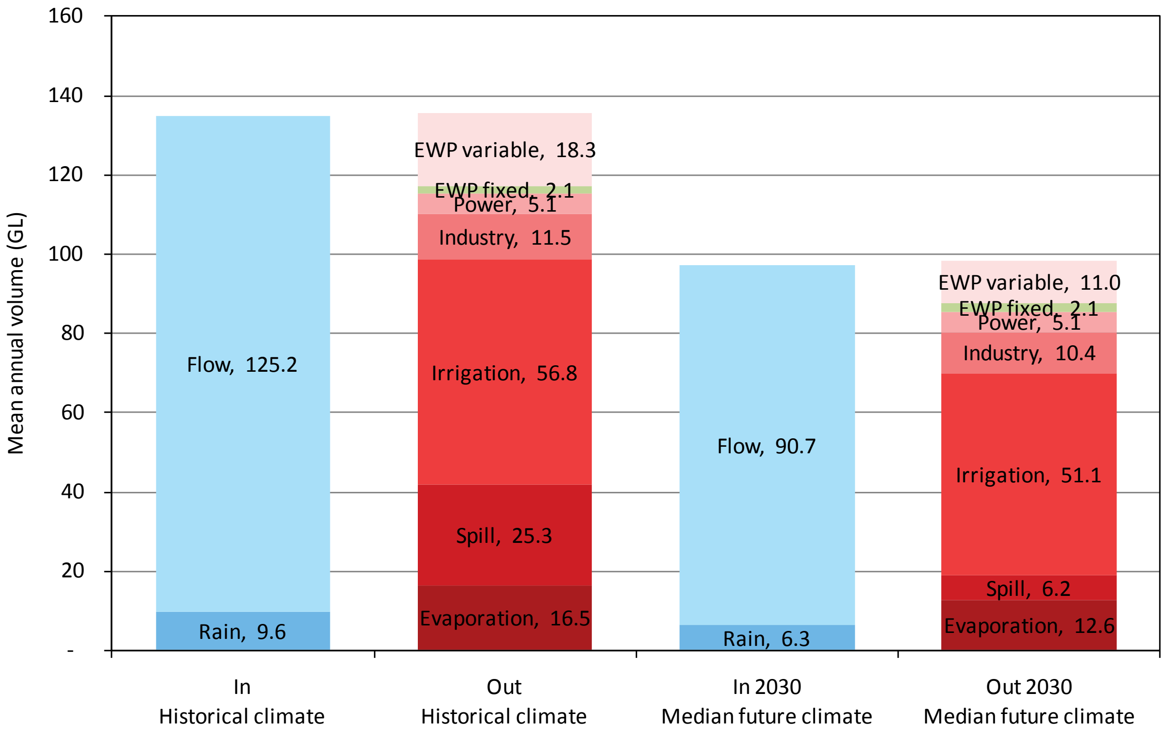


Figure 22 Mean annual water balances for Scenario 0.3

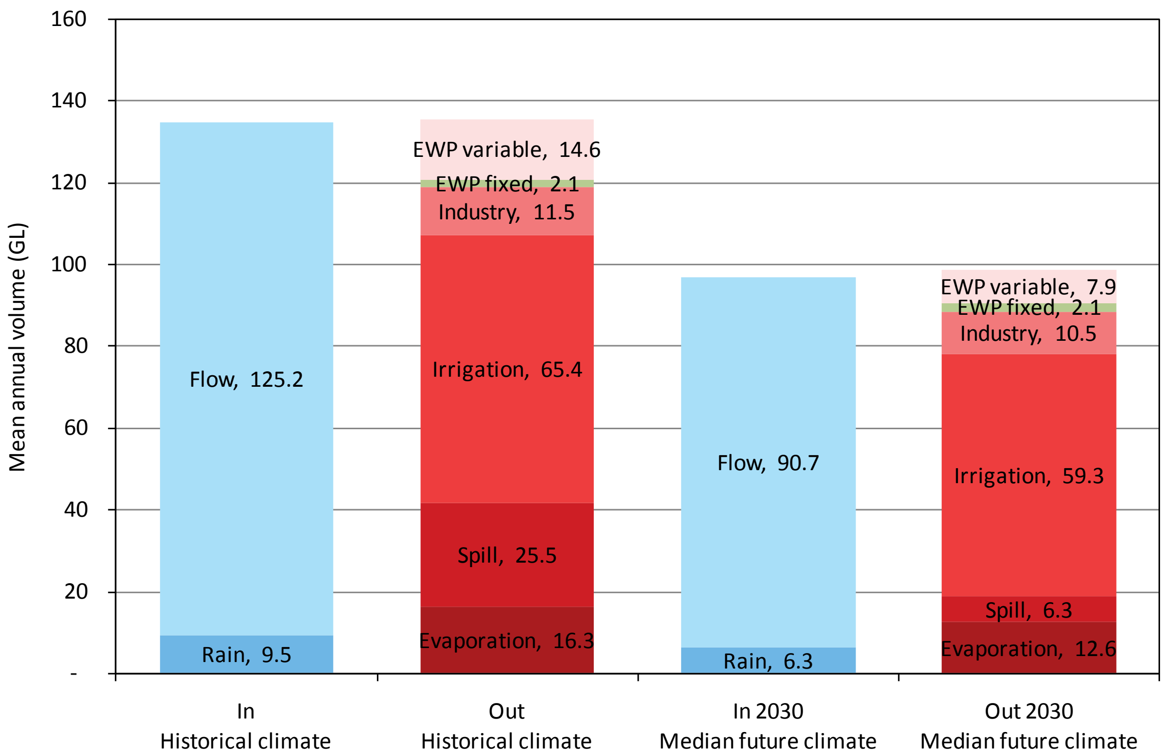


Figure 23 Mean annual water balances for Scenario 3.4

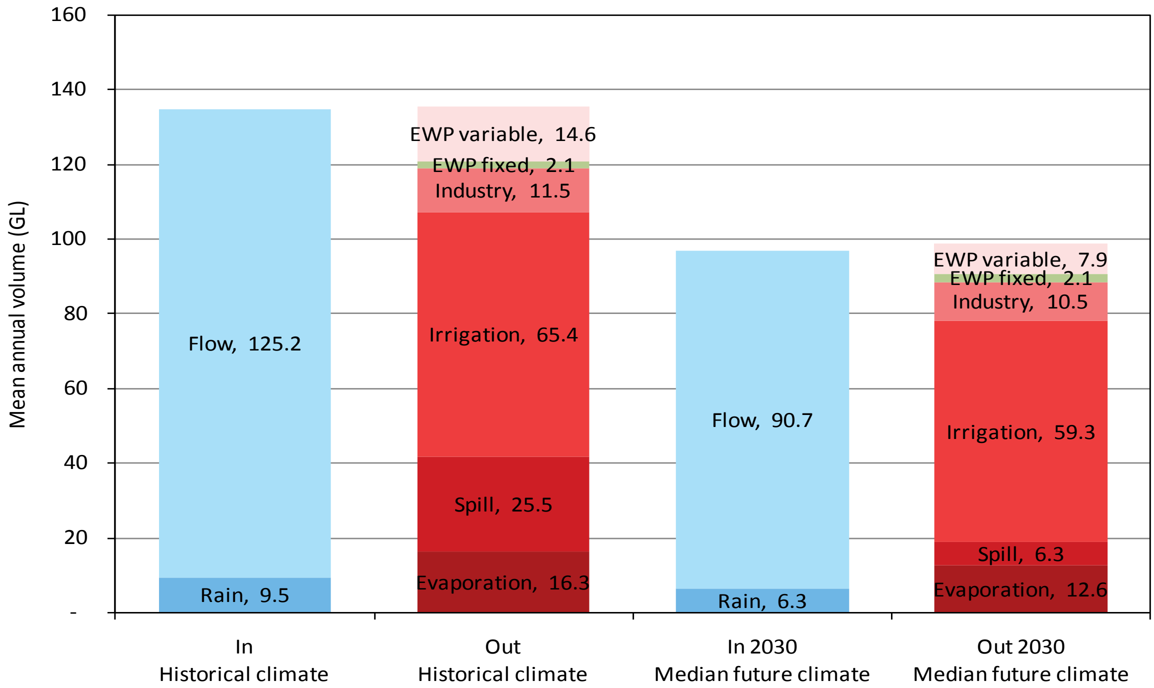


Figure 24 Mean annual water balances for Scenario 4.7

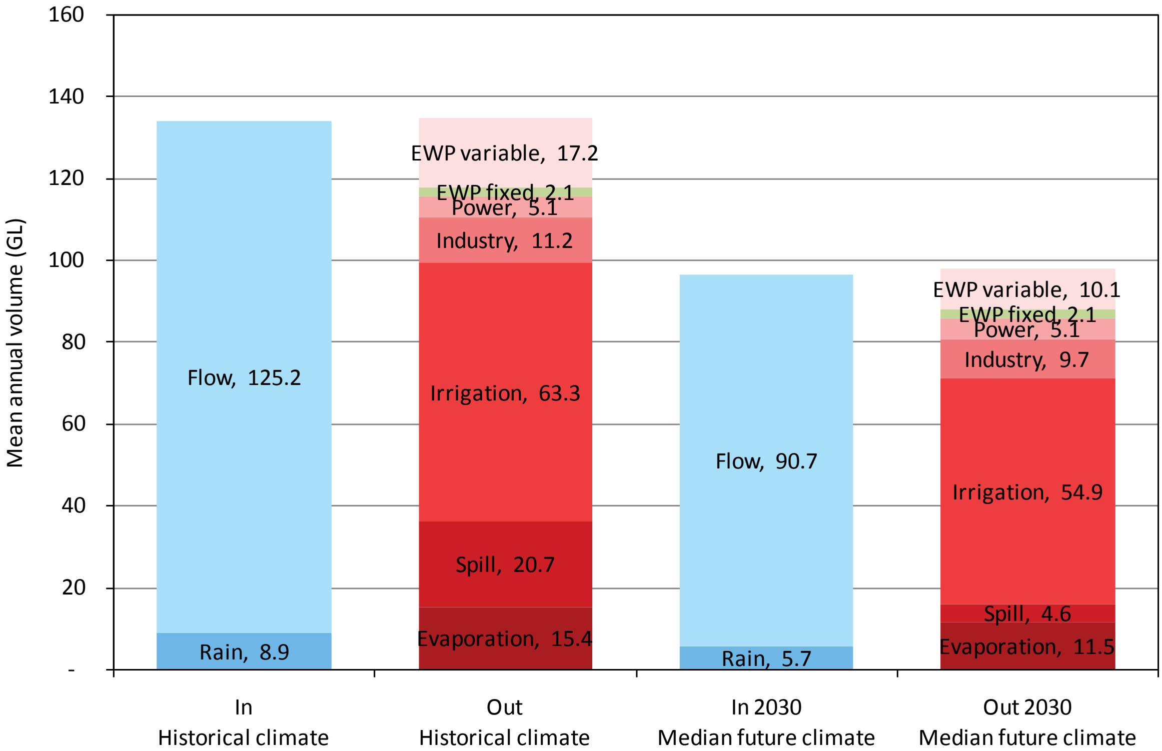


Figure 25 Mean annual water balances for Scenario 4.8

Appendices

Appendix A – Ecological values and water requirements in the lower Collie allocation plan area

Ecological values

Fauna found in the lower Collie surface water allocation plan area – collated using the references listed under ‘Environmental flow studies’ in Section 2.2 includes:

- Seven native and three non-native fish species – five of which are regional endemics common in rivers of south-western Australia and none of which are listed under state or federal conservation legislation.
- Marron *(Cherax cainii)* and gilgies (*Cherax quinquecarinatus)* which occur throughout the plan area. Gilgies are more widespread and abundant than marron, which is typical of rivers in the south-west.
- A cosmopolitan macroinvertebrate assemblage present in Henty Brook and the lower Collie river with few rare, restricted or significant species.
- An ecologically significant, endemic, rare and indicator species forming part of the macroinvertebrate community of the Augustus River (WRM 2005).
- Macroinvertebrate assemblages in the upper reaches of the Brunswick River that indicate an undisturbed ecosystem, and communities in the lower reach which indicate a system enriched with nutrients
- The freshwater mussel *(Westralunio carteri)* which is widespread in the plan area. The freshwater mussel is declining throughout the south-west due to habitat fragmentation, salinisation and sedimentation. It is currently listed as a Priority 4 species (DEC 2010) and as vulnerable under the IUCN *Red list of threatened species* (WRM 2009, Donohue et al 2009, WRM 2005).
- Several species of frogs, mammals and reptiles which have been recorded in the plan area as part of opportunistic surveys associated with permanent and seasonal waterways including:
    - Water rat (*Hydromys chrysogaster)* (Priority 4 species, DEC 2010)
    - Long-necked tortoise (*Chelodina oblonga)*
    - Glauert’s froglet (*Crinia glauerti)*
    - Quacking froglet (*Crinia georgiana)*
    - Slender tree frog (*Litoria adelaidensis)* (WRM 2009, Donohue et al 2009)
- Several common species of waterbirds which have been recorded in proximity to the lower Collie and Brunswick rivers and the Henty Brook. The cattle egret (*Ardea ibis)* recorded at Henty Brook is listed under JAMBA, CAMBA and CMS treaties and therefore protected under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*.

Flora in the lower Collie surface water allocation plan area – collated using the references listed under ‘Environmental flow studies’ in Section 2.2 includes:

- Jarrah – marri open woodland (*Eucalyptus marginata, Corymbia calophylla*) and communities of *Acacia pulchella* and *Melaleuca* species. Wetland species including *Baumea vaginalis* and *Astartea fascicularis* on granite outcrops on the darling scarp and plateau
- An overstorey of bull banksia (*B. grandis*), sheoaks (*Allocasuarina fraseriana*) and wandoo (*Eucalyptus wandoo) and* peppermint (*Agonis linearifolia*) blackbutt (*Eucalyptus patens)* and flooded gum (*Eucalyptus rudis)* along watercourses along the lower slopes of the darling scarp
- Fringing wetland species of flooded gum (*Eucalyptus rudis*) and swamp paperbark (*Melaleuca rhaphiophylla*) and understorey rush and sedge species on the Swan Coastal Plain.

Most of the remaining native vegetation in the plan area is jarrah–marri woodland. There are patches of vegetation typical of the lower slopes, riparian and Swan Coastal Plain communities, but these are now highly fragmented and variable in condition.

The general condition of the remnant vegetation in the plan area is collated against each subarea below. This information has been used to rate each resource in the plan area according to its ecological value.

Brunswick subarea

The upper part of the Brunswick subarea (resources 1, 2, 3, and 4) is mostly protected as part of state and national parks. Approximately three-quarters is composed of intact native vegetation dominated by jarrah – marri open woodland, with the balance cleared for industry and private agriculture.

The majority of the lower part of the Brunswick subarea on the coastal plain is now cleared of native vegetation. Riparian vegetation in this area is generally restricted to a single row of trees along the river bank, with an understorey of introduced weed species and pasture. Some sections of the Brunswick river are highly eroded.

The majority of the Augustus River catchment is mature native forest in an intact condition. Small pockets have been cleared and there is evidence of past logging activity (WRM 2005)

Riparian vegetation below the Worsley Reservoir is dense and in good condition with a low incidence of weeds. The mature forest adjacent to the river provides a source of large woody debris to the channel, creating a diversity of habitats.

Wellesley subarea

Native remnant vegetation covers 24% of the Wellesley subarea. There are no reports or surveys available for the Wellesley area which describe the condition or extent of the vegetation in the Wellesley subarea in detail.

Lower Collie subarea

The riparian vegetation between the Wellington Reservoir and the Burekup Weir is in good condition. National parks protect 90% of the catchment and 98% of the existing vegetation is native forest. The riparian vegetation is dominated by mixed eucalyptus woodlands and fringing sedge land communities out to 2 m from the river bank.

Riparian vegetation along the lower Collie River from the Burekup Weir to the point of estuarine influence is in poor to very poor condition, with an understorey composed mainly of pasture grasses and weeds. An open overstorey of flooded gum, peppermint and tea tree persists along the river bank in isolated pockets. Except for encroaching grass and weeds there is limited overhanging, in-channel vegetation. The banks of the lower Collie River and Henty Brook are characterised by poor stability and severe erosion in the form of bank slumping, channel widening, undercutting and often extensive sedimentation.

Table 16   Fish and macroinvertebrates present in each river of the plan area

	Wellesley	Augustus	Brunswick (lower)	Brunswick (upper)	Lower Collie (dam to weir)	Lower Collie (Shentons)	Lower Collie (below Shentons)	Henty
Fish species								
Bostockia porosa (nightfish)	✓	✓	✓	✓	✓	✓	✓	✓
Galaxias occidentalis (western minnow)	✓	✓	✓	✓	✓	✓	✓	✓
Edelia vittata (western pygmy perch)	✓	✓	✓	✓	✓	✓	✓	✓
Tandanus bostocki (cobbler)	✓	✓	✓	✓	✓	✓	✓	✓
Geotria australis (pouched lamprey)		✓	✓				✓	
Pseudogobius olorium (Swan River goby)			✓		✓	✓	✓	
Afurcagobius suppositus (long headed goby)	✓		✓				✓	
**Oncorhynchus mykiss* (rainbow trout)		✓		✓		✓	✓	
**Gambusia holbrooki* (mosquitofish)			✓			✓	✓	
**Perca fluviatilis* (redfin perch)			✓			✓	✓	
Macroinvertebrates								
Cherax cainii (smooth marron)		✓	✓	✓	✓	✓	✓	
Cherax quinquecarinatus (gilgie)	✓	✓	✓	✓	✓		✓	✓
Westralunio carteri (freshwater mussel)		✓	✓	✓		✓	✓	✓
Cherax destructor (yabby)	✓							

The information for this table is from relevant ecological water requirement reports and Framework for the assessment of river and wetland health (Storer 2010) monitoring results.

* *denotes an exotic species*

Ecological water requirements

The general water requirements of flora and fauna in the lower Collie allocation plan area have been used to develop flow–ecology thresholds, yield estimates and environmental releases as part of the allocation plan. The general water requirements are summarised in Appendix B.

None of the native fish recorded in the plan area have physiological adaptations to withstand desiccation and therefore require permanent water year round.

Winter flows are a breeding cue for at least three native fish species (pygmy perch, western minnow and nightfish). These species migrate upstream in winter and spring to breed and spawn on flooded vegetation – if water levels fall too soon, or fluctuate greatly, the eggs may dry out and fail to hatch. Continued inundation is important post-spawning to provide sheltered, low velocity nursery areas for growing juveniles.

Frequent periods or ‘pulses’ of high flow in winter and spring, that last several hours, are required to submerge barriers (e.g. logs, riffles, waterfalls and granite outcrops) and allow fish to migrate upstream to suitable spawning sites. Depths of 10 cm for small-bodied fish (e.g. western minnow) and 20 cm for larger bodied fish (e.g. cobbler) over obstacles and riffles are generally regarded as the minimum required to allow migration.

Gilgies are able to withstand prolonged periods of drought so long as their burrows remain damp and their gills stay hydrated. Marron are believed to be generally more sensitive to environmental fluctuations including temperature and dissolved oxygen, and require access to permanent flows or pools.

The majority of aquatic invertebrates spawn in spring and summer. Few species breed in winter, in more than one season or year round. Also, the majority of species sampled do not have physiological or life history stages that allow them to survive seasonal drying.

Riffles and sandy runs tend to support a higher density and variety of invertebrates than other aquatic habitats. It is important to maintain sufficient flows to ensure rocks, riffles and sandy runs are inundated.

All frogs need water during certain stages of their life cycle in which to lay eggs and for tadpoles to survive and metamorphose. The surface water requirements for frogs are linked to inundation of riparian vegetation and flooding of backwater habitats (where available) to maintain habitat and spawning sites as well as provide a food source.

The water rat (*Hydromys chrysogaster)* is the mammal found in the plan area that is most closely associated with water. It relies on healthy riparian vegetation and stable river banks to build nesting burrows, aquatic fauna for a source of food and it suffers heat stress without access to permanent water during summer.

The long-necked tortoise (*Chelodina oblonga)* is common throughout the plan area. Survival of the tortoise depends on the presence of permanent water and on nearby areas of soft, damp soils in which to lay their eggs. In areas with permanent flowing water the tortoise has two breeding periods, while in ephemeral river systems they tend to breed once a year in spring.

Perennial reaches along larger rivers may be important as drought refuge in summer for waterbirds. Sections of the Brunswick River where the banks are still lined with paperbark and eucalypts provide important breeding habitat for a limited variety of waterbirds. The paperbark swamps adjacent to the Brunswick River provide roosting sites for Australian White Ibis and Straw Neck Ibis (Donohue et al 2009).

The majority of Australian riparian plant species germinate during autumn under waterlogged conditions, while few species germinate during summer (Britton & Brock 1994). Annual inundation of the floodplain, to a shallow depth, to facilitate seed dispersal, saturate soils and to promote successful recruitment is recommended for flooded gum (*Eucalyptus rudis*) and swamp paperbark (*Melaleuca rhaphiophylla*).

Aboriginal cultural values

The surface water resources in the lower Collie plan area are important in the lives of Nyungar people. Rivers in the plan area are a source of water, food and recreation, and support traditional mythological and spiritual beliefs (Beckwith 2009b).

The entire Collie and Brunswick rivers are registered permanent sites. The rivers are connected to Ngarngungudditj Walgu, a mythical water snake thought to have created the Collie River, the Collie River valley, hills and the Leschenault estuary.

A study commissioned by the department examined the social and cultural values that local Nyungar people place on the Collie River. Of the 36 locations identified by Nyungar representatives as having social values, only nine are on the Western Australian *Register of Aboriginal sites* (Beckwith 2009b).

There are numerous Indigenous and non-Indigenous cultural sites throughout the lower Collie plan area. Sites associated with surface water that are identified as permanent on the Western Australian *Register of Aboriginal sites* are:

- the entire Brunswick River is a registered mythological site and there are two other permanent sites on the register related to surface water in the Brunswick sub area (Beckwith 2009a & 2009b)
- there is only one permanent site associated with surface water within the Wellesley subarea (Beckwith 2009a)
- The entire Collie River is a permanent site registered on the Western Australian *Register of Aboriginal sites* (Beckwith 2009b).

During the Indigenous values scoping study of the Collie River, and subsequent consultation between Indigenous representatives and the department (30 September 2010), the reach between Wellington Reservoir and Burekup Weir was identified as having high value. It was also confirmed that river flow is vital for Indigenous cultural values to ensure that deep river pools never dry.

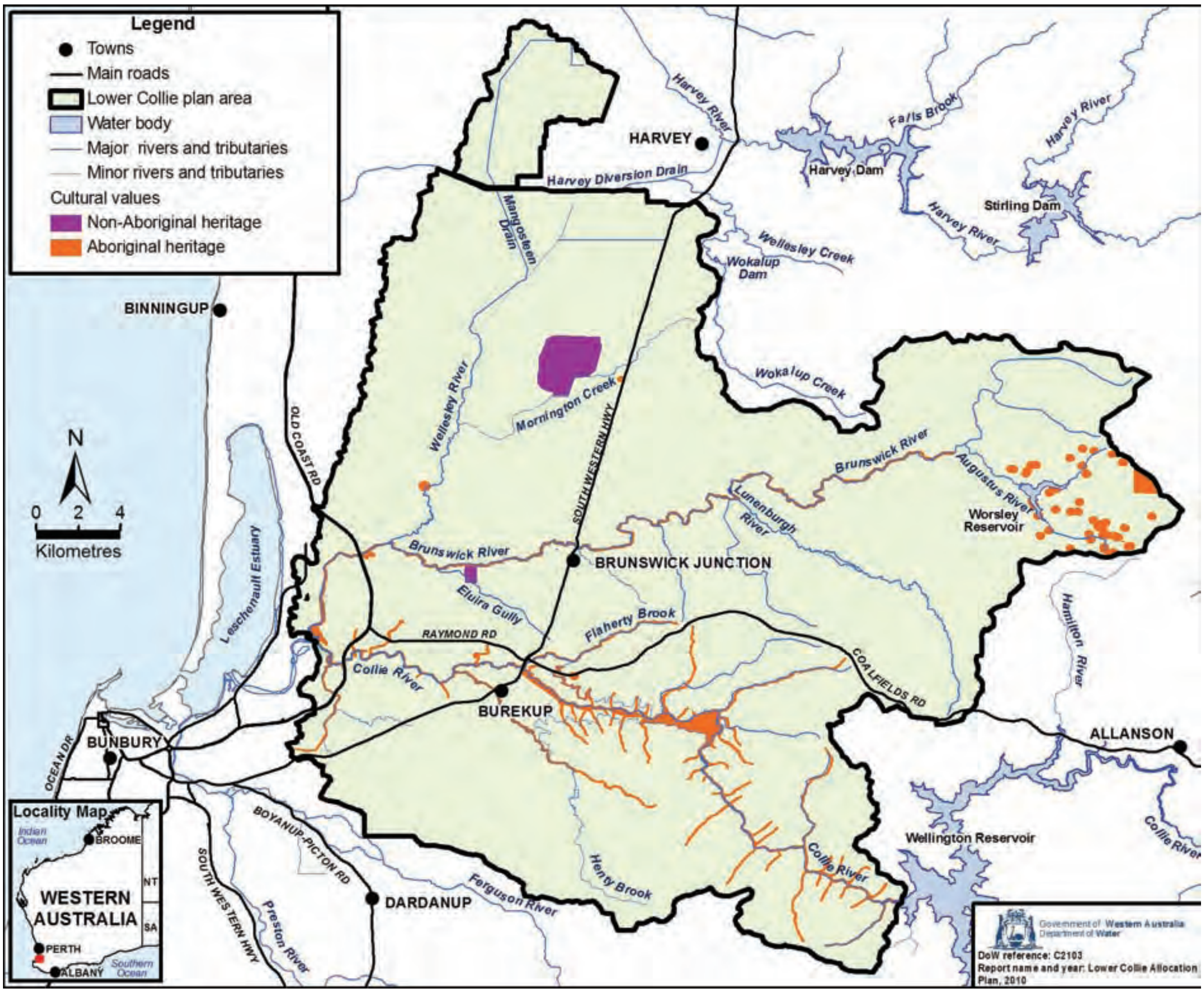


Figure 26 Cultural values for the lower Collie allocation plan area

Other social values

As part of developing the *Lower Collie River social values study* (Beckwith 2008) community representatives were asked to identify values associated with surface water in the lower Collie area. These are summarised below for each subarea in the plan area and summarised in Table 17.

Brunswick subarea values

- Marroning in January and February
- trout fishing from the headwaters to the South Western Highway – from September to April

- swimming and picnicking at the Brunswick River pool (Brunswick resource 10)- Harvey Water releases an average of 0.8 GL/yr into the Brunswick River pool to help maintain water levels in the Brunswick River pool
- camping at Moonlight pool and Treasure Bridge year round
- the Munda Biddi Trail runs along a short portion (about 5 km) of the Brunswick River (Brunswick 3 resource)
- Elbow Reserve (Brunswick 11 resource) for boating, canoeing and picnicking.

Several community representatives also stated that a significant dam on the Brunswick River would compromise the social values of the Brunswick River and Leschenault Estuary (Beckwith 2009a).

Wellesley subarea values

- Benger Swamp (Wellesley River 2 resource) for bird watching.

Lower Collie and tributaries subarea values (from the base of the Wellington Dam to the Burekup Weir)

- Honeymoon Pool, Long Pool, Rapids, Big Rock and Little Rock for marroning, swimming, picnicking, fishing and canoeing
- hiking, four-wheel driving and cycling trails within the national park downstream of Wellington Reservoir
- abseiling and rock climbing at the Wellington Reservoir quarry
- commercial tourism ventures as well as educational and scientific pursuits (Beckwith 2009a).

Several community members commented that releases from the Wellington Reservoir from October to April for irrigation make canoeing and swimming possible along the river in summer. The cessation of scour releases from Wellington Dam may threaten social values downstream of the reservoir.

Lower Collie and tributaries subarea values (from the South West Highway bridge to the plan boundary (Lower Collie tributary 10)

- boating and fishing between the point where the Brunswick River meets the Collie River and the Australind bypass.

Several community members commented that water quality is the greatest risk to the social values of this stretch of the lower Collie River. This is reinforced by fish kills in recent years. Interviewees noted that sedimentation, saltwater intrusion and habitat loss are also a risk to the social values.

Social values are limited to fishing, boating and canoeing in this subarea. This is mainly due to limited public access to the river. No social values were identified for the river segment between Burekup Weir and the South Western Highway bridge. This was attributed to the lack of public access points, steep foreshores, narrow channel upstream of the bridge and obstructions to the river (e.g. fences, private property) (Beckwith 2009a).

There are four non-Indigenous heritage sites located along the Brunswick River that are listed on the Shire of Harvey municipal inventory. Only one, Alverstoke Homestead Complex, is listed on the Heritage Council of Western Australia register (Beckwith 2009a).

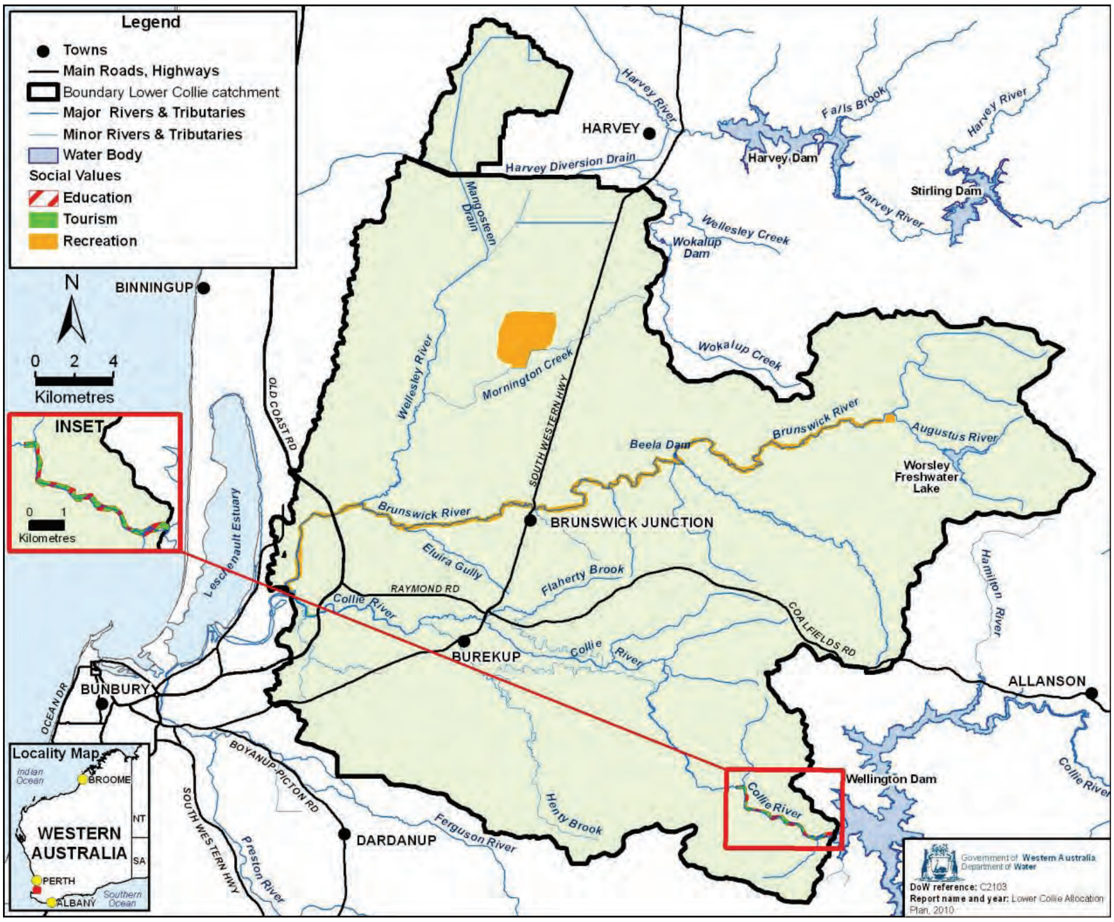


Figure 27 Social values in the lower Collie surface water allocation plan area

Table 17 Summary of social and cultural values in the lower Collie surface water allocation plan area

	Brunswick	**Wellesley**	**Collie**	
			Wellington dam to Burekup weir	**Burekup weir to river mouth**
Aboriginal heritage	✓	✓	✓	✓
Non-Aboriginal heritage	✓			
Picnicking	✓		✓	
Swimming	✓		✓	
Fishing	✓		✓	✓
Marroning	✓		✓	
Boating	✓			✓
Canoeing	✓		✓	✓
Birding		✓		
Tourism	✓		✓	
Education			✓	
Hiking			✓	
Cycling	✓		✓	
4WD			✓	
Camping	✓		✓	

Appendix B – Flow–ecology thresholds developed as part of environmental flow studies

Table 18 Ecologically critical flow rates for Shenton's Elbow reach, lower Collie River

Ecological objective	Flow objective	Ecologically critical flow rate m^3/s	Ecologically critical flow rate ML/day
*Maintain summer breeding habitat for cobbler	Minimum 80 cm water depth in pools	0.05	4.32
*Provide summer habitat for macroinvertebrates	Water depth of 5 cm over 50% of width of riffle runs	0.05	4.32
*Maintain water quality and dissolved oxygen levels in pools for summer refuge of aquatic fauna Downstream carbon movement maintained by connectivity between pools	Minimum flow velocity of 0.01 m/s	0.07	6.05
Allow upstream spawning migration of small-bodied native fish	Minimum thalweg depth of 10 cm at shallowest cross-section	0.28	24.2
*Provide winter habitat for macroinvertebrates	Water depth of 5 cm over entire width of riffle runs	0.41	35.4
Allow upstream spawning migration of cobbler	Minimum thalweg depth of 20 cm at shallowest cross-section	1.20	104
Scour and maintain low-flow channel Prevent incursion of terrestrial vegetation	Inundate active channel	1.56	135
Inundate trailing vegetation, providing fish cover and spawning sites	Inundate trailing vegetation	1.92	166
Flush organic matter into river system Inundate trailing and emergent vegetation	Inundate low benches	3.75	324
Flush organic matter into river system High-energy flows to scour pools and maintain channel morphology	Inundate high benches	12.26	1059
Flush organic matter into river system Inundate channel and floodplain riparian vegetation High-energy flows to scour pools and maintain channel morphology	Inundate top of bank	33.3	2879

The ecological objectives and their critical flow rates denoted above are those that satisfy the water resource objectives set out in Table 11.

Table 19 Ecologically critical flow rates for Reach 1 and Reach 2 of the Brunswick River

Flow-ecology rule	Ecologically critical flow rate* Reach 1 m³/s	Reach 1 ML/day	Reach 2 m³/s	Reach 2 ML/day	Ecological objective
Minimum flow velocity of 0.01 m/s	0.02	1.7	0.02	1.7	• Maintain water quality and dissolved oxygen levels in pools. • Downstream carbon movement maintained by connectivity between pools.
Water depth of 5 cm over 50% of width of sandy runs	0.06	5.2	0.17	14.7	• Provide summer habitat for macroinvertebrates.
Water depth of 5 cm over entire width of sandy runs	0.11	9.5	1.4	119	• Provide winter habitat for macroinvertebrates.
Minimum thalweg depth of 10 cm at shallowest cross-section	0.11	9.5	0.04	3.5	• Allow upstream spawning migration of small-bodied native fish.
Minimum thalweg depth of 20 cm at shallowest cross-section	0.25	21.6	0.32	27.6	• Allow upstream spawning migration of large-bodied native fish. • Inundate trailing vegetation.
Inundate low benches	0.36	31.1	2.1	177	• Flush organic matter into river system. • Inundate trailing vegetation, providing fish cover and spawning sites.
Inundate medium benches	4.1	352	N/A - no medium benches		• Flush organic matter into river system. • Inundate trailing and emergent vegetation. • Provide spawning habitat.
Inundate active channel	10.5	907	2.1	177	• Scour and maintain low-flow channel. • Inundate trailing vegetation. • Prevent incursion of terrestrial vegetation. • Flush organic matter into river system.

Flow-ecology rule	Ecologically critical flow rate*				Ecological objective
	Reach 1		Reach 2		
	m^3/s	ML/day	m^3/s	ML/day	
Inundate high benches	15.9	1374	6.1	524	• Flush organic matter into river system. • Inundate riparian vegetation. • High energy flows to scour pools and maintain channel morphology.
Inundate floodplain	22.8	1974	25.7	2217	• Inundate and recharge floodplain wetlands. • Maintain floodplain wetland nursery areas for fish and tadpoles. • Inundate channel and floodplain riparian vegetation. • High energy flows to scour pools and maintain channel morphology.

**The critical flows denoted above are those that satisfy the water resource objectives set out in Table 11.*

Table 20 Ecologically critical flow rates for Wellington reach, below Wellington Dam

Ecological objective	Flow objective	Ecologically critical flow rate	
		m^3/s	ML/day
#Maintain pools as spawning habitat for cobbler	Minimum pool depth of 80 cm	0	0
#Inundate gravel runs and riffles as summer habitat for aquatic invertebrates	Riffles inundated to a depth of at least 5 cm over 50% of total riffle width	0.026	2.25
#Maintain water quality and dissolved oxygen levels in pools as summer refuge for aquatic fauna. Maintain upstream to downstream carbon transfer	Maintain dissolved oxygen above 5 mg/L Maintain connectivity	0.026	2.25
#Inundate gravel runs and riffles as winter habitat for aquatic invertebrates	Riffles inundated to provide sufficient winter habitat	0.168	14.5
Maintain active channel morphology, scour pools and prevent incursion of terrestrial vegetation	Sufficient water levels to fill the active channel	4.7	406
#Inundate aquatic and trailing	Sufficient water depth to	4.7	406

Ecological objective	Flow objective	Ecologically critical flow rate	
		m^3/s	ML/day
vegetation as habitat for invertebrates and vertebrates, and as spawning sites for fish and amphibians	commence inundation of fringing vegetation		
#Allow upstream migration of small-bodied fish during spawning season	Water depth of at least 10 cm over obstacles.	6	518
Allow upstream migration of cobbler during spawning season	Water depth of at least 20 cm over obstacles.	8.43	728
Maintain channel morphology and scour pools.	High flow events.	40	3456
Provide overbank flows to aid seed dispersal and germination of riparian vegetation	1:3 year event (undammed flow regime).	55	4752

#The ecological objectives and their critical flow rates denoted above are those that satisfy the water resource objectives set out in Table 11.

Shortened forms

EWR	Ecological water requirement
DEC	Department of Environment and Conservation
DoW	Department of Water
PADFLOW	Proportional abstraction of daily flow
REYSM	River ecological sustainable yield model
SDL	Sustainable diversion limit
SKM	Sinclair Knight Merz

Glossary

The terms that are used the most in reference to water resource management of the lower Collie surface water allocation area are listed below.

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.
Allocation limit	Annual volume of water set aside for use from a water resource.
Catchment	The area of land from which rainfall run-off contributes to a single watercourse, wetland or aquifer.
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.
Consumptive use	The use of water for private benefit consumptive purposes including irrigation, industry, urban and stock and domestic use.
Dam	Embankments constructed to store or regulate surface water flow. A dam can be constructed in or outside a watercourse
Dissolved oxygen	The concentration of oxygen dissolved in water normally measured in milligrams per litre (mg/L).
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, for instance a lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environmental flow regime	The water regime needed to maintain the current ecological values (including assets, functions and processes) of water-dependent ecosystems consistent with the objectives of the environmental flow study.
Environmental objective	An ecological objective is a goal to maintain, protect, restore or enhance an identified ecological asset, process or function
Environmental water provision	The water regime resulting from the water allocation decision-making process taking into account ecological, social, cultural and economic impacts. They may meet in part or in full the ecological

	water requirements.
Evaporation	Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.
FARWH	Framework for assessment of river and wetland health.
Flow	Streamflow in terms of m^3/a, m^3/d or ML/a. May also be referred to as discharge.
Flow–ecology threshold	Flow–ecology linkages describe the water depths and related flow rates which maintain populations of fish and macroinvertebrates, vegetation community structure and composition, water quality, channel geomorphology and ecosystem processes. The flow required to meet each flow–ecology linkage is estimated using survey information and observed stream flow.
Groundwater	Water which occupies the pores and crevices of rock or soil beneath the land surface.
Groundwater recharge	The rate at which infiltration water reaches the water table.
Hectare	A surface measure of area equal to 10 000 square metres or approximately 2.47 acres.
Hydrograph	A graph showing the height of a water surface above an established datum plane for level, flow, velocity, or other property of water with respect to time.
Inflows	Surface water runoff; deep drainage to groundwater (groundwater recharge); and transfers into the water system (both surface and groundwater), for a defined area
Indigenous heritage	Indigenous heritage includes tangible and intangible expressions of culture that links generations of Indigenous people over time. Indigenous People express their cultural heritage through ‘the person’, their relationship with country, people, beliefs, knowledge, law, language, symbols, ways of living, sea, land and objects all of which arise from Indigenous spirituality
Licence	A formal permit which entitles the licence holder to ‘take’ water from a watercourse, wetland or underground source.
Over allocated	Sum of water access entitlements is more than 100 % of the allocation limit
Over allocation	Refers to situations where with full development of water access entitlements in a particular system, the total volume of water able to be extracted by *entitlement holders* at a given time exceeds the *environmentally sustainable level of extraction* for that system.
REG6	A simple regional mean annual flow model that provides an estimate of mean annual flow from a catchment, for the period

	1975 to 2003, based on land clearing and rainfall data for the same period. REG 6 used the lesser of the 10th%ile annual flow and 60% of the mean annual flow.
REG75	A simple regional mean annual flow model that provides an estimate of mean annual flow from a catchment, for the period 1975 to 2003, based on land clearing and rainfall data for the same period. REG75 used 18% of the mean annual flow for the rainfall period.
Reliability	The frequency with which water allocated under a water access entitlement is able to be supplied in full
Reservoir	A natural or artificial place where water is collected and stored for use, especially water for supplying a community, irrigating land, furnishing power, etc.
Reservoir simulation	Computer simulations of reservoir behaviour are carried out to determine the quantities of water that can be reliably diverted from reservoirs or released to meet downriver water demands (including downstream environmental flows) Simulations of this type are used to determine how best to allocated and manage water resources given the available storage and the highly variable nature of streamflow
Riffle	Swift-flowing areas, where the water is rippled or broken and cascades over rocks. Logs are known as riffle zone
Riparian rights	'The right of riparian land owner to take water from a watercourse, that flows through their property, unlicensed and free of charge for the purpose of stock and domestic use, without sensibly diminishing the flow of water downstream'.
River reach	An aggregation of river links that identifies a section of river with relatively uniform physical characteristics.
Self-supply	Water diverted from a source by a private individual, company or public body for their own individual requirements.
Salinity	The measure of total soluble salt or mineral constituents in water. Water resources are classified based on salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt).
Social value	A particular in-situ quality, attribute or use that is important for public benefit, welfare, state or health (physical and spiritual).
Social water requirement	Elements of the water regime that are needed to maintain social and cultural values.
Streamflow	The net flow of water through a stream channel that integrates all contributing components, e.g., overland flow, interflow, and groundwater discharge

Subarea	A sub-division within a Surface or Groundwater Area, defined for the purpose of managing the allocation of groundwater or surface water resources. Sub-areas are not proclaimed and can therefore be changed internally without being gazetted.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Transferable (tradeable) water entitlement	The ability to transfer or trade a water entitlement, or a part thereof, to another person within a common water resource.
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
Watercourse	(a) Any river, creek, stream or brook in which water flows; (b) Any collection of water (including a reservoir) into, through or out of which anything coming within paragraph (a) flows; c) Any place where water flows that is prescribed by local by-laws to be a watercourse. A watercourse includes the bed and banks of any thing referred to in paragraph (a), (b) or (c).
Water entitlement	The quantity of water that a person is entitled to take annually in accordance with the *Rights in Water and Irrigation Act 1914* or a licence.
Watertable	The saturated level of the unconfined groundwater. Wetlands in low-lying areas are often seasonal or permanent surface expressions of the watertable.
Waterways	All streams, creeks, stormwater drains, rivers, estuaries, coastal lagoons, inlets and harbours.
Water management objective	The department of water develops management objectives to indentify the ways in which we will implement the resource objectives in an area
Water resource objective	The department develops resource objectives to indentify whether we need to maintain, increase, improve, restore or reduce surface and groundwater flow, and or water quality in an area.
Wetland	Wetlands are areas that are permanently, seasonally or intermittently waterlogged or inundated with water that may be fresh, saline, flowing or static, including areas of marine water of

which the depth at low tide does not exceed 6 metres.

Yield estimate Establishes the amount of water that can be abstracted whilst still meeting the environmental water objectives for the resource.

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1 000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 megalitre	(ML)
One billion litres	1 000 000 000 litres	1 gigalitre	(GL)

References and additional reading

ANZECC & ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water* quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Bates BC, Hope P, Ryan B, Smith I and Charles S 2008, 'Key findings from the Indian Ocean Climate Initiative and their impact on policy development in Australia', *Climate Change*, 89 (3-4), 339-334. doi: 10.1007/s10584-007-9390-9.

Beckwith 2008, *Lower Collie river social values study*, report prepared by Beckwith Environmental Planning for the Department of Water, Perth.

——2009a, *The social values of south west water resources*, report prepared for the Department of Water, Western Australia, Perth.

——2009b, *Nyungar values of the Collie river*, report prepared for the Department of Water, Government of Western Australia, Perth, Western Australia.

Bennett, K & Green, A 2011a, in preparation, *Ecological flow regime of the lower Collie river: Wellington reach*, Department of Water, Perth.

——2011b, in preparation, *Ecological flow regime of the lower Collie river: Shenton's Elbow reach*, Department of Water, Perth.

Britton DL & Brock MA 1994, Seasonal germination from wetland seedbanks, *Australian Journal of Marine and Freshwater Research,* 45: 1445–1457.

CSIRO 2009, *Surface water yields in the south-west Western Australia*, A report to the Australian Government from the CSIRO South-West Sustainable Yields Project, CSIRO Water for a Healthy Country Flagship, Australia.

Department of Environment and Conservation 2010, Listing of species and ecological communities, Department of Environment and Conservation, Government of Western Australia,Perth, viewed on 14th March 2011<http://www.dec.wa.gov.au/content/view/852/2010/>.

Department of Land Information 2009, *Spatial cadastral database,* Department of Land Information, Perth.

Department of Water 2007, *Hydrography, linear,* Department of Water, Perth.

——2009a, *Upper Collie water allocation plan,* Department of Water, Government of Western Australia, Perth.

——2011a, *Lower Collie surface water allocation plan: for public comment,* Department of Water, Perth.

——2011b, *Surface water hydrology of the lower Collie catchment,* Department of Water, Perth.

——2011a in preparation, Wellington Reservoir water balance simulation, a summary of the Two Res model, Western Australia; water availability under a range of possible demand scenarios, Perth

——2011b, in preparation, *Leschenault water quality improvement plan,* Department of Water, Perth.

Department of Water & GHD 2011, in preparation, *Water use survey: lower Collie,* Department of Water, Perth.

Donohue, R, Green, A, Bennett, K, Pauli, N, Lynas, J & Storey, A 2009, *Ecological water requirements of the Brunswick River,* Department of Water, Perth.

Fu G, Charles S and Chiew F 2007, A two-parameter climate elasticity of streamflow index to assess climate change effects on annual streamflow. Water Resource Research, 43 (W11419, doi: 10.1029/2007WR005890).

Hardcastle H, Rose T, Pearcey M and Storey A 2003, *Lower Collie River ecological water requirements review: stream morphology, riparian vegetation and fish passage*, unpublished draft report, Department of Water, Perth.

Hart B, Bailey P, Edwards R, Hortle K, James K, McMahon A, Meredith C & Swadling K 1991, 'A review of the salt sensitivity of the Australian freshwater biota', *Hydrobiologia* 210, pp. 105–44.

Harvey Water 2010, *Harvey Water: Annual Report 2009/10*, Harvey Water, Western Australia, Harvey.

Horrigan N, Choy S, Marshall J & Recknagel F 2005, 'Response of stream macroinvertebrates to changes in salinity and the development of a salinity index', *Marine and Freshwater Research* 56, pp. 825–33.

Landgate 2004, *Bunbury orthomosaic*, Landgate, Perth.

——2006, *Bunbury orthomosaic,* Landgate, Perth.

Marillier, B, Hall, J and Shakya, D 2010 *Water-balance modelling of the Leschenault catchment*, Water science technical series no. WST 10, Department of Water, Western Australia, Perth.

Kelsey, P. Hall, J. 2010, *Nutrient-export modelling of the Leschenault catchment,* Water science technical series no. WST 11, Department of Water, Government of Western Australia, Perth.

Sinclair Knight Merz 2008a, *Estimation of sustainable diversion limits for south-west Western Australian catchments (regionalisation of sustainable diversion limits for catchments)*, report for the Department of Water, Perth.

——2008b, *Approach for determining sustainable diversion limits for south-west Western Australia*, report for the Department of Water, Perth.

——2010, in preparation, *Identification and mapping of groundwater-dependent ecosystems associated with the Collie River: final draft*, report for the Department of Water, Perth.

Storer T, Galvin L, O'Neil K, White G, Kitsios A 2010 Framework for the assessment of river and wetland health for south-west Western Australia, Final Report, Department of Water, Western Australia.

Storey A 2003, *Wellington below – EWR review: Fish community including migration requirements*, unpublished report by Wetland Research and Management for the Water and Rivers Commission, Perth.

Streamtec 2000, *Lower Collie River including Henty Brook, environmental water requirements,* report by Streamtec Pty Ltd for the Water and Rivers Commission, Perth.

Thomas, J F 2008, *Water future for Western Australia 200 –2030 : Volume 2: Report for the regions*, report prepared for the Department of Water, Perth.

Welker Environmental Consultancy & Streamtec 2002, *Lower Collie River and Henty Brook preliminary environmental water provisions: Discussion paper,* unpublished report to the Water and Rivers Commission, Perth.

Water Corporation 1999, Wellington, Harris and Mungalup Reservoirs: Water Resource Managemetn Operation Strategy, Water Corporation, Perth.

——2003, *Wellington, Harris and Mungalup reservoirs (includes transfers to IWSS) water resource management operation strategy*, Water Corporation, Perth.

——2010, *Beela Dam Management Strategy,* Water Corporation, Perth.

WRM 2005, *Ecological water requirements of Augustus River – intermediary assessment*, unpublished report by Wetland Research and Management to Worsley Alumina Pty Ltd.

——2009, *Collie River ecological values assessment 2008*, unpublished report by Wetland Research & Management to the Department of Water, Perth.

——2010, *Lower Collie River trial environmental releases: Wellington Dam to Burekup Weir*, unpublished report by Wetland Research & Management to the Department of Water, Perth.

Legislation

Government of Western Australia, *Rights in Water and Irrigation Act1914*, Perth.

——*Country Areas Water Supply Act 1947*, Perth.

Australian Government, *Environmental Protection and Biodiversity Conservation Act 1999*, Canberra.

Policy

Water and Rivers Commission 2000, Statewide policy no 5 – *Environmental water provisions policy for Western Australia,* Perth.

Additional reading

Annan, K 2006, *A comparison of techniques for investigating groundwater–surface water interaction along the Brunswick River*, Western Australia, CEED honours thesis for University of Western Australia in conjunction with Department of Water.

Aquaterra 2002, *Kemerton water study – phase 2 final report*, prepared by Aquaterra for Landcorp, Perth.

Burnash RJC, Ferral RL & McGuire RA 1973, *A generalised streamflow simulation system – conceptual modelling for digital computers*, US department of Commerce, National Weather Service and State of California, Department of Water Resources.

Department of Industry & Investment 2010, Salinity Tolerance in Irrigated Crops, Department of Industry & Investment, Government of New South Wales, NSW, Viewed on October 16th 2010 < <www.dpi.nsw.gov.au/agriculture/resources/soils/salinity/crops/tolerance-irrigated>.

Department of Water 2003, *Review of quantities released from Wellington Reservoir and diverted at Burekup Weir from 1997 to 2001*, Department of Water internal memorandum, Perth.

——2003, *Wellington dam yield estimation*, Department of Water, Perth.

——2007, *The Leschenault estuarine system south-western Australia condition statement and recommendations for management*, Department of Water, Perth.

——2009, *South West groundwater areas allocation plan*, Department of Water, Perth.

——2010, *Nutrient export modelling of the Leschenault catchment*, Report no. WST 11, Department of Water, Perth.

Littlewood I, Down K, Parker J and Post D 1997, *IHACRES Catchment-scale rainfall–streamflow modelling (PC version) Version 1.0*, The Australian National University, Institute of Hydrology and Centre for Ecology and Hydrology, Australia, Canberra.

KPMG 2010*, Independent review of options to reduce salinity in the Upper Collie River Basin: Summary report*, prepared for the Minister for Water and Mental Health, Perth.

Weaving, S 1998, *Geographe Bay catchment natural resource atlas*, Department of Agriculture, Perth.

Water Corporation 2010, *Statewide Dam Storage: Storage at Wellington Dam from October 2005 to October 2010*, Water Corporation, Perth, viewed on 9 October 2010 <www.watercorporation.com.au/D/dams_storagedetail.cfm?id=18320>.

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