Water source options in the Collie-Wellington Basin

Final report to the Minister for Water Resources

Collie-Wellington Basin
Water Source Options Steering Committee

May 2007

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1. Executive Summary

The Minister for Water Resources appointed the Collie-Wellington Basin Water Source Options Steering Committee to investigate options for the future development of the water resources contained within the Collie Coal Basin and Wellington Dam.

The findings of this pre-feasibility study, which took approximately 4 months to complete, are based on information obtained from local stakeholders, public and private companies, independent consultants, the Department of Water, the Water Corporation, and representatives of the Departments of Health, Environment, Agriculture and Treasury and Finance.

Wellington Dam, the largest surface water catchment in the southwest of Western Australia, has the potential to become an important source of water for a number of possible uses. The Dam, which is currently under utilised, supplies irrigation water to the Collie Irrigation District for use on the flood irrigation of pasture. The Dam and its surrounds are also popular recreational areas for the town of Collie and the nearby region.

The utilisation of Wellington Dam water is compromised by its salinity level, which over the past 30 years has risen to the point where it is now approximately twice the potable limit. As a consequence, Dam water is barely suitable for irrigation and unsuitable for most other higher value forms of use.

The task of developing Wellington Dam as a potential source of potable water and solving the environmental issues caused by salinity is both challenging and complex. Be this as it may, the size of the resource coupled with the general decline in the availability of potable water still means that the recovery of the Dam and the direction of its water to higher value forms of use deserves a very high priority. This view is supported by Water Corporation, which, in its Source Development Plan for the Integrated Water Supply Scheme (April 2005), describes Wellington Dam as "the most significant surface water source in the southwest".

While accepting that Wellington Dam has potential to be a source of urban water it may well be that the use of the water by local industry, or indeed continuing to direct it towards irrigated agriculture may be preferable. Final development costs, economies of scale and comparisons with the costs of potable water from other sources (amongst other things) will ultimately determine which form of productive use is most appropriate.

Irrespective of the final answer, the ongoing recovery of the Collie River and achieving a reduction in the amount of salt entering the Dam, thereby reducing the salinity of its water, forms an essential part of any development strategy.

In line with the requirements of the Terms of Reference, this report identifies the issues associated with developing the water resource to render it fit for a number of higher forms of use; evaluates a range of options; establishes indicative water costs for each option; makes preliminary recommendations as to which options appear to be most promising and, most importantly, recommends a way forward.

Finally, given that an amount of information critical to achieving a definitive answer does not exist and also that the quantums of the additional time and resources needed to develop this information are of beyond those allowed for in this study, then the findings (and in particular the costings on which these are based) should be considered as indicative and therefore warranting further study and refinement.

1.1 Key Findings

The key findings of the investigation based on the terms of reference are:

1. The best productive use of water from the Collie-Wellington Basin will not be achieved without reducing the salinity of the Collie River. The quickest means to achieve this is by diverting approximately 14 GL of early winter saline stream flows into mine voids then removing the diverted water from the catchment, either by piping it to the ocean, or by treating it by reverse osmosis to produce approximately12 GL of potable water.
2. All productive uses of water require a reduction in salinity levels and, in the case of drinking water, additional water treatment. The price of 'fit for purpose' water is largely determined by the costs associated with the level of treatment required and the costs of piping it to the point of use. These costs vary with the volume of water delivered. Economies of scale dictate that low unit costs are associated with high delivered volumes. The most productive uses are urban consumption followed by industrial use (particularly if this includes the needs of the region's power stations).
3. Demands for water from the Collie-Wellington Basin for 'higher value' uses, at the volumes and qualities needed to render them

competitive, will reduce the amount of water available for irrigation and possibly require further restrictions to be placed on the recreational pursuits permitted within the catchment. Both of these outcomes would have important economic and social implications for the region that would need to be addressed in close consultation with stakeholders.

4. It is likely that a combination of water source options, treatments and delivery methods will best provide water at required volumes and standards; also it is possible that these can be staged. Further studies are needed to establish water source limits and availability, existing infrastructure capacity, sustainable limits to water availability and the most cost effective method of implementation. (A range of options for treating water to make it fit for purpose together with indicative development costs and delivered costs of water for each are presented in the body of the report.)

5. Opportunities exist for private as well as public sector involvement. Opportunities for the private sector include the outright ownership of facilities as well as the provision of planning, design, operational management and contracting services. Given the complexity and variety of water source options, treatments and infrastructure needs, any such involvement must accord with a predetermined delivery structure and form part of an actionable, strategic plan.

1.2 Recommendations

The Steering Committee has made 9 recommendations, which, it believes will assist the State Government in setting future directions for the strategic development of water sources in the Collie-Wellington Basin.

Recommendation 1. The work carried out in this pre-feasibility study should be extended and refined in order to establish a definitive water resource development plan for the Collie-Wellington Basin. This work should include, but not be limited to, establishing future demands by types of use, required standards and forms of treatment needed to achieve these, definitive costs (including those associated with integration into the IWSS), sources and availabilities of water etc. In completing this work, due consideration must be give to social and environmental issues in addition to the economics of the project.

Recommendation 2. The volume of water diverted from the Collie River East diversion should be increased to 14 GL. However this recommendation is conditional upon the outcomes of the further work needed to confirm the overall technical, economic, environmental and social feasibility of using Wellington Dam as a major source of urban and/or industrial water.

Recommendation 3. The feasibility of using groundwater generated by mine dewatering as a source of drinking water should be subjected to further investigation.

Recommendation 4. The future demand for fit for purpose water for industry and agriculture in the Greater Bunbury area needs to be determined. The future statutory water management plan for the Collie-Wellington Basin should consider allocations for these uses.

Recommendation 5. Managed recreation within the Wellington Dam catchment should continue; however more stringent control is needed over this. The implications for water quality of activities that involve direct contact with water should be reviewed. Further, any future investigation into the use of Wellington Dam as source of potable water should be required to establish the additional treatment cost which needs to be incurred in order to permit recreational activities to occur within the catchment.

Recommendation 6. Given the Water Corporation's role as a purchaser and provider of bulk water it is recommended that high level strategic water source planning be separated from the role of water service provision.

Recommendation 7. Government should encourage the private sector to become involved in the future development of the water resources of the Collie-Wellington Basin. Opportunities for this involvement include the rationalisation and delivery of water produced as a result of mine dewatering, the ownership and/or operation of treatment plants, the ownership and operation of pipelines as well as for the more traditional forms of participation such the provision of design, operational management and construction services.

Recommendation 8. Participation by the private sector in certain aspects of water supply within the Collie Wellington Basin needs to be accommodated within the integrated plans prepared for the region and care taken to ensure that such participation conforms with other elements such as those applicable to land and water use, economic development, physical and social infrastructure and the environment.

Recommendation 9. Work on the implementation of the Salinity Recovery Plan for the Collie River, including river restoration, reafforestation and diversion of the Collie River East Branch in its current form should continue.

2. Introduction

On 18 October 2006, the Minister for Water Resources, John Kobelke MLA, announced an investigation into the proposed future uses of water from the Collie Coal Basin and Wellington Dam.

The investigation was initiated as part of the State Government's commitment to delivering a secure water supply to Western Australia. With increasing demands on water supply coupled with the effects of a drying climate, the State Government has implemented a number of key initiatives designed to assist in finding solutions to the State's water shortage. One of these directions is to maximise the productive use of water from the Collie Coal Basin and Wellington Dam.

The Collie Coal Basin and Wellington Dam are located within the Collie River catchment. The Dam and the underground water contained within the Basin have complex water use arrangements and serve a diverse range of interests. In addition, Wellington Dam and other water sources in the Collie Coal Basin are considered to be highly strategic with the capability in the medium term of serving as a high volume source of potable water for Perth.

Work has commenced on water resource management and planning within the Collie River catchment. However the complexity and range of issues involved require that a strategic approach be taken in order to establish the best form of productive use for the water from the Collie Coal Basin and Wellington Dam.

As an initial planning step, the Collie-Wellington Basin Water Source Options Steering Committee was established to identify, assess and prioritise current and potential water source options for the Collie-Wellington Basin and outline the future direction of assessment and stakeholder engagement.

The Minister appointed a five-member Steering Committee with expertise in water management and conservation, planning, engineering and economics to undertake the investigation. The Steering Committee consisted of three independent members, Mr Ross Kelly (Chairman), Ms Verity Allan and Mr Simon Holthouse; and two Government representatives, the Director General of the Department of Water, Mr Paul Frewer, and an Executive Director of the Department of Treasury and Finance, Mr David Smith.

The Steering Committee was asked to report its findings to the Minister for Water Resources.

3. Terms of Reference

The endorsed terms of reference are as follows.

To advise the Minister for Water Resources on the:

1. best productive uses of water in the Collie Basin, taking into account all potential and existing users of the water resource at the local and state level
2. range of water source development options in the Collie Basin, the outstanding issues and uncertainties associated with each and the timeframe required for the option to begin delivering water
3. best prioritisation of projects to deliver water to required standards. In determining priorities consideration will include but not be limited to the following:
    - the highest value use of the water
    - the cost-effectiveness of different water use options
    - how to best integrate projects to optimise the use of the resource
    - timelines for developing each option to optimise the integration
    - balancing the social, economic and environmental outcomes
4. preferred approach based on timing, hydrological, economic, social and environmental assessments
5. most appropriate method of assessment for private and public sector options. This does not extend to recommending a preferred supplier(s)
6. most appropriate approaches to engage proponents for developing water source options, taking into account that one proponent may not be responsible for all the different infrastructure and development aspects of a project.

4. Investigation Process

The Steering Committee began its investigation at the end of October 2006. In consideration of the Terms of Reference and the short timeframe allowed to complete the investigation, the Steering Committee approached its task with several stages running in parallel.

4.1 Consultation and Support

The Steering Committee toured the Collie River catchment at the commencement of the study, travelling from the eastern catchment through the Collie Coal Basin to the Swan Coastal Plain. The Committee viewed the various features of the catchment, including land uses and management practices, and met with key stakeholders associated with specific elements of the catchment.

Additional consultation was initiated by a call for submissions through advertisements in the West Australian and local community newspapers throughout November 2006. The open ‘Invitation to Comment’ requested interested parties to present development concepts for current and potential water sources in the Collie-Wellington Basin. Respondents were asked to describe the proposal and consider timing, and the costs and benefits of hydrological, economic, social and environmental options. This process attracted ten submissions. Respondents included water and power providers; organisations with innovative solutions; representative industry and aquaculture associations and academic institutions. A list of those organisations and individuals that made submissions is presented in Appendix 1. Five of the respondents that submitted development concepts were invited to present to the Steering Committee in person.

The Steering Committee considered the development concepts received through the public consultation process along with a number of options previously developed by the Department of Water as part of the Department’s work on the Salinity Recovery Plan for the Collie River. The Committee also developed several new options.

Independent engineering consultants, GHD Pty Ltd, provided technical advice on all concepts and options, as well as ongoing advice to the Steering Committee throughout the investigation. The engineering consultants, who had been previously selected by the Department of Water for their expertise in civil engineering projects, were already employed to assist with finalising the Salinity Recovery Plan at the time the Steering Committee was established.

The Steering Committee was also supported by a working group, which provided technical information and advice on the water source options considered, and relevant background information. This group consisted of representatives from the Departments of Water, Health, Environment and Conservation, Agriculture and Food, Treasury and Finance; Water Corporation; and Harvey Water.

4.2 Assessment

The range of water source options considered were broadly categorised into “coastal options, inland options”, and “combined options”. Preliminary criteria were used to shortlist the range of options that were then further assessed to identify several preferred options.

The viability of each option was assessed according to:

- Technical requirements such as infrastructure required, levels and types of water treatment
- Capital and operational costs
- Hydrological issues including groundwater and surface water allocations, water quality and volume of water yielded
- Synergistic opportunities and benefits both within and beyond the Collie catchment
- Opportunities for private and public sector involvement.

The options were considered with social and environmental issues in mind, in accordance with the terms of reference. These included:

- Local benefits to industry and the Collie Irrigation District
- Recreational access to Wellington Dam
- Downstream environmental water flows and water quality.

In order to establish a cost benchmark, the cost effectiveness of each option was compared to a hypothetical seawater desalination plant located 50-80 km from Serpentine Dam. The terms of reference limited the comparison of options with other source developments such as the South West Yarragadee proposal or managed aquifer recharge.

Given the conceptual nature of the task and the limited time available, this investigation is essentially a pre-feasibility study which identifies the overall technical viability, indicative cost and relative risk for the development options considered.

5. Water Sources in the Collie River Catchment

The Collie River catchment covers an area of 2823 km^2 and contains Wellington Dam, Harris Dam and the Collie Coal Basin (Figure 1).

The salinity of the catchment’s main water resource, Wellington Dam, is a critical issue. Salinity is a consequence of rising saline watertables caused by clearing within the catchment and the transfer of salt by rivers into Wellington Dam. Catchment management responses to this water quality issue include:

- In 1976 clearing, which commenced in 1900, was banned. 677 km^2 of the catchment had been cleared at the time the ban came into effect.
- In 1980, a State Government land buy-back and re-afforestation programme commenced. Since that time, approximately 6700 ha have been planted. Further State Government funded planting is unlikely.
- An additional 13,000 ha of private plantations (existing as well as planned) will reduce the total cleared area to less than 25% of the catchment.

As a result of all the above, the average flow weighted salinity of Wellington Dam peaked at 1100 mg/L in 1972 and then declined to the current level of 950 mg/L. A further small reduction in dam salinity is likely as tree plantations continue to reach maturity.

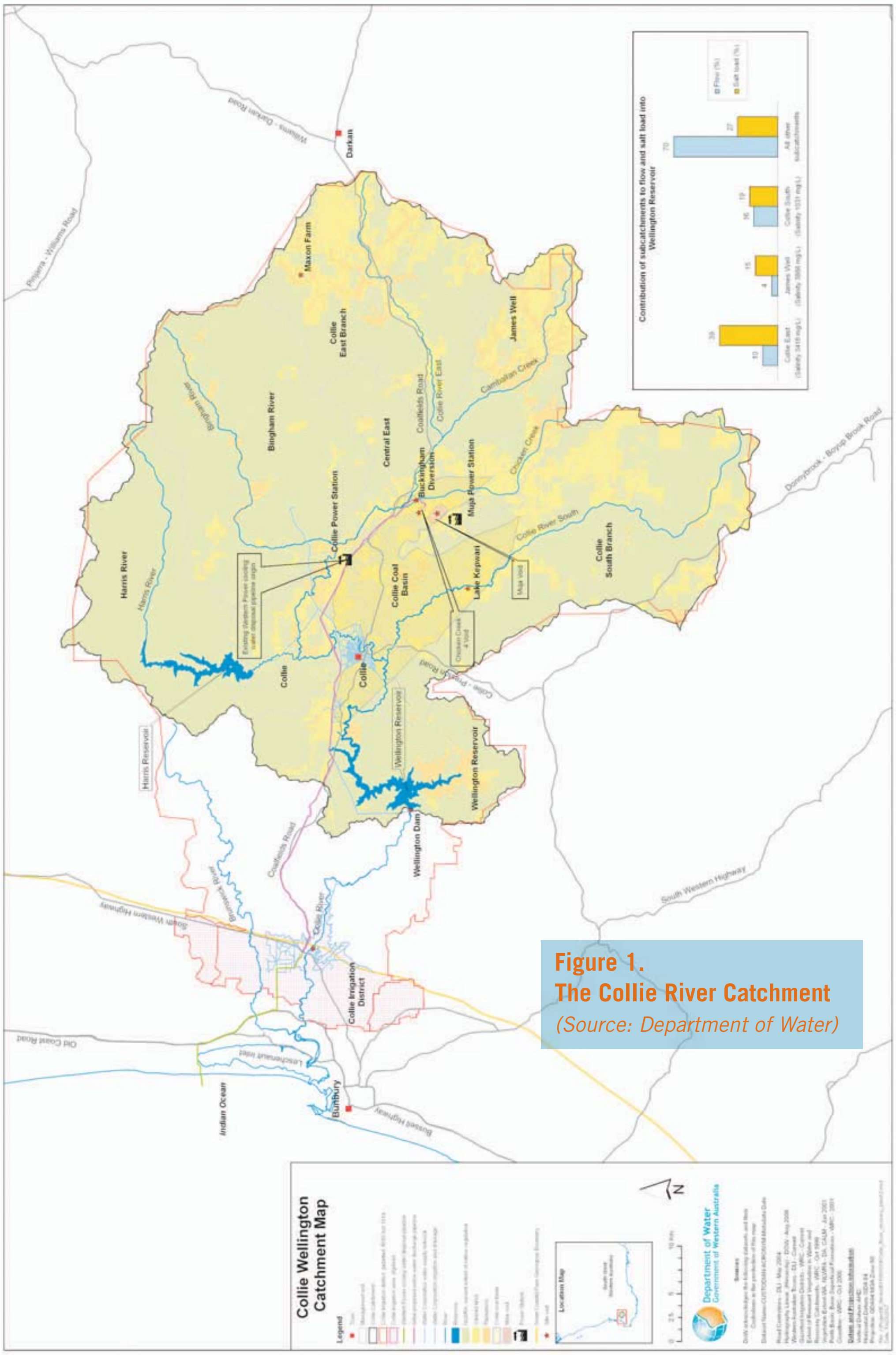


Figure 1.
The Collie River Catchment
(Source: Department of Water)

5.1 Wellington Dam

Wellington Dam has a capacity of 186GL. 85GL of this capacity is currently allocated.

Since 2001, the average inflow has been only 74 GL. Further development of Wellington Dam must make adequate provision for the potential further impact of declining rainfall on the availability water.

Figure 2 shows this effect for Wellington Dam for the period 1973-2006 inclusive.

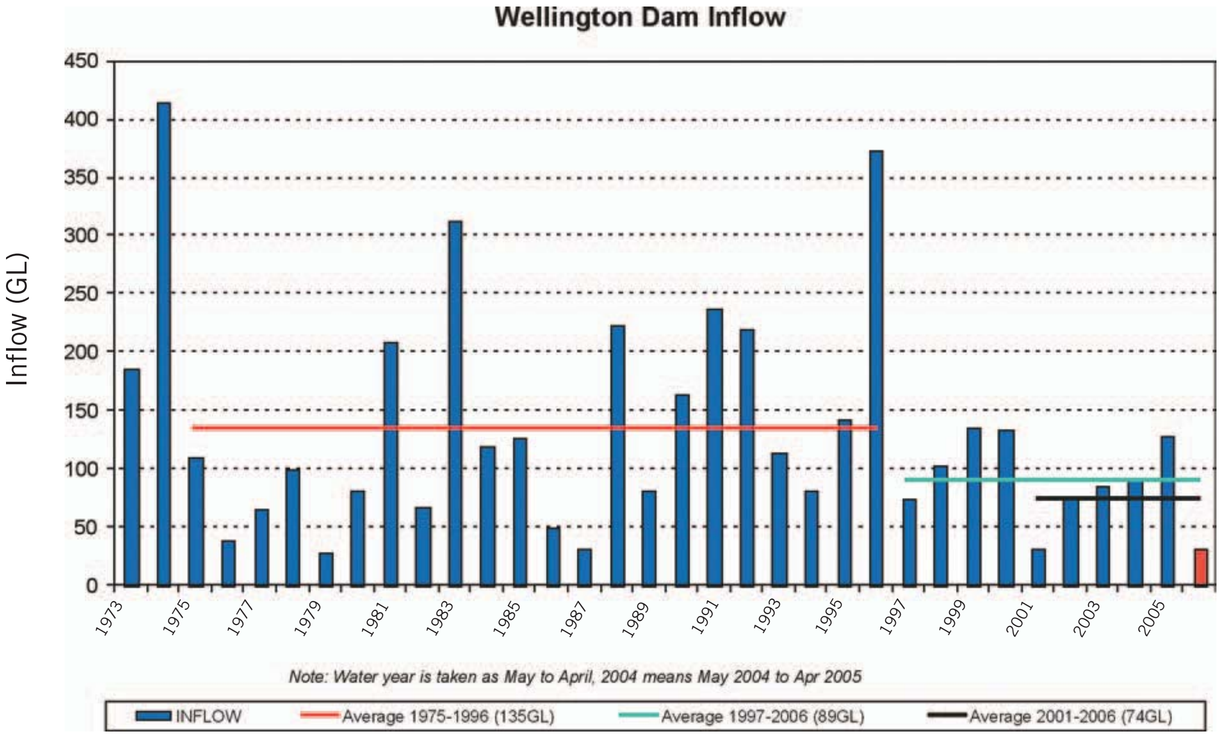


Figure 2. Inflows to Wellington Dam 1973-2006 *(Source: Water Corporation)*

Currently, 85GL of water from Wellington Dam is allocated, predominantly for irrigated agriculture within the Collie Irrigation District (Figure 3). Part of Wellington Dam's allocation is not being used mostly due to the poor water quality. Water is released for environmental requirements, in addition to the allocation for consumptive use.

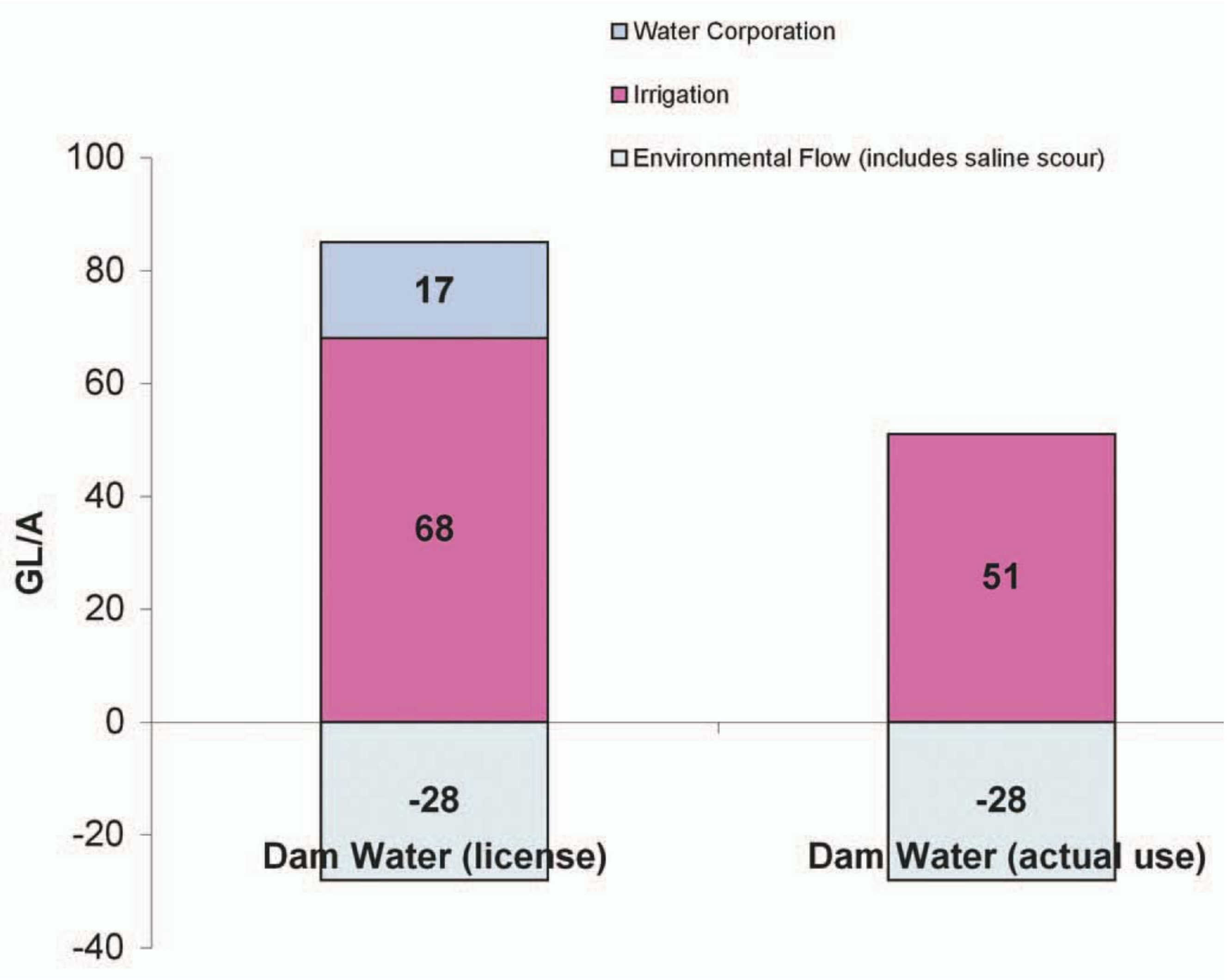


Figure 3. Allocation of water from Wellington Dam *(Source: Department of Water)*

Despite Wellington Dam's size and relatively high yield, its water is currently non potable and barely suitable for irrigation. Wellington Dam water contains high levels of salt and bromide and is subject to the risk of contamination by pathogens.

Salinity: Currently salt levels in Wellington Dam average 950 mg/L, on a flow-weighted basis, peaking at 1200 mg/L in dry periods.

Bromide: is associated with naturally occurring salts in groundwater and possibly with the accumulation of organic matter in the water. The presence of bromide in Wellington Dam water will contribute to the formation of trihalomethane, a by-product of disinfection by chlorine. Trihalomethane production depends on the amount of chlorine used to achieve acceptable free residual chlorine levels and also on the amount of organic matter in the water.

Over the past 4 years bromide levels in Wellington Dam have ranged between 0.8 mg/L and 3 mg/L. Health guidelines recommend trihalomethane levels of 0.25 mg/L or less with daily fluctuations of up to 1 mg/L being permissible.

Pathogen risk: Wellington Dam water is considered to be at risk of contamination by pathogens due to:

- Recreational activities (e.g. boating, fishing, swimming, and camping) that occur in and around the dam. Activities involving direct bodily contact with water pose a higher significant risk.
- The presence of two towns within the catchment, Collie and Allanson. Both use septic tanks to some extent.
- Significant industrial activity within the catchment including power generation, coal mining and light industry.
- Farming and grazing activities within approximately 20% of the catchment, mainly to the east.

5.2 Harris Dam

Harris Dam is located in the north of the Collie River catchment and has a capacity of 71 GL. The dam was built in 1989 to supply water to the Great Southern Towns Water Supply Scheme when supply to this scheme was under threat due to rising salinity levels in the previous source, Wellington Dam. Harris Dam has also experienced declining inflows (Figure 4).

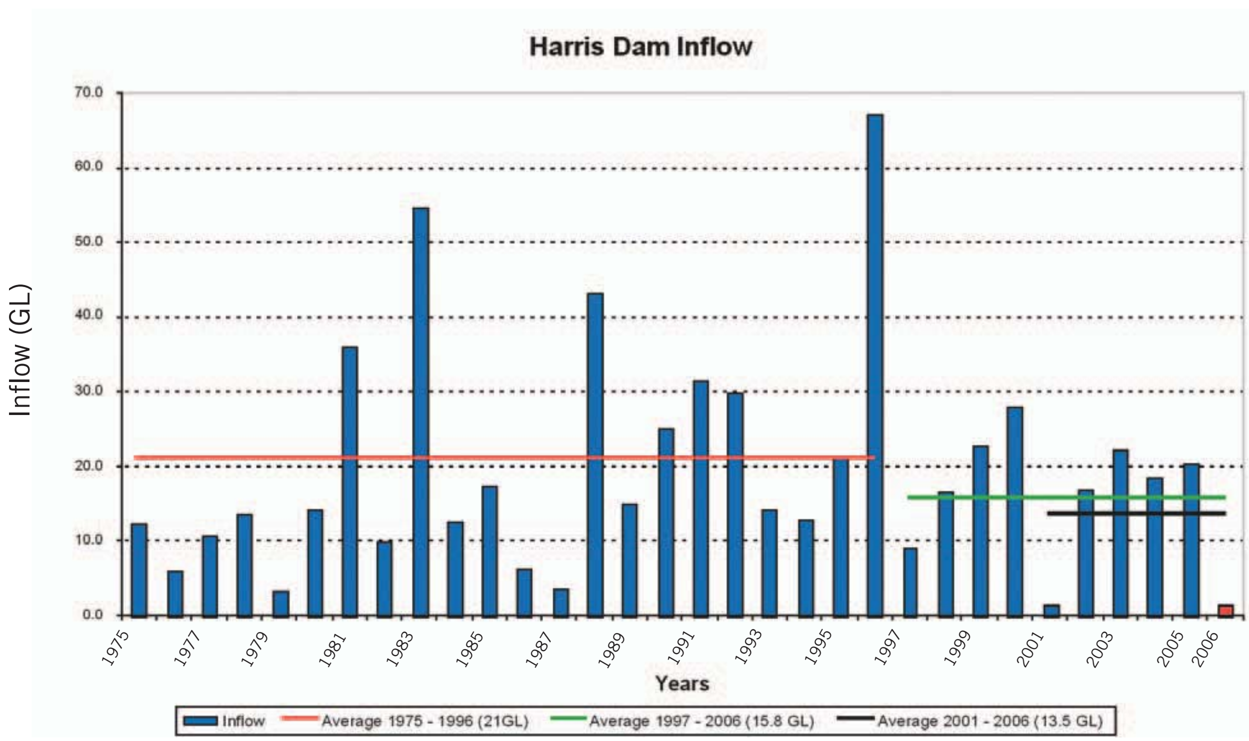


Figure 4. Inflows to Harris Dam 1975-2006 *(Source: Water Corporation)*

In contrast to Wellington Dam, Harris Dam water contains low levels of salt and bromide and is not exposed to the same level of recreational activity in the catchment. It is generally believed that the Dam's capability would be improved if higher water levels could be maintained, thereby reducing the risk of turbidity. Furthermore, Harris Dam can play an important role in receiving additional water redirected from the Collie-Wellington Basin, (potentially 12GL/A).

17.5 GL of water is currently allocated from Harris Dam as is shown in Figure 5.

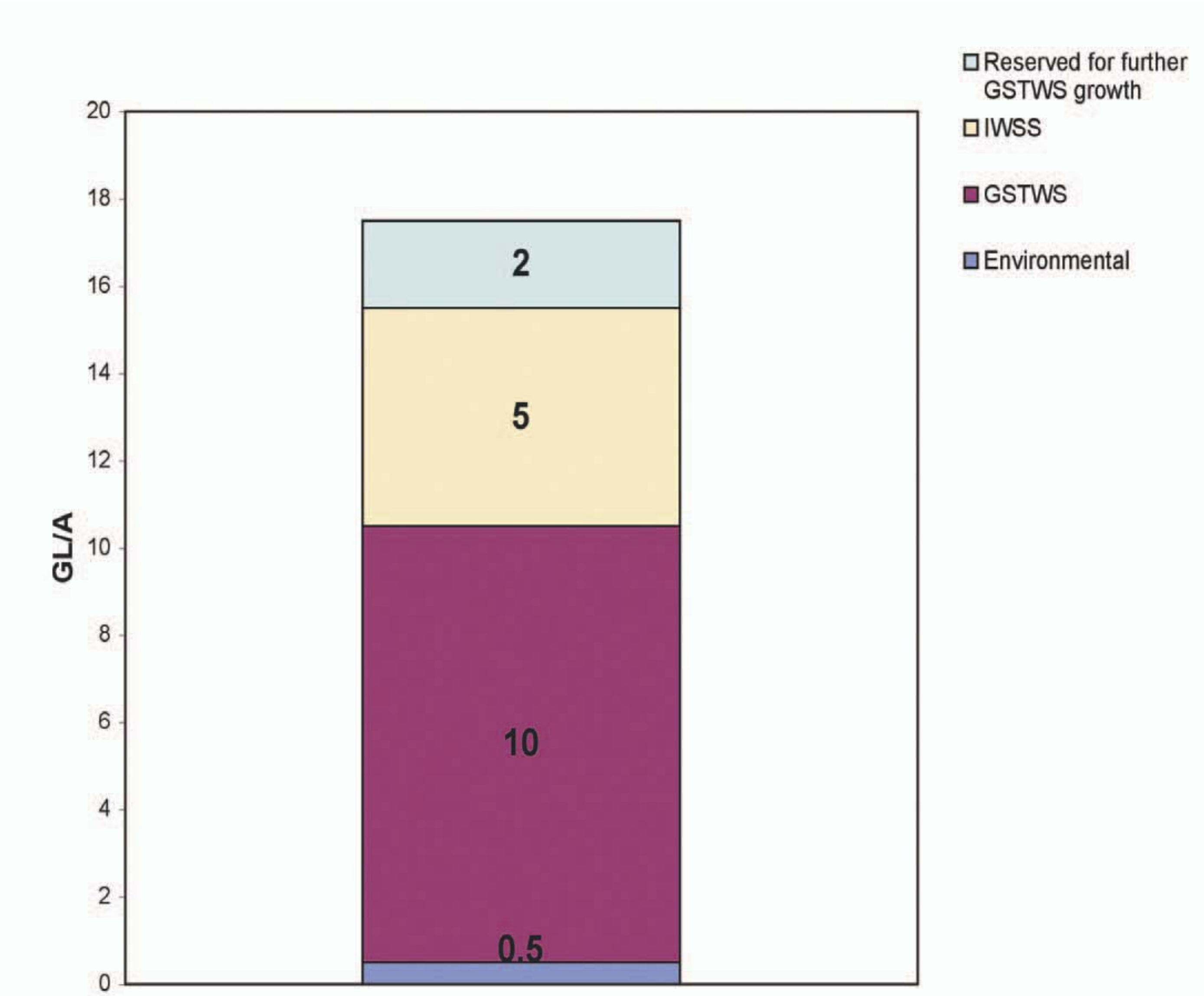


Figure 5. Allocation of water from Harris Dam *(Source: Department of Water)*

5.3 Collie Coal Basin

The Collie Coal Basin is a small sedimentary basin approximately 27 km long and 13 km wide, covering an area of 225 km2 that sits in the middle of the Collie River catchment. The Collie Coal Basin contains large coal deposits and substantial groundwater resources.

The Collie Coal Basin hosts a fresh water aquifer estimated to contain 7000 GL of potable water. The aquifer comprises two discrete basins, Cardiff and Premier.

Cardiff Basin contains two-thirds of the resource. It generally surrounds and underlies the lower Collie River South Branch.

Premier Basin runs parallel to and to the north of Cardiff Basin, and is bounded to the north by the Collie River East Branch.

Groundwater flows within the Collie Coal Basin are complex, mirroring the geology and are further complicated by abstraction and the presence of mining voids. Groundwater recharge occurs at the point where the South Branch enters the basin (Cardiff) and near Buckingham (Premier). Discharge from the Cardiff and Premier Basins occurs into both the South and East branches at discrete points.

Recharge, which is estimated to be about 20 GL/A, has also been impacted by declining rainfall.

Groundwater quality is generally good; however there are some areas with salinity levels above 750 mg/L.

In their natural condition, surficial aquifers are unconfined near the surface and give rise to damplands, wetlands and some permanent pools in both river branches, particularly in the South Branch.

Groundwater abstraction within the Collie Coal Basin is managed under a strategy developed by the Collie Water Advisory Group (CWAG). This strategy "considers the interaction between water resources, the management of coal mining, power generation, future industry, the environment and social aspects of water availability". The strategy also calls for groundwater abstraction to be minimised while recognising the importance of mining and power generation.

Under the strategy, water from mine dewatering is to be diverted primarily to power stations: a direct consequence of Wellington Dam's water being too saline to use.

Overdraw of groundwater to service mining or power generation is permissible provided that stock and domestic supplies are adequately maintained, river pools and the aesthetic quality of the river near the town, as far as practicable, are protected, and other beneficial uses as determined from time to time by the Government, are not compromised.

Despite management of groundwater abstraction, a number of adverse impacts caused by localised lowering of the water table have occurred. Consequently a number of pools, mainly in the Collie River South Branch, are being supplied with supplementary water in order to sustain them.

By 2010, mine dewatering abstraction is expected to be 22-37 GL/A. Although this will permit the drawdown from the Shotts and Cardiff bore fields to be reduced to standby status, total abstraction is still expected to exceed current levels.

Figure 6 illustrates the current and future groundwater use within the Collie Coal Basin. Of the 22-37 GL/A produced, 20 GL is allocated to power stations, leaving 2-17 GL available for other forms of use.

Careful management will be needed to contain the adverse impacts on the environment to levels that currently apply. Studies and experience indicate that with such management, and even after groundwater abstraction has ceased, recovery of the water table to previous levels will be slow. Supplementary water to mitigate environmental impacts will be needed for a considerable time into the future.

Given that the quality of water produced as a by-product of mine dewatering is generally good, there is potential for this water to be used as drinking water or alternatively as cooling water for power stations.

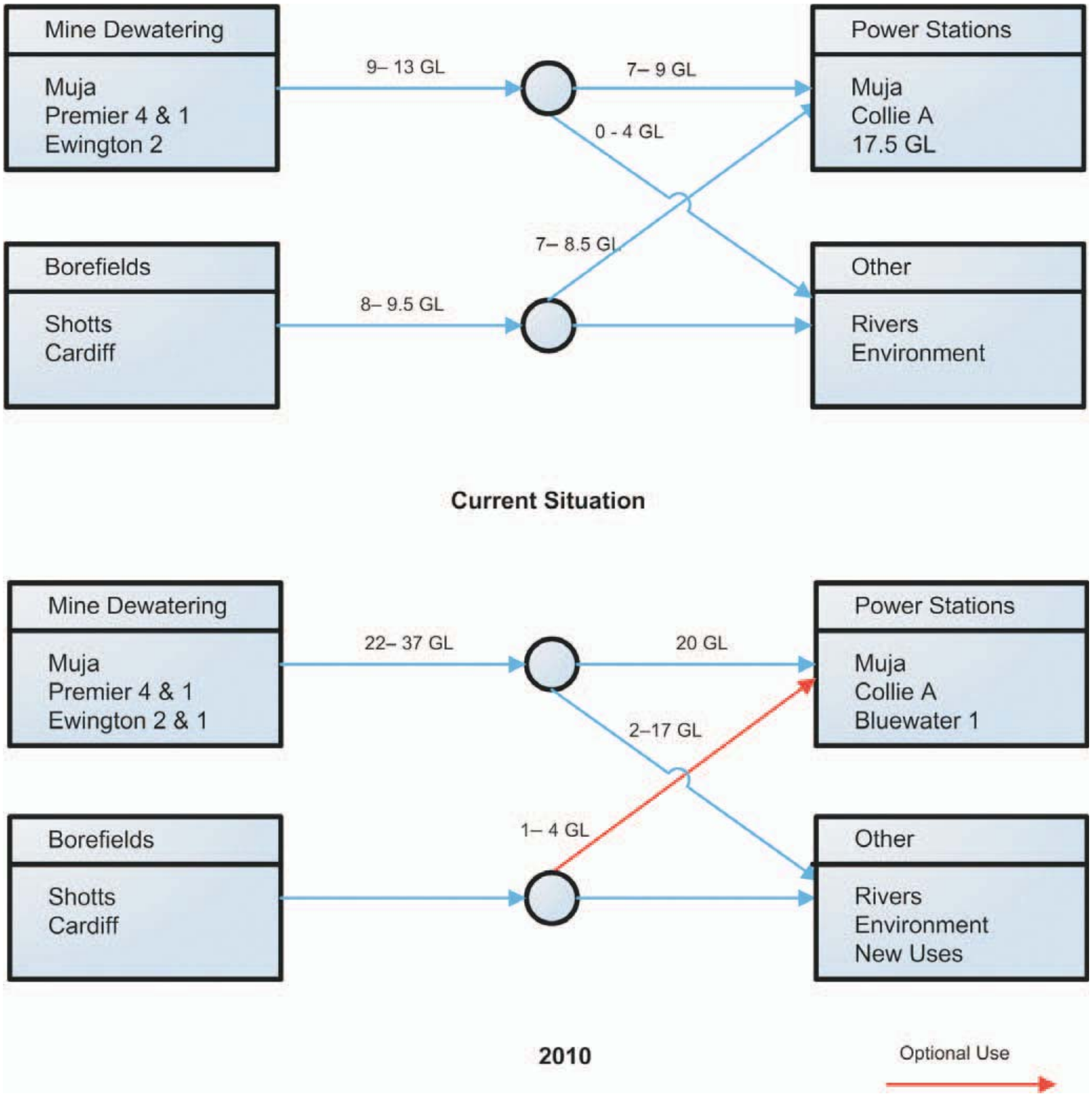


Figure 6. Groundwater use in the Collie Coal Basin

6. Findings on the Terms of Reference

6.1 Reducing Salinity in Wellington Dam

The best productive use of water from the Collie-Wellington Basin will not be achieved without reducing the salinity of the Collie River. The quickest means to achieve this is by diverting approximately 14 GL of early winter saline stream flows into mine voids then removing the diverted water from the catchment, either by piping it to the ocean, or by treating it by reverse osmosis to produce approximately 12 GL of potable water.

The use of Wellington Dam for productive and high value activities is dependent on the ability to reduce salinity to potable levels of 500 mg/L or less. The State Salinity Action Plan and State Salinity Strategy have both set 2015 as the deadline for the recovery of the Collie River.

Reducing the salinity of Wellington Dam has social and environmental benefits. Any improvement to salinity levels benefits the users of water from Wellington Dam, the catchment of Wellington Dam and downstream riverine environments.

Catchment management and engineering techniques examined by the Department of Water for reducing salinity include:

- Further upland and lowland tree plantations
- Planting specialist deep rooted perennial crops or pastures
- Groundwater pumping and drainage
- Diversion of saline river flows.

The diversion of saline river flows has the greatest potential to generate significant reductions in salinity levels in the shortest time. Stakeholder and community consultation conducted as part of the Salinity Recovery Plan for the Collie River determined the following reasons for using diversion:

- Overall cost effectiveness
- Shorter elapsed time needed to achieve a given salinity outcome
- Greater social and economic acceptability by landholders.

Diversion relies on the fact that salinity levels within rivers feeding into Wellington Dam vary widely and that a disproportional amount of salt is delivered by early winter flows when first winter rains flush accumulated salt into waterways.

Within the Collie River catchment, the Collie River East Branch and James Well tributary have been identified as contributing 13.8% of the annual flow and 53.6% of the annual salt load into Wellington Dam. A diversion of the Collie River East Branch below the junction of James Well at the Buckingham Locality is considered to be highly appropriate because it would capture this high salt load with minor impact on the inflows entering Wellington Dam. Final acceptance of this is subject to financial justification.

A range of options for diverting the Collie River East Branch at Buckingham has been modelled by the Department of Water (Table 1).

Table 1. Diversion options

Amount of Water Diverted (GL/A)	Final Salinity Level in Wellington Dam (mg/L)
0	740
1.8	680
5	545
10	490
14	430

In addition to future improvements from existing plantations and modifications to farming systems, a 14 GL diversion can reduce salinity in Wellington Dam from 950 mg/L to below 500 mg/L within several years of commencement, as illustrated in Figure 7.

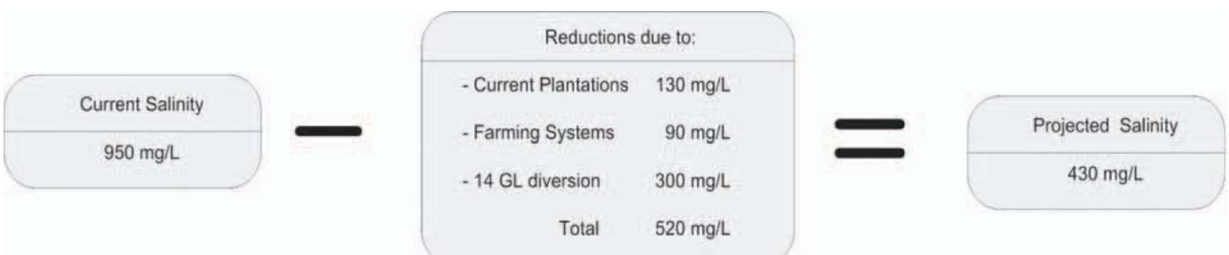


Figure 7. Current and projected salinity of Wellington Dam

In May 2005, the Department of Water commenced a trial using a temporary pipeline and mobile pumping equipment to divert 1.8GL of saline river water into the disused Chicken Creek 4 mine void. The success of this trial to date indicates that future large scale reductions in the salinity of Wellington Dam are achievable.

Should greater volumes be diverted in the future, additional storage with larger holding capacities would be required. Concerns have also been expressed about the possibility of saline water migrating from the mine void into the aquifer with consequent impacts on the groundwater quality. Studies indicate that such migration, if any, would be slow and have very little impact. However, this will require confirmation.

The least costly means of transferring the 14GL of diverted water from the mining void in which it is temporarily stored involves piping the entire 14 GL to the ocean via a new pipeline. An alternative would be to remove the salt from the diverted water using reverse osmosis treatment to produce 12 GL of fresh water that can be used for productive purposes (including human consumption). The 2GL of highly saline by-product generated by this process would be piped to the ocean via the pipeline currently used by Verve Energy to dispose of waste water from its power stations.

The costs associated with diversion are discussed later in this report.

6.2 Productive Water Uses

All productive uses of water require a reduction in salinity levels and, in the case of drinking water, additional water treatment. The price of ‘fit for purpose’ water is largely determined by the costs associated with the level of treatment required and the costs of piping it to the point of use. These costs vary with the volume of water delivered. Economies of scale dictate that low unit costs are associated with high delivered volumes. The most productive uses are urban consumption followed by industrial use. (Particularly if this includes the needs of the region’s power stations).

6.2.1 Industrial Use

Power Stations

A significant proportion of southern Western Australia’s power is generated in and adjacent to the Collie Coal Basin. Power generation is critically dependent on a reliable supply of high quality water for use as boiler feed and for cooling.

Two power stations, Muja and Collie A, are currently operating, while a third, Bluewater I, is due to come on stream in 2009. Additional power stations planned over the next 10 years include Collie B and/or Bluewater II. All will require water. Power stations currently require 17.5 GL/A of water and this is expected to increase to approximately 20 GL/A by 2010.

Before long, water generated as a consequence of dewatering for coal mining is expected to exceed the demand from power stations. In line with the CWAG strategy, this will permit the bore fields to revert to standby supply status with their yield being reduced to almost zero.

The growth in the amount of water generated by dewatering indicates that there should be sufficient water to cater for the future demand from power stations.

Other Industry

In addition to power stations, there are other major industries either in or adjacent to the Collie River catchment that require water.

Local alumina producers, Worsley and Alcoa, currently obtain their water from other local sources. However, as demand for water increases over time, it is likely that water will need to be sourced from the Collie River catchment.

The proposed development of the Kemerton Industrial Estate on the Swan Coastal Plain and the Coolangatta Industrial Estate near Collie means that there may be potential to develop an integrated industrial water supply system to deliver water drawn from the Collie River catchment. Under current plans, the Kemerton Industrial Estate will be supplied with water sourced from the South West Yarragadee aquifer.

6.2.2 Irrigated Agriculture

Currently most of the water drawn from Wellington Dam is used for irrigation. Irrigation demand is likely to continue to be substantial even after allowing for the possible impacts of better application methods and water trading.

Irrigated agriculture occurs within the Collie Irrigation District located on the Swan Coastal Plain downstream of the Collie River catchment. The District is bounded by the foothills of the Darling Escarpment to the east and extends approximately to Waterloo in the west.

The north-south axis extends from Benger in the north through Brunswick to Dardanup in the south (Figure 1).

The following represents a broad overview of the District:

- The District supports 265 irrigators on 4000 ha of irrigated land and is managed by the Harvey Irrigation Cooperative, Harvey Water.
- Most of the water is applied using flood irrigation techniques to grow pasture for beef and dairy production.
- Harvey Water allocates water to users on the basis of 9.2 ML/ha to one third of the total land area held.

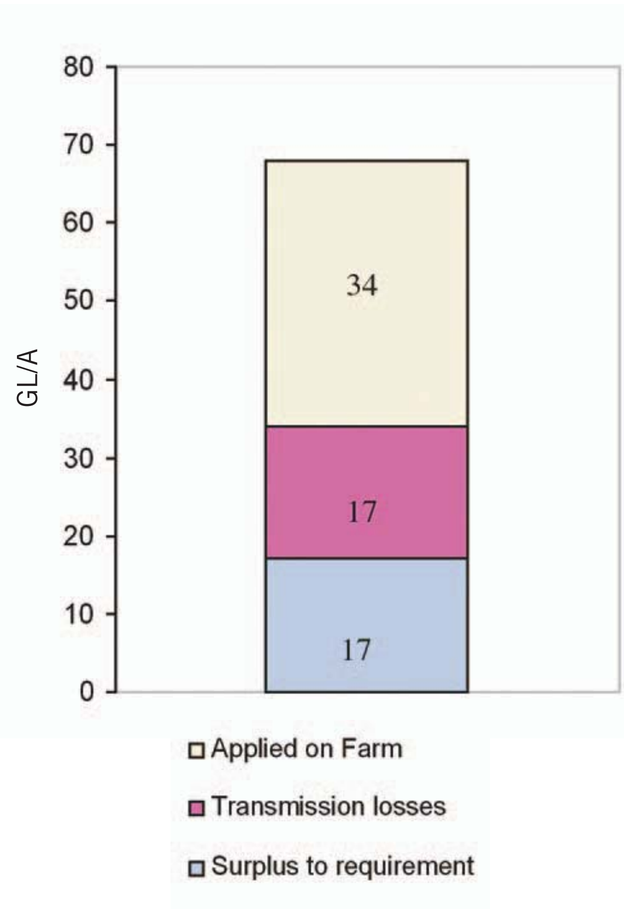


Figure 8. Water allocation in the Collie Irrigation District *(Source: Department of Water)*

68 GL/A of water is allocated from Wellington Dam for use within the Collie Irrigation District. However, only half of this water is actually applied on the farms. (See Figure 8.)

It is significant that:

- The demand for irrigation water is decreasing. This is partly a consequence of water salinity.
- Approximately one third of the water drawn from Wellington Dam is lost through seepage and evaporation from open distribution channels.
- 25% of the total allocation is surplus to current requirements.

Application and production efficiencies within the Collie Irrigation District are low. A recent study by Brennan (2006) suggests that the gross profits per megalitre of water are $35 for dairying and $10 for beef production. These are low when compared to a calculated asset value for the water used of $629/ML.

Low application efficiency results from the widespread use of flood irrigation. (The open channel distribution system and the consequent inability to deliver water under pressure prevent more efficient application methods from being readily used.) High salinity levels also dictate the need for high flood application rates and consequently the volume of tail water generated is high.

Low production efficiency results from a combination of the highly saline water and poor soil types.

On-farm salinities in excess of Wellington Dam's average of 950 mg/L occur from time to time. These levels are too high for most forms of horticulture and also give rise to low productivity on pasture.

About 25% of the soil within the area is Bungum clay. This is a tight low quality soil, which is widely considered as not being well suited to irrigation or to applications other than pasture production.

6.2.3 Urban Use

There is significant potential for Collie-Wellington water to be used for urban purposes. The potential sources of urban water are Wellington Dam, diverted Collie River water and groundwater from the Collie Coal Basin.

The use of these sources for this purpose requires salinity and other water quality parameters to be maintained at appropriately low levels.

6.2.4 Recreation in the Collie River Catchment

Wellington Dam, the Collie River and a number of natural and man-made lakes within the catchment are used by residents of Collie and elsewhere for recreational purposes.

A broad range of recreational activities currently occurs in and around Wellington Dam. This includes bushwalking, swimming, camping, canoeing, four wheel driving, mountain bike riding, fishing and marroning. In 1990, when Wellington Dam ceased to be used as a major drinking water source, the controls in place to protect its catchment were relaxed to permit a limited amount of recreational activity and tourism on and adjacent to the dam. There are claims that despite this relaxation, some forms of recreational activity contravene the guidelines.

Precise figures for the number of visitors are not available but estimates place the number of visitors to the main dam at between 100,000 and 150,000 per annum. This figure does not include people visiting backwaters or other parts of the catchment.

6.2.5 Issues and Uncertainties

Issues and uncertainties to be resolved before water in the Collie-Wellington Basin can be diverted to higher forms of use include:

1. The social, cultural and environmental values associated with water resources within the Collie River catchment need to be identified. Furthermore the impacts on these of proposals to direct water to other uses need to be considered along with economic factors.
2. The impact of climate change on the amount of water available requires close consideration.
3. The long term local and regional demands for irrigation, industrial and drinking water need to be determined.

6.3 Water Source Development Options

Demands for water from the Collie-Wellington Basin for 'higher value' uses, at the volumes and qualities needed to render them competitive, will reduce the amount of water available for irrigation and possibly require further restrictions to be placed on the recreational pursuits permitted within the catchment. Both of these outcomes would have important economic and social implications for the region that would need to be addressed in close consultation with stakeholders.

6.3.1 Priorities for Use

The highest value and preferred use for Wellington Dam water is for water of drinking quality standard. (Figure 9)

Such use however assumes that Wellington dam water is demonstrably preferable on economic, social and environmental grounds to water from all other competing sources.

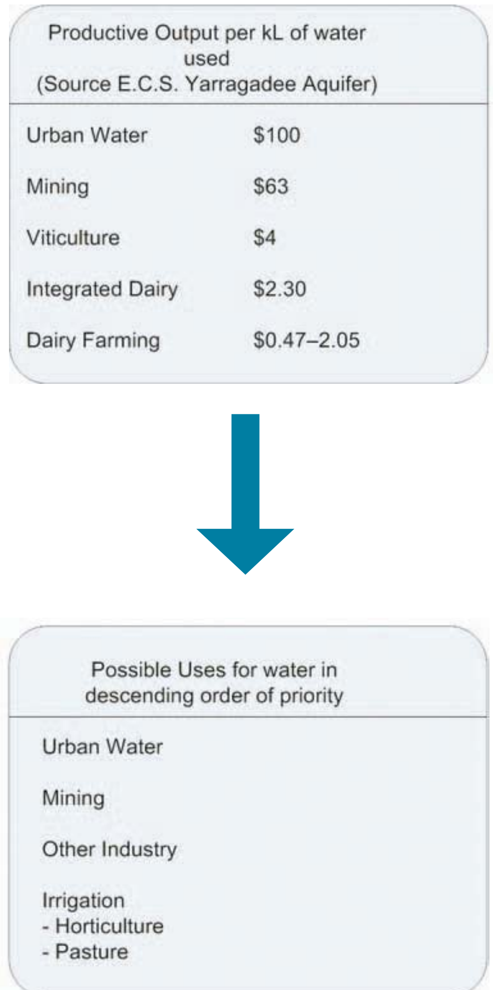


Figure 9. Priorities for water use from the Collie-Wellington Basin (i)

The next highest priority use is water for local industry. Up to 30 GL/A could be required for this purpose, however this estimate is preliminary and subject also to the cost of delivered water, which is still to be established.

It is possible that further investigation will establish that an urban scheme and an industrial water scheme are economically and socially desirable. In this case, almost no water would be available for irrigation.

Note (i) The figures shown relate to Gross Value of Production and therefore differ from those attributed to Brennan previously in this report which relate to Gross Profit.

If neither an urban nor an industrial scheme is viable then the preferred priority is water for irrigated agriculture. Sufficient water would be available under this scenario to support greatly enhanced levels of agricultural activity.

Water will also be required for power generation, however, the volumes needed have not been considered, as they do not impact the water available from Wellington Dam.

Estimates of the economic worth of recreation and the relative worth of each recreational activity do not exist. However based on the Logue Brook study, the economic value is likely to be low compared to the value attributed to water for domestic consumption.

6.3.2 Water Treatments and Costs

All development options require salt levels to be reduced to levels appropriate to the water's category of use. As previously highlighted, the most effective means of lowering dam salinity quickly is to institute a 14GL diversion of the East Collie River at Buckingham.

The potential for dam water to be contaminated in other ways dictates that all water used for domestic consumption must undergo additional treatment. The type and level of treatment needed depends on the water quality issue that needs to be addressed.

The five main methods used to treat water for domestic consumption are reverse osmosis, micro-filtration, ultraviolet irradiation plus chlorine sterilisation, and dilution and dam retention. The water quality issues addressed by each of these are presented in Table 2 below.

Table 2. Water quality treatment methods

Treatment Method	Water Quality Issue			
	Salt	Bromide	Organics	Pathogens
Reverse Osmosis	Y	Y	Y	Y
Micro Filtration	-	-	Y	Y
Ultraviolet/Chlorination	-	-	-	Y
Dam Detention	-	-	-	Y
Dilution	Y	Y	Y	Y

Preliminary advice suggests that a "multiple barrier approach" will need to be adopted in order to render water from Wellington Dam fit for integration into the IWSS. The multiple barrier approach recommended by Water Corporation is presented in Figure 10.

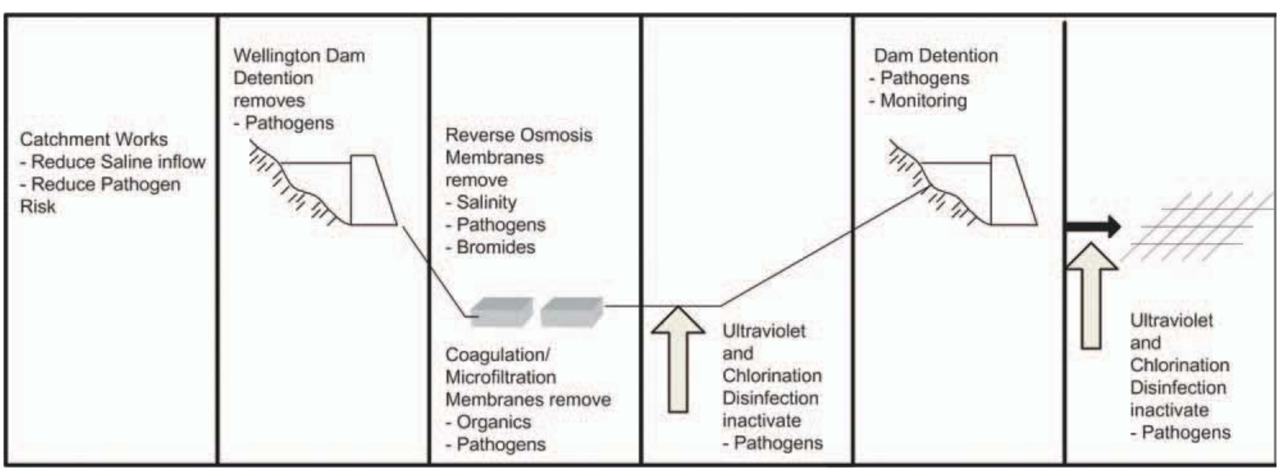


Figure 10. **Recommended multiple barrier treatment approach** *(Source: Water Corporation)*

The costs associated with a 14 GL diversion, (including those of either piping diverted water to the ocean or treating for further use) are presented in Figure 11.

The indicative cost of piping the diverted saline water 70 km to the ocean is $157M. This amount, if allocated across the full sustainable yield of Wellington Dam (85GL), is equivalent to a unit cost of 15 c/kL. If the total cost is attributed solely to a major urban water scheme of volume 45 GL/A (say) then the unit cost of diversion increases to 28c/kl.

Reverse osmosis treatment of the diverted water renders it fit for integration into the IWSS. Desalination by reverse osmosis of 14 GL of diverted water yields 12 GL of potable water at a cost (delivered into Harris Dam) of 240 c/kL compared with a cost of 92 c/kL for disposal by pipeline into the ocean. The incremental cost of the potable water at 148 c/kL is therefore cost competitive with other sources of supply.

14 GL Diversion and Pipeline to Ocean			
Item	Capital Cost	Annual Cost	Water Cost
Pipeline from Diversion	$51.8M	$4.5M	32 c/kL
Pipe to ocean	$105.2M	$8.4M	60 c/kL
Total	$157M	$12.9M	92 c/kL
92 c/kL			

VS

Treatment of diversion and disposal of Saline Residue by Verve Pipeline			
Item	Capital Cost	Annual Cost	Water Cost
Reverse Osmosis Plant	$112.4M	$16.9M	140 c/kL
Pipeline from Diversion	$51.8M	$4.5M	38 c/kL
Pipe to Harris	-	$3.0M	25 c/kL
Harris-Stirling Upgrade	$60M	$4.4M	37 c/kL
Total	$224.2M	$28.8M	240 c/kL
240 c/kL			

Figure 11. Cost comparisons between piping diverted water to the ocean and treating it by reverse osmosis

The mix of water treatment methods selected will determine the overall treatment cost and ultimately whether the delivered cost of Wellington Dam water is competitive with supplies from other sources. Indicative costs for the different methods vary. For example, the approximate cost of treating 45 GL by reverse osmosis at Brunswick is 110 c/kL. This compares with costs at the same location of 56 c/kL for microfiltration and 19 c/kL for ultraviolet radiation and chlorination.

6.3.3 Types of Development Options

The range of development options considered involves the use of water from Wellington Dam, diverted water from the Collie River, and groundwater from the Collie Coal Basin.

These options have been broadly grouped into three categories: coastal treatment, inland treatment, and approaches involving both coastal and inland treatment.

Coastal treatment options involve treating water from Wellington Dam at a large scale treatment plant located on the Swan Coastal Plain near Brunswick and pumping it to Serpentine Dam for supply within the IWSS.

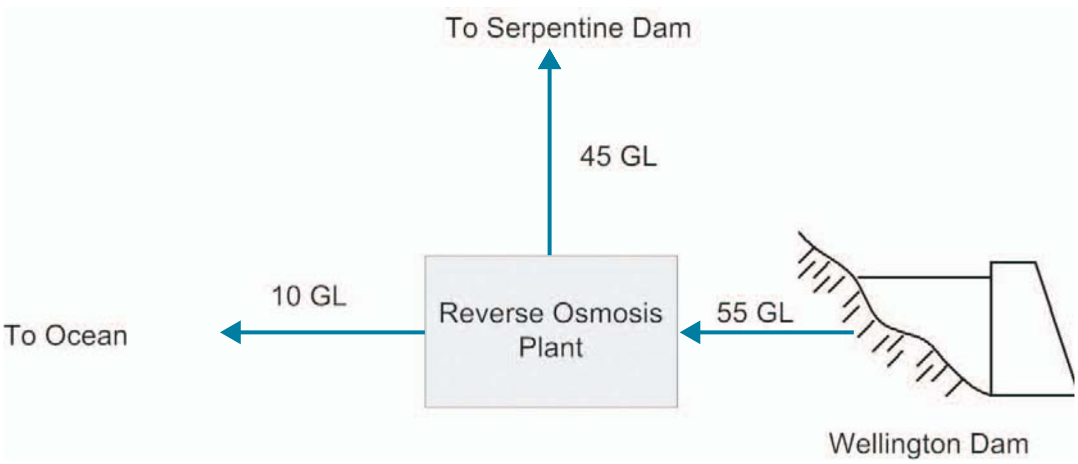
Inland treatment options involve the construction of a treatment plant(s) in the vicinity of Collie and pumping water to Serpentine via a new pipeline and/or transferring water into the IWSS via Harris Dam and an upgraded Stirling Dam trunk main. Wellington Dam, the Collie River diversion and groundwater from the Collie Coal Basin all serve as sources of “inland water”.

6.3.4 Range of Development Options

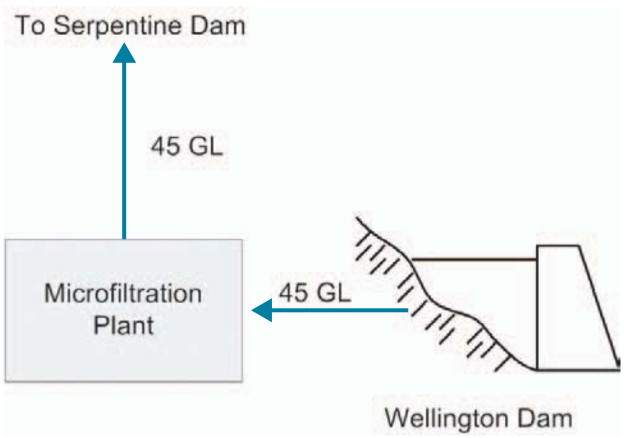
The options considered together with the quantity of water delivered and the associated unit cost of water are summarised in Table 3. Additional options initially considered are presented in the consultant’s report, which is yet to be received.

Table 3. Short-listed options

	Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Coastal treatment options	**Option 1** Treat 45 GL of Wellington Dam water by reverse osmosis (includes microfiltration pre-treatment and UV/Chlorine post treatment) at Brunswick then pipe to Serpentine Dam.	45 GL	$784M	197 c/kL



	Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Combined Options	**Option 2** Treat 45 GL of Wellington Dam water by micro filtration (includes UV/Chlorine post treatment) at Brunswick then pipe to Serpentine Dam. Reverse osmosis treat 14 GL diversion, yielding 12 GL, and then pipe to Serpentine Dam via Harris Dam. Water from each source uses different pipelines and routes to the IWSS. Cost depends on level of treatment.	57 GL	$849M	155-165 c/kL



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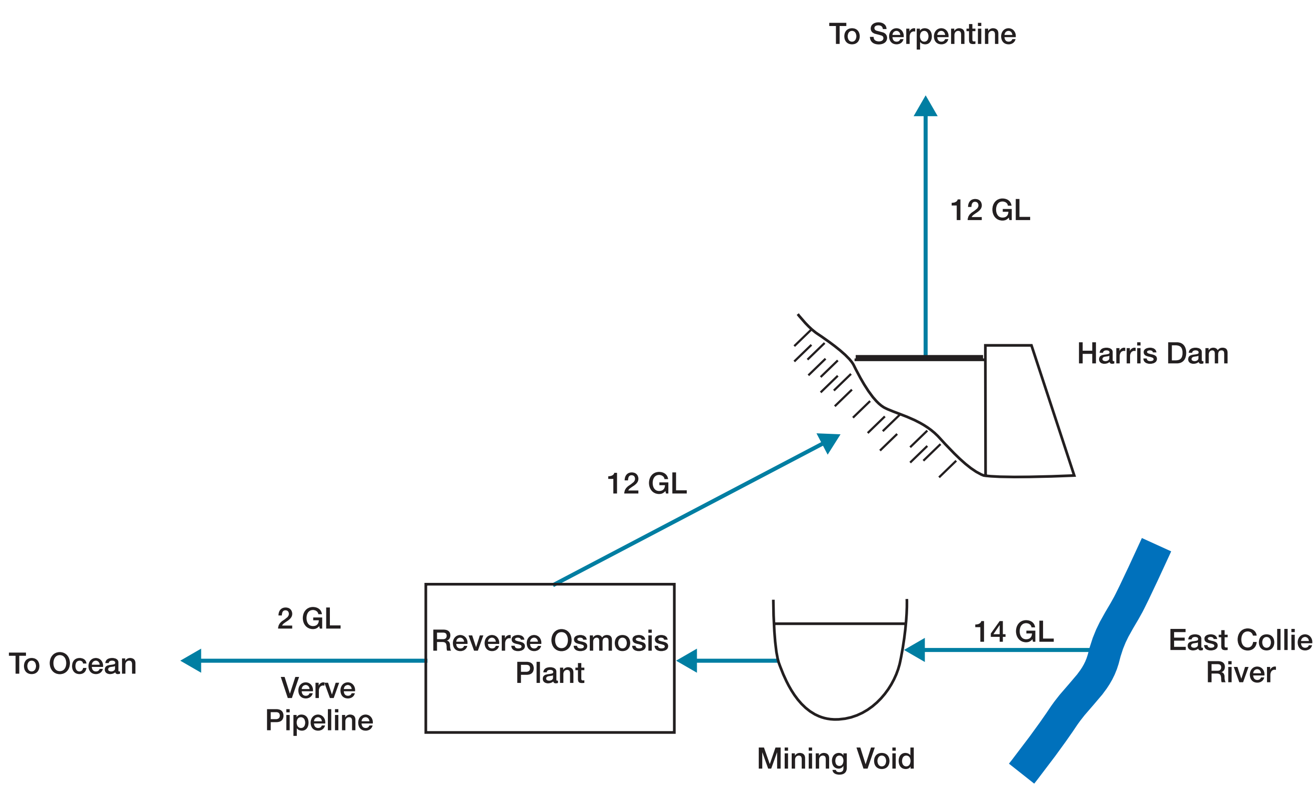
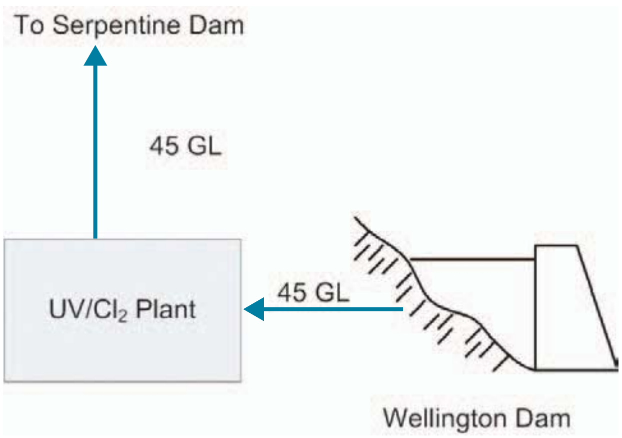


Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 3 Treat 45 GL using ultraviolet irradiation plus chlorine sterilisation at Brunswick using Wellington Dam water then pipe to Serpentine Dam. Desalinate 14 GL diversion water and pipe to Serpentine Dam via Harris Dam.	57 GL	$719M	124-135 c/kL



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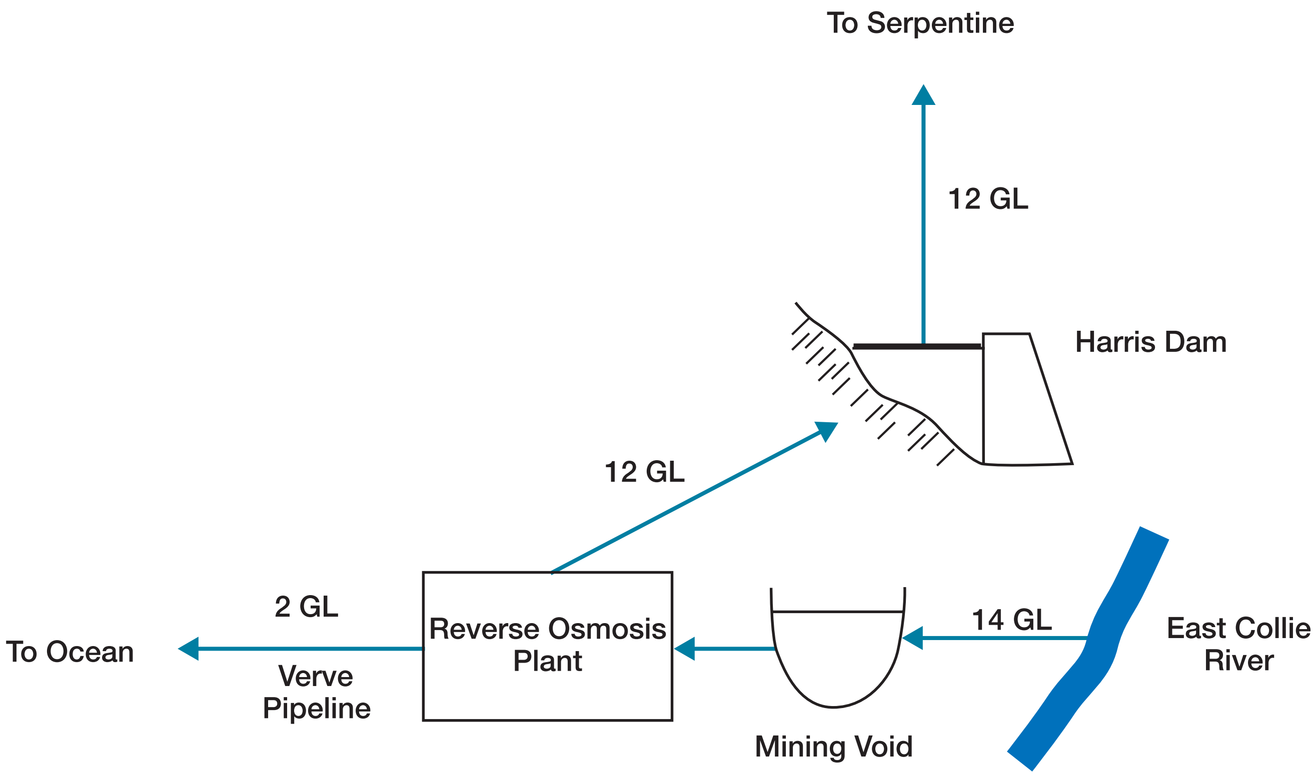
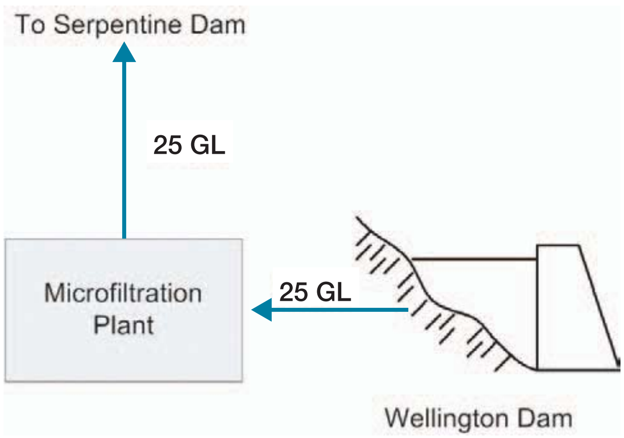


Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 4 Treat 25 GL of Wellington Dam water by micro filtration (includes UV/Chlorine post treatment) at Brunswick. Reverse osmosis treat 14 GL diversion, yielding 12 GL. Water from each source uses different pipelines and routes. Cost depends on level of treatment.	37 GL	$719M	188-212 c/kL



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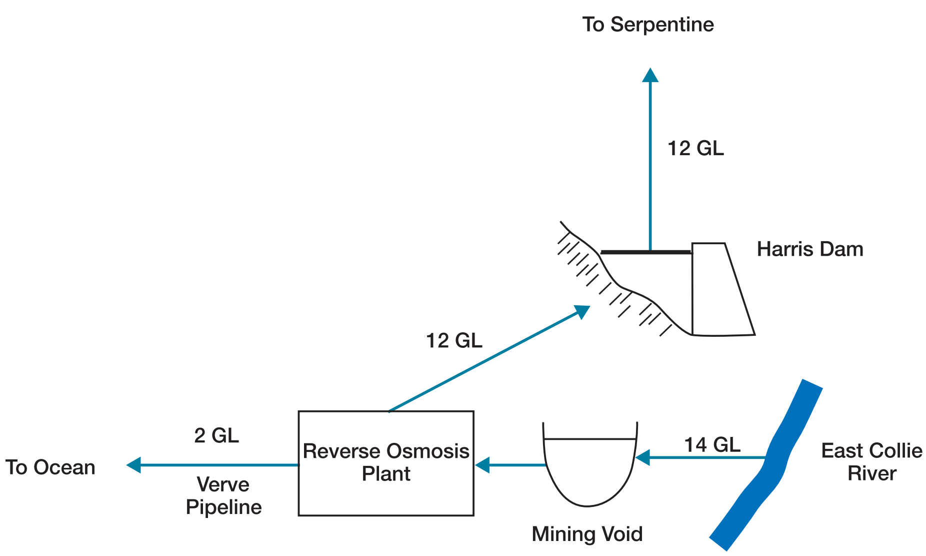
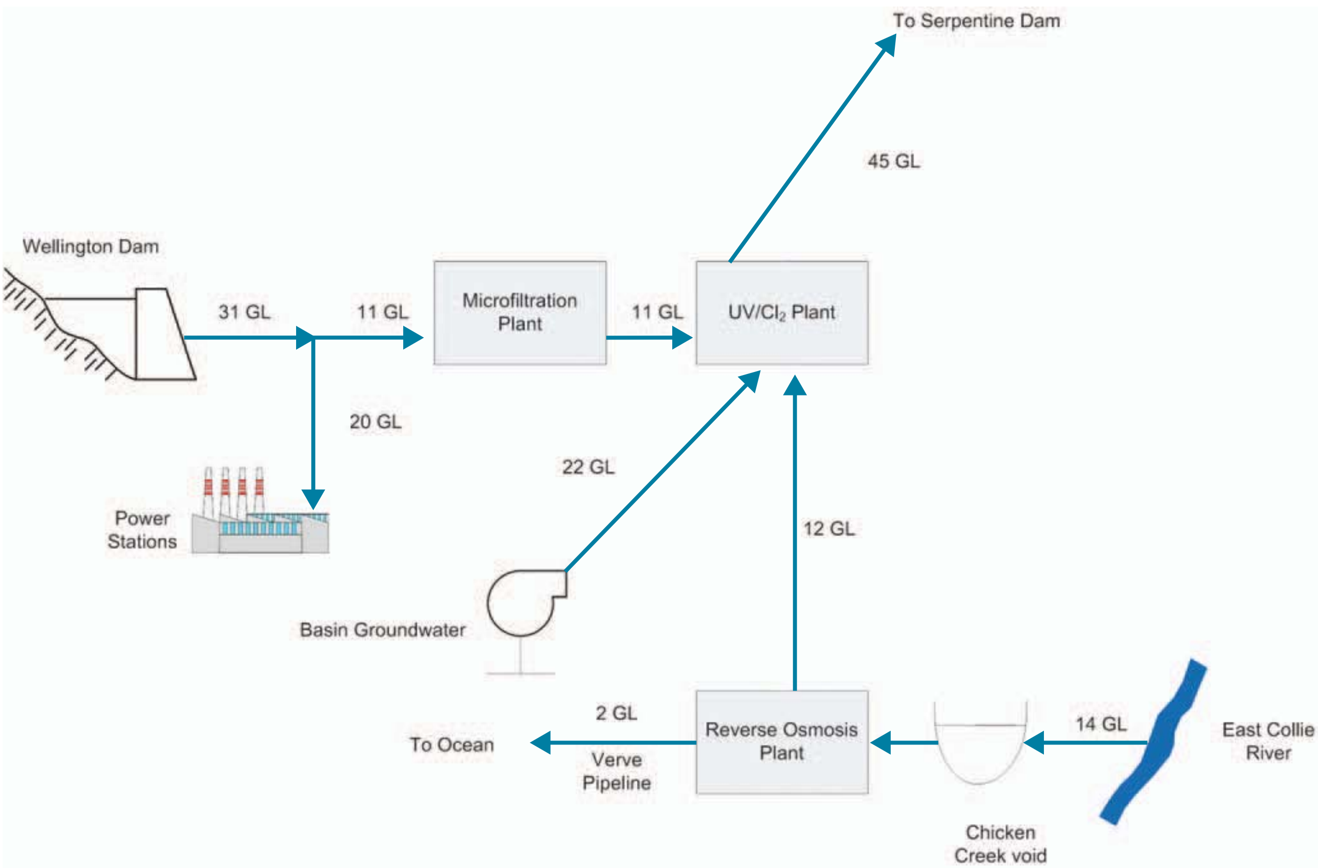
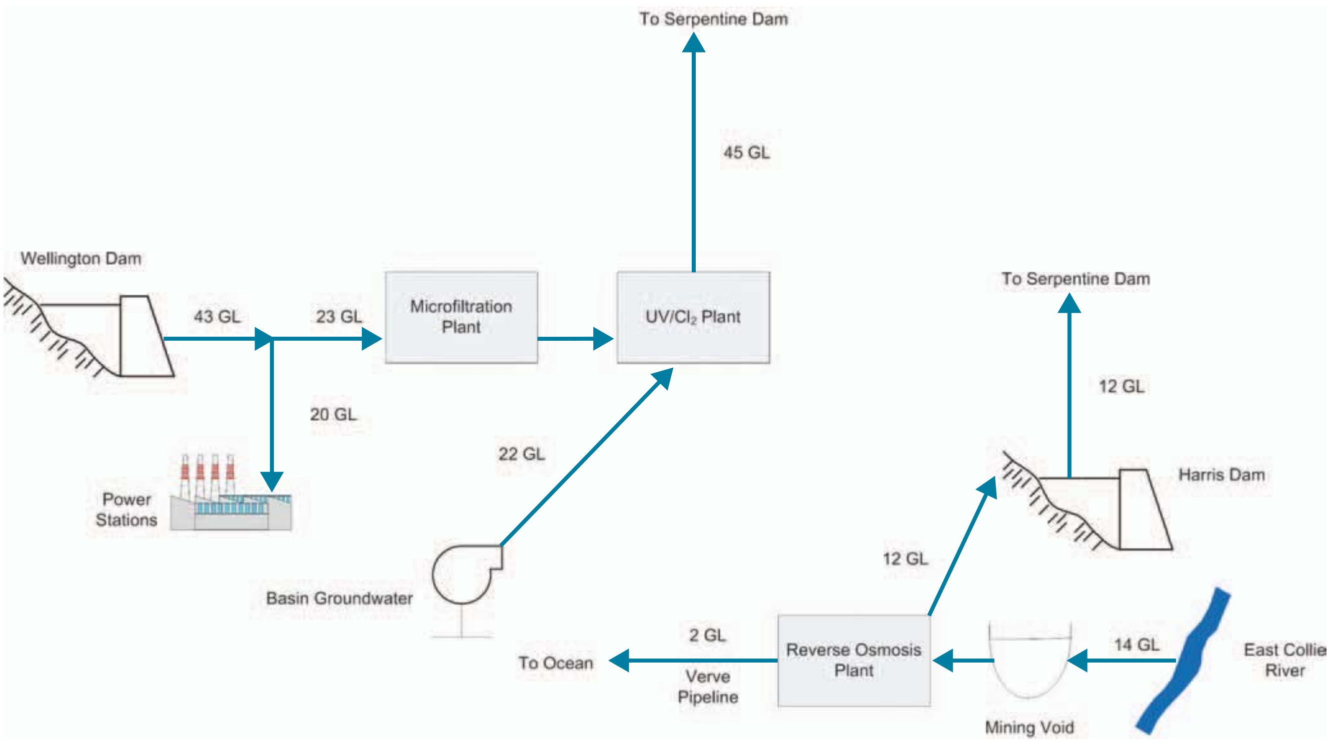


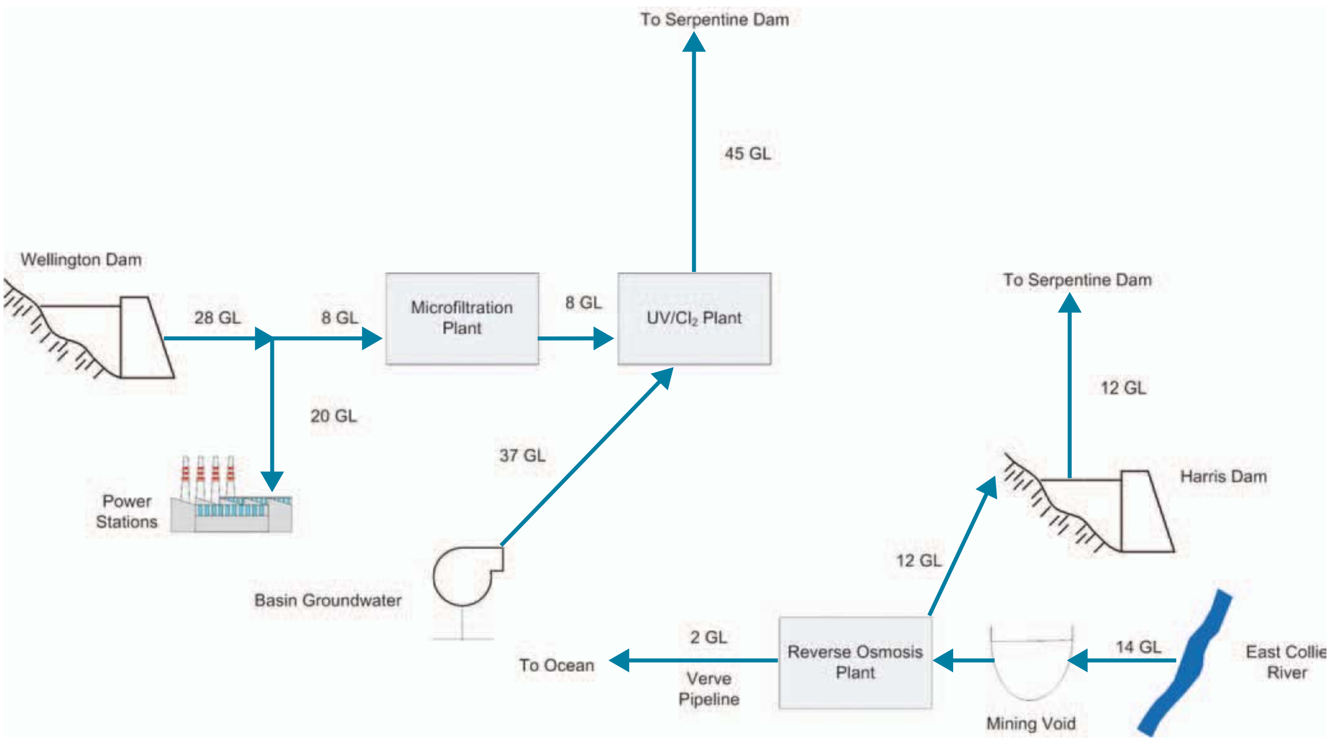
	Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Inland options	**Option 5** Assume 22 GL groundwater yield. Substitute 20 GL power station water with Wellington Dam water. Microfilter 11 GL of Wellington Dam water. Reverse osmosis treat 14 GL blended water. Shandy all treated water with 22 GL groundwater. Ultraviolet/chlorine treat and pipe to Serpentine Dam.	45 GL	$770M	155-173 c/kL



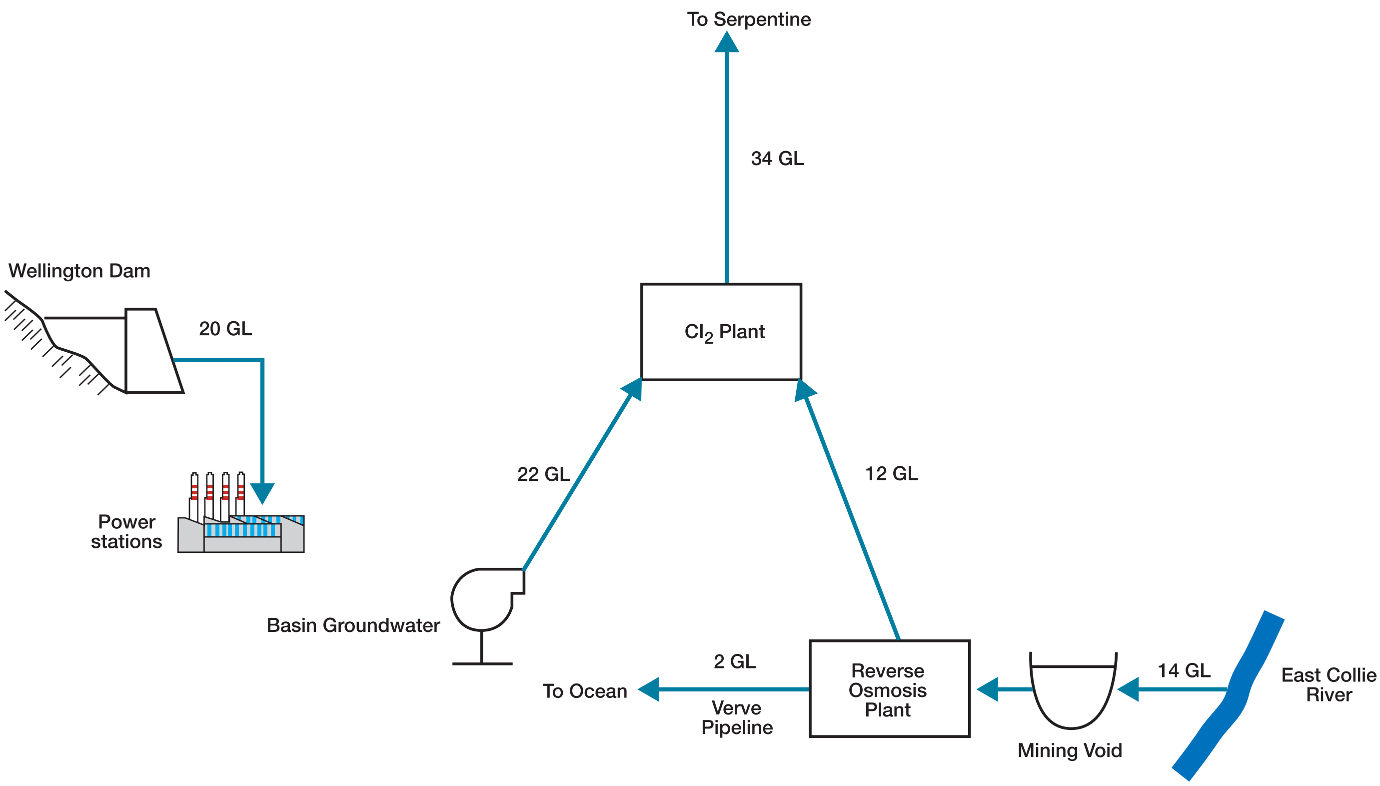
Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 6	57 GL	$871M	153-164 c/kL
Assume 22 GL groundwater yield. Substitute 20 GL of power station water with Wellington Dam water. Microfilter 23 GL of Wellington Dam water, blend with 22 GL of groundwater. Reverse osmosis treat 14 GL diversion. Blend all and post treat with UV/chlorine. Pipe to Serpentine.			



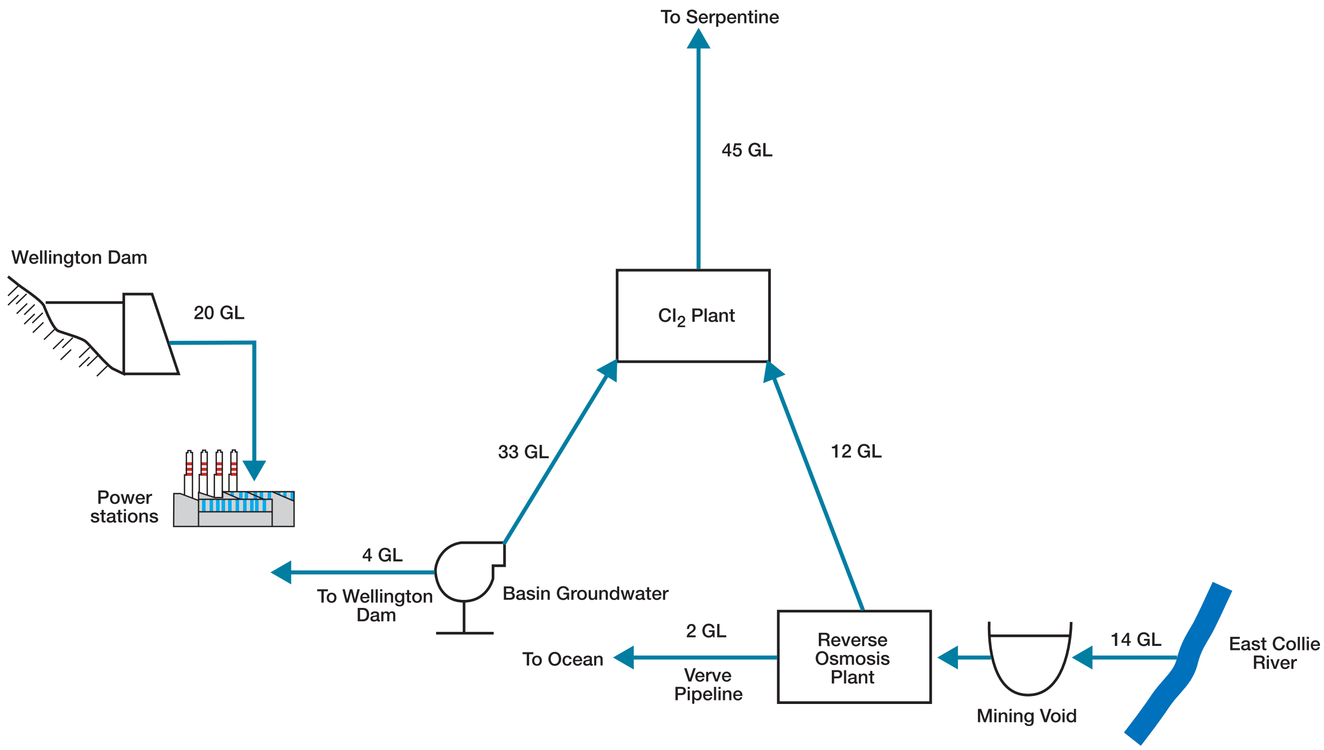
Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 7 Assume 37 GL groundwater yield. Substitute 20 GL power station water with Wellington Dam water. Microfilter 8 GL of Wellington Dam water. Shandy with 37 GL of groundwater. Ultraviolet/chlorine treat and pipe to Serpentine Dam. Reverse osmosis treat 14 GL diverted water and pipe to Serpentine Dam via Harris Dam.	57 GL	$836M	140-155 c/kL



Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 8 Substitute 20 GL power station water with Wellington Dam water. Reverse osmosis treat 14 GL diversion. Blend with 22 GL of groundwater. Sterilise with chlorine and pipe to Serpentine.	34 GL	$700M	170-199 c/kL



Description	Total Volume Yielded	Estimated Capital Cost	Total Water Cost
Option 9	45 GL	$693M	132-154 c/kL
Assume 37 GL groundwater yield. Substitute 20 GL power station water with Wellington Dam water. Shandy 12 GL output with 33 GL groundwater chlorinated and pipe to Serpentine Dam.			



6.4 Prioritisation of Projects

It is likely that a combination of water source options, treatments and delivery methods will best provide water at required volumes and standards; also it is possible that these can be staged. Further studies are needed to establish water source limits and availability, existing infrastructure capacity, sustainable limits to water and the most cost effective method of implementation. (A range of options for treating water to make it fit for purpose together with indicative development costs and delivered costs of water for each are presented in the body of the report.)

6.4.1 Supply for Urban Use

Distance from Perth combined with the need for water treatment mean that Wellington Dam is potentially a high cost resource compared with other possible sources of urban water. Therefore, in order to be financially viable, an urban water scheme based on Wellington Dam must be configured in a manner that not only involves high water volumes (say 45GL or more) but also delivers water of the required quality at minimum treatment cost.

Water Acquisition

Wellington Dam is fully allocated with most of its water either used on, or reserved for, irrigated agriculture. It follows that the implementation of a viable urban scheme would involve an appreciable reduction in the irrigation allocation. (See Figure 12.)

Wellington Dam				
Type of Use	Allocated	Available	Used	Spare
Irrigation (i)	68 GL	68 GL	51 GL	17 GL
Water Corporation/ Verve Energy	17 GL	17 GL	-	17 GL
Total	85 GL	85 GL	51 GL	34 GL
Available 17–34 GL/A				

Figure 12. Water available from Wellington Dam

It can be seen that a 45GL scheme would require 28GL to be acquired from the irrigation allocation. (17gl of this amount, though allocated, is currently unused.)

Groundwater from the Collie Coal Basin could also be a valuable source of urban water. Given that water will need to be directed away from irrigation and the possible difficulties involved with this, the amount of groundwater available could ultimately determine whether or not an urban water scheme proceeds.

Groundwater also requires less treatment than Wellington Dam water and, as will be shown subsequently, may play an important role in reducing the overall costs of treatment.

Forecasts suggest that 37 GL of groundwater will be produced annually by mine dewatering. 20 GL/A of this is required for power generation potentially leaving 17GL/A available for other purposes. Historically however, actual groundwater yields consistently fall short of forecast by about 40 percent. Therefore, until more independent work by the Department of Water and/or actual output confirms otherwise, a groundwater yield of 22 GL/A, with 2GL/A being available for urban water, can only be assumed.

Finally a major urban water scheme should only be contemplated seriously if risk to supply from reduced rainfall is demonstrably low. Given the competition for available water, it may be prudent to secure more water than needed as insurance against the impact of climate change. This could be done either by taking an option over additional water or purchasing extra water outright and leasing it back to irrigators.

Means of Water Acquisition

Additional water from the irrigation allocation could be acquired by:

1. Piping the irrigation area's distribution system to prevent water being lost through seepage and evaporation. Losses are currently estimated at 17 GL/A. Piping the distribution system at an indicative capital cost of $180 million delivers a predictable volume of water; however the cost of 77 c/kL, is high (Figure 13).

Cost of water saved by piping distribution system	
Capital Cost	$180M
Annual cost	$M/A
Depreciation	$2.25
Cost of capital @ 6%	$10.80
Total	$13.05
Volume saved	17 GL/A
77 c/kL	

Figure 13. Cost of water saved by piping the distribution system

2. Purchasing all or part of Harvey Water's unused allocation. (Potentially 17 GL/A).
3. Buying water entitlements from irrigators. Up to 51 GL/A is potentially available subject to price and social and political acceptability.

The relatively low returns achieved by dairy farmers and beef producers in the area may permit water to be purchased at a reasonable cost while at the same time providing an attractive outcome for irrigators. At present dairy farmers achieve a gross margin of $35 on each megalitre of water they use. If they were to sell water at prices per kilolitre that permitted it to be used as urban water and then invested the proceeds at an assured return of 7%, they would achieve many times their current return.

Table 3B in Appendix 3 presents the 'purchase option' from both the buyer's and seller's perspective for a range of water purchase prices. A dairy farmer is used as the base case and the cost per megalitre is calculated assuming a 50 year project life and 6% cost of capital. It is also assumed that the distribution losses (equivalent to 50% of the volume of water purchased) are obtained at zero cost as part of the purchase. It can be seen from Table 3B that purchasing water at an effective price of 10 cents per kilolitre would provide a yield to an irrigator equal to five times that obtainable from dairying.

The 'buyback option' may have particular application to the 25% of the district where the soil type is Bungum clay and consequently where productivity is particularly low.

The diversion of water away from irrigated agriculture for urban use will have social and economic impacts on the region, which must be carefully considered.

The type of treatment, the output volume and the amount of groundwater assumed to be available determines the volume of water that needs to be diverted away from irrigated agriculture. For example, at a minimum groundwater yield of 22 GL/A, a 45 GL reverse osmosis scheme at Brunswick with a 2 GL diversion at Buckingham would require a 65% reduction to the irrigation allocation and a 53% reduction to the amount of water actually used.

On the other hand, a scheme that delivers 25 GL/A of water by micro filtration at Brunswick plus 12 GL of water at Collie (by treating the diversion water by reverse osmosis) would only use 11 GL of the allocation and would result in no reduction in the amount of water actually used for irrigation. However, the cost of water delivered by such a scheme would be high and therefore unlikely to be economic when compared to other options.

Obviously, the ability to acquire sufficient volumes of reliable water at a competitive cost is a prerequisite to establishing an urban water scheme. Further, the full costs acquiring water must be considered when comparing Wellington Dam with other sources of water.

Water acquisition strategies for a range of likely development options are presented in table 3A Appendix 3.

Urban Water Treatment Costs

The costs of treating water and delivering it to Serpentine Dam are derived in Appendix 2 and summarised in Table 4.

Table 4. Development Options - Summary of Costs

				Irrigation Water Required		Costs			
Option	Output (GL)	Treatment Method	Groundwater Yield (GL)	Volume (GL)	% of Allocation	Capital ($M)	Annual ($M)	Total c/kL (i)	Plus Water Purchase Cost (c/kL) (ii)
1	45	Reverse osmosis	22	36	53	784	84	187	197
2	57	Microfilter	22	26	38	849	89	145-155	155-165
3	57	UV/Chlorine	22	26	38	719	71	114-125	124-135
4	37	Microfilter	22	8	16	719	75	178-202	188-212
5	45	Microfilter/Shandy	22	14	21	770	74	145-163	155-173
6	57	Microfilter/Shandy	22	26	38	871	88	143-154	153-164
7	57	Microfilter/Shandy	37	11	16	836	83	130-145	140-155
8	34	Groundwater	22	3	4	700	65	160-189	170-199
9	45	Groundwater	37	-	-	693	65	122-144	132-154

Note:

(i) The lower figure includes an urban water scheme's 'share' of the diversion costs i.e. 15 c/kL. The higher figure assumes the full cost of diversion is attributed to the urban water scheme.

(ii) An indicative amount of 10 c/kL has been arbitrarily assumed as the cost of acquiring the water.

Options 5, 6 and 7 shown in Table 4 require groundwater used by power stations to be replaced with low salinity dam water. The ground water is then used as a component of the water which is sent to Perth for domestic use, This is done in order to reduce bromide concentration to a level below that requiring treatment by reverse osmosis, thereby lowering treatment cost.

Delivery to the Integrated Water Supply Scheme

The costs of piping water to Serpentine Dam represent between 50 percent and 70 percent of total delivered costs for the options considered. Furthermore, the unit cost of piping water reduces significantly as the volume of water being piped increases. A comparison between the costs of piping 45 GL/A and 25 GL/A from Brunswick to Serpentine Dam is presented in Table 5.

Table 5. Cost of transporting 45GL and 25GL 159km via Brunswick to Serpentine Dam

Item	45 GL/A Scheme	25 GL/A Scheme
Capital Cost	$489M	$404M
Annual Costs		
• Depreciation	$6.1M	$5.0M
• Capital Cost	$29.3M	$24.1M
• Operating Cost	$6.9M	$4.3M
Total Annual Costs	$42.3M	$33.4M
Transport Cost	94 c/kL	134 c/kL

This demonstrates clearly that a low cost urban water scheme must involve volumes of water of the order 40-50 GL/A.

Given that the distance between Wellington Dam and Serpentine Dam is approximately 160 KM, it is significant that the minimum cost of water delivered to the IWSS (i.e.without making any allowance for the costs of treatment, salinity reduction or water acquisition) is approximately 100 cents per kilolitre.

Options 5-9 inclusive assume water treatment takes place upstream of Wellington Dam. Under certain of these options 12GL/A is transferred to the IWSS via Harris and Stirling Dams at reduced cost using existing links which have been suitably upgraded. The existing pipeline routes between and around Harris and Stirling Dams are shown in figure 14.

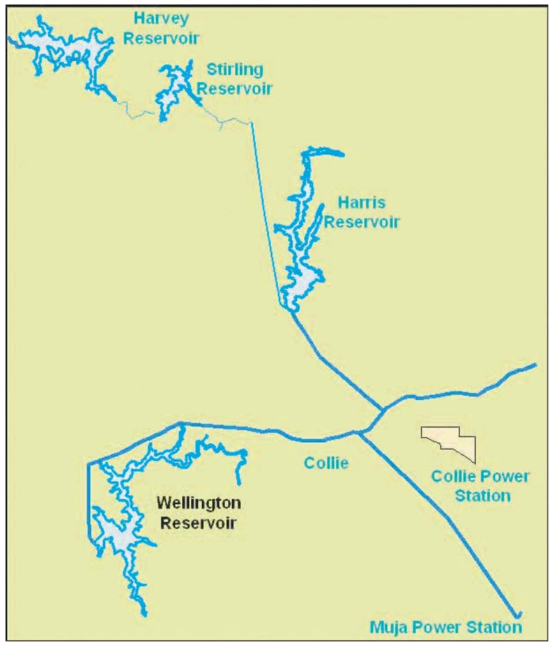


Figure 14. Piping infrastructure from Wellington Dam *(Source: Water Corporation)*

Recreation in and around Wellington Dam

Balancing recreational needs with the requirement to supply safe drinking water is a complex issue, especially in regard to Wellington Dam. When Wellington Dam ceased to be used as a major drinking source in 1990, the controls in place to protect the catchment were relaxed to permit limited recreational and tourism activities on and near the dam. Relaxation of these controls was done on the understanding that they would be reintroduced should Wellington Dam be reinstated as a source of drinking water.

Banning recreation will not entirely eliminate the risk of contamination, as there are other potential sources of contamination within the catchment that can neither be banned nor removed. Examples of these include the towns of Allanson and Collie, major roads that traverse the catchment and significant industrial and farming activities that take place mainly to the east of the Dam.

In considering the extent to which recreational activity needs to be restricted or banned it is important to better understand and take account of the impacts that effectively quarantining the catchment will have on the ongoing development of Allanson, Collie and the wider region. This is particularly relevant if consideration is given to the fact that the incremental risk posed by recreation has not been quantified. (Yet needs to be).

In any case, appropriate management strategies which take account of the realities associated with Wellington Dam must be developed, implemented and continue to apply whether or not a total ban on recreation is ultimately considered necessary.

Cost Effectiveness of Water For Urban Supply

The terms of reference calls for the cost effectiveness of different water use options to be assessed. This implies a need for the unit costs of water for the various Wellington Dam options to be compared with the cost of urban water potentially available from other sources.

The following comments are made with respect to a comparison between the Wellington dam options and the likely costs of water delivered into Serpentine Dam from a hypothetical seawater desalination plant.

An indicative cost for processing 45 GL/A of seawater by reverse osmosis is 132 c/kl. (Hence before considering transportation costs, all Wellington Dam options are lower than those of hypothetically desalinated seawater.) In order to obtain a cost suitable for comparison, the cost of transporting the desalinated water by 45 GL capacity pipelines to Serpentine Dam must be added. On the assumption that the hypothetical plant can be located on the coast at a distance that is between 50 and 80 km from Serpentine Dam, then the delivered cost of water will lie within the range 160-180 c/kL.

Assuming a water acquisition cost of 10 c/kL for all Wellington options then the likely competitiveness of each Wellington dam option as compared with seawater desalination is set out below:

Table 6. Competitiveness of options against a hypothetical desalination plant

Option	Total cost + acquisition cost (c/kL)	Indicative Competitiveness	Comment
1	197	Uncompetitive	High cost and low efficiency of water usage
2	155-165	Competitive	Subject to water quality assessment
3	124-135	Very competitive	Subject to water quality assessment
4	188-212	Uncompetitive	High cost. Subject to water quality assessment
5	155-173	Competitive	
6	153-164	Competitive	
7	140-155	Very Competitive	Assumes 37GL/A of groundwater
8	170-199	Uncompetitive	
9	132-154	Very competitive	Assumes 37GL/A of groundwater

It is emphasised that a valid comparison requires consideration to given to other factors in addition to cost. A seawater desalination plant uses more electricity than any Wellington option. Hence its greenhouse emissions would be higher as would be the risk of its costs being impacted adversely by rising electricity prices or a carbon tax. On the other hand, Wellington options have an exposure to the risk of decreased water availability due to declining rainfall.........and so on.

6.4.2 Supply to Industry

Untreated Wellington Dam water, provided its salinity is relatively low and constant, has the potential to be used in much the same way as recycled wastewater is used at Kwinana. Preliminary estimates suggest that the long term total industrial demand for the region could be as high as 30 GL/A. Furthermore up to half of this quantity could be needed in the short to medium term (5 years).

Kemerton Industrial Estate is short of water and there are claims that this is hindering its development. The Water Corporation plans to use water from the adjacent South West Yarragadee pipeline to service Kemerton. However, depending on the final demand, it may be preferable to use untreated water from Wellington Dam. The costs of piping water from the dam and reticulating the industrial estate would be appreciable but could be reduced by taking water from the main channel serving the Collie Irrigation District.

Industrial users with greatest potential include local alumina producers, Worsley Alumina and Alcoa, and a new industrial enterprise mooted for the Coolangata industrial estate.

The actual costs of distributing industrial water have not been established and need to be. However in order to recover the costs of the diversion at Buckingham, a minimum price ex dam of 15 c/kl would need to be charged. For some potential users it is possible that reliability of supply is more critical than cost. If this is the case, and given that Wellington Dam is a reliable source, then the demand for industrial water will be high irrespective of price relative to a less reliable source.

Power Stations

Although power stations currently rely on groundwater for their boiler feed water and cooling water, the amount of groundwater abstracted is determined by the need to dewater for mining rather then by the requirement to generate power. Hence the replacement of the groundwater used by power stations with low salinity Wellington Dam water will not relieve environmental stress within the Basin.

The use of Wellington Dam water in power stations will however, free up groundwater that can be used as part of an urban water scheme with a consequent reduction in the complexity of treatment needed and hence a lower urban water treatment cost.

Acquisition of Water

Under most scenarios some industrial water would need to be acquired from the irrigation allocation.

The amount to be acquired will depend upon:

- The amount of water eventually needed by industry.
- Whether or not an urban scheme is implemented in addition to an industrial scheme.

In the event that an urban water scheme does not proceed, the maximum forecast industrial demand could be satisfied from the unused portion of the irrigation allocation, without impacting the amount of water actually used for irrigation (51 GL/A).

On the other hand should a 57 GL/A urban scheme be implemented in parallel with a 30GL/A industrial scheme, then 56 GL/A (80%) of the 68 GL/A allocated to irrigation would need to be acquired and effectively irrigated agriculture within the Collie Irrigation District would cease.

6.4.3 Supply for Irrigated Agriculture

The productive output per kilolitre of water is estimated to be twenty times higher for urban use than for agricultural use. Hence the case for quarantining water for agricultural purposes in preference to using it for urban purposes cannot be justified readily on economic grounds.

The impacts of salinity and soil types on productivity have been canvassed previously. Even under the most aggressive assumptions for improvements in output which result from lowering water salinity, a case for agriculture will, as a minimum, require one or all of the following to eventuate:

- Wellington Dam water to be found to be unsuitable for use within the IWSS.
- Wellington Dam water to be a more expensive source of water than water from competing sources.
- Additional indirect benefits of sufficient magnitude to justify using the water for agriculture to be identified.

In the event that the full consumptive yield reverted to irrigated agriculture sufficient water would be available to support a significant increase in the amount of irrigated agriculture carried out within the region. However more fertile agricultural land with access to irrigation water would also be needed to support this.

Given the increased pressure on horticultural land close to Perth, it is possible that over time an amount of intensive horticultural activity could relocate to the Harvey and/or Collie irrigation areas. An assessment of the possibility and likely extent of this occurrence could form part of the investigation into the future of irrigated agriculture, which is planned for the Gnangara Mound.

Finally, although history suggests that it is difficult to use planning mechanisms to cause individuals and/or industries to relocate in a predetermined manner, it is possible that certain initiatives (e.g. the provision of incentives coupled with the onset of water trading), if implemented in Gnangara, could impact positively on the demand for land and irrigation water at Harvey.

6.4.4 Issues and Uncertainties

Issues and uncertainties relating to the development of water source options include:

1. The need for more information related to water quality, availability, water acquisition and the costs of water treatment and how these relate to productive use.
2. The possibility of further reduction to the consumptive yield of Wellington Dam.
3. The volume of ground water likely to be available as a result of dewatering activity and its long term reliability of supply.
4. The amount of water that can be acquired by purchasing water entitlements from irrigators is uncertain. There is a need to better understand the price/volume relationship and also the political, social and economic impacts of purchasing up to half the irrigation allocation and transferring it to urban use.
5. Further work is required to clarify the level of treatment required to render Wellington Dam water fit for drinking.
6. The costs assume that existing infrastructure is at full capacity. If indeed there is spare capacity in the system, then the costs of delivery could be significantly lower, particularly for schemes involving lower volumes than those assessed in this report.
7. Recreational activity on and around Wellington Dam impacts on the level of water treatment needed. A major issue to be resolved is whether or not recreational activities should continue in and around Wellington Dam in the event that Wellington Dam water is used as a source of domestic water.

6.5 Preferred Approach

Approaches which involve the substitution of groundwater used in power stations with treated Collie River water, and which then use the groundwater so released in combination with treated Wellington Dam water to supply the IWSS, offer the most promise.

Development of the preferred options for supply to the IWSS would be carried out in stages.

The first of these would involve building a 14GL/A diversion plus reverse osmosis treatment plant, upgrading the existing Harris - Stirling - Serpentine link and directing the 12GL of potable water produced by reverse osmosis to the IWSS.

Approximately four years would be required to complete the first stage. This time allows for appropriate planning and implementation of the diversion, for construction of the desalination plant and distribution pipelines, and most importantly, for sufficient water to be stored to enable the desalination plant, once commissioned, to run continuously.

The second stage involves the construction of a treatment plant, and once salinity has achieved the required level, substituting power station water with low salinity untreated dam water, building a new inland 45 GL/A pipeline to Serpentine, and finally commencing to pipe a blend of treated dam water plus groundwater to Serpentine. The second stage would require 6 years to complete.

Time required to confirm the feasibility of the project; to clarify the issues associated with water availability, acquisition and treatment; and to complete the design and tendering processes is additional. However certain of the design and tendering elements would occur in parallel with the phases 1 and 2.

The main elements of the two preferred options are outlined below.

Table 7. Preferred Options for Supply to the IWSS

Preferred Option A

57 GL/A for Urban Supply

Final Wellington Dam salinity 430 mg/L

Stage 1

Reverse osmosis treat 14 GL diversion water

Pipe resultant 12 GL to Serpentine Dam via Harris Dam

Stage 2

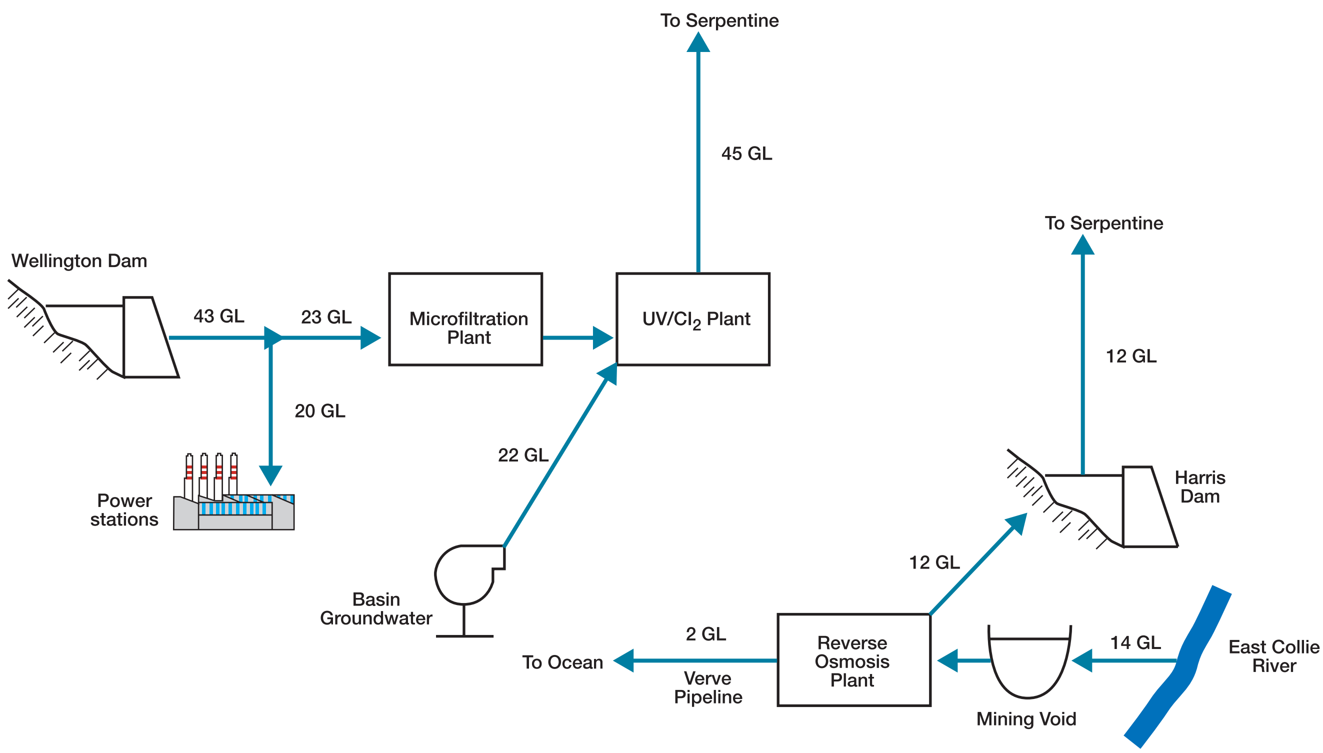
Substitute 20 GL groundwater used for power stations with Wellington Dam water

Treat additional 23 GL Wellington Dam water and blend with 22 GL groundwater, then further treat resultant combined water

Pipe treated 45 GL to IWSS via Serpentine Dam

Estimated capital cost $871M

Total water cost 155-164 c/kL



Preferred Option B

45 GL/A for Urban Supply

Final Wellington Dam salinity 430 mg/L

Stage 1

Reverse osmosis treat 14 GL diversion water

Pipe resultant 12 GL to to treatment plant

Stage 2

Substitute 20 GL groundwater used for power stations with Wellington Dam water

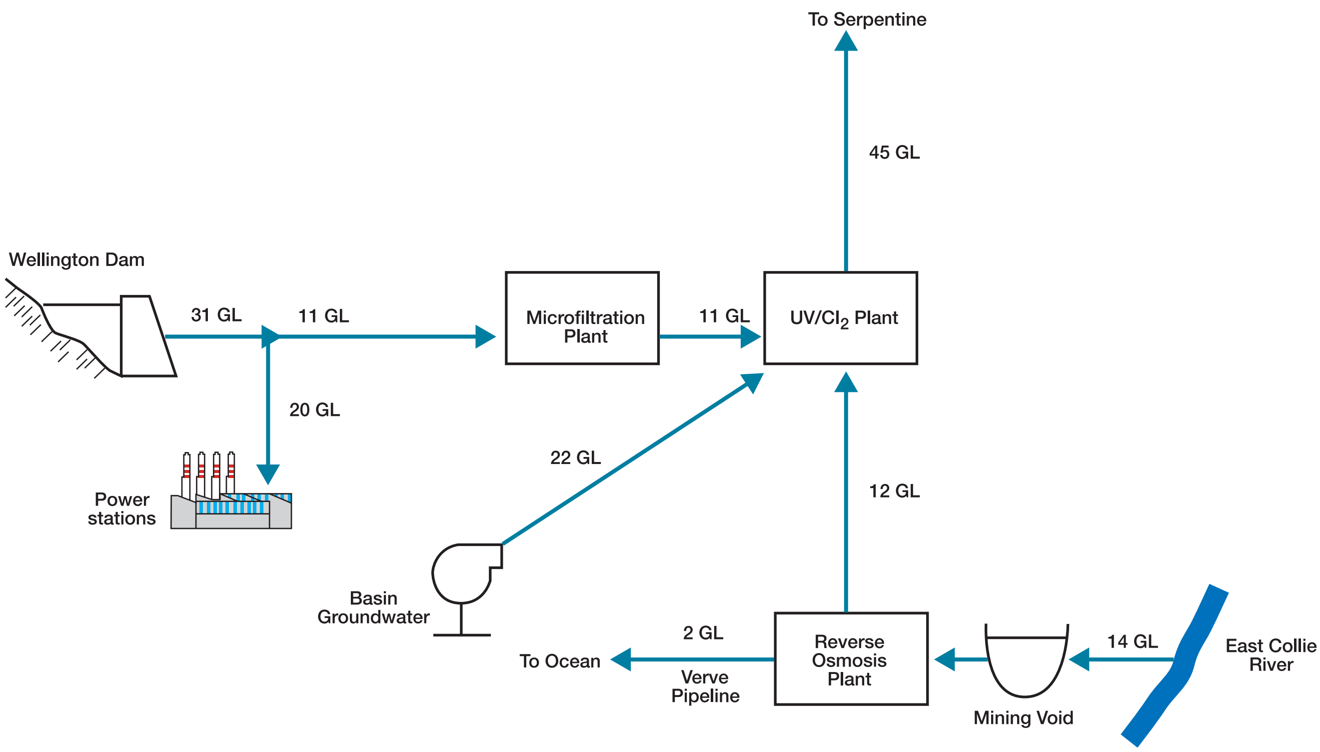
Treat additional 11 GL Wellington Dam water

Blend treated Wellington Dam water with 22 GL groundwater and 12 GL treated diversion water

Pipe treated 45 GL to IWSS via Serpentine Dam

Estimated capital cost $770M

Total water cost 155-173 c/kL



These options assume the following:

1. That the combined effects of
   - A 14 GL diversion of the Collie River;
   - Blending and diluting Wellington Dam water with groundwater; and
   - Treating Wellington Dam water by microfiltration and ultraviolet irradiation plus chlorine sterilisation

   render the final water so produced fit for human consumption.

2. The following approach to multiple barrier protection is suitable

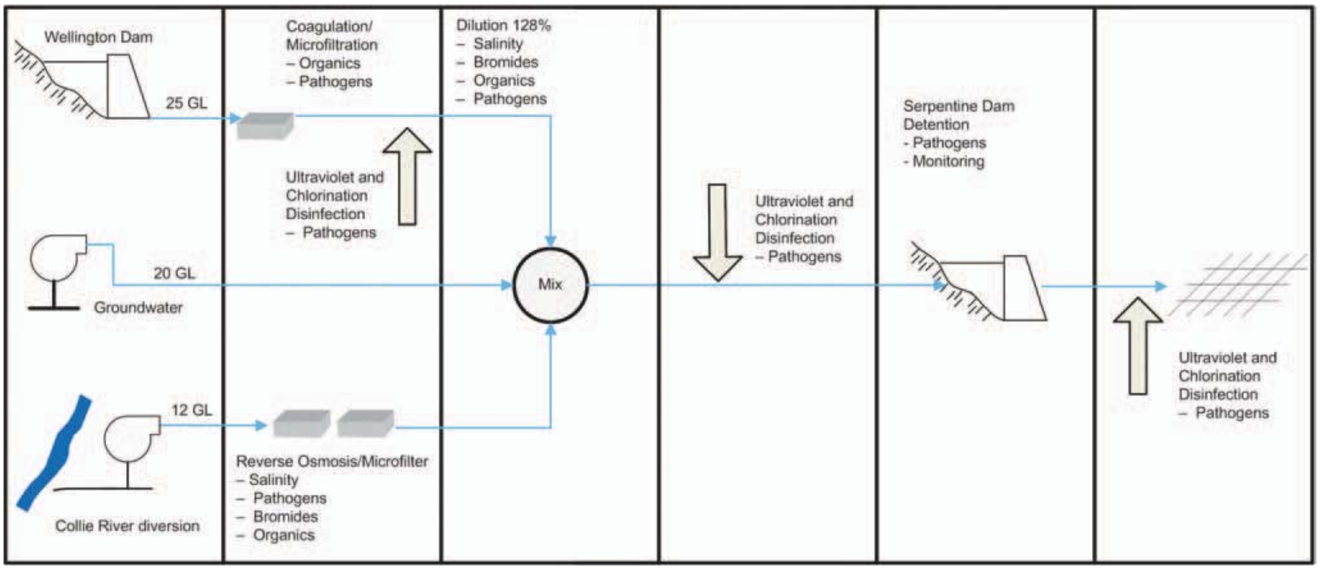


Figure 15. Suggested multiple barrier approach for the preferred options

3. That 22 GL/A of groundwater produced as a consequence of dewatering is available.

Other Issues

The total time required for the full development of the Collie-Wellington Basin is estimated to be 8 years. Should significant development commence in the near future, 2015 would therefore be earliest date for completion.

Further studies are required as part of any development. These would involve the confirmation of financial, social, environmental and technical feasibility, plus the preparation of detailed costings, including those associated with integration, into existing water infrastructure and water acquisition.

A high level of community consultation would be required particularly on issues relating to social and environmental assessments, and the associated local impacts.

The types of water treatment required and the safe threshold level for each potential contaminant also need to be clarified.

6.5.1 Issues and Uncertainties

Issues and uncertainties relating to the preferred options include:

1. Further evaluation on the sustainability of the preferred option is required, taking into account, local and regional costs and benefits.
2. Negotiations need to occur with owners of current infrastructure to address capacity and clarify costs.

6.6 Private and Public Sector Involvement

Opportunities exist for private as well as public sector involvement. Opportunities for the private sector include the outright ownership of facilities as well as the provision of planning, design, operational management and contracting services. Given the complexity and variety of water source options, treatments and infrastructure needs, any such involvement must accord with a predetermined delivery structure and form part of an actionable strategic plan.

There is scope for both the public and the private sector to be involved in the future development of Western Australia’s water resources.

The cost of developing Wellington Dam as a source of urban water is likely to be of the order of $750 million to $1 billion and encompass a diversity of elements. The private sector has shown a willingness to be involved in developments of such a large scale. Private participation has the potential to introduce competition into Western Australia’s water industry, encourage innovative and efficient production and benefit consumers. However for this to occur each stage of any development must be carefully structured.

Expressions of Interest should be directed at suitably qualified organisations and present opportunities for ownership and operation of installations and facilities as well as for the supply of expertise and other services.

Potential participants should possess relevant specific expertise, have experience on similar large-scale water projects and be asked to demonstrate that they can work and deliver value on projects of international scale and complexity.

The manner in which projects are specified is critical. Private sector participants should be given every opportunity to use their expertise to develop innovative packages for the development of new water sources and projects and contract conditions, including methods of payment, should be structured accordingly. Performance based specifications allow greater scope for the use of expertise than do those which require conformance with a particular design or approach. It is generally accepted that the ability to influence the ultimate cost and output performance of a project resides with the conceptual design and initial selection of the project parameters.

In all of the above, due account must be taken of the fact that Governments can access money at a lower cost than can the private sector and also that private participants require a margin above the cost of their capital (while Governments, of course, do not). In order to offset this inherent cost disadvantage (which is most evident in highly capital intensive projects such these) offerings from private participants sometimes come with a higher level of associated risk. Future risk is important. The State Government, as owner, will bear the consequences of an overly aggressive tender price and/or design strategy that increases the risk of reduced reliability or output quality.

Finally, given the size, diversity and complexity of the undertaking it may well be beneficial to employ a separate contractor to oversee and manage its overall design, procurement and construction.

6.6.1 Issues and Uncertainties

Issues and uncertainties relating to private and public sector involvement include:

1. Some forms of private sector involvement could be uncompetitive due to the Government having access to low cost money.
2. In order to ensure that the appropriate expertise sought is effectively delivered, careful attention must be given to the structure of projects and also to the way that contractors and other private participants are selected, managed and recompensed.
3. The dual role of the Water Corporation as a purchaser and provider of bulk water may serve as a deterrent to greater private sector involvement.

7. Recommendations

Recommendation 1. The work carried out in this pre-feasibility study should be extended and refined in order to establish a definitive water resource development plan for the Collie-Wellington Basin. This work should include, but not be limited to, establishing future demands by type of use, required standards and forms of treatment needed to achieve these, definitive costs (including those associated with integration into the IWSS), sources and availabilities of water, etc. In completing this work, due consideration must be given to social and environmental issues in addition to the economics of the project.

Recommendation 2. The volume of water diverted from the Collie River East should be increased to 14 GL. However this recommendation is conditional upon the outcomes of the further work needed to confirm the overall technical, economic, environmental and social feasibility of using Wellington Dam as a major source of urban and/or industrial water.

Recommendation 3. The feasibility of using groundwater generated by mine dewatering as a source of drinking water should be subjected to further investigation.

Recommendation 4. The future demand for "fit for purpose" water for industry and agriculture in the Greater Bunbury area needs to be determined. The future statutory water management plan for the Collie-Wellington Basin should consider allocations for these uses.

Recommendation 5. Managed recreation within the Wellington Dam catchment should continue; however more stringent control is needed over this. The implications for water quality of activities that involve direct contact with water should be reviewed. Further any future investigation into the use of Wellington Dam as a source of potable water should be required to establish the additional treatment cost which needs to be incurred in order to permit recreational activities to occur within the catchment.

Recommendation 6. Given the Water Corporation's role as a purchaser and provider of bulk water it is recommended that high level strategic water source planning be separated from the role of water service provision.

Recommendation 7. Government should encourage the private sector to become involved in the future development of the water resources of the Collie-Wellington Basin. Opportunities for this involvement include the rationalisation and delivery of water produced as a result of mine dewatering, the ownership and/or operation of treatment plants, the ownership and operation of pipelines as well as for the more traditional forms of participation such as the provision of design, operational management and construction services.

Recommendation 8. Participation by the private sector in certain aspects of water supply within the Collie - Wellington Basin needs to be accommodated within the integrated plans prepared for the region and care taken to ensure that such participation conforms with other elements such as those applicable to land and water use, economic development, physical and social infrastructure and the environment.

Recommendation 9. Work on the implementation of the Salinity Recovery Plan for the Collie River, including river restoration, re-afforestation and diversion of the Collie River East Branch in its current form should continue.

8. Conclusion

It is important to note that while the Steering Committee has focussed on the potential of the Collie Coal Basin and Wellington Dam as a future water source for Perth, other potential sources for integration into the IWSS may be available and these need to be examined in a consistent manner.

When considering the preferred development options for the Collie-Wellington Basin, the economics are primarily dictated by the costs associated with the distance of Wellington Dam from Perth and treating the water to render it fit for human consumption. The removal of salt from Wellington Dam and acquiring enough water has a much smaller influence on the final cost of water.

This investigation was undertaken over a short period of time and hence the technical and cost information that support this report and its recommendations need to be verified and in certain instances developed further. Examples where this is required include, the capacity of relevant parts of the current Water Corporation distribution system, the level of water treatment required, the cost of major treatment works such those required for desalination or micro-filtration, and the demand for industrial water.

The Department of Water is currently completing the Salinity Recovery Plan for the Collie River. It is not the intention of this report to hinder the continuation of the Salinity Recovery Plan for the Collie River. Indeed any improvement in the state of the Collie River catchment fundamentally improves the water quality of Wellington Dam, and therefore provides wider benefits, not just to those productive uses identified in this investigation.

In addition, a water management plan for the Collie River catchment has commenced. This plan will become a statutory management plan for the Collie-Wellington area that will clarify the water entitlements for power generation, public water supply and irrigation.

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10. Appendices

Appendix 1. Public Submissions

Public Submissions

Public submissions were received from:

Agritech Smartwater

Aquaculture Council of Western Australia

Bunbury Wellington Economic Alliance

Centre of Excellence for Sustainable Mine Lakes, Curtin University of Technology

Collie Water

Griffin Coal

Harvey Water

Member for Collie-Wellington

Verve Energy

Water Corporation

Preliminary Assessment of Submissions

A preliminary proposal to treat the 14 GL of diversion water by reverse osmosis and deliver the potable output into Harris Dam was presented to the Steering Committee. The proposal indicated a capital cost of $70M would be applicable and that the delivered price of water would be 140 c/kL. On the surface, the above appears attractive compared with equivalent prices and capital costs determined by the Committee of $164M and 204 c/kL respectively. However, part of the difference could be due to the fact that the costs of diversion are included in the Committee's estimated costs.

A second proposal presented to the Steering Committee, promoting a scheme involving the desalination of saline groundwater drained from the eastern catchment and beyond, was comprehensive and involved a number of innovative elements.

This proposal included:

- Saline groundwater being collected from the eastern catchment and beyond using a network of open canals.
- Part of the water collected being channelled through a brackish water reverse osmosis plant, the remainder being piped to the ocean.
- The desalination plant was driven by hydrostatic pressure created by difference in elevation between the top of the Darling Scarp and Brunswick, where the reverse osmosis plant was located.
- While the canals are being built and until they became fully operational, the plant would use Wellington Dam water as its input.

Many elements of the scheme fall outside this investigation's Terms of Reference. Moreover, given its complexity, much more time would be needed than that available to complete this investigation, as a proper assessment of the engineering and financial feasibility of the main scheme is required. The desalinated water under this proposal is essentially a by-product of the canal drainage scheme and as such its feasibility stands or falls with the main scheme.

Accepting this:

- The reverse osmosis element of the proposal suffers from the same disadvantage relative to seawater, as does the reverse osmosis option discussed previously.
- The indicative capital costs given were lower than those used by the Steering Committee. If these are correct, they may offset the above disadvantage.
- The use of the pressure drop to drive the process is attractive. However, the power consumption of a brackish water plant is much lower than a seawater desalination plant and also all options evaluated in this investigation enjoy a power credit by incorporating a turbine in the input pipeline to the plant and using the differential head to generate electricity.

Appendix 2. Assumptions, Element Breakdowns and Synthesis of Costs

The data for pipe, pump and water treatment cost estimates were sourced from GHD Pty Ltd. The methodology for calculating the capital, annual and unit water costs, and the salinity credit were developed by the Steering Committee.

Table 2A. Assumptions

Distances	
Wellington Dam - Brunswick	32 km
Brunswick - Ocean	15 km
Brunswick - Serpentine	127 km
Wellington - Intersection (inland route)	29 km
Intersection - Serpentine (inland route)	144 km
Power consumption and operating	
Brackish water desalination Power demand (feed TDS < 3000 mg/L)	1.5 kWhr/kL
Brackish water desalination Power demand (feed TDS > 3000 mg/L)	1.8 kWhr/kL
Microfiltration power demand	0.15 kWhr/kL
UV/Chlorination power demand	0.08 kWhr/kL
45 GL Salt water desalination power demand	4 kWhr/kL
Power cost	5 c/kWhr
Power Recovery	0.5 kWhr/kL
Contingency	
Allowance on capital expenditure	30%
Depreciation Lives	
Pipelines	80 years
Plant and Equipment	20 years
Cost of Capital	6%

Table 2B. Breakdown of elements

Brunswick			
B1	**Reverse Osmosis Plant - 45 GL**		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	256		
Depreciation		13	28
Cost of capital		15	34
Power		3	7
Power credit		+ 1	+ 2
Other Operating		8	18
Total	256	38	85

B2	**Microfiltration Plant - 45 GL**		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	130		
Depreciation		6	14
Cost of capital		8	17
Power		0.3	0.7
Power credit		+ 1	+ 2
Other Operating		4	9
Total	130	17	38

B3	**Ultra Violet/Chlorine - 45 GL**		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	6		
Depreciation		0.3	0.7
Cost of capital		0.4	0.9
Power		0.2	0.4
Power credit		(+ 1)	+ 2
Other Operating		0.2	0.4
Total	6.5	1 (0)	2 (0)

B4	Microfiltration Plant - 25 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	90		
Depreciation		5	18
Cost of capital		5	22
Power		0.2	0.8
Power credit		+ 0.6	+ 2
Other Operating		3	11
Total	90	13 (12)	52 (50)

B5	Inlet Pipeline - 55 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	106		
Depreciation		1	2
Cost of capital		6	12
Operating Costs		3	5
Total	106	10	19

B6	Inlet Pipeline - 45 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	104		
Depreciation		1	3
Cost of capital		6	14
Operating Costs		2	4
Total	104	9	21

B7	Inlet Pipeline - 25 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	84		
Depreciation		1	4
Cost of capital		5	21
Operating Costs		1	5
Total	84	7	30

B8	Saline Discharge Pipeline - 10 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	36		
Depreciation		0.5	5
Cost of capital		2	22
Operating Costs		0.5	5
Total	36	3	32

B9	Delivery Pipeline - 45 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	385		
Depreciation		5	11
Cost of capital		23	51
Operating Costs		5	11
Total	385	33	73

B10	Delivery Pipeline - 25 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	320		
Depreciation		4.0	16
Cost of capital		19	77
Operating Costs		3	12
Total	320	26	105

C1	Microfiltration Plant 25 GL (Nominal)		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	90		
Depreciation		5	18
Cost of capital		5	22
Power		0.2	0.8
Operating Costs		3.0	12
Total	90	13	53

C2	Microfiltration Plant 10 GL (Nominal)		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	52		
Depreciation		2	26
Cost of capital		3	31
Power		0.1	1
Operating Costs		2	16
Total	52	7	74

C3	UV/Chlorine Treatment Plant - 33 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	5		
Depreciation		0.2	0.6
Cost of capital		0.2	0.6
Power		0.1	0.3
Operating Costs		0.2	0.6
Total	5	0.7	2

C4	Reverse Osmosis Plant - 10 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	112		
Depreciation		6	47
Cost of capital		7	56
Power		1	9
Operating Costs		3	29
Total	112	17	141

C5	Feed Pipeline from Wellington Dam - 30 GL (Nominal)		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	87		
Depreciation		1	4
Cost of capital		5	17
Operating Costs		1	3
Total	87	7	24

C6	Feed Pipeline from Wellington Dam - 45 GL (Nominal)		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	90		
Depreciation		1	2
Cost of capital		6	12
Operating Costs		1	3
Total	90	8	17

C7	Feed Pipeline from Wellington Dam - 20 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	73		
Depreciation		0.9	4
Cost of capital		4	22
Operating Costs		0.7	4
Total	73	6	30

C8	Feed Pipeline from Buckingham Diversion - 14 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	52		
Depreciation		0.6	4
Cost of capital		3	22
Operating Costs		0.8	6
Total	52	4	32

C9	Basin Groundwater Collection Pipe Network - 22 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	26		
Depreciation		0.3	1
Cost of capital		1	8
Operating Costs		0.3	1
Total	26	2	10

C10	Basin Groundwater Collection Pipe Network - 37 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	31		
Depreciation		0.4	1
Cost of capital		2	5
Operating Costs		0.9	3
Total	32	3	9

C11	Delivery Pipeline To Serpentine Dam - 45 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	419		
Depreciation		5	11
Cost of capital		25	56
Operating Costs		3	7
Total	419	33	74

C11	Delivery Pipeline To Serpentine Dam - 45 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	419		
Depreciation		5	11
Cost of capital		25	56
Operating Costs		3	7
Total	419	33	74

C12	Delivery Pipeline to Serpentine Dam - 34 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	415		
Depreciation		5	15
Cost of capital		25	73
Operating Costs		3	8
Total	415	33	96

C13	Upgrade Pipeline to Harris Dam - 12 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost			
Depreciation			
Cost of capital			
Operating Costs		3	25
Total		3	25

C14	Upgrade Pipeline to Harris - Serpentine Dam - 12 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	60		
Depreciation		0.75	6
Cost of capital		3	30
Operating Costs		-	
Total	60	4	36

C15	Diversion Pipeline to Ocean - 14 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	105		
Depreciation		1	9
Cost of capital		6	45
Operating Costs		1	6
Total	105	8	60

C16	Pipeline from intersection to Collie Power Station - 20 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	16		
Depreciation		0.2	1
Cost of capital		1.0	5
Operating Costs		0.3	2
Total	16	2	8

C17	Pipeline from Wellington Dam to intersection - 10 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	48		
Depreciation		0.6	6
Cost of capital		3	29
Operating Costs		0.4	4
Total	48	4	39

D1	Base Cost of Seawater Desalination Plant - 45 GL		
Item	Capital Cost ($M)	Annual Cost ($M)	c/kL
Capital cost	358		
Depreciation		18	40
Cost of capital		21	48
Power		9	20
Operating Costs		11	24
Total	358	59	132

D2	Salinity Credit
The synthesis of costs completed in this report attribute the final cost of lowering dam salinity to the option being costed. Only that portion of this cost attributable to the volume of dam water actually used should be included. Thus a credit is given for the amount of the sustainable yield that is not used by the option. The value of this credit is calculated at the rate of 10.5c/kL on the amount of the sustainable yield not used by the option being considered.	

Table 2C. Synthesis of costs

Option	Volume	Description	Cost Element	Costs		
				Capital ($M)	Annual ($M)	c/kL
1	45 GL	Reverse Osmosis (including Microfilter pre-treatment and UV/Chlorine post-treatment at Brunswick using Wellington Dam water and pipe to Serpentine	B1	256	38	85
			B5	107	10	23
			B8	36	3	7
			B9	385	33	72
			Total	**784**	**84**	**187**
2	57 GL	Microfilter (including uv/chlorine post treat) at Brunswick and pipe to Serpentine plus RO treat 14 GL diversion and pipe to Serpentine using upgraded basin - Harris Serpentine links	B2	130	17	31
			B6	104	9	17
			B9	385	33	57
			C4	112	17	30
			C8	52	4	8
			C13		3	5
			C14	60	4	7
			Subtotal	**843**	**87**	**155**
			D2	-	(6)	(11)
			Total	**843**	**81**	**144**
3	57 GL	UV/Chlorine treat at Brunswick and pipe to Serpentine plus RO treat 14 GL diversion and pipe to Serpentine using upgraded basin - Harris Serpentine links	B3	6	0	0
			B6	104	9	17
			B9	385	33	57
			C4	112	17	30
			C8	52	4	8
			C13		3	5
			C14	60	4	8
			Subtotal	**719**	**70**	**125**
			D2	-	(6)	(11)
			Total	**719**	**64**	**114**
4	37 GL	Microfilter (Including uv/chlorine post treat) at Brunswick and pipe to Serpentine plus RO treat 14 GL diversion and pipe to Serpentine using upgraded basin Harris - Serpentine links.	B4	90	12	33
			B7	84	7	20
			B10	320	26	71
			C4	112	17	45
			C8	52	4	12
			C13		3	8
			C14	60	4	12
			Subtotal	**718**	**73**	**201**

Option	Volume	Description	Cost Element	Costs		
				Capital ($M)	Annual ($M)	c/kL
			D2	-	(9.0)	(24.0)
			Total	**718**	**64**	**177**
5	45 GL	Substitute 20 GL power station water with Wellington water. Microfilter 11 GL Wellington water. RO treat 14 GL diverted water. Blend both above with 22 GL groundwater. UV/Chlorine treat and pipe to Serpentine	C2	52	7	17
			C5	87	7	16
			C9	26	2	5
			C11	419	33	74
			C16	16	2	3
			C4	112	17	37
			C8	52	4	10
			B3	6	1	2
			Subtotal	**770**	**73**	**164**
			D2	-	(8)	(18)
			Total	**770**	**65**	**146**
6	57 GL	Substitute 20 GL power station water with Wellington water. Microfilter 23 GL of Wellington Water. RO treat 14GL diverted water. Blend 23 GL of Wellington water with 22GL groundwater. UV/chlorinate and pipe to Serpentine. Pipe RO treated water to Perth via upgraded basin - Harris Serpentine link.	C1	90	13	23
			C6	90	8	13.2
			B3	6	0	0
			C9	26	2	4
			C11	419	33	58
			C16	16	2	3
			C4	112	17	30
			C8	51	4	8
			C13		3	5
			C14	60	4	8
			Subtotal	**870**	**86**	**152**
			D2	-	(6)	(11)
			Total	**870**	**80**	**141**
7	57 GL	Substitute 20 GL power station water with Wellington water. Microfilter 8 GL Wellington water. Blend with 37 GL groundwater. UV/chlorine treat and pipe to Serpentine. RO treat 14 GL diverted river water and pipe to Serpentine via upgraded basin - Harris - Serpentine link.	C2	52	7	13
			C5	87	7	13
			B3	6	1	2
			C10	32	3	5
			C16	16	2	2
			C11	419	33	59
			C4	112	17	30

Option	Volume	Description	Cost Element	Costs		
				Capital ($M)	Annual ($M)	c/kL
			C8	52	4	7
			C13		3	5
			C14	60.0	4	8
			Subtotal	**836**	**81**	**144**
			D2	-	(9)	(15)
			Total	**836**	**72**	**129**
8	34 GL	Substitute 20 GL power station water with Wellington water. RO treat 14 GL diverted river water. Shandy chlorine treat and pipe to Serpentine	C7	73	6	18
			C9	26	2	5
			C16	16	1	4
			C4	112	17	49
			C8	52	4	13
			C12	415	33	96
			C3	5	1	2
			Subtotal	**699**	**64**	**187**
			D2	-	(10)	(29)
			Total	**699**	**54**	**158**
9	45 GL	Substitute 20 GL power station water with Wellington water. RO treat 14 GL diverted river water. Shandy 33 GL groundwater and 12 GL treated diversion water. Chlorine treat and pipe to Serpentine	C7	73	6	13
			C10	32	3	7
			C3	5	1	2
			C11	419	33	74
			C16	16	2	3
			C4	112	17	37
			C8	52	4	10
			Subtotal	**709**	**66**	**146**
			D2	-	(10)	(22)
			Total	**709**	**56**	**124**

Appendix 3. Volume and Possible Water Acquisition Sources for Urban Water

The source of water for each option is outlined in Table 3A. This shows that water sourced from irrigation ranges from 0-36 GL. The effective cost is outlined in Table 3B.

Water source development schemes with low delivered volumes are less controversial because they require lower volumes of water to be diverted from irrigation than do high volume schemes. However they are disadvantaged in that their cost/GL to pipe water to Serpentine Dam is higher than those for schemes involving higher volumes.

It is assumed that water will be acquired from irrigation in the following order of priority:

- Unused allocation (17 GL)
- Bungum clay (13 GL max - including losses)
- Other soils (38 GL max - including losses)

The option to acquire 17 GL by piping the Collie Irrigation Area to save 17 GL at a cost of $180M still exists. The effective cost of 77 c/kL of water purchased adds 30 cents for every kilolitre of water delivered by a 45 GL scheme. This is considered too much to pay and has not been considered further.

Table 3A. Breakdown of water acquisition components for each water source option

		Water Volumes (GL)			Source of Input Water (GL)				Source of Irrigation Water (GL)					
Option	Diversion (GL/A)	Output	Input	Efficiency (%)	Water Corporation Allocation	Groundwater	Diversion	Irrigation	Unused Allocation	Bungum Clay	Other soils	Losses	% Total Allocation	% Actual Applied
1	2	45	57	79	17	2	2	36	17	9	4	6	53	38
2	14	57	59	97	17	2	14	26	17	6	-	3	38	18
3	14	57	59	97	17	2	14	26	17	6	-	3	38	18
4	14	37	37	95	17	2	14	8	8	-	-	-	16	-
5	14	45	47	96	17	2	14	14	14	-	-	-	21	-
6	14	57	59	97	17	2	14	26	17	6	-	3	38	18
7	14	57	59	97	17	17	14	11	11	-	-	-	16	-
8	14	34	36	94	17	2	14	3	3	-	-	-	4	-
9	14	45	47	96	17	16	14	-	-	-	-	-	-	-

Table 3B. Effective cost per kilolitre of purchasing water entitlements from irrigators

Irrigator			State Government		
Purchase Price ($/ML of Entitlement)	Return of Farmer at 7% rate of return ($)	Benefit Factor*	Effective Price including Losses ($/ML)	Capital Cost to Acquire 17GL ($M)	Equivalent Cost/kL at 50 year life + 6% (CPV = 17) (c/kL)
500	35	1	333	5.66	1.9
750	52.5	1.5	500	8.5	2.9
1000	70	2	667	11.34	3.9
1250	87.5	2.5	833	14.16	4.9
1500	105	3	1000	17	5.9
1750	122.5	3.5	1167	19.83	6.9
2000	140	4	1333	22.66	7.8
2250	157.5	4.5	1500	25.5	8.8
2500	175	5	1667	28.3	9.8
2750	192.5	5.5	1833	31.2	10.8
3000	210	6	2000	34	11.8
15,882	1,112	32	10,588	180	62

* Denotes the ratio of the return from selling water to the amount currently generated by using it on dairying.

• Effective cost of piping option shown in bold