Water Purification Scheme for the ACT

A report outlining recommendations for the development of a water purification scheme for the ACT to deliver purified water from the Lower Molonglo Water Quality Control Centre to the Cotter Reservoir.

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ACTEW CORPORATION

WATER security program
safe • secure • sustainable

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Key Abbreviations

Abbreviation	Description
µg/L	Micrograms per litre
µS/cm	Micro Siemens per centimetre (a common unit of electrical conductivity)
ACT	Australian Capital Territory
ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Reuse
AHMC	Australian Health Ministers' Conference
ANU	Australian Natural University
ANZECC	Australian & New Zealand Environment and Conservation Council
ANU	Australian National University
AOP	Advanced oxidation process
ARMCANZ	Agriculture & Resource Management Council of Australia and New Zealand
AU$	Australian dollars
BAC	Biological Activated Carbon
BMP	Baseline Monitoring Program
CCP	critical control points
CCTV	Closed Circuit Television
CIP	Clean in Place
cm	Centimetre
CP	Concentration polarisation
CPS	Cotter Pumping Station
CRCWQT	Cooperative Research Centre for Water Quality and Treatment
DA	Development Application
DAF	Dissolved Air Flotation
DAFF	Dissolved Air Flotation and Filtration
DALY	Disability adjusted life year
DBP(s)	Disinfection byproduct(s)
DNA	Deoxyribonucleic acid
DOC	Dissolved organic carbon
DWI	Deep Well Injection
EC	Electrical Conductivity
ED	Electrodialysis
EDR	Electrodialysis Reversal
EDC(s)	Endocrine Disrupting Compound(s)
EIS	Environment Impact Study

Abbreviation	Description
EPBC	Environmental Protection and Biodiversity
EPA	Environment Protection Authority
EPHC	Environment Protection and Heritage Council
EU	European Union
FCC	Forced Circulation Crystalliser
FSTP	Fyshwick Sewage Treatment Plant
FWO	Future Water Options study
GAC	Granular Activated Carbon
GL/a	Gigalitres per annum
GV	Guideline value(s)
H_2O_2	Hydrogen Peroxide
ha	Hectare
HAA(s)	Haloacetic Acid(s)
HACCP	Hazard Analysis and Critical Control Point
HERO	High Efficiency Reverse Osmosis
HV	High voltage
km	Kilometre
kV	Kilovolt
kW	Kilowatt
LMWQCC	Lower Molonglo Water Quality Control Centre
LPHO	low pressure high output
LV	Low voltage
MBR	Membrane bioreactor
MBBR	Moving bed biological reactor
MCA	Multi Criteria Analysis
MF	Membrane filtration
MF/UF	micro filtration/ultra filtration
mg/L	Milligrams per litre
ML/d	Megalitres per day
ML/yr	Megalitres per year
MLR	Mixed liquor return
MW	Megawatt
N	Nitrogen
NCA	National Capital Authority
NDMA	N-nitrosodimethylamine
NHMRC	National Health and Medical Research Council
NO_3-N	Nitrate Nitrogen

Abbreviation	Description
NCWRS	North Canberra Water Reuse Scheme
NRC	National Research Council (USA)
NRMMC	National Resource Management Ministerial Council
ORP	Oxidation Reduction Potential
O_3	Ozone
P	Phosphorus
PAC	Powdered activated carbon
PCP(s)	Personal Care Products
pH	Measure of Acidity or Alkalinity
PHaC	Pharmaceutically Active Compounds
PMP	Pilot Monitoring Program
PPCP	Pharmaceutical and Personal Care Products
PS	Precipitative Softening
PSA	Pressure Swing Adsorption (As applies to ozone generation)
RAS	return activated sludge
RWQCB	Regional Water Quality Control Board
RNA	Ribonucleic Acid
RO	Reverse Osmosis
ROC	RO Concentrate
SAMP	Sampling and Monitoring Program
SCADA	Supervisory Control and Data Acquisition
SDWA	***Safe Water Drinking Act*** (2003), Victoria
SDWR	***Safe Water Drinking Regulation*** (2005), Victoria
SOC(s)	Synthetic organic compound
t	Tonnes
t/d	Tonnes per day
TDS	Total Dissolved Salts
TMP	Trans membrane pressure
TOC	Total Organic Carbon
UF	Ultrafiltration
USA	United States of America
USEPA	United States of America Environment Protection Agency
UV	Ultraviolet irradiation
VOC	Volatile Organic Compounds
VSEP	Vibratory Shear Enhanced Processing
WHO	World Health Organisation
WPP	Water Purification Plant

Abbreviation	Description
WSUD	Water sensitive urban design
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
yr	Year
ZLD	Zero liquid discharge

Executive Summary

Context and Purpose

Climate change predictions indicate that the climate would become more variable; droughts are likely to be longer and more severe, storms and flood events are likely to increase and temperatures would continue to rise. These conditions indicate that further investment in new infrastructure is required to address these changes in climate.

Since 2005, ACTEW has implemented a range of actions to increase the reliability of supply for Canberra. However, these measures would not provide sufficient water to ensure a safe, secure and sustainable water supply into the future under this more variable climate.

A significant factor to be considered is that if the recent climate is typical of the future it may be necessary to allow for worse drought events than previously considered and at worst, the possibility that we may have entered into a completely new climate pattern with greatly reduced long term rainfall averages[1]; as has happened in Perth and is now a real possibility here. The level of uncertainty with any prediction has greatly increased, which means that if a dam or dams are built, it may take many more years for them to fill.

Whilst such a scenario seems unlikely, it is a possibility and must be considered for future water security. Therefore, previous recommendations must be revisited and further investigations must look into options that are less reliant on rainfall. One of these options is to purify our used water.

This report therefore explores whether it is viable to treat water from Lower Molonglo Water Quality Control Centre (LMWQCC) to a very high level and then transfer the purified water through an environmental buffer for blending and storage with catchment water. Final treatment would be provided at the Stromlo Water Treatment Plant (Stromlo WTP) before distribution to Canberra and Queanbeyan.

The proposal to augment the Canberra water system with additional supply, is known as the Water Purification Scheme and includes; a Water Purification Plant (WPP), pump and pipeline infrastructure to carry the treated water to a newly constructed wetland above the Cotter reservoir and utilisation of the reservoir, which would be substantially enlarged, to store the water prior to use.

Regulatory Review and Best Practice

In order for a Water Purification Scheme to be considered, reviews of current legislation, policy and various approval process issues surrounding a project of this nature have been undertaken. Reviews include; the study of current national and international guidelines, regulations on drinking water, reclaimed water quality and experiences of similar water purification schemes around the world. Based on these findings, a comprehensive and rigorous water quality monitoring program which meets Australian and International best practice for indirect potable water use can be developed and implemented for this scheme.

[1] Even worse than assumed in previous modelling which adopted CSIRO predictions for reduced rainfall in the Canberra catchments in future due to climate change.

Water Purification Scheme

This study examines the most appropriate water treatment processes for water purification, the quality and quantity of LMWQCC feed water and the expected quality of product water to be produced by a Water Purification Plant for the Scheme. This report outlines an extensive water quality monitoring program which draws from Australian and International best practice.

The Water Purification Scheme recommended would provide highly treated purified water from the Water Purification Plant, which could be introduced through a wetland environmental buffer for temperature adjustment, prior to discharging into the Cotter Reservoir. The blended water source is then to be further treated and disinfected in the downstream Stromlo WTP.

The water purification technologies recommended for the Water Purification Plant are used internationally to enhance the final water quality discharged from conventional wastewater treatment processes. A multiple barrier approach is adopted to ensure that there is removal of any pathogens and chemicals of concern through a series of individual treatment process barriers. The treatment process selected would produce highly purified water which can augment the drinking water supply of Canberra.

An initial stage 25 ML/d Dual Membrane Water Purification Plant with membrane filtration and reverse osmosis has been identified based on; proven high quality drinking water produced, plant operational reliability and its salinity and nutrient removal capability prior to the Cotter Reservoir. If required the plant can be readily upgraded to a maximum capacity of 50 ML/d based on the existing flows at LMWQCC.

Waste brine produced by the Water Purification Plant, is to be directly discharged into the Murrumbidgee River for the 25 ML/d first stage. Water Purification Plant capacity above 25 ML/d would require other brine disposal methods, as higher salinity levels in the river could impact on the environment. Other brine disposal methods include; dewatering onsite and offsite, or discharge at the coast.

Scheme Development

The Water Purification Plant and associated infrastructure would require approximately three (3) hectares of land and a significant power supply. The plant would be best situated at the LMWQCC site with a pump station to pump purified water to an artificial wetland near the Cotter reservoir backwaters. A 10 km (approximate) pipeline is proposed to the wetlands location and is expected to follow the eastern and western sections of the Uriarra and Brindabella Road reserves to minimise construction access difficulties, environmental disturbances and river crossings.

The scheme can be programmed to produce purified water into the Cotter Reservoir at the earliest by March 2010, assuming a number of key milestones are met from September 2007.

Environment

Any instruction to proceed with the scheme would initiate extensive background studies to be commissioned, to address numerous technical questions as part of the approval process. Much of the necessary background work has not yet been completed for the water purification scheme and the scope of the studies cannot be completed until the concept design for the plant and pipeline is agreed upon. However, any studies conducted are expected to include issues such as; cultural heritage, aquatic flora and fauna, terrestrial flora and fauna, catchment and landscape analysis and social impacts.

Risk and Sustainability

It is considered that the public health risks associated with the use of the proposed technologies for the Water Purification Plant are acceptable as these technologies have been in use in other locations worldwide for an extended period without identifiable health impacts.

The scheme is more expensive option than others considered in the Water Security Project in both financial and energy (greenhouse gas production) terms, although the local environmental impact appears to be low.

Public Consultation

There has been considerable debate on this proposal since its announcement in January 2007. ACTEW has undertaken an extensive public consultation program from March to June 2007 as this proposal has been developed. The analysis of the community's response is that while a minority had considerable concerns, the majority of the community were positive about proceeding, provided ACTEW gave assurances that safeguards would be implemented.

Estimated Cost

The estimated project capital and operating costs are provided in the tables below. The operating costs assume the plant is in operation all of the time.

Table i - Capital Costs

Treatment Capacity	**Capital costs (AU$M)**		
	Water Purification Plant	**Pump Station and Pipeline**	**TOTAL**
25 ML/d	161	20	181
Additional 25 ML/d	92	1	93
Total 50 ML/d	253	21	274

Table ii - Operating and Maintenance Costs

Treatment Capacity	**Operating Costs (AU$M/yr)**		
	Water Purification Plant	**Pump Station and Pipeline**	**TOTAL**
25 ML/d	8.5	1.20	9.7
Additional 25 ML/d	12.4	1.10	13.5
Total 50 ML/d	20.9	2.30	23.2

Recommendations

The analysis has shown that safe drinking water can be produced by the Water Purification Scheme, however it is more expensive than other options, but less dependent on rainfall than most other options.

The ACT Government commissioned an Expert Panel on Health to consider the health aspects of the Water2WATER ***proposal. In addition, ACT Health, as the health regulator, is also considering this proposal. The Expert Panel on Health recently advised the ACT Government that the project could proceed as long as certain safeguards were implemented.***

ACTEW recommends that further detail investigation, design and analysis be undertaken to confirm the feasibility of the water purification plant.

1 Introduction

1.1 Background

1.1.1 Historical Water Security Planning

This report discusses a proposal to augment the Canberra water system with additional supply derived from the treatment of water produced by the Lower Molonglo Water Quality Control Centre (LMWQCC). The proposal is discussed in detail in this report. This proposal is known as the 'Water Purification Scheme'.

Water supply in Canberra is a complex matter and subject to changing circumstances. It is of interest to a broad spectrum of the community and for this reason ACTEW Corporation (ACTEW) has endeavored to make all the relevant research material and discussion papers generated during the development of this proposal available to the public[2] to ensure that debate and discussion is as fully informed as possible. An important aspect of this is an understanding of the genesis of this proposal which is discussed below.

The future water supply security for Canberra and the region has been a key matter of consideration for successive Governments. The boundary of the ACT was defined to ensure inclusion of the Cotter and Gudgenby catchments to provide the Territory with control of its water supply. More recently (1976), Googong Dam was constructed by the Commonwealth as demand outgrew the dam infrastructure on the Cotter River and, with agreement from NSW, its water was vested in the Territory. On the commencement of ACT self government in 1988, planning provision was made in the National Capital Plan and following from that the Territory Plan, for future dams at Tennent and Cotter. The situation was kept under review by ACTEW and its predecessors to ensure that the supply remained adequate to meet projected future needs.[3] As a consequence of all this, Canberra has had a water supply that has been more than adequate until recently.

1.1.2 Recycled Water Schemes in Canberra

ACTEW and the ACT Government have had an ongoing interest in the possibility of water recycling and a number of non-potable water recycling schemes are already in place.

Fyshwick Sewage Treatment Plant

The North Canberra Water Reuse Scheme (NCWRS) treats wastewater at the Fyshwick Sewage Treatment Plant (FSTP) before being pumped to the North Canberra Water Reuse Facility (NCWRF) for further treatment. Once fully treated, the water is pumped up to the Lower Russell reservoir for distribution.

From 1972 to 1999, treated wastewater from the FSTP was used to water the golf course and sports grounds at the Royal Military College, Duntroon. New treatment facilities (the Water Reuse Facility) were commissioned in 2004, using microfiltration to comply with the 1999 ACT Effluent Reuse Guidelines. Prior to connecting customers, an extended testing period was

[2] ACTEW reports are available on ACTEW Corporation web site: www.actew.com.au or by contacting ACTEW's Water Security hotline (02) 6248 3563.

[3] In the past prediction of new water source requirements was based closely on estimates of population growth. Before the drought and other impacts discussed above, it was estimated that a new water supply would be needed when the Canberra and Queanbeyan population reached 405,000 which was expected (based on Australian Bureau of Statistics data) in 2017. The total lead time for a new dam is about ten years, so serious investigatory work would not have needed to commence until 2007.

undertaken to guarantee high quality targets for the recycled water were met. The quality of the recycled water meets stringent environmental and public health requirements established by the Environment Protection Authority and ACT Health. After this testing, the scheme began delivering water for irrigation to seven sites, totaling 70 hectares across North Canberra.

Southwell Park

A small treatment plant at Southwell Park, supplies treated effluent for irrigation of 10 hectares of sporting fields. This process is known as ***Watermining®***. Wastewater is extracted from a sewer, treated and used for irrigation. The plant, commissioned in 1995, uses a combination of biological treatment and membrane filtration processes, coupled with disinfection, to satisfy the strict standards of the environmental and public health requirements established by the Environment Protection Authority (EPA) and ACT Health. Solids are returned to the sewer for further treatment at LMWQCC.

LMWQCC Effluent Reuse Scheme

A proportion of the wastewater treated at LMWQCC is supplied to nearby vineyards (100 hectares) and a golf course (30 hectares) for irrigation without requiring further treatment. This scheme has been in place since 1988.

1.1.3 Changing Times

Several new factors have now come into play, dramatically altering the water supply situation:

- a drought commenced in 2001 and has continued to the present which has been of unprecedented severity. By way of comparison, an ordinary severe drought would have ended in 2005. This current drought must now be considered to be the worst ever recorded;
- the January 2003 bushfires caused extensive damage to the Cotter River catchment, affecting the water quality with erosion runoff. As a result of the fire impacts on the catchment a treatment plant was constructed at Stromlo Water Treatment Plant (Stromlo WTP); and
- predictions of climate change are becoming increasingly apparent with the current drought opening up the possibility that the impact may be sooner and more severe than expected.

In response to these changing circumstances the ACT Government together with ACTEW has fostered an increasing community focus on the question of water security for the long term for the Territory. The impact of the current drought and the 2003 bushfires in particular, meant solutions that were considered likely to be required only in the long term, such as the enlarged Cotter and new Tennent Dam, needed to be reviewed for potential immediate implementation.

1.1.4 Think water, act water

Dams are a potentially costly infrastructure in both dollar and environmental terms and an early decision was made to review the dam options within a more holistic approach to the whole question of water supply and use. This generated the ***Think water, act water Strategy*** (ACT Government 2004). ***Think water, act water*** has six key objectives:

- provide a long term, reliable source of water for the ACT and region;
- increase the efficiency of water usage;

- promote development and implementation of an integrated regional approach to ACT/New South Wales cross border water supply and management;
- protect the water quality in ACT rivers, lakes and aquifers, to maintain and enhance environmental, amenity, recreational and designated use values and to protect the health of people in the ACT and down river;
- facilitate incorporation of water sensitive urban design (WSUD) principals into urban, commercial and industrial development; and
- promote and provide for community involvement and partnership in managing the ACT water resources strategy.

The strategy initiated the introduction of a range of water use management measures throughout Canberra that would reduce water consumption at a household, business and community level. Many of these measures are now in place and showing successful outcomes[4].

1.1.5 Options for the Next ACT Water Source

Work on the first of the above objectives related to a long term reliable water source for the ACT was carried forward by ACTEW. Taking the Cotter and Tennent dams as a starting point ACTEW reviewed all possible water storage options that could meet this objective. The results of this work were published in ***Options for the Next ACT Water Source*** (ACTEW 2004) to accompany the ***Think water, act water Strategy*** (ACT Government 2004).

The 2004 options paper canvassed nearly 30 possible alternatives for long term supply; eleven of these were subject to further analysis and then three were recommended for more detailed evaluation. The preferred water source options were:

- Enlarged Cotter Dam;
- Tennent Dam; and
- Sourcing water via Tantangara Dam.

Each of these included sub options, for example, smaller or larger versions of the dams and a virtual dam option for Tennent. A dedicated project Future Water Options (FWO) was initiated to determine based on these three options, the preferred approach to meet the ***Think water, act water*** objective which is to; '***Provide a long term reliable source of water for the ACT Region***.' Reports detailing the findings of the FWO project were published, (ACTEW 2005b-f).

1.1.6 Future Water Options

The outcome of the options study was that one scheme should proceed to detailed investigation and implementation in the short term and several others should be subject to further evaluation:

- the first recommendation of the FWO study was that the Angle Crossing option should proceed to implementation. This was a scheme for pumping water from the Murrumbidgee River at Angle Crossing to the Googong Reservoir, which currently has excess capacity;
- the second recommendation was that the enlarged Cotter Dam, the Tennent Dam and the option of transferring Tantangara Reservoir water down the Murrumbidgee River all be retained as future viable options; and

[4] It is estimated that, exclusive of the effect of water restrictions, demand has reduced by 10 – 15% at the household level – FWO review report 14 May 2007 draft, sec 3.2.

- the third recommendation was that a more detailed technical assessment on the dam options should proceed.

1.1.7 The Cotter to Googong Bulk Transfer

Investigations for the Angle Crossing option confirmed the availability of excess storage capacity at Googong. This opened up a possibility that had not been previously considered; the concept of transferring excess water from the Cotter catchment to storage in Googong Reservoir.

On average some 29 GL of water spills from Bendora and Cotter Reservoirs each year. The scheme that is now known as the Cotter to Googong Bulk Transfer involves capturing a proportion of these spills, transferring it via Canberra's existing water mains and storing it in Googong Reservoir[5]. Modeling at the time suggested that about 12 GL of water could be obtained each year by this method at a low capital cost (about $20 million) and importantly, it could be implemented within 12 months. A decision was made to proceed with this scheme and it has proven to be very effective with 12 GL being transferred to the end of June 2007.

The effectiveness of this scheme was equivalent to the Angle Crossing option and because it was about half the cost and could be implemented with no delay it was clearly the preferred approach.

1.1.8 Drought Contingency Scheme

As work on the FWO was progressing, ACTEW continued to monitor the overall water supply situation and came to the view that, as the drought was persisting, some contingency measures may be required, noting that any of the major options would take, at best, several years to implement.

Use of water from the Murrumbidgee River and the existing Cotter Dam, which had not been used for some years due to quality issues, was now possible because of the construction of the new Stromlo Water Treatment Plant (Stromlo WTP), which had become necessary following the bushfire impacts on water quality in the upper Cotter catchment. A drought contingency scheme was put in place involving refurbishment of the Cotter Pumping Station (CPS), assessment of the condition of pipe connections to the existing Cotter Dam and the installation of a pump station in the Murrumbidgee River to feed river water into the CPS[6]. The contingency scheme was not a solution to the larger water supply question because the volume of supply available from the existing Cotter Reservoir is small and the use of water from the Murrumbidgee is constrained by the quality of the river water and capacity to treat this water at Stromlo WTP.

The introduction of the Stromlo WTP, including an ultraviolet irradiation (UV) disinfection process to inactivate pathogens, would when completed in late 2007, allow greater volumes of Murrumbidgee River water, extracted at the Cotter Pump Station, to be feed directly into the water supply pipe network via Stromlo WTP. Pumping of water from the Murrumbidgee River is proceeding at present in the absence of the UV system under strict operating rules agreed with ACT Health.

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[5] The fact that Googong Reservoir is at a lower level than Bendora means that this is essentially a gravity system however supplementary pumps have been installed to boost capacity. Because the water passes through the Canberra pipe system it must be treated so it is put through the Stromlo treatment plant; a bypass pipe has been installed to allow it to flow around the Googong plant and into the reservoir.

[6] Use of Murrumbidgee River water and water from the existing Cotter Dam which had not previously been used was now possible because of the construction of the Stromlo Water Treatment Plant, which was necessary following the bushfire impacts on water quality in the upper Cotter catchment.

The drought contingency pumping facilities have the capacity to further improve the transfer concept and deliver water from the Murrumbidgee River to Googong Reservoir.

The Angle Crossing project is still considered a viable option and is further detailed in the Angle Crossing Option Project Plan (Atechgroup 2007).

1.1.9 Water Security in 2005

The process described above, although complex, has led to the implementation of measures based on information available in mid 2005, which was to provide water security through to the year 2023, with the intent to continue with technical investigations for a future dam, which would need to be implemented at around that time.

A key expectation at the time was that the drought, which by then had reached almost worst ever status, would end soon. However, this has not been the case and work has continued on the exploration of options for the future.

1.1.10 Water Security in 2007

A significant new factor to be considered is that if the current drought continues, there would be a requirement for future predictions to allow for worse drought events than previously considered and at worst, the possibility that we may have entered into a completely new or modified climate pattern with greatly reduced long term rainfall averages,[7] as has happened in Perth and is now a real possibility here. The level of uncertainty with any prediction has greatly increased, which means that if a dam or dams are built, it may take many more years for them to fill.

Whilst such a scenario seems unlikely, it is a possibility and must be considered in our future water security. Therefore, FWO recommendations must be revisited and future investigations must look at options that are less reliant on rainfall. One of these is the reuse of treated wastewater, which is the subject of this report.

A second alternative is desalination of seawater and piping it to Canberra. This option has been examined and reported in GHD 2007. As may be expected it was found to be costly and less viable in comparison with a Water Purification Scheme. It has not been further considered.

The third alternative is to source water via Tantangara Reservoir. This is described in ACTEW 2005c.

1.1.11 The Cotter Dam and the Water Purification Scheme Proposal

The FWO report recommended that work should be initiated on both the Cotter and Tennent dams. Over the past two years, work has been progressing on defining key environmental and planning issues related these two dam construction projects, with a focus on the enlargement of the Cotter Dam, which was identified as the preferred site in 2005.

The Water Purification Scheme proposal would ideally be located at LMWQCC and would require an associated water storage facility. Preliminary work has established that the Cotter Reservoir would be suitable. Whilst enlargement of the Cotter Dam appears to be necessary for the Water Purification Scheme, it is independent of it and the possibility exists for the enlargement of the dam to proceed with or without the Water Purification Scheme.

[7] Even worse than assumed in previous modelling which adopted CSIRO predictions for reduced rainfall in the Canberra catchments in future due to climate change.

The implementation of the Water Purification Scheme is fully explored in this report and supporting documents.

1.2 Public Consultation

ACTEW has undertaken an extensive public engagement program from 22 March 2007 to 22 June 2007, as this proposal has been developed. The outcomes of the public consultation are recorded in a separate report and the issues raised are discussed in detail in that report (Manidis Roberts 2007).

The ACT Government requested ACTEW to undertake a community consultation program whilst technical studies for securing the ACT's water supply were completed. The consultation program was limited to a focus on the ACT and Queanbeyan communities' views and issues related to the Water Purification Scheme and the enlargement of the Cotter Dam.

ACTEW collected views through surveys, the Water***2WATER*** Project Office, community meetings and forums, stakeholder meetings, local events and shopping centre displays and via the Water***2WATER*** website.

More than 3,300 direct contacts were made with the Water***2WATER*** project during the consultation period. In addition, ACTEW reached the wider community through advertising, the Water***2WATER*** website and media coverage of Water***2WATER***.

During the community consultation program, six key issue areas emerged, each containing a number of sub issues. These issues have been individually analysed, categorised and allocated to the community consultation tools where they were identified.

The two primary issues identified were; health and planning/other options and the secondary issues identified were; cost, environment, quality assurance and government transparency.

The ACT Government established an Expert Panel on Health, which was briefed on the community consultation strategy and was an observer at key activities such as the community forums and community briefings.

The following are key outcomes of the consultation:

- the majority of people surveyed were positive or conditionally positive about the project. Where they had concerns, these were about health aspects and a desire to see better planning for water security in the ACT;
- there is not widespread community opposition to the Water***2WATER*** proposal;
- there are some individuals and groups (665 people), particularly those actively involved through community forums, the online survey, telephone, email and mail, who expressed significant dissatisfaction with the water purification component of the Water***2WATER*** proposal. Their major issues were:
  - health with a focus on removal of drugs and hormones;
  - investigation and communication of all water supply/security options;
  - environmental factors, particularly energy usage;
  - cost to the end user;
  - quality assurance/monitoring; and
  - community confidence in ACT Government and ACTEW.

- a significant number of individuals and groups (2548 people), typically those who were passively involved through community and stakeholder briefings, shopping centre displays and events, were conditionally supportive of the Water***2WATER*** proposal. Where they had concerns, these were similar to the smaller group; and
- there are no significant differences between the ACT and Queanbeyan communities' attitudes toward the ***Water2WATER*** proposal.

It is concluded that the community appears to be open to the Water***2WATER*** project proceeding, provided the following conditions are met:

- ensuring an adequate response to the six major issues raised during the consultation; and
- ensuring that a robust consultation process is a core function of any future planning and approvals process and includes all stakeholder groups.

2 Regulatory & Strategic Context

This section outlines the legislative and planning context relating to development of a water purification scheme and considers the different planning jurisdictions which would impact on the scheme.

It also considers the context for water quality regulation for a water purification plant and the appropriate water quality management and monitoring framework for the Water Purification Scheme.

2.1 ACT Legislation and Policy

Currently all development in the ACT is controlled under the Land (Planning and Environment) Act 1991. This is soon to be superseded by new legislation. The Planning and Development Bill was introduced to the ACT Legislative Assembly in December 2006.

The Planning Authority is currently working on new legislation which means that the proposals that are the subject of this report may be dealt with under the new legislation. For the purposes of this report, it is therefore assumed that the new legislation is in place and in line with the provisions in the Bill.

Associated with the new Act are a series of schedules and regulations that have not yet been drafted or made public. The approval process and related legislation is described below.

2.2 Commonwealth Legislation and Policy

2.2.1 Commonwealth planning legislation and policy

The National Capital Plan[8] (NCP) controls the management and future development of land in the Territory; the Territory Plan, which is given effect by the Land Act, must be consistent with the NCP (National Capital Authority 1988). The NCP makes specific provision by way of a Policy Plan for development in the Murrumbidgee River Corridor. The coverage of the policy plan includes the LMWQCC site and designates it for Public Utility use. A public utility is defined in the NCP and includes:

"Headwork and network undertakings for the provision of sewerage and drainage services or the reticulation of water, electricity, or gas except for gas manufacture and storage.;"

It is concluded that the Water Purification Scheme proposal is in accord with the provisions of the NCP. The pipeline alignment would cross the Murrumbidgee corridor and this aspect would require the approval of the National Capital Authority (NCA).

2.2.2 Commonwealth environmental legislation and policy

Under the environmental assessment provisions of the (Commonwealth) ***Environment Protection and Biodiversity Conservation (EPBC) Act*** 1999, actions that are likely to have a significant impact on a matter of national environmental significance are subject to a rigorous assessment and approval process. An action includes a project, development, undertaking,

[8] The Australian Capital Territory ***(Planning and Land Management) Act*** 1988 established the National Capital Authority and National Capital Plan, which sets out special requirements for development in selected areas.

activity, or series of activities. The Act identifies seven matters of national environmental significance, one of which is nationally listed threatened species and ecological communities.

The Pink-tailed Worm Lizard (***Aprasia parapulchella)*** is listed as a vulnerable species under the EPBC Act 1999 and so the provisions of that Act are expected to apply. The Water Purification Scheme proposal would require approval from the Commonwealth Environment Minister as it may have a significant impact on ***A. parapulchella*** and consideration would also have to be given to the possible impact on endangered fish species in the Cotter Reservoir. The potential for impact on the fish exists whether or not the dam is enlarged because the purified water would pass through the Cotter Reservoir in either case. Due to factors such as temperature fluctuation the fish may be affected.

Surveys of the pipeline alignment and proposed wetland site would be required to determine the existence of any species or ecological communities that may trigger the requirements of the EPBC Act.

The types of impacts that would trigger a referral include:

- long term reduction in the size of a population;
- fragmentation of the habitat of an existing population;
- disruption to the breeding cycle of a population;
- modification, destruction, removal, isolation or reduction of the availability or quality of habitat to the extent that the species is likely to decline;
- an invasive species directly effecting a threatened species, or indirectly effecting a threatened species by becoming established in their habitat; and
- interference with the recovery of a threatened species.

It is assumed that the Federal Minister would rely upon the Environmental Impact Statement (EIS) under the ACT legislation to address any issues.

2.2.3 Commonwealth heritage legislation and policy

The ***Australian Heritage Council Act*** 2003 has replaced the ***Australian Heritage Commission Act*** 1975. The Murrumbidgee River Corridor within the ACT and specific features within it (for example, the Cotter Pumping Station) are entered in the Register of the National Estate pursuant to this legislation. Such places or sites cannot be damaged unless there are no feasible or prudent alternatives and Australian Heritage Council advice must be sought before any action that might affect such areas is taken. The Water Purification Scheme proposal and the associated pipeline across the Molonglo and Murrumbidgee rivers would require clearance under this legislation prior to proceeding.

2.3 NSW legislation and policy

An aspect of the water purification process could be the need to dispose of brine (salt solution), which would be a by product of the purification process. Alternatives include; disposal to the river, crystallisation and transport of dried salt by road to a land fill disposal; possibly at the Woodlawn Bioreactor facility at Tarago in NSW or the construction of a pipeline from the ACT to the NSW coast for the transport of brine to ocean disposal. It is assumed that the land fill option would come within the existing environmental licensing arrangements for the land fill facility at Woodlawn. The pipeline would be subject to NSW planning and environmental legislation.

The ***Environmental Planning and Assessment Act*** 1979 established the development assessment system for NSW. Any major water infrastructure project may be a designated development or an integrated development requiring approval under multiple enactments. It is likely that the pipeline would be classified as an integrated development (Part 4 of the Act).

Procedures for environmental impact assessment are mandated where a proposal is likely to significantly affect the environment (Part 5 of the Act).

Infrastructure or disposal options that potentially impact the environment in both NSW and the ACT may have to proceed in an integrated and concurrent manner under a formal NSW/ACT agreement covering integrated environmental assessment.

The ***Protection of the Environment Operations Act*** 1997, allocates responsibilities between the (NSW) Environment Protection Authority (EPA), local councils and other public authorities, authorises Protection of the Environment Policies and establishes licences for activities that may impact the environment. Appropriate licences for any pipeline would be required.

All of the above legislation is administered at a State Government level and indeed a pipeline proposal may be declared a project of state significance, putting the development approval in state rather than local government hands. It would nevertheless be essential that consultation and discussion is held with the local Government Authorities (the Queanbeyan City Council and Palerang and Eurobodalla Shires) prior to and during the further development of a firm proposal.

2.4 ACT Approvals Processes

The approval process for the Water Purification Scheme project is discussed below. The discussion assumes approval under the proposed new Planning and Development Act.

Development Applications under the new Act would be assessed in one of three streams; Code, Merit or Impact.

The Impact Track applies to proposals that:

- are listed in a Development Table in the Territory Plan as requiring impact assessment (not yet publicly available);
- would trigger an EIS (Schedule 4, includes a major dam and any proposal with the potential to have a significant impact on a domestic water supply catchment or a water use purpose mentioned in the Territory Plan),;
- are not foreseen in the Development Table (unusual projects such as Water Purification Scheme would probably be in this category); or
- the Planning Minister or the Minister for Public Health make a declaration that the Impact Track applies.

Based on this, it is almost certain that both the enlargement of the Cotter Dam and the Water Security Program projects would be assessed under the Impact Track.

All projects assessed under the Impact Track require an EIS (s126), unless specifically exempted by the Minister. It is considered that due to the nature of the Water Security Program projects and the recognised potential for some impact on the environment, that the Minister would be unlikely to grant exemption for the project.

2.4.1 Environmental Impact Statement

An EIS would be prepared by the proponent in response to a scoping document that would be prepared by the Planning Authority.

The scoping document would be prepared by the Planning Authority in consultation with interested parties. A regulation would be written when the new Act is promulgated to define the interested parties, it is expected to include relevant community groups.

Further public consultation is required when the Draft EIS is presented.

Many of the component steps of the EIS process have statutory timeframes. These may be extended by the Chief Planner or the Minister if the project is particularly sensitive or complex in nature. There are also many critical steps that do not have timeframes assigned to them, making it difficult to estimate the total time for the process.

The Water Security Program projects (Enlargement of Cotter Dam and Water Purification Scheme) would also be, in all likelihood, the first projects to trigger an EIS under the new Act, which would make them test cases for the process. This may have a negative effect on timing if unforeseen issues arise.

2.4.2 Varying the Territory Plan

The introduction of the new Planning and Development Act would be accompanied by a rewritten Territory Plan. It is intended that the new Territory Plan would maintain the existing allowable uses on all land within the Territory.

Consideration of the Water Purification Scheme project indicates that a variation may be required to Appendix 1 of the Territory Plan. Within the Water Supply Catchment policies, ***Discharge – treated wastewater*** is not currently listed in Schedule 3 which applies to the Cotter River catchment. Schedule 4, which applies to the catchment between Bendora Dam and the Cotter Reservoir, also needs to be modified to list ***Discharge – treated wastewater*** as an allowable activity.

In the Protection of Water Quality policies under part 2.2 of Appendix 1, the statement “c) discharge of wastewater shall not be permitted within the catchment;” needs to be removed or alternatively the term wastewater needs to be defined to exclude the water output from a Water Purification Scheme project, which is clearly not wastewater.

This assessment is based on the assumption that the treated water from the Water Purification Plant is still considered to be treated wastewater. This may depend upon the location of the off-take from LMWQCC into the water purification process. If Water Purification Plant drew water from downstream in the Molonglo River, it may not be considered to be treated wastewater.

The Territory Plan is silent on the issue of discharging water treated to potable standards into the water supply catchment.

The plan variation process could be run in parallel with the EIS. The statutory timeframes for plan variations indicate that the variation should not be on the critical path, although coordination of the timing would need to be carefully managed.

2.4.3 Development Application

The lodging of a Development Application under the new Act is similar to the existing process. For the Water Security Program projects, a completed EIS would have to accompany the application. The EIS would provide the bulk of the documentation necessary for the assessment of the application.

The total time for approval should be no more than 45 days which is the statutory limit and a possible extension of 20 days if additional information is required.

Longer periods may be required for a project such as the Water Purification Scheme as it can be complex and sensitive.

2.4.4 Other ACT Approvals

Any Development Application (DA) in the impact track would be referred to the Environment and Heritage Unit (Department of Territory and Municipal Services), the Conservator of Flora and Fauna, ACT Health, Emergency Services Authority and ActewAGL.[9]

In addition, applications that may affect a place listed on the Heritage Register would be referred to the Heritage Council and applications on unleased land would be referred to the land custodian. It is not anticipated that the Water Purification Scheme proposal would require referral to the Heritage unit; the pipeline component may traverse unleased land and may require referral to the land custodian.

This highlights the importance of engaging with these entities during the EIS scoping study to identify their requirements and ensures the draft EIS addresses the necessary issues. This would ensure that the DA assessment process runs smoothly and that related licenses and permissions are issued and construction can commence without undue delay.

2.4.5 Approval Timeframe

The approval timeframe for this project has been addressed in CB Richard Ellis 2007. A standardised approval timeframe allows for tasks to be sequential. In particular the environmental assessment process precedes the development approval process which is then run in parallel with the territory plan variation if required and Commonwealth approval processes. This mirrors the apparent intent of the proposed legislation. It is possible that regulations under the Act would modify these processes and allow for some elements to be processed in parallel as is currently the case where a DA can be processed in parallel with a plan variation. If some risk of abortive work is accepted then work streams can be undertaken in parallel with the possibility of achieving a saving of approximately 12 months on the total elapsed time. Under this scenario all environmental and planning approvals could be in place by mid 2008.

If a further decision were taken to bring forward the design of the facility to also parallel the approval process, then the prospect exists of construction commencing immediately on receipt of approvals, i.e. in mid 2008.

The Government may wish to consider the introduction of special purpose legislation to assist with the implementation of the project. The legislation would recognise the benefits of the project to the community, assist with the necessary assessments and streamline the approval processes.

[9] All major development proposals are referred to all agencies as a matter of course and a statutory requirement; clearly in this case the referral to ActewAGL would be a formality.

2.5 Water Quality Regulation Review

This section reviews Australian and international drinking water quality regulation and provides comment on how indirect potable recycling plants are regulated around the world. Key domestic and international drinking water regulations were sourced and reviewed in light of:

- whether the regulation specifically refers to indirect potable reuse;
- whether the regulation specifically refers to indirect potable reuse plants; and
- whether there were any other salient points of note in the regulation.

Australian legislation, specifically ACT, Victoria and Queensland, was reviewed. Currently, the only jurisdiction, which has a specific drinking water Act in place, is Victoria.

2.5.1 Australian Capital Territory

The supply of drinking water in the ACT is declared a Licensable Public Health Risk Activity under the ***Public Health Act 1997***. Operators of water systems (water utilities) are required to obtain a licence under the Public Health Act and that licence may include standard conditions. The licence holder is required to comply with the ***Public Health (Drinking Water) Code of Practice*** (2007).

ACTEW is licensed under the Utilities Act to provide water supply utility services within the ACT. It is also licensed under the Public Health Act to provide drinking water utility services.

ACTEW is a Territory Owned Corporation and is established under the ***Territory Owned Corporation Act*** 1999. ACTEW's legal and policy obligations are summarised below:

- decision making should be based on the triple bottom line;
- provision of water management should follow ecologically sustainable development principles; and
- the reduction of pollution at source (in relation to aquifers and waterways, to restore damage where possible) should be promoted; and protection of waterways and aquifers from damage should be promoted including the limitation of other uses in catchments if those uses are likely to compromise the role of the catchment in the provision of water supply.

The key ACT instruments of relevance to ACTEW in terms of protecting water supply and catchments are:

- ***Land (Planning and Environment) Act*** (1991) (encompassing the Territory Plan as a statutory instrument);
- ***Environment Protection Act*** (1997);
- ***Public Health Act*** (1997):
  - Public Health (Drinking Water) Code of Practice No. 1 (ACT Health, 2007);
  - ACTEW Corporation Drinking Water Utility Licence issued by ACT Health under the ***Public Health Act*** 1997 and required under the ***Utilities Act*** 2000 (s. 21).
- ***Water Resources Act*** (1998);
- ***Utilities Act*** (2000);
- Utilities Services Licence (2002); and

- ***Water and Sewerage Act*** (2000).

In addition, a Utilities Management Agreement exists between ActewAGL and ACTEW Corporation. The Water Division of ActewAGL provides services to Canberra and Queanbeyan (bulk water only), for the management of water supply and sewerage assets owned by ACTEW under this agreement.

No specific regulation exists within the ACT for developing and operating a Water Purification Plant which would return purified water back to the Canberra drinking water supply. It is anticipated that this activity would be deemed to be a public health risk activity as defined under the Public Health Act 1997 and regulated via an amended ***Public Health (Drinking Water) Code of Practice*** or a separate but similar code.

2.5.2 Victoria

Victoria has a ***Safe Drinking Water Act*** (2003) (SDWA) and ***Safe Drinking Water Regulations*** (2005) (SDWR). The SDWA became effective as of 1 July 2004. It incorporates:

- a risk management framework from catchment to tap; and
- a set of standards for water quality criteria.

In outline the SDWA requires:

- water suppliers and water storage managers to prepare and implement plans to manage risks in relation to drinking water and some types of non-potable water;
- auditing of those plans by approved auditors;
- water suppliers to ensure that the drinking water they supply meets quality standards specified by the regulations;
- water suppliers to disclose to the public information concerning the quality of drinking water;
- variation, after community consultation, of water quality standards that relate only to aesthetic factors; and
- the reporting of known or suspected contamination of drinking water to the Secretary to the Department of Human Services noting that the Act empowers the Secretary to enforce the Act.

The Victorian SDWR became effective as of 19 July 2005 and incorporates:

- a requirement to develop a risk management plan;
- a requirement that the risk management plan be audited; and
- a set of water quality standards including testing and reporting requirements.

2.5.3 Queensland

Queensland is instigating a Water Purification Scheme in their state. Water will pass through several multiple barriers before it is abstracted from the environment and treated at a water treatment plant. The barriers that will be used in Queensland's Western Corridor Recycled Water Project are:

- source control;
- wastewater treatment plant;

- microfiltration;
- reverse osmosis;
- disinfection and advanced oxidation;
- natural environment; and
- water treatment plant.

A new regulatory regime is being established to govern the scheme and to ensure strict health and safety standards. The regulatory regime will be reviewed and have input from an Expert Advisory Panel.

The regulator for the new regime will be the Department of Natural Resources and Water and is likely to involve a hazard analysis and critical control point (HACCP) type management approach for the whole of the water supply chain including sewer catchment, sewage treatment, water recycling plant, raw water storage transfer and water treatment plant.

2.6 Water Quality Standards and Guidelines

As part of this Water Purification Scheme a comprehensive and rigorous water quality monitoring program which meets Australian and international best practice for indirect potable water use is to be developed and implemented.

This water quality monitoring program is to be used for:

- the initial scoping of the feed water quality to the new advanced water purification plant for preliminary and detailed design;
- the assessment of potential public health and environmental risks associated with the water produced by the facility;
- the performance monitoring of demonstration (pilot) plants to be used for process selection and the selection of key process equipment and equipment suppliers;
- demonstrating the performance and integrity of the full scale water purification plant against the licence issued for the facility by ACT Health under the ***Public Health Act 1997*** and under the HACCP system to be developed for the wastewater network;
- determining the impact of the water from the advanced Water Purification Plant on the water quality in the Cotter Reservoir and in the Canberra drinking water supply system; and
- determining any potential impact of the water from the advanced Water Purification Plant on the water quality delivered from the Stromlo WTP.

This section reviews the current national and international guidelines and regulations on drinking water quality and reclaimed water quality and documents the experiences of similar water purification facilities around the world (Ecowise 2007b).

This review also considers water quality monitoring programs implemented at a number of international water purification facilities and data gathered by these programs and have been used as the basis for developing the initial monitoring program for the ACT.

2.6.1 Australia

In terms of drinking water quality, there are three main guiding documents:

- the Australian Drinking Water Guidelines (NHMRC and NRMMC 2004) (ADWG);
- the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (NRMMC, EPHC and AHMC, 2006); and
- the draft Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies (NRMMC, EPHC and AHMC, 2007) (AGWR).

Individual states and territories have guidelines for using recycled water for non potable purposes and they are:

- ACT Wastewater Reuse for Irrigation – environment protection policy (Urban Services, 1999);
- NSW Guidelines for Urban and Residential Use of Reclaimed Water (NSW Government, 1993);
- Queensland Water Recycling Guidelines (QLD EPA, 2005);
- SA Reclaimed Water Guidelines – Treated Effluent (SA Department of Human Services and EPA SA, 1999);
- Environmental Guidelines for the Use of Recycled Water in Tasmania (Tasmania Department of Primary Industries, Water & Environment, 2002); and
- Guidelines for Environmental Management – Use of Reclaimed Water (EPA VIC, 2003).

However, the guidelines for ACT, NSW and SA specifically exclude direct or indirect potable reuse and the other guidelines only make brief comments as to how direct or indirect potable reuse schemes should be handled.

2.6.2 United States of America

The ***Guidelines for Water Reuse*** (The United States Environmental Protection Agency 1992, updated in 2004) summarises the regulations and guidelines available from various states in America. The types of reuse currently practiced in America are:

- unrestricted urban (i.e. irrigation, toilet flushing, fire protection, construction, landscaping and street cleaning);
- restricted urban;
- agriculture (food and non food crops);
- unrestricted recreational;
- restricted recreational; and
- environmental (wetlands).

Only four states in America have regulations or guidelines pertaining to indirect potable reuse.

2.6.3 World Health Organisation

The World Health Organisation (WHO) has guidelines for drinking water quality and the safe use of wastewater, excreta and greywater for use in aquaculture and agriculture. WHO has also commissioned a report on the health risk of aquifer recharge using reclaimed water.

The ***Guidelines for Drinking-Water Quality*** (WHO, 2006) (WHO Guidelines) uses a framework of health based targets and water safety plans (developed by applying the risk management process) to ensure water supply is safe for consumption.

The setting of the health based targets can be conducted by various means depending on the type of target being assessed.

2.6.4 Singapore

Singapore has a number of Water Purification Plants, producing water to augment their potable water supplies, which have been in operation since May 2000. However, no national guidelines on indirect potable reuse are in place.

Singapore has adopted the WHO Guidelines as the Singapore water quality standards for the interim. The Public Utilities Board (PUB), as the municipal supplier of drinking water, has set its own internal product water quality which is above the WHO Guidelines.

A Technical Committee has recently been formed to develop a set of National Drinking Water Quality Standards for subsequent adoption by the National Environment Agency.

2.6.5 Africa

Namibia has had a direct potable treatment plant since 1968 and a new, larger reclamation plant was put into operation in 2002 (Goreangab Reclamation Plant). The new plant is utilising the WHO Guidelines, the Rand Water Guidelines and the Namibian Guidelines for Group A Water (NamWater, 1998).

2.6.6 Japan

Water recycling in Japan has been limited to non potable applications including:

- toilet flushing;
- environmental water;
- agricultural irrigation;
- snow melting;
- industrial water;
- cleansing water;
- cooling water;
- dilution water;
- tree planting; and
- dust control on construction site.

No information on Japan's management of Water Purification Schemes could be identified. Ogoshi et al. (2001, p. 21) stated that:

"***Although there have been no uniformly enforceable national water quality standards for wastewater and reuse, various Japanese ministries have established applicable reclaimed water quality criteria for toilet flushing, landscape irrigation and environmental water".***

2.6.7 Europe

Currently, there are no supra national (i.e. EU) regulations on water reuse in Europe and there is a lack of widely accepted standards in terms of required water quality, treatment technology and distribution system design and operation. However, several member states or autonomous regions have now published their own standards or regulations.

2.7 Water Quality Monitoring Programs for similar Water Purification Facilities

2.7.1 Comparable International Facilities

There are now a number of water supply systems in place worldwide that utilise a component of recycled water either directly or indirectly, some of which are listed below (see Ecowise Environmental 2007b for further details):

- NEWater Facilities in Singapore;
- Upper Occoquan Sewage Authority Water Reclamation Plant, Fairfax County, Virginia, USA;
- Clayton County Water Authority Land Application System and Wetlands, Georgia, USA;
- Chelmer Augmentation Wastewater Reuse Scheme, Essex, England, UK;
- Hueco Bolson Recharge Project, El Paso, Texas, USA;
- Montebello Forebay Groundwater Recharge Project, California, USA;
- New Goreangab Water Reclamation Plant, Windhoek, Namibia;
- Scottsdale Water Campus, Scottsdale, Arizona, USA;
- F. Wayne Hill Water Resource Center, Lawrenceville, Georgia, USA;
- West Basin Water Recycling Program, El Segundo, California, USA;
- Wulpen, Belgium; and
- Orange County, California, USA Groundwater Replenishment System (incorporating the former Water Factory 21, now demolished).

In order to review water quality monitoring programs for indirect potable reuse facilities ACTEW received information on monitoring programs being used at similar facilities within Australia and overseas. Specifically, data was received from:

- Public Utilities Board of Singapore;
- Windhoek City Council, Windhoek, Namibia;
- Gwinnett County Department of Public Utilities, Lawrenceville, GA, USA;
- Clayton County Water Authority, Morrow, GA, USA;
- Upper Occoquan Sewage Authority, Centreville, VA, USA; and
- West Basin Municipal Water District, Carson CA, USA.
- Orange County Water District, Fountain Valley, CA, USA;

Brief details on these facilities are set out below.

Public Utilities Board of Singapore

Treated water from the plant is discharged to a reservoir which is the source water for a water treatment plant. The adopted treatment train is microfiltration, reverse osmosis and ultraviolet disinfection.

Windhoek City Council, Windhoek, Namibia

Treated water from the plant is discharged to a reservoir that is source water for a water treatment plant. The adopted treatment train includes ozonation, dissolved air flotation, sand filtration, biologically active carbon, granular activated carbon, ultrafiltration and chlorination.

Gwinnett County Department of Public Utilities, Lawrenceville, GA, USA

Secondary treated wastewater is passed through a microfiltration system followed by granular activated carbon absorption and ozonation before release to the Chattahoochee River. In the near future it is planned to release water to Lake Lanier. Both the river and the lake are current drinking water supply sources.

Clayton County Water Authority, Morrow, GA, USA

Secondary treated wastewater from an extended aeration plant is part discharged to land for land-filtration and part discharged to wetlands. Water then enters a reservoir which is the source water for a water treatment plant.

Upper Occoquan Sewage Authority, Centreville, VA, USA

The plant discharges to the Occoquan River, upstream of a water supply reservoir which is the source water for a water treatment plant. The adopted treatment train is lime precipitation softening, two stage recarbonation, granular media filtration, granular activated carbon, chlorination and dechlorination.

West Basin Municipal Water District, Carson CA, USA

The plant discharges water to groundwater (to combat seawater intrusion), with some used directly by commerce and industry for non potable uses. The plant is designed to produce multiple grades of water for five separate uses. Treatment process trains of interest are; microfiltration, reverse osmosis (single and dual pass) and advanced oxidation using ultraviolet/ hydrogen peroxide to produce reverse osmosis (RO) Water and ultra pure RO Water.

Orange County Water District, Fountain Valley, CA, USA

The original plant (Interim Water Factory 21) discharged to groundwater with some used directly for landscape irrigation. The adopted treatment train for the new facility, Ground Water Replenishment Scheme is; microfiltration, reverse osmosis and advanced oxidation using ultraviolet and hydrogen peroxide. This plant is currently under reconstruction and due to be commissioned in late 2007.

2.7.2 Sampling Regimes at Comparable Facilities

2.7.2.1 Monitoring Regimes and Water Quality Parameters

All international facilities discussed in Section 2.7.1 have sampling regimes in place to enable monitoring of source and product water, for assessment against the relevant standards.

Sampling information relating to these facilities was only provided for locations directly associated with the advanced water treatment (potable reuse) train. In all cases the wastewater is pre treated to secondary, advanced secondary or tertiary levels before being used as a feedstock for the potable reuse treatment train.

The sampling regimes assessed, apply to the immediate feed water to the water purification treatment train and the product water leaving the plant. Water purification treatment trains have monitoring programs for water quality within the various process units employed, however this information is currently only available for Singapore's NEWater water purification plant and Namibia's New Goreangab Reclamation Plant.

The NEWater water purification plant in Singapore monitors water quality parameters prior to and following, the microfiltration and the reverse osmosis processes.

The New Goreangab Reclamation Plant monitors water quality following the dissolved air flotation, sand filtration, ozonation, biologically active carbon, granular activated carbon and membrane processes.

Based on the information currently to hand there appears to be some differences in the sampling and monitoring programs adopted by each authority.

The most significant difference observed in current data is;, the variability in the degree to which the feed water is monitored between various agencies.

With only a few minor exceptions, Singapore monitors the same analytes in the feed water as they do in the product water, albeit on a generally lower frequency.

A general trend observed from the other data currently available is that more analytes are monitored in the product water than the feed water and where both are monitored, the monitoring frequency is often greater for the product water.

The product water analytes monitored by Singapore, Orange County and Namibia vary considerably.

The sampling frequency for the schemes for which data is currently available (Orange County, Singapore and Namibia) were examined and compared. For many analytes it was noted that Singapore monitors more frequently than Orange County.

The analytical limits of detection are currently only available for the Public Utilities Board's Singapore plants and the Orange County plant.

The findings of the Singapore Expert Review Panel, commenting on the operation of the Singapore plant noted that:

"Owing to the extremely low concentrations of various parameters present in the NEWater and/or limitations of the analytical technique, an absolute value thus could not be determined. In fact, the majority of the NEWater test results are below the detection limit. This is also known as not detectable (ND) and is reported at the "estimated quantitation limit" or EQL, which is the lowest practical reportable concentration within a specified confidence limit.

For the NEWater Study we have adopted the following approach: If the number of non-detectable results is more than 50% of the number of test results, the mean is not calculated because the result would not be meaningful. In such cases, the mean is stated as "Not Calculated" or "NC".

If the number of detectable results is more than 50% of the number of test results, the mean is computed using the detected values plus the detection limit for the non-detectable results. A mean will not be computed if the number of test results is fewer than seven. Some of the newer tests may fall into this category.

It should be noted that this method of handling non-detectable data will tend to slightly overestimate the arithmetic mean. It is necessary to stress that the lowest or more stringent of either the current USEPA National Primary and Secondary Drinking Water Standards or WHO Guidelines for Drinking Water Quality has been used in these comparisons." (Singapore Expert Review Panel 2002).

With respect to the Orange County Water District plant, Californian Regional Water Quality Control Board (RWQCB) has mandated the maximum limits for each of the analytes and also reportable detection limits (RWQCB 2004).

2.7.2.2 Results of Monitoring Programs

Monitoring data has been received from the Public Utilities Board NEWater plants in Singapore (period 2000 to 2003 and 2004 to 2007) and the Orange County plant (period 2005).

The Expert Panel reviewing the results of the Singapore plant (2002) reported that the quality of the product water consistently met the requirements of the USEPA's National Primary and Secondary Drinking Water Standard and the WHO Guidelines. The Panel did note that the product water monitoring program had detected some parameters in the following groups; inorganic compounds, metals, herbicides and pesticides, radionuclides, wastewater signature compounds and microbiological. However, all detected parameters were below the USEPA and WHO standards/guidelines or, in the case of organic compounds, were considered insignificant because of rarity and/or low concentrations (Singapore Expert Review Panel, 2002).

Orange County presents data on the results of their monitoring program with respect to their performance against the limits imposed by regulatory agencies in the Orange County Water Factory 21 Plant Report (Orange County Water District, 2005). This report showed that the plant was in compliance with all permit conditions for the 2005 reporting year.

2.8 Management of Drinking Water Augmentation with Recycled Water

The draft AGWR (NRMMC, EPHC and AHMC 2007) deals with the use of recycled water to augment drinking water supplies (potable reuse). These guidelines are designed to provide an authoritative reference that can be used to support beneficial and sustainable recycling of waters that have been traditionally discarded and wasted.

The ADWG (NHMRC and NRMMC, 2004) is the authoritative document regarding drinking water quality. The AGWR, once approved, would complement but not supersede the ADWG. The AGWR module focuses on the source of water, initial treatment processes and blending of recycled water with drinking water sources. The core of both documents is the application of a preventive risk management approach and the ***Framework for Management of Recycled Water Quality and Use*** (in the AWRG) is derived from the ***Framework for Management of Drinking Water Quality*** (in the ADWG).

There are some points of difference that reflect the later publication of the AGWR. The AGWR includes:

- a specific definition of safety, particularly for microbiological quality based on the use of Disability Adjusted Life Years (DALYs);
- health based performance targets including required reductions of microbial and chemical hazards; and
- use of reference pathogens.

The use of DALYs, performance targets and reference pathogens is based on the approach described in the WHO Guidelines (WHO, 2006).

The AGWR includes greater discussion of pharmaceuticals, personal care products and compounds with potential endocrine disrupting activity. This reflects a heightened concern when recycled water is used to augment drinking water supplies. Increased guidance is also provided on community consultation which is a vital component of implementing drinking water augmentation.

The ***Framework for Management of Recycled Water Quality and Use*** in AGWR (NHMRC and NRMMC, 2004) describes the elements that should be applied to all combinations of recycled water sources and end uses.

The Water Purification Scheme would include implementation of this framework in the application to drinking water augmentation.

The basic framework elements which would be adopted are:

- commitment to responsible use and management of recycled water quality (Element 1);
- assessment of the recycled water system (Element 2);
- preventive measures for recycled water management (Element 3);
- operational procedures and process control (Element 4);
- verification of recycled water quality and environmental performance (Element 5);
- management of incidents and emergencies (Element 6);
- operator and contractor awareness and training (Element 7);
- community involvement and awareness (Element 8);
- validation, research and development (Element 9);
- documentation and reporting (Element 10);
- evaluation and audit (Element 11); and
- review and continual improvement (Element 12).

3 Input and Output Water Quality

This section provides an overview on the expected feed water quality to the Water Purification Plant (WPP) and the expected quality of water to be produced by the WPP for supply to the Cotter reservoir. It also outlines the planned water quality monitoring program to be implemented prior to and after commissioning of the WPP.

The material in this section draws from a number of reports from studies commissioned by ACTEW as part of this project including:

- ***Technical feasibility Assessment of a Water Purification Plant at Lower Molonglo Water Quality Control Centre*** (CH2M HILL, 2007a);
- Indirect Pota***ble Use Options Assessment Study Volume 1*** (CH2M HILL, 2007b) and associated sub-reports;
- ***Preliminary Review of Environmental Factors for Discharge of Recycled Water into the Cotter Catchment*** (Ecowise Environmental, 2007a)
- ***Water Quality Monitoring Program for Use of Purified Water in the Canberra Water Supply Network*** (Ecowise Environmental, 2007b); and
- ***Inputs to the Indirect Potable Use Water Purification Process – Preliminary Assessment, Technical Advisory Paper*** (Water Futures, 2007)

This section also draws on information from the report ***Health and Public Safety in Water Purification – An Issues Paper on the Water2WATER proposal'*** (ACT Government's Expert Panel on Health, 2007).

3.1 Characteristics of Feed Water to the Water Purification Plant

3.1.1 LMWQCC Treated Water Characteristics and Analysis.

The LMWQCC receives wastewater from a substantially domestic catchment. Whilst there are a number of service industries in the catchment a suitable trade waste program would ensure appropriate management of discharges to sewer.

The quality of water which would be treated by the WPP is based on recent historical water quality data from the LMWQCC effluent (period 2000-2007).

Table 3-1 shows a statistical summary of data on key water quality parameters from water discharged from LMWQCC for the period January 2000 to April 2007.

A more detailed analysis of other water quality characteristics for the LMWQCC effluent is provided in Ecowise Environmental 2007b.

A review of water quality data available indicate a low presence of heavy metals and organic chemicals of concern, in the treated water discharged from LMWQCC. However, the list of parameters tested is not comprehensive and the limits of detection for the analytes tested are not as low as those typically applied for indirect potable use projects.

The LMWQCC water quality monitoring program focuses primarily on discharge authorisation compliance assessment. Refer to Section 3.3 for the comprehensive Water Sampling and Monitoring Program (SAMP) that is proposed for the WPP.

Table 3-1 - LMWQCC - Summary Effluent Water Quality Data - Jan 2000 to April 2007

Parameter	Unit	Number of samples	Mean
		Number of Samples - site 3003	After final chlorination – site 3003 (Discharge to River)
Biochemical Oxygen Demand (BOD)	mg/L	2671	<2
Chemical Oxygen Demand (COD)	mg/L	2670	14
Conductivity	µS/cm	2670	700
Dissolved Organic Carbon (DOC)	mg/L	14	6.2
pH		2701	7.7
Suspended Solids	mg/L	2702	<2
Temperature	ºC	2644	21
Total Dissolved Solids (TDS)	mg/L	2671	480
Total Organic Carbon (TOC)	mg/L	130	5.7
Turbidity	NTU	342	1.7
Ammonia	mg/L	2673	0.1
Oxidised Nitrogen (NO_X)	mg/L	2673	22
Total Nitrogen (TN)	mg/L	2673	23
Orthophosphate	mg/L	2673	0.062
Soluble Phosphorus	mg/L	29	0.099
Total Phosphorus (TP)	mg/L	2673	0.15

3.1.2 Liquid Waste Discharge Assessment

The types and quantities of inputs to sewers within Canberra's sewer network will determine the quality and hence the potential risk of the waste stream within a water purification scheme context. Canberra's sewer inputs appear to largely fall within the broad categories found in other jurisdictions, these are:

- regulated - including; industrial, non-residential, tankered, sewage treatment plants and sewage treatment plants sludge; and
- non regulated – including; inflow/infiltration, illegal dumping, illegal connections, emergency discharges, process and cleaning chemicals and domestic discharges.

ACTEW has a range of controls in place for the control of discharges to sewers, which in principle, are to commensurate with those used in other jurisdictions. These controls fall naturally into the categories of direct and indirect control. Examples of direct control are Trade Waste Agreements and examples of indirect control are education fact sheets on what should and should not be discharged to sewer.

At present the key focus of controls on discharges to sewers relate to the following areas:

- sewer asset protection (primarily against blockages and corrosion);
- occupational health and safety and protection of staff and public;
- protection of sewage treatment processes (biological); and
- treatment facility discharge authorisation compliance.

As is the case with water supply, the focus on the management for the water purification scheme needs to be on the source of the raw materials i.e. the sewer catchment and the sewage stream.

Under the ***Utilities Act*** 2000, ACTEW has a licence to provide water supply and sewerage services within the ACT. As part of the licence condition, ACTEW is obligated to abide by several codes of practice, one being the ***Water Supply and Sewerage Service Standards Code,*** 2000 under the ***Utilities Act 2000***.

Obligations under the code are:

- that all domestic sewage and wastewater arising from domestic water uses be accepted into the sewerage utility's sewerage network (s 16.1); and
- that ACTEW develops a Liquid Waste Acceptance Policy which effectively sets the standard for safe discharges (other than domestic) into the sewerage network.

To commensurate with other jurisdictions, sewer source controls for the Canberra sewer network naturally fall into two categories, direct and indirect.

3.1.2.1 Direct Control – Source

Liquid Waste

A formal process for the control of regulated inputs to Canberra's sewer network is in place including:

- ActewAGL's formal Trade Waste Control Program incorporating:
  - Trade Waste Approvals;
  - Trade Waste Monitoring; and
  - Trade Waste Reactive Process;
- standards for inputs within the Sewage and Liquid Waste Discharge Rules (ACTEW, 2007) (draft under development); and
- education fact sheets in the form of Trade Waste Acceptance Notes (e.g. Trade Waste Acceptance Note TW 1 General Acceptance Criteria for Liquid Waste, July 2005) on ActewAGL's website[10].

A formally recognised trade waste database for recording regulated inputs does not currently exist.

There appear to be no atypical industries in Canberra, compared to other jurisdictions that are currently undertaking recycling projects involving water purification within Australia, which may be unmanageable within Canberra's water purification scheme context. Risks derived from Canberra's sewer system inputs appear to be manageable down to tolerable levels through a combination of; source control, monitoring and treatment mechanisms. A review, however, would be carried out to ensure that discharges to sewer are suitable if the WPP is constructed. Such a review would focus on hospitals and research institutions, among others.

Further detailed examination of Canberra's sewer network (sewer inputs and management) is currently being undertaken. A management system would be developed which would use the same terms and parlance as ActewAGL's existing Drinking Water HACCP Plan and would be incorporated into the existing Water Supply HACCP plan.

[10] http://www.actewagl.com.au/wastewater/tradewaste.aspx

Sewer and Sewage Treatment Plant Process and Cleaning Chemicals

ActewAGL uses a range of chemicals in the management of the sewer network for the control of tree roots (root inhibitors) and in the operation and maintenance of sewage treatment facilities.

Assessment of the potential impact of these chemicals on the water purification plant is currently being undertaken (see above).

Tankered Waste

ActewAGL only accepts nightsoil or septic tank waste which is disposed to sewer at a controlled access facility in Weston. The above study would review the acceptance processes for tankered waste.

3.1.2.2 Indirect Control – Source

Domestic Sewerage

Under the Utilities Act 2000 ***Water and sewerage services connection and supply standard customer contract*** (http://www.actewagl.com.au/publications/waterContract.aspx), premise owners to lodge an application for supply with ActewAGL. Customers have various obligations including:

- the requirement to inform ActewAGL if there is a change in contact details, access to meter or changes to water or sewer pipes or appliances which have the potential to affect the quality or safety of supply;
- without prior written consent, discharge anything into the sewerage network other than ordinary domestic waste in ordinary domestic volumes, or permit anyone else to do so;
- being responsible for the operation and maintenance of equipment including ensuring that equipment complies with ActewAGL's Service and Installation Rules; and
- ensuring that any person performing work on equipment is accredited for that type of work.

In general, acceptable domestic inputs are classified as:

- use of water from normal domestic human activities, such as bathing, showers, washing up and toilet use.

Unacceptable inputs are classified as:

- items such as fat, acids, pesticides, paint, petroleum products, very hot liquids, large solids and other substances that can corrode the sewers, harm the treatment process, affect the environment or present an occupational health and safety hazard to the public or staff.

A ***Sewer Blockages and Surcharges*** fact sheet[11] is available which includes information on what should and should not be put down the sewer.

However, even though there is a customer contract in place, the contract largely relies on customers doing the right thing and therefore, domestic inputs have been classified as an indirect control.

[11] http://www.actewagl.com.au/publications/water/sewerBlockagesAndSurcharges.pdf

Inflow/Infiltration

Inflow or infiltration into existing pipe systems can occur particularly where pipe infrastructure is aged. Where this occurs the possibility exists for contaminants to enter the wastewater stream.

ActewAGL does not have a formal inflow/infiltration program, however there is a sewer rehabilitation program in place, which is designed for the control of blockages but has incidental inflow/infiltration benefits.

3.1.2.3 Direct Control – Effluent

Control of the production of effluent of feed water to the Water Purification Plant is via the LMWQCC. LMWQCC has certified management and control systems in place including:

- AS/NZS ISO 9002 – Quality Management Systems; and
- AS/NZS ISO 14001 – Environmental Management Systems.

These management systems are planned to be upgraded to link with the existing ActewAGL Water Supply HACCP Plan to manage and control risks of the treated effluent as it enters the proposed water purification cycle. This HACCP plan would match the requirements of the ***Framework for Management of Recycled Water Quality and Use*** (in the AWRG) and the ***Framework for Management of Drinking Water Quality*** (in the ADWG) which are likely to be mandated by ACT Health under the provisions of:

- Public Health Act 1997 (ACT); and
- Public Health (Drinking Water) Code of Practice 2007 (as amended).

3.2 Characteristics of Treated Water from the Water Purification Plant

3.2.1 Canberra's Current Water Quality

3.2.1.1 Canberra's Current Water Cycle

Currently there are two water treatment plants (WTP) operating for Canberra - Stromlo WTP and Googong WTP for drinking water treatment.

At full capacity the water storage reservoirs for Canberra's water supply hold just over three years supply, given a level of use without restrictions.

Average rainfall is expected to replenish these storages as they are used for the water supply. In 2007 storage fell to approximately 30% after very low rainfall and minimal run off into the reservoirs for a period of years, however, at the time of this report (July 2007) the overall reservoir storage capacity was at approximately 40% full.

Figure 3.1 is a flow diagram showing Canberra's current water and sewage treatment processes and the proposed water purification facility.

Figure 3.1 - Schematic of Canberra's Water Supply & Sewerage Networks

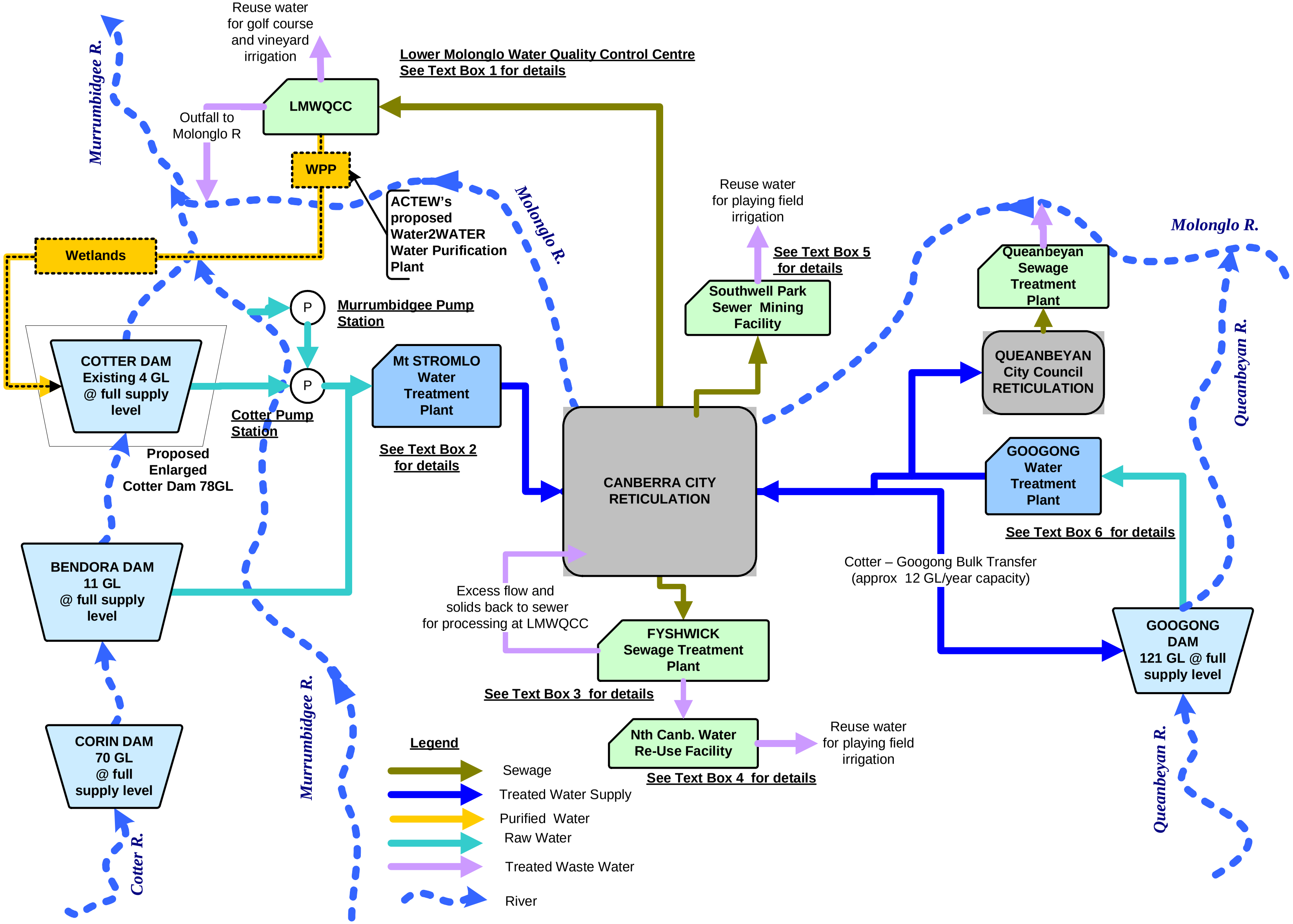


Figure 3-1 – Schematic of Canberra' Water supply and sewerage Networks (continued)

Text Box 1 – Lower Molonglo Water Quality Control Centre
Capacity - 90 ML/d – nominal
Key Processes - 7 Steps

1. Screening: Remove large objects, post-screening add chemicals: ferrous chloride & lime, grit removal.
2. Primary sedimentation: Chemical treatment precipitates: heavy metals, organics, phosphates (binds together (flocculation)) by addition of polymer. Settles solids to bottom of tanks, skims fats and soaps from the surface. Sludge and scum removal (refer Step 7).
3. Biological Reactor Tanks: Remove ammonia. Settled effluent mixed with activated sludge containing microorganisms converting ammonia to nitrates under aerobic conditions, and converts nitrates to nitrogen gas under anoxic conditions.
4. Secondary Clarification: Remove microorganisms from secondary treated effluent and recycle microorganisms to biological reactor tanks.
5. Addition of more ferrous chloride to remove phosphorus. Water passes through filters of finely crushed coal and sand.
6. Chlorination/De-Chlorination: Chlorine added to disinfect for microbiological pathogens (45 minute detention) and then treated with sulphur dioxide gas to remove excess chlorine.
7. Solids Separation and Incineration (0.7 ML/d): Sludge converted to Agri-Ash, scum incinerated.
Catch Dam: Capacity 140 ML to capture partially treated wastewater from by-passses, spillages and drainage and return to process for treatment.

Text Box 2 Mt Stromlo Water Treatment Plant
Capacity - 250 ML/d
Key Processes:

- Direct Filtration
- Dissolved air flotation and filtration
- Coagulation & flocculation
- Optional dissolved air flotation
- Dissolved air flotation & filtration or direct filtration.
- Disinfection by chlorination.
- pH adjustment and stabilization with lime and carbon dioxide
- Fluoridation by Sodium Silico Fluoride.
- Ultraviolet Disinfection (under construction)

Text Box 5 - Southwell Park Sewer Mining Facility
Capacity – 0.5 ML/d
Key Processes:

- Pre-Screening
- Chemical Pre-Dosing
- Biological organic carbon removal & nitrification
- Membrane Filtration
- Chemical Post-Dosing
- Chlorine Disinfection

Text Box 3 – Fyshwick Sewage Treatment Plant
Capacity – 5 ML/d (nominal)
Key Processes:

(Industrial & Domestic Sewage)
- Primary Sedimentation
- Trickling Filters
- Humus Tanks
- Maturation Lagoons
- Emergency Storage Lagoon

Text Box 4 – North Canberra Water Re-use Facility
Capacity – 1.78 ML/d
Key Processes:

- Membrane Filtration
- Chlorine Disinfection

Text Box 6 - Googong Water Treatment Plant
Capacity – 270 ML/d
Key Processes:

- Clarification & filtration system + Dissolved air flotation and filtration.
- Optional powdered activated carbon for organic matter removal
- coagulation and flocculation
- dissolved air flotation and direct filtration (90 ML/d)
- Flocculation, clarification and filtration (180 ML/d)
- chlorination
- pH adjustment
- Fluoridation
- Chlorine disinfection

The majority of wastewater treatment takes place at LMWQCC with some additional treatment taking place at the smaller FSTP. The North Canberra Water Reuse Facility and the Southwell Park Sewer Mining Facility treat wastewater, which is then recycled for watering recreational areas such as sports ovals and golf courses. The recycled water is disinfected with chlorine prior to use for irrigation.

3.2.1.2 Stromlo WTP Drinking Water Quality

Stromlo WTP operates to produce water which meets the requirements of the ADWG (NHMRC and NRMMC, 2004).

Monitoring is carried out to set protocols and reported to ACT Health, which is responsible for assuring that the treated water meets the guideline values. Additionally, the operation of the Stromlo WTP is carried out in accordance with a third party certified HACCP Plan.

This plant is equipped to handle a wide range of water qualities from Cotter and Bendora Reservoirs. The plant is being further upgraded at present to include a UV disinfection system to allow water to be drawn from the Murrumbidgee under a range of flow conditions.

Summary quality data of the Stromlo WTP drinking water product for 2005 to 2006 is provided in the Table 3-2 below.

Table 3-2 - Stromlo WTP – Summary Water Quality

Parameter	Target/Units	Time Period 1-JUL-2005 to 30-JUN-2006					
		No. of Samples	meeting target	% meeting target	Mean	Min	Max
pH	6.5 to 8.5	49	49	100.0%	7.7	7.4	8.1
Alkalinity	<200 mg/L as CaCO3	13	13	100.0%	40	31	51
Hardness	<200 mg/L as CaCO3	3	3	100.0%	45	35	57
Turbidity	<5 NTU	49	49	100.0%	0.29	<1	1
Colour	<15 Pt-Co	49	49	100.0%	1.1	<1	2
Chlorine	<5 mg/L	320	320	100.0%	1.14	0.82	1.40
Fluoride	<1.2 mg/L	49	49	100.0%	0.81	<0.05	1.1
THMs(tot)	<250 mg/L	12	12	100.0%	10.7	4	16
Aluminium(tot)	<0.2 mg/L	51	51	100.0%	0.050	0.010	0.18
Iron(tot)	<0.3 mg/L	50	50	100.0%	0.013	0.010	0.06
Manganese(tot)	<0.1 mg/L	50	50	100.0%	0.005	0.001	0.026
Copper(tot)	<2 mg/L	1	1	100.0%	<0.001	<0.001	<0.001
Lead(tot)	<0.01 mg/L	1	1	100.0%	<0.0002	<0.0002	<0.0002
Total Coliforms	0 CFU/100mL in 95% of	343	343	100.0%	0	0	<1
Faecal Coliforms	0 CFU/100mL in 98% of	343	343	100.0%	0	0	<1

3.2.1.3 Googong WTP Drinking Water Quality

The original design of the Googong WTP was a very high performance treatment train as it was anticipated that the catchment water would be of relatively low quality. The large capacity and long residence time for water in this reservoir resulted in better than expected raw water, although the reservoir is subject to blue green algae blooms.

This plant is equipped to handle a wide range of water qualities from the Googong Reservoir. The treatment plant was recently upgraded, increasing capacity and providing ability to use powdered activated carbon to remove taste and odour compounds and potentially to remove cyanobacterial toxins from the water. Mixers have also recently been installed in the Googong Reservoir to improve raw water quality.

The plant operates under the same regulatory guidelines as the Stromlo plant and the water from the plant enters the same main supply network as water from Stromlo.

Monitoring is carried out to set protocols and reported to ACT Health, which is responsible for assuring that the treated water meets the guideline values. Additionally, the operation of the Googong WTP is carried out in accordance with a third party certified HACCP Plan.

A Summary of water quality data of the Googong WTP drinking water product for 2005 to 2006 is provided in Table 3-3.

Table 3-3 - Googong WTP – Summary Water Quality

Parameter	Target/Units	Time Period 1-JUL-2005 to 30-JUN-2006					
		No. of Samples	meeting target	% meeting target	Mean	Min	Max
pH	6.5 to 8.5	6	6	100.0%	7.6	7.3	7.7
Alkalinity	<200 mg/L as CaCO3	2	2	100.0%	64	58	69
Hardness	<200 mg/L as CaCO3	2	2	100.0%	68	66	70
Turbidity	<5 NTU	6	6	100.0%	0.38	0.10	0.60
Colour	<15 Pt-Co	6	6	100.0%	2.8	2.0	4.0
Chlorine	<5 mg/L	43	43	100.0%	1.2	0.13	2
Fluoride	<1.2 mg/L	6	6	100.0%	0.86	0.69	1.0
THMs(tot)	<250 mg/L	2	2	100.0%	95.5	91	100
Aluminium(tot)	<0.2 mg/L	6	6	100.0%	0.097	0.050	0.15
Iron(tot)	<0.3 mg/L	1	1	100.0%	0.020	0.020	0.020
Manganese(tot)	<0.1 mg/L	6	6	100.0%	0.007	0.002	0.018
Copper(tot)	<2 mg/L	0					
Lead(tot)	<0.01 mg/L	1	1	100.0%	0.0003	0.0003	0.0003
Total Coliforms	0 CFU/100mL in 95% of samples	44	44	100.0%	0	0	<1
Faecal Coliforms	0 CFU/100mL in 98% of samples	44	44	100.0%	0	0	<1

3.2.2 Quality of Water for the Water Purification Plant

3.2.2.1 Indirect Potable Use Water Quality Parameters

Sections 2.5 and 2.6 of this report provide a review of national and international water quality regulation and guidelines for indirect potable use.

There are currently no specific drinking water quality guidelines for water purification in Australia. AGWR is currently under development by the National Resource Management Ministerial Council and the Environment Protection and Heritage Council.

Phase 1 of the Guidelines for water recycling was published in 2006 and provides guidance on managing the health and environmental risks associated with the uses of recycled water other than the development or management of potable water recycling schemes. The guidelines currently being developed will form Phase 2 of the AGWR (NRMMC, EPHC and AHMC 2007) and will include indirect potable reuse as methods for recycling reclaimed water.

In addition to the AGWR, there are a number of other documents which outline standards and principles that any indirect potable recycling scheme would be required to meet as a minimum. They include:

- ***A guide to Hazard Identification and Risk Assessment for Drinking Water Supplies*** (Cooperative Research Centre (CRC) for Water Quality and Treatment (CRCWQT 2004), developed in support of the ADWG's (NHMRC and NRMMC 2004) new focus on risk assessment and management.
- Health Impact Assessment Guidelines (enHealth Council 2001);
- Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth Council 2002); and
- ADWG (NHMRC and NRMMC 2004).

In the absence of any specific guidelines for water purification plant, the ADWG have been adopted for preliminary design purposes but other standards guidelines have been referenced where no details are provided in the ADWG, or more current information is available.

Once Phase 2 of the AGWR is finalised and published it is considered that it will compliment the ADWG and take precedence in areas relating to direct potable use of water.

In the interim ACTEW proposes to adopt the draft ***Australian Guidelines for Water Recycling – augmentation of drinking water supplies*** (NRMMC, EPHC and AHMC 2007) in conjunction with the ADWG as the basis for the determining water quality requirements for the water purification plant and for the management processes for developing and operating this facility.

Based on the robustness of the proposed water purification process it is unlikely that any changes to the above guidelines would have any significant impact on the Water Purification Plant and overall system design.

While the ADWG include a range of notionally tolerable contaminant concentration limits by which potable water can be assessed, other guidelines introduce additional aspects of water management best practice.

For example, the CRCWQT guidelines introduce the importance of generic advice on risk assessment for potable water supplies. The enHealth Council guidelines provide frameworks for how risk should be assessed in general terms and details on how the technical assessment process might be carried out.

These guidelines also provide a reference set of criteria for assessing the strengths and limitations of risk studies undertaken for potable water reuse examples in the literature and for any future projects in Australia. They describe current best practices in terms of Australian regulations, which are fully consistent with the recommendations of the USA National Research Council 1998 report.

3.2.2.2 Hazard Analysis and Critical Control Point (HACCP) Accreditation

The quality of purified water from the proposed Water Purification Plant is crucial to the health and safety of the community.

To ensure health and safety is not compromised, ACTEW would have in place a HACCP accreditation for the proposed Water Purification Plant, the existing LMWQCC and the sewerage collection system prior to the commissioning of the new facility. This system would be fully integrated with the existing Water Supply HACCP plan.

This system would incorporate the ADWG ***Framework for management of drinking water quality*** (NHMRC and NRMMC 2004) and the AGWR F***ramework management of recycled water quality and use*** (NRMMC & EP&HC 2007).

3.3 Water Quality for Discharge to Cotter Reservoir

In addition to the water quality requirements for maintenance of public health, water quality standards for the release of water to the Cotter Reservoir are also important from an environmental perspective and need to be assessed to ensure minimal impact on the reservoir and its aquatic life.

This section considers key water quality aspects for water release - namely nutrient (nitrogen and phosphorus) concentrations and water temperature.

3.3.1 Cotter Reservoir Water Quality

A consideration in the selection of treatment technologies in a multi barrier approach where a wetland and a reservoir are proposed as the environmental buffers, is the environmental water quality objectives in meeting the requirements for potable use.

In this case it is proposed that the purified water could discharge to the Cotter Reservoir via a wetland system.

Analysis of water quality records in the Cotter Reservoir indicates that the water quality is generally good, however the catchment has been partly been disturbed by bushfires and is substantially cleared of trees and over recent years has suffered from impact of erosion following heavy rainfall events.

Analysis of records of algal counts in the Cotter Reservoir for the years 2004 to 2006 (Ecowise Environmental, 2007b) indicates that algal cell counts are very low for most of the time but there are occasional blooms of Cyanophyta (blue green algae).

If good water quality conditions are to prevail in the Cotter Reservoir following the addition of purified water it will be important that conditions favouring Cyanophyta are not induced by the addition of recycled water to the reservoir.

It is must be noted that data collected to date is for the existing reservoir and that enlarged reservoir would be considerably deeper than the existing reservoir and would create a different environment for algae. The increased depth would be more favorable to the development of anoxic conditions at the lower depths and the impacts on water quality would need to be investigated.

The development of a hydrodynamic model of the enlarged Cotter Reservoir is planned as part of the Enlargement of the Cotter Dam project. Notwithstanding any future investigation, it is concluded that it would be advantageous for both the existing reservoir and proposed new reservoir to ensure that reservoir mixing is included as part of the water quality management strategy and that nitrate levels are not set too low such that nitrate does not become the limiting nutrient. (Note the existing reservoir is maintained fully mixed to a depth of approximately 12 m to management water quality, specifically iron and manganese.)

In selecting the Water Purification Plant design necessary to achieve water suitable for both environmental discharge and supply to the Canberra water supply system it was necessary to consider the impacts of different processes on water quality as outlined below:

- consideration of nutrient loading on the Cotter Reservoir and to nuisance algal blooms;
- consideration of physical changes in water quality due to changes in salinity, temperature or nitrates which can impact adversely on the aquatic ecosystem; and
- consideration of salinity changes in any discharges to the Murrumbidgee River and the water supply system;

Water quality objectives for nutrients have been set to minimise adverse changes in conditions in the Cotter Reservoir which might stimulate nuisance algal blooms and to avoid any toxicity effects from nitrates (NO_3-N). The target nutrient levels are low and in line with the ambient water quality conditions in the Cotter Reservoir and have been based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000).

While ammonia (NH_4-N) concentrations in the LMWQCC effluent are already very low and are at the limits of conventional biological removal (a mean concentration of approximately 0.1

mg/L), the nitrate concentrations for the LMWQCC effluent considerably exceed the nitrate level for the water entering the Cotter Reservoir.

Effluent ortho -phosphorus (soluble phosphorus PO_4-P) concentration is already very low (0.06 mg/L). The total phosphorus concentration including the particulate phosphorus component averages around 0.15 mg/L which is slightly higher than the target quality for the Cotter catchment.

The treatment processes in the Water Purification Plant and proposed wetland would therefore need to accommodate the requirements for additional nitrate and phosphorus removal as shown in Table 3-4.

Table 3-4 - Nutrient Targets for water discharge to Cotter Reservoir

Parameter	Nitrate (NO_3-N) mg/L	Total Phosphorus (TP) mg/L
Effluent from the LMWQCC (target after the planned secondary treatment plant upgrade)	12	0.2
Water quality target in Cotter Reservoir	0.7	<0.1
Total additional removal required	11.3	>0.1

3.3.2 Wetland Design Considerations

3.3.2.1 Nutrients

Investigations were carried out (Ecowise Environmental, 2007a; CH2M HILL, 2007b) to assess the potential for the use of an artificial wetland for final nutrient polishing prior to the release of water to the Cotter Reservoir.

Nitrogen

The ANZECC and ARMCANZ 2000 guidelines indicate that for the protection of 99% of taxa in freshwater, nitrate concentration should not exceed 0.017 mg/L as shown in Table 3-5. The trigger values increase from 0.7 mg/L for 95% level protection to 17.0 mg/L for 80 % protection.

For ammonia trigger values, the Cotter catchment is modified, so a 99% level of protection may be deemed excessive.

Given that nitrate is not as toxic as ammonia and that the background concentrations of nitrate in the Cotter Reservoir already exceed the 99% trigger values, it is recommended that the 95% trigger value of 0.7 mg/L be adopted as a minimum requirement for water leaving the proposed wetlands.

More detailed modeling of the historic nutrient and flow data would be required before a final trigger value for nitrate can be determined.

Table 3-5 - ANZECC and ARMCANZ (2000) Water quality guidelines for the protection of aquatic ecosystems trigger values for ammonia and nitrate in freshwaters

Trigger Values for Freshwater (mg/L)				
	Level of Protection			
Chemical	**99%** species protected	**95%** species protected	**90%** species protected	**80%** species protected
Ammonia	0.32	0.90	1.43	2.30
Nitrate	0.017	0.70	3.4	17.0

Phosphorus

Phosphorus is another key element that is regarded as essential for algal and plant growth. Phosphorus exists in the water as available phosphorus in the inorganic form as phosphates. Studies have indicated that when filterable (inorganic/available P) phosphorus exceeds 0.08 mg/L then this contributes heavily to the onset of eutrophication and the subsequent development of algal blooms.

The average concentration of orthophosphate in the Cotter Reservoir is 0.0046 mg/L and a maximum concentration 0.01 mg/L has been determined, suggesting little likelihood of an algal bloom in the reservoir.

Nitrogen to Phosphorus Ratio

In water bodies with high levels of nutrients, the ratio of nitrogen to phosphorous is significant in favouring dominance of Cyanophyta.

It is desirable that the nitrate to phosphorous ratio (N:P) is greater than seven (Redfield Ratio) to avoid nitrogen limiting conditions in the Cotter Reservoir (CH2M HILL, 2007b).

This is necessary to avoid the formation of algal toxins. The N:P ratio that is required to avoid blue green algal blooms in the Burrinjuck Reservoir was identified in the LMWQCC process audit (SCM 1992) as above 15.

Further detailed assessment of this aspect is required to finalise the target concentration of nitrogen in the discharge to the Cotter Reservoir which is a key design input to the Water Purification Plant and its associated denitrification facilities and for the design and sizing of the wetland.

3.3.2.2 Temperature

One of the key environmental issues investigated was the temperature of the water being released to the Cotter Reservoir from the wetland and for these being significantly different from the water in the Cotter River or the Cotter Reservoir.

For the purposes of preliminary assessment it is assumed that the purified water temperature leaving the Water Purification Plant would be approximately the same as the present release from LMWQCC to the Molonglo River.

Various wetland sizes have been modeled to determine how the wetlands would moderate the temperatures to bring the water leaving the wetland system to a temperature similar to that of the water in the Cotter Reservoir.

Data (Ecowise Environmental 2007a and Ecowise Environmental 2007b) indicate that the temperature of water leaving the water purification plant in summer is likely to be very similar to the temperature of the surface layers of the reservoir. However in winter, the Cotter Reservoir surface water temperature falls to 8.5°C compared with a temperature of approximately 17°C for the water leaving LMWQCC.

3.3.2.3 Summary of Water Quality Objectives for Discharge to Cotter Reservoir

Table 3-6 presents a summary of suggested water quality objectives for effluent discharged from the wetlands into Cotter Dam based on studies and modeling work carried out to date.

As this data is preliminary only it will be necessary to undertake further studies and pilot modeling of water quality parameters prior to any wetlands construction.

Table 3-6 - Draft Water Quality Objectives for water entering Cotter Reservoir

Parameter	Suggested Water Quality Limit (Wetland Effluent)
Ammonia	0.32 mg/L
Nitrate	0.7 mg/L
Phosphorus (total)	<0.1mg/L
Temperature	Summer: 23-25°C Autumn: 15-22°C Winter: 8-10°C Spring: 13-19°C
Dissolved oxygen	Summer: > 7.3 mg/L Autumn: > 5.3 mg/L Winter: > 9.3 mg/L Spring: > 7.3 mg/L
pH	To be determined
Electrical conductivity	39-50 μS/cm

3.4 Water Quality Sampling and Monitoring Program

3.4.1 International Water Sampling and Monitoring References

Overseas and interstate practice provides a valuable source of background information that can be applied to the development of water reuse schemes in Canberra. As part of the development of a suitable water sampling and monitoring program, an extensive study was carried out of practices elsewhere and this is reported in Sections 2.5 to 2.7 above.

3.4.2 Water Purification Scheme Sampling and Monitoring Program

A comprehensive knowledge of the constituents of the feed water and product water and impact of the water purification scheme is critical to managing the facility and management of the public health risks of water purification.

An extensive sampling and monitoring program (SAMP) would be developed and implemented based on the Guideline Values (GV) for the existing ADWG, the requirements for the draft AGWR for potable water reuse and other appropriate international guidance. ACTEW would target to achieve water quality below all appropriate guideline values.

It is anticipated the quality and management process for production of purified water would be subject to both ACTEW initiated internal and external audits and also ACT Health regulatory audits.

The detailed development of all water quality monitoring programs would be undertaken in consultation with the ACT Health Department and the EPA.

Water quality testing is an important component of any water treatment scheme to ensure that water is produced in accordance with required standards. Testing on the WPP feed and product water would also include a comprehensive list of compounds not necessarily covered in the ADWG. All samples would be sent to accredited laboratories for analysis.

The SAMP would be established to test an extensive list of parameters covered under the following key groupings;

- physical characteristics;
- inorganic chemical agent and disinfection by products;
- inorganic chemicals;
- organic disinfection by product;
- organic compounds;
- organic indicators;
- pesticides;
- radiological quality;
- microbiological;
- wastewater signature compounds;
- synthetic and natural hormones;
- persistent organic pollutants; and
- chemical contaminants.

Health effects testing (as occurs in similar water purification plants overseas) is also expected to be carried out to monitor for potential long term or chronic health impacts and a list of emerging pathogens would be developed for testing and monitoring. Details of this aspect of the program are still to be considered.

The microbiological analysis would include (at a minimum) the following organisms;

- Cryptosporidium parvum, Camphylobacter, Rotavirus;
- Clostridium perfringens, Somatic coliphage, Male-specific coliphage, Giardia lamblia, E.coli; and
- others as agreed with ACT Health.

The proposed monitoring program would generally be based on the monitoring programs of water purification schemes in Orange County, CA, USA, Public Utilities Board, Singapore and Windhoek, Namibia. As Singapore tests for more parameters than the other facilities, the proposed sampling and monitoring programs planned for Canberra focus mainly on analytes and sampling frequencies used by the Public Utilities Board, Singapore.

Should there be other contaminants of concern found as the result of further investigations into Canberra's sewer network and/or from national or international sources, they would be included in the monitoring program.

The proposed sampling and monitoring program for the water purification scheme is divided into three phases:

- baseline monitoring program;
- pilot testing program; and
- ongoing monitoring program.

These programs are detailed further in the sections below.

3.4.3 Baseline Monitoring Program

There are two components to the recommended baseline monitoring program (BMP):

- an initial analysis of all pertinent analytes as suggested by the ADWG (NHMRC & NRMMC, 2004) and the AGWR (NRMMC & EPHC 2007) and currently operating water purification facilities in the world; and
- a slightly refined monitoring regime to obtain ongoing baseline data.

The details of the BMP can be found in Ecowise Environmental 2007b.

The key objective of this program is to obtain comprehensive baseline water quality information across the existing sewerage collection system and treatment plants and water supply system prior to the development of the water purification scheme.

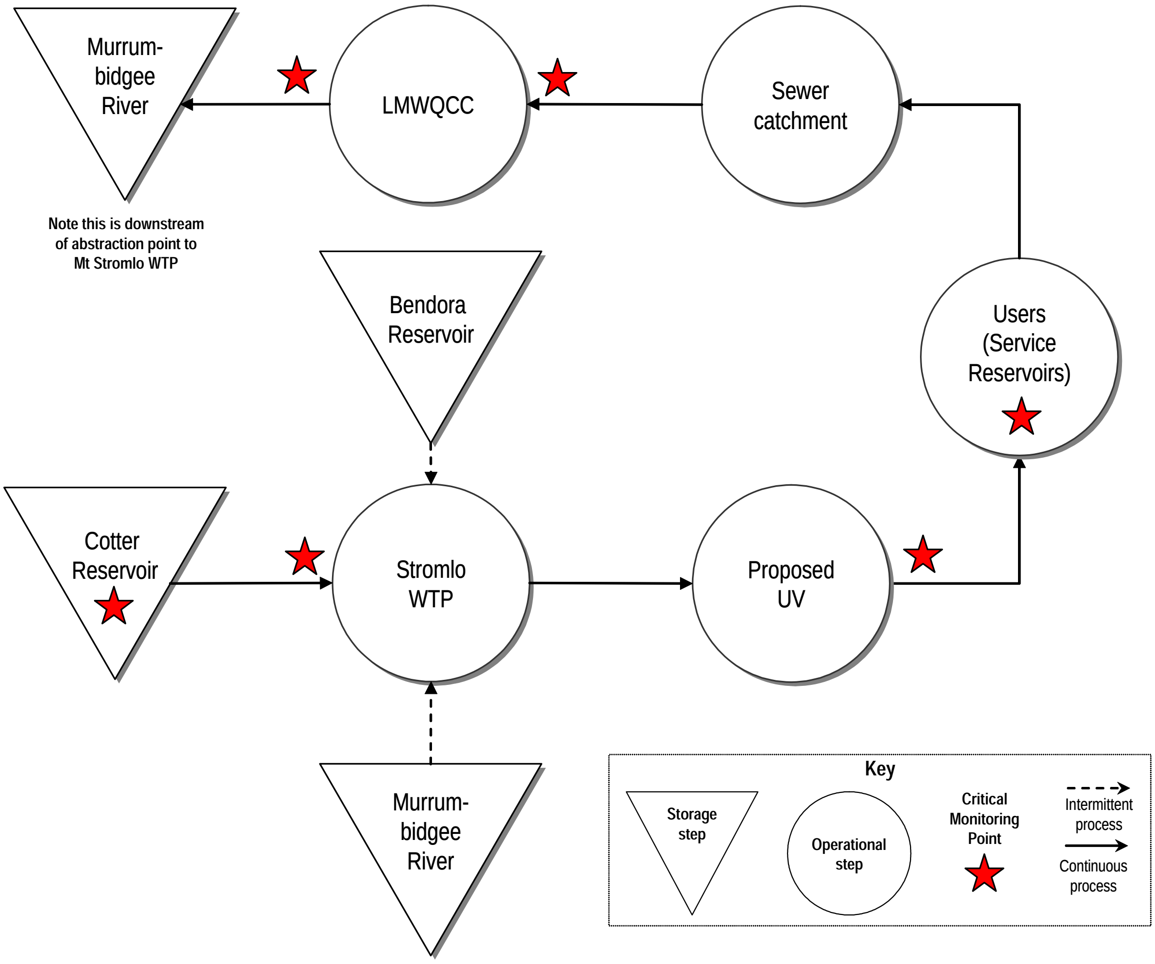
The key focus of the BMP would be on water quality in the sewerage collection system and treatment plant effluent. Sampling at Cotter reservoir and in the water reticulation system are planned to be less frequent than at these plants.

The BMP sampling frequencies would be at least quarterly and more often for specific locations.

Information gathered from the BMP would then be available for more comprehensive public health risk assessment, licencing processes and for input into the water purification plant design. It would also provide a basis for determining changes to water quality into the future once the proposed plant comes into operation.

Figure 3-2 shows proposed sampling locations for the BMP at critical monitoring points within Canberra's water and wastewater system.

Figure 3-2 - Sampling locations for the Baseline Monitoring Program



3.4.4 Water Purification Scheme Pilot Monitoring Program

Once a pilot plant is constructed and commissioned at LMWQCC, a pilot plant monitoring program (PMP) would be implemented. The objectives of the monitoring program would be to collect data:

- during stable pilot plant operation to provide information on the performance of unit processes and to understand the contribution each of these make in the overall plant performance;
- collection of data which may assist in the specification of the water purification plant design; and
- ability of the process train to achieve desired overall water quality outcomes.

It is envisaged that the Pilot Monitoring Program (PMP) would be much the same as the BMP, with similar analytes. Sampling frequency would be tailored to the operation of the pilot plant.

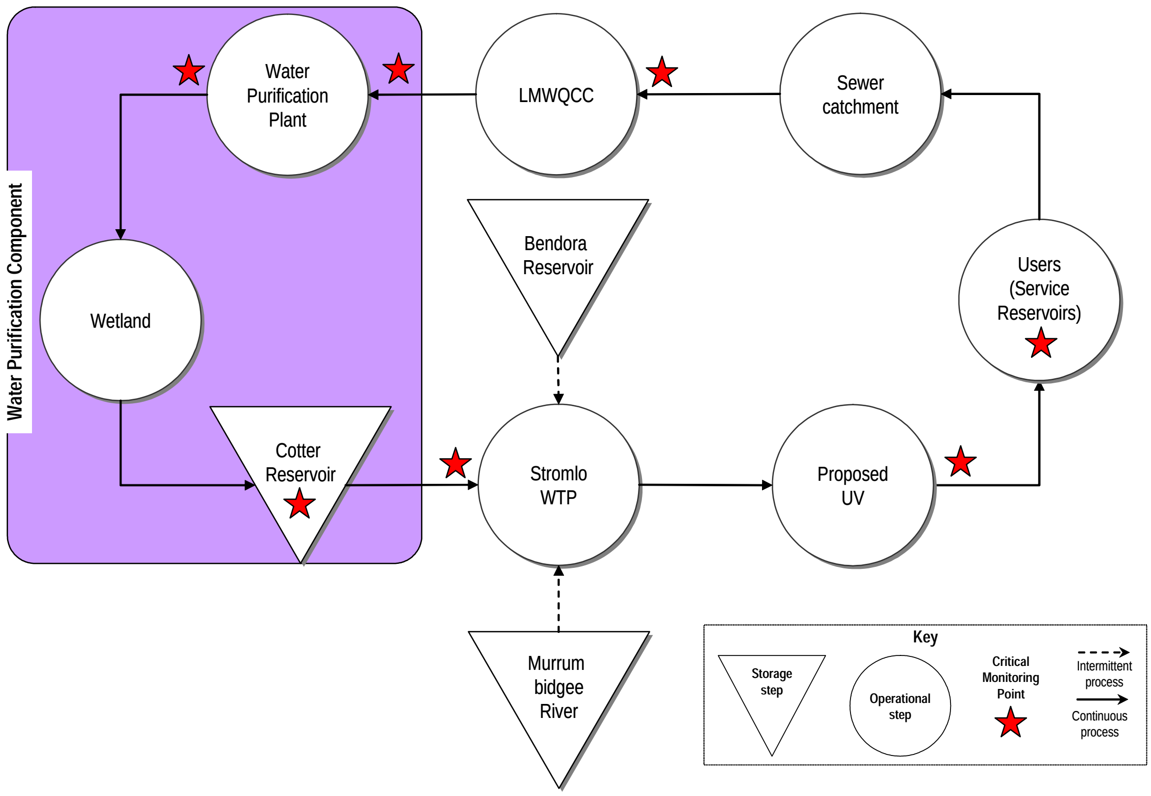
3.4.5 Water Purification Scheme Operational and Ongoing Monitoring Program

The sampling and monitoring program of the water purification plant during commissioning, early operation and ongoing operation are considered at this stage to be similar to the base line monitoring and pilot plant monitoring programs. The key differences would be:

- additional sampling locations within the water purification plant processes would be established (similar to the pilot plant program); and
- sampling frequency would be more intense during commissioning and early phases of operation until stable operation is demonstrated.

Critical monitoring points once the water purification plant is in operation are schematically shown in Figure 3-3. This diagram does not show planned monitoring between unit treatment processes.

Figure 3-3 - Sampling locations for the Ongoing Sampling and Monitoring Program (SAMP)



From the results of the BMP and PMP, it may be possible to reduce the number of analytes tested and/or their frequencies. More frequent testing of indicator analytes (i.e. gross alpha/beta as a radionuclide indicator) could be done where individual analytes would only be tested if the indicator result is above a predetermined trigger value.

Nevertheless, a risk assessment would be conducted to ensure that any analytes deleted from the monitoring program or reduction of sampling frequencies would not result in increased risks to human health.

The ongoing monitoring program should reflect the level of maximum health risk and confidence in the barriers within the Water Purification Scheme to remove contaminants prior to the water reaching customer taps.

The above water quality monitoring program would be complementary to detailed continuous online process monitoring of the Water Purification Plant. Details of the proposed online monitoring of the plant are provided in Sections **5** and **6** of this report.

4 Water Purification Scheme Process Options

4.1 Multiple Barrier Approach to Water Purification

A range of water purification treatment technologies have been adopted worldwide to enhance the final water quality discharged from conventional wastewater treatment processes to potable standards. This section reviews treatment technology options considered suitable for water purification in Canberra and outlines the selection processes used to determine the preferred processes for the water purification plant.

In all modern water supply systems the multiple barrier approach is adopted to ensure that the reduction of pathogens and chemicals of concern is achieved through a series of individual treatment processes or barriers, each of which provides an additional level of protection.

There are seven key barriers in the system proposed by ACTEW. These barriers are:

- source control in sewerage collection system;
- LMWQCC;
- micro/ultra filtration;
- reverse osmosis;
- advanced oxidation;
- blending of purified water into cotter Reservoir; and
- Stromlo Water Treatment Plant.

Wastewater from industrial and domestic sources is collected and treated in the wastewater treatment plants (WWTP) to remove; suspended solids, organic matter and nutrients. In the water purification process this WWTP effluent undergoes advanced treatment where each individual process step is responsible for the progressive removal of dissolved and suspended solids as well as; turbidity, colour, inorganics, chemicals of concern and protozoa, bacteria, viruses and other pathogens.

Highly treated purified water from the Water Purification Plant is then blended through an environmental buffer (Cotter Reservoir) with other water sources to form a consistent water source which undergoes further treatment and disinfection in a water treatment plant (WTP) prior to being delivered to customers.

4.2 Technology and Treatment Options

4.2.1 Water Purification Process Technologies

The water purification process can be categorised into several different treatment steps where the overall objective is to produce high quality, purified water for discharge to ground or surface water, ultimately to be used as part of the potable water supply.

Current advances in water purification technologies make them capable of removing or inactivating pathogens and reducing the concentrations of organic and inorganic chemicals to acceptably low levels for potable water use.

When considering the viability of producing purified water for indirect potable use an assessment should be made with respect to the quantity and reliability of the raw water source, the quality of purified water, the treatment options available and cost effectiveness of the treatment options.

The water purification process comprises conventional and advanced water treatment technologies which are summarised here.

4.2.1.1 Conventional Treatment Technologies

Over the past 20 years and prior to the emergence of membranes technologies, a diverse range of treatment technologies has been applied for the removal of residual constituents found in treated wastewater plant effluent. These treatment technologies include; filtration, electro dialysis, adsorption, air stripping, ion exchange, advanced oxidation, distillation, chemical precipitation, chemical oxidation, ultraviolet (UV) irradiation, ozonation and chlorination.

Constituents removed by these technologies include inorganic and organic colloidal and suspended solids, dissolved organic and inorganic matter, biological contaminants and chemicals of concern.

Using these technologies, secondary or tertiary treated WWTP effluent is further treated to remove inorganic and organic suspended solids carried over from processes in the WWTP upstream. This step is critical to ensure that the downstream water purification processes can efficiently remove dissolved organic and inorganic matter, biological contaminants and chemicals of concern.

Typically coagulation and flocculation processes are used to promote the formation of floccs that can be removed by a combination of deep bed filtration, surface filtration, adsorption (activated carbon), ion exchange, chemical precipitation and chemical oxidation or distillation.

The remaining organic matter (total organic carbon (TOC) and dissolved organic carbon (DOC)) in the water, including volatile organic compounds (VOC), pharmaceutical compounds, surfactants and refractory organics, are removed through processes such as filtration, electrodialysis, adsorption, air stripping, ion exchange, distillation, chemical precipitation or chemical oxidation.

Subsequent treatment of the water is required to remove or inactivate any remaining biological contaminants such as protozoa, cysts, oocysts and viruses. Technologies effective in reducing biological contaminants included UV, ozone and chlorine. Ozone and UV have been used extensively in wastewater treatment applications since the early 1990's. Prior to this, chlorine was predominately used to disinfect the treated water.

Stabilisation of the product water is required after disinfection to restore pH, alkalinity and hardness to prevent corrosion of the distribution pipe work. The most common approach used to stabilise soft water prior to distribution is through the addition of calcium in the form of quicklime (CaO) or hydrated lime ($Ca(OH)_2$).

The stabilised water is typically blended through an environmental buffer, such as a dam, river or underground aquifer with other water sources such as rainwater before extraction and treatment for potable water supply. The environmental buffer provides additional natural treatment through biological and physiochemical factors such as sunlight, temperature and pH. Besides exposure to these natural biological and chemical processes, the use of an environmental buffer provides the potential for an additional time delay and dilution with the natural environmental water sources.

4.2.1.2 Treatment Technologies: Removal of Biological Contaminants

During the early 1990's, the use of conventional treatment technologies was supplemented by more advanced technologies.

Biological contaminants such as bacteria, viruses, protozoa and helminthes are found in secondary and tertiary treated effluent streams. Generally immuno compromised individuals in contact with such microorganisms are at greater risk of contracting illnesses such as gastroenteritis, respiratory diseases, Legionnaire's disease, cholera, meningo-encephalitis and taeniasis.

Advanced treatment processes such membrane filtration, chlorination, ozonation and UV irradiation can be adopted to remove or inactivate microorganisms from the potable water supply, thereby minimising health risks to the end user.

Membrane filtration coupled with disinfection such as UV, ozonation, chlorination or advanced oxidation is now used to produce highly treated purified water. The key water treatment process technologies and the areas of their application within water purification are outlined in Table 4-1 and discussed in further detail below.

Table 4-1 - Treatment Technologies used in Water Purification

Residual Constituent	Micro-filtration	Ultra-filtration	Reverse Osmosis	Advanced Oxidation	UV	Ozone	Chlorine
Inorganic and organic colloidal and suspended solids	X	X	X				
Dissolved Organic Matter			X	X			
Dissolved Inorganic Matter			X				
Biological Contaminants	X	X	X		X	X	X
Chemicals of Concern				X	X		

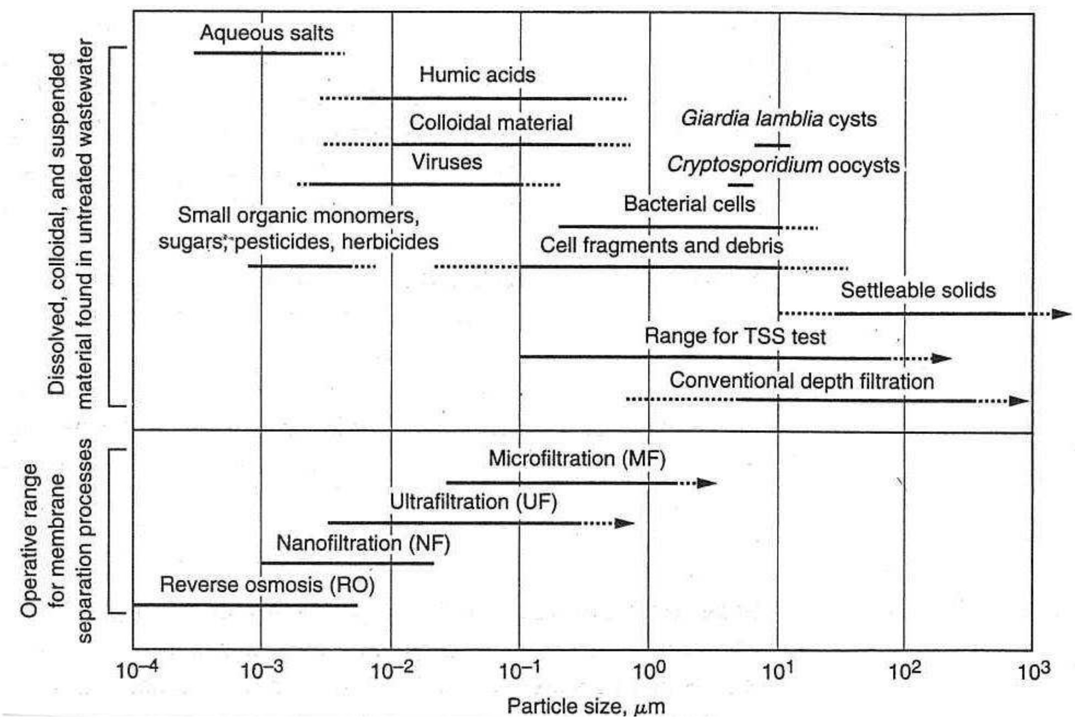
Membrane Filtration Processes

Membrane filtration is a process of separating particles from water as it passes through a physical barrier (a membrane containing pores). Depending on the application and geometry of the membrane, this can be either under a positive pressure on the feed side of the membrane, or by drawing the water through the membrane by applying a negative (vacuum) pressure on the filtrate side of the membrane. The size of the particles removed by the membrane depends on the effective pore size within the membrane. Particles greater than the pore size are retained on the feed surface of the membrane.

Microfiltration membranes generally have larger pore sizes than ultrafiltration membranes. Microfiltration membranes typically remove all bacteria, Giardia cysts and Cryptosporidium oocysts, while ultrafiltration membranes will typically remove all bacteria, Giardia cysts and Cryptosporidium oocysts, as well as most virus particles.

As shown in Figure 4-1 different membrane pore sizes can be used to selectively reject contaminants of a particular size.

Figure 4-1 - Operating Size Ranges for Membrane Technologies



Chlorination

Chlorination has been used extensively as a disinfectant to remove bacteria. Chlorine, being a strong oxidant, reacts with the cell wall of the organism to inhibit its enzyme activity and damage the cell DNA and RNA. Bacteria have a high lipid (fatty acid) content in the cell membrane which makes them more susceptible to destruction when compared to other organisms. Although chlorination is able to kill bacteria effectively, robust oocysts such as Cryptosporidium parvum and viruses are highly resistant to chlorine disinfection.

One of the limitations of chlorine includes the potential formation of disinfection byproducts (DBPs); predominately trihalomethanes (THMs) and haloacetates (HAAs). The formation of DBPs is dependant on a number of factors including the presence of organic precursors, free chlorine concentration, bromide concentration, pH and temperature. Generally these parameters can be optimised to reduce the formation of DBPs, however when not controlled the impacts of DBPs can adversely impact the taste, odour and colour of the potable water. In addition, some DBPs are considered to be chemicals of concern due to the potential impact of these byproducts on public health and the environment.

Ozonation

An alternative disinfection technique to chlorination is ozonation. Ozone (O_3) is a strong oxidizing agent which can directly oxidise compounds through the action of molecular ozone or via oxidation with hydroxyl free radicals that are formed during the decomposition of ozone. The free radicals have a very high oxidising potential and are the active form in the disinfection process, possessing the power to react with other impurities in the aqueous solution.

Disinfection occurs when the ozone reacts with the bacteria causing the disintegration of the cell wall, otherwise known as cell lysis. Ozone is a very good viricide and is more effective than chlorine. Advantages of ozone as compared to chlorine include the ability to convert organic compounds to carbon dioxide and other inorganic oxides (minereralise), ability to fully oxidise the ammonium ion and independence of pH to the process.

Ozone is more effective than chlorine in inactivating most viruses, spores, cysts and oocysts. Microorganisms such as bacteria display the highest sensitivity to ozone followed by viruses and protozoans. Ozone's biocidal properties are not influenced by pH, it oxidises sulfide, requires less contact time than chlorine and therefore less space and contributes dissolved oxygen to the treated water.

As with chlorine, when ozone is used in isolation disadvantages include the formation of DBPs and oxidation of manganese and other inorganic and organic compounds, therefore reducing the disinfectant potential. However, when ozone is coupled with activated carbon, removal of these oxidised products can be achieved. Alternatively, the oxidant dose can be increased to achieve full mineralisation.

Ultraviolet Irradiation

Germicidal properties of ultraviolet (UV) irradiation were discovered in the early 1900's and developments in technology have enabled the use of UV as a water and wastewater disinfectant process.

UV light exists in the region of the electromagnetic spectrum that lies between x-rays and visible light. The generation of UV light occurs when a voltage is applied across a gas mixture, resulting in the discharge of photons. The specific wavelength of light emitted as photons is dependent upon the elemental composition of the gas and the power of the lamp. UV light in the germicidal wavelength range of 220 nm to 320 nm (peaking at approximately 254 nm) is effective at penetrating the walls of microorganisms and eventually being absorbed by DNA and RNA. Consequently cells exposed to an appropriate UV dose will either die or cease replication. Common microorganisms such as Giardia, Cryptosporidium, E. Coli, Rotaviruses and Hepatitis are highly sensitive to UV irradiation.

The effectiveness of the UV disinfection process depends on a number of variables including; the characteristics of the UV disinfection system, the overall system hydraulics, the presence of particulates and the chemical characteristics of the water effecting UV light transmission and the characteristics of the targeted microorganisms.

When compared to other disinfection technologies, UV is most effective in inactivating viruses, bacterial spores and oo/cysts.

4.2.1.3 Advanced Treatment Technologies: Removal of Chemicals of Concern

There is a continuous emergence in the number of chemicals of concern detected in treated effluent streams. These include; pharmaceuticals, personal care products (PCPs), natural and synthetic hormones, volatile organic compounds (VOCs), disinfection by products (DBP), heavy metals, pesticides, herbicides and compound mixtures.

The physicochemical characteristics of the chemicals and the treatment technologies selected determine the effectiveness of their removal. Advanced treatment technologies such as membrane filtration, activated carbon adsorption and advanced oxidation are preferred for the treatment and removal of these chemicals.

Reverse Osmosis Membrane Applications (RO)

The rejection (removal) of chemical contaminants across a semi permeable membrane barrier is governed by the molecular interaction between the solute (chemical), solvent (water) and a particular membrane charge. Thin film composite reverse osmosis (RO) membranes are designed with chemical functional groups attached to the membrane surface to facilitate the electrostatic repulsion of susceptible chemicals such as pharmaceuticals and endocrine disrupting compounds (EDCs). In addition, the molecular size of the chemicals, electrostatic properties and polarity are all relevant when selecting the membrane material.

Whilst many chemicals are effectively removed by RO membranes, others, such as monochloramine, N-nitrosodimethylamine (NDMA) and 1,4-dioxane, were insufficiently removed by RO membranes. Other toxic organic solvents, pharmaceutical products, hormones, industrial and DBP were shown to be rejected by the membrane (CH2M HILL 2007a; Bellona et al 2004).

Adsorptive Treatment Process

Powdered activated carbon (PAC) or granulated activated carbon (GAC) can be used for the removal of a diverse range of lipophilic[12] organic compounds as well as some relatively lipophilic inorganic compounds such as nitrogen, sulfides and heavy metals. Highly polar compounds are inadequately removed by activated carbon adsorption.

It has been demonstrated that PAC is an effective process for the removal of a wide range of trace compounds such as organic chemical contaminants, pharmaceutically active steroidal hormones, endocrine disruptors and pesticides from relatively clean water sources. It has also been demonstrated that higher PAC dosages can improve the removal of these compounds (Westerhoff et al 2005).

Biological Activated Carbon (BAC) with Ozone is a step process, where Ozone is dosed into water which then flows through granular activated carbon (GAC) filter beds. The highly reactive ozone breaks down organic molecules into smaller organic molecules. These are then adsorbed on the GAC media and provide a food source for biological activity. The process reduces dissolved organic carbon (DOC) and removes problematic compounds such as pesticides, tastes and odours and algal toxins.

In water purification schemes in which the reduction in total dissolved solids (TDS) is not necessarily a quality target, adsorptive treatment processes to remove organic molecules may be employed.

Advanced Oxidation Process

Advanced oxidation processes combine the use of strong oxidants (either ozone or hydrogen peroxide) together with intense UV irradiation to optimise the formation of free radicals through the photochemical reaction known as photolysis. With sufficient doses, organic chemicals may be completely mineralised (converted to carbon dioxide and other inorganic oxides) or their structure is cleaved into smaller fragments.

Advanced oxidation treatment processes are used to destroy trace organic compounds (for example, endocrine disruptors, 1,4-dioxane, VOCs, or synthetic organic compounds (SOCs) including pesticides) and NDMA that are resistant to the upstream processes.

[12] Lipophilic or lipid loving molecules are attracted to lipids. A substance is lipophilic if it is able to dissolve much more easily in lipid (a class of oily organic compounds) than in water

NDMA is not easily removed from water because it is highly soluble, resists adsorption and has low volatility. As a consequence, traditional treatment methodologies such as carbon adsorption, coagulation, filtration and even RO are not fully effective. However, strong chemical oxidants (such as ozone and hydrogen peroxide) are effective for the degradation of trace organic compounds. This oxidative degradation can occur either by direct reaction with the applied oxidant, or via the production of highly reactive secondary species, most commonly, hydroxyl radicals. The hydroxyl radical is one of the most powerful oxidants and reacts rapidly with organic constituents in the water, including micro pollutants, breaking them down into their elemental components.

NDMA is degraded relatively quickly when exposed to ultraviolet irradiation in the presence of hydrogen peroxide. This is performed in optimised UV reactors containing lamps with the spectral characteristics needed to destroy NDMA. As an added benefit to NDMA treatment, using UV provides an additional disinfection barrier. Simultaneously, many compounds are broken down directly by the UV light through photolysis.

Unless mineralisation is achieved by advanced oxidation of highly pre treated water, many contaminants will form degradation products which will persist in the water. These are often further removed by biodegradative processes (Yavich & Masten 2003; Yavich et al. 2004) or coagulation processes (Chaiket et al. 2002; Singer et al. 2003). However, investigations on some active pharmaceuticals such as ethynylestradiol (Huber et al. 2004) and carbamazepine (McDowell et al. 2005) have shown that even partial oxidation is sufficient to reduce pharmacological activity and toxicity of these agents.

Wetlands

As part of an overall multiple barrier treatment strategy a wetland component may be used as an adjunct to an appropriate water purification technology process.

Wetland treatment systems use naturally occurring physical, chemical and biological processes to provide an additional treatment barrier for pathogens, residual organics, inorganics and emerging contaminants of concern, such as endocrine disrupting compounds (EDCs).

The major categories of wetland treatment systems include:

- surface flow wetlands;
- subsurface flow wetlands;
- floating aquatic plant systems; and
- natural wetlands.

The use of wetland and aquatic ecological systems to improve water quality has been recognised for more than 25 years. A significant number of pilot and demonstration projects have proven and refined the wetland treatment system technology and many full scale applications exist throughout much of North America, Europe and Australia. Owners have found that wetland systems often provided cost effective, low energy, natural alternatives to energy intensive conventional treatment. In addition to providing water quality improvement, wetland treatment systems can provide significant ancillary benefits, for example, wildlife habitat creation. There are a number of wetland systems in NSW in similar climatic zones to Canberra. Colder temperatures result in lower reaction rates and wetlands are usually sized for the loading rates appropriate to the lower temperature conditions.

Wetlands can be used as an environmental buffer zone, for temperature attenuation and to provide a final polishing treatment step to reduce the levels of nutrients, to ensure that nutrient water quality objectives are achieved.

Studies have shown that constructed wetlands may remove some amounts of non nutrient constituents. For example, EDCs are a group of compounds that, at certain concentrations, can cause disturbance to the endocrine system of aquatic organisms and wildlife, affecting their hormonal control of development (Ying et al. 2004). The effects of these chemicals on aquatic organisms and wildlife have been conclusively documented in the literature. However, the impacts on humans are yet to be firmly established. While precise reductions of EDCs and other emerging contaminants of concern in wetlands are difficult to quantify at this stage, it can be reasonably assumed that wetlands will provide an additional treatment barrier for these compounds.

4.2.2 Water Purification Plant Process Options for Canberra

There are a number of alternative process and equipment options which may prove suitable in the longer term but are not sufficiently developed to warrant serious consideration at this stage.

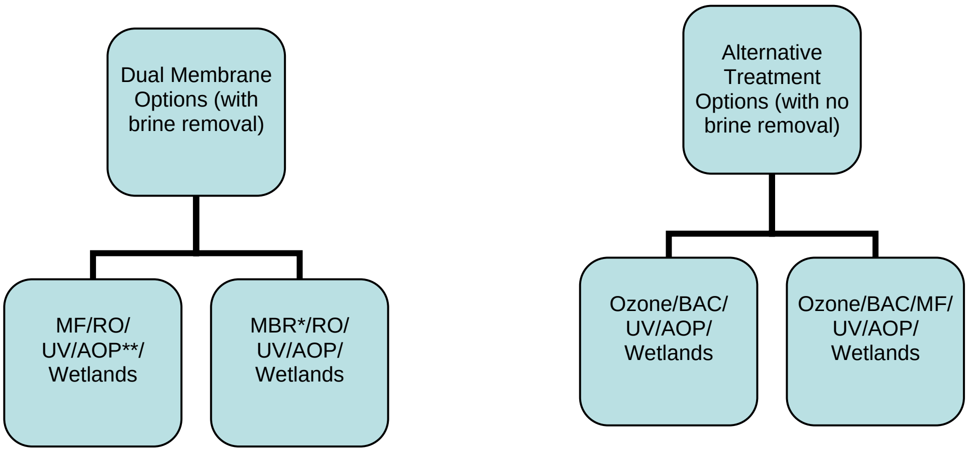
The selection of suitable options for Canberra from the various available, has been made on the basis that the process and equipment used has been fully developed and has been proven operationally to produce water of an acceptable potable standard.

On this basis, two main process options emerge as possible choices for the water purification plant at LMWQCC. These are:

- dual membrane option (membrane filtration and reverse osmosis); and
- ozone/biological activated carbon (BAC).

Figure 4-2 diagrammatically shows the variants of the process options assessed.

Figure 4-2 - Process Options Considered



* Membrane Bio reactor
** Advanced Oxidization Process

4.2.2.1 Dual Membrane

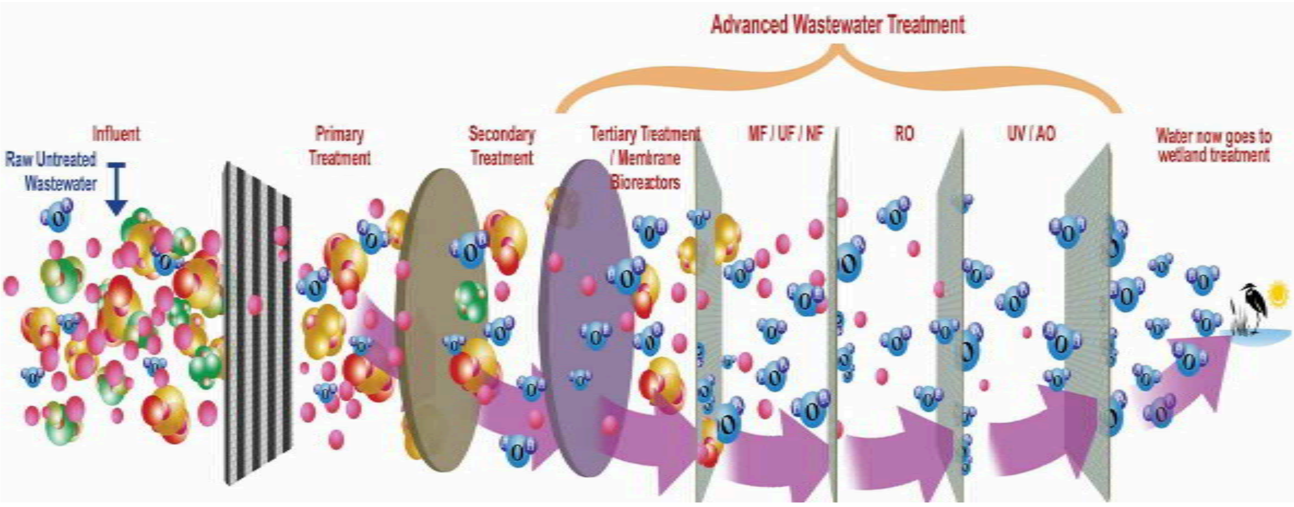
Dual membrane systems involve membrane filtration (either microfiltration or ultrafiltration) in series with reverse osmosis (RO).

The membrane filtration (MF) system removes sub micron (less than 10^{-6} m) particles including; bacteria, large colloids and other suspended solids from the tertiary effluent. They also improve the performance and prevent fouling of the RO membrane system. This minimises the RO membrane chemical cleaning requirements.

The RO system will selectively remove a high percentage of the dissolved solids including ionised salts, organic molecules down to relatively low molecular weight, viruses, oocysts, pathogens and trace compounds. The mechanisms for RO removal is primarily by size exclusion.

Figure 4-3 shows an artists impression of the proposed dual membrane process barriers.

Figure 4-3 - Artists impression of dual membrane process barriers



The RO process removes salt from the water; disposal of this salt (brine solution) needs to be effectively managed.

The RO permeate is oxidised by the advanced oxidation process (AOP) which utilises high intensity UV irradiation of the product water in conjunction with the dosing of hydrogen peroxide. This produces hydroxyl radicals that are effective in the oxidation of residual organics, inorganic compounds, trace compounds and the inactivation of any residual viruses and pathogens.

Advantages of the dual membrane process option are:

- proven technology;
- salt removal;
- modular in construction and can be readily upgraded (i.e. membranes replaced); and
- as shown diagrammatically in Figure 4-3 they provide physical barriers for removal of inorganic and organic compounds and biological particles.

The removal of salt, whilst advantageous in some respects as it removes salt from discharges to any receiving waters, does cause additional process and environmental complexity. The salt, once removed, needs to be concentrated (removal of water) and the resulting residue needs to be disposed of or a suitable use found for this salt product.

Dual membrane technology is a proven technology for indirect potable use and there are operating plants in Singapore (NEWater factories), Belgium and in the USA.

The Western Corridor Project in South East Queensland, of which various sections are currently being constructed, includes three dual membrane water purification plants, with total capacity exceeding 200 ML/d, which are being designed for indirect potable use. Currently these dual membrane plants have been designed to supply water to two power stations and irrigators in the Lockyer Valley. However, in the event that the drought continues the plants will supply water into the Wivenhoe Reservoir which is the main source of water for Brisbane.

4.2.2.2 Ozone/Biological Activated Carbon (ozone/BAC)

For the ozone/BAC option, ozone is generated on site and is mixed with the treated wastewater, which is then passed through a bed of activated carbon.

In this configuration, the activated carbon bed is usually referred to as biological activated carbon (BAC), because a biofilm develops on the surface of the carbon granules and contributes to the breakdown of residual organic matter or cell fragments which have been partially oxidised by the ozone.

The ozone/BAC treated water is further oxidised by the AOP which utilises high intensity UV irradiation of the final water in conjunction with the dosing of hydrogen peroxide. This produces hydroxyl radicals that are effective in the oxidation of residual organics, inorganic compounds, trace compounds and the inactivation of any residual viruses and pathogens.

For ozone to be effective it is best to remove as much of the organic material as possible prior to ozonation. Ozonation is normally preceded by some form of filtration, whether it is by granular media filtration, dissolved air flotation filtration (DAFF) or membrane filtration. The LMWQCC plant already utilises dual media filtration prior to chlorination and discharge to the Molonglo River.

There are a number of water purification plants utilising the Ozone/BAC process operating in the US, Namibia and in Europe. The Fort Wayne Hill Water Resources Water Facility, Gwinnett County, Georgia, USA uses a two stage ozonation process involving pre ozonation followed by activated carbon absorption and final post ozonation to treat secondary treated wastewater supplied from either granular media filters or a microfiltration facility. The new Goreangab Water Reclamation Plant, Windhoek, Namibia uses an Ozone/BAC/GAC/UF treatment train to supply water directly into the city water supply system. The Advanced Water Treatment Plant at Langford, Essex in the UK has an Ozone/BAC/UF treatment train although it has been noted that the plant produces lower quality product water than the dual membrane plants in Singapore (Gardner, T., Yeates, C and Shaw, R. (2007)).

In Australia there are two plants which utilise Ozone/BAC, one at Caboolture and one at Landsborough, both in South East Queensland. Both plants were conceived as water purification plants, however neither plant has been operated to supply a source of potable water.

4.2.3 Water Purification Plant Residuals Technologies

The two key process trains under consideration for the Water Purification Plant for Canberra are:

- dual membrane; and
- ozone/BAC.

This section applies to residual management options in the case of a dual membrane process; membrane filtration followed by reverse osmosis (MF/RO) being selected for the water purification plant for Canberra and in particular residuals management from the RO process.

For the alternative Ozone/BAC treatment process there is no significant residual issues or brine production as the process does not remove salts (dissolved solids).

It is anticipated that other process wastes (i.e. the backwash water from the denitrification and membrane filtration processes) would be pumped directly back to the head of the LMWQCC for reprocessing.

4.2.3.1 Brine concentration Technologies

There are a number of technologies which could be used to concentrate the brine solution prior to disposal. This section outlines technologies which have been considered as part of this study.

Electrodialysis (ED) and Electrodialysis Reversal (EDR)

Electrodialysis (ED) is a process in which solutions are desalted or concentrated electrically. Salts in water dissociate into positively and negatively charged ions. The key to the ED process is a semi permeable barrier, which allows passage of either positively charged ions (cations) or negatively charged ions (anions) while excluding passage of ions of the opposite charge. These semi permeable barriers are commonly known as ion exchange, ion selective or electrodialysis membranes. The product water does not pass through a membrane barrier in these processes, so they are used primarily for desalting and demineralisation applications. There is no removal of pathogens or most chemicals of concern.

Solar Thermal Desalination

Solar thermal desalination is an emerging technology that may have significant impacts on this process in the future. The Australian National University (ANU) Solar Thermal Group conducts research and development activities that contribute to the progress on the conversion of solar energy to power generation using flat plate non concentrating systems and mirrored solar concentrators.

ANU has a 400 m^2 dish which is the world's largest paraboloidal dish solar concentrator. This dish is the prototype of a design that is intended for use in large scale solar power generation systems. Although this emerging solar thermal technology has the potential to provide a low cost alternative for the concentration of the RO brine stream, it has not been included as one of the possible options for salt management, as this has not yet been commercially proven. However, one aspect of this solar thermal technology that may have merit, once it is proven, is the use of this technology to pre heat the RO feedwater. One Australian desalination company is providing funding assistance to ANU to help them to develop this approach as it could result in significant capital cost savings for RO desalination plants by significantly reducing the number of RO membranes. There is a possible downside to this as, the warmer reuse stream would then require more cooling before it could be returned to the Cotter Reservoir without impacting the temperature in the reservoir.

Vibratory Shear Enhanced Processing (VSEP) Membrane System

To reduce scaling potential and increase recovery an alternative method for producing intense shear waves on the face of a membrane has been developed. This process, like EDR, would decrease the amount of brine/concentrate that requires disposal. However, an ultimate disposal mechanism such as crystallisation/landfill would still be required to completely dispose of the brine/concentrate. The technique is called Vibratory Shear Enhanced Processing (VSEP). In a VSEP system, the feed slurry remains nearly stationary, moving in an oscillatory flow between parallel membrane leaf elements. Shear cleaning action is created by vigorously vibrating the leaf elements in a direction tangential to the faces of the membranes.

The vibration helps reduce the level of concentration at the surface of the membrane, a process known as concentration polarisation (CP). In addition to cutting down on the flux performance of the membrane, the CP layer produces a maximum concentration of salt at the membrane surface, promoting precipitation of salt (scaling).

The shear waves produced by the vibration of the membrane cause potential foulants to be lifted off the membrane surface and remixed with the bulk material flowing through the membrane stack. This high shear processing exposes the membrane pores for maximum output that is typically between 3 and 10 times the throughput of conventional cross flow systems.

RO membrane modules for VSEP application are not the same as conventional RO modules. The systems occupy much more space than conventional RO for the same capacity and use approximately five times as much energy. However, these systems require much less pre treatment of the feed water and claim to be able to produce supersaturated brine continuously where conventional RO systems can not.

Whilst the technology offers great opportunities, it has yet to be demonstrated successfully on municipal water reuse brine/concentrate treatment and is very energy intensive.

Precipitative Softening/Reverse Osmosis

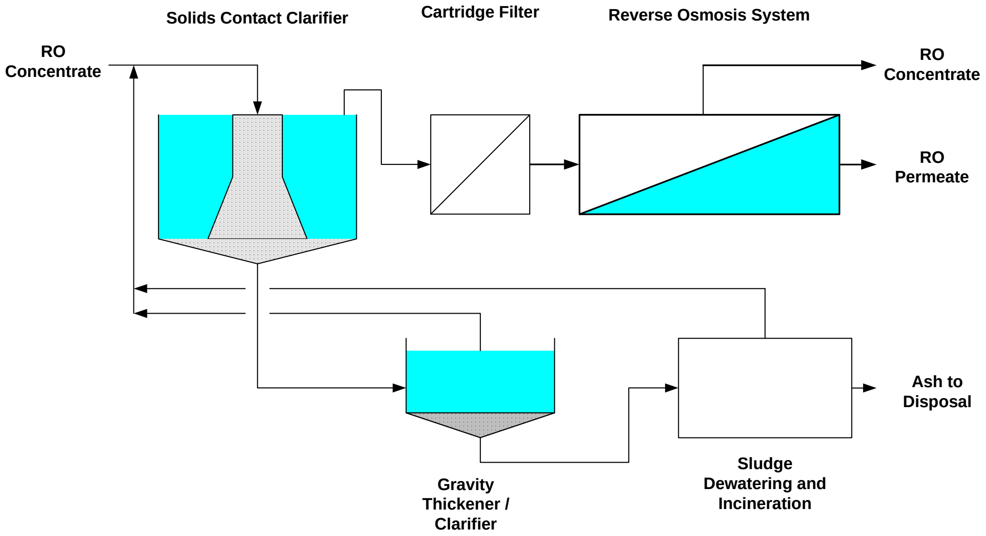
A combined process involving precipitative softening and RO is a proven and viable option for treating the brine/concentrate from a main RO system.

Precipitative softening processes, for example, lime softening, are effective at removing calcium, barium and strontium (major scale forming ions) which allows an RO process to operate at higher recoveries in the precipitation of sparingly soluble inorganic salts.

In this process the brine solution is dosed with calcium hydroxide and soda ash to precipitate scale forming ions from solution as sludge.

A process flow diagram of the proposed process and an example of a typical solids contact clarifier and gravity thickener is shown in Figure 4-4.

Figure 4-4 - Precipitative Softening & Secondary RO process flow diagram



The solids (sludge) from the clarifier may be dewatered and subsequently disposed to landfill or may be co incinerated with sludge from the LMWQCC treatment processes.

High Efficiency Reverse Osmosis (HERO™)

The HERO process consists of several proven pre-treatment steps in combination with reverse osmosis operating at high pH. The basic process consists of three steps:

- hardness and suspended solids removal;
- carbon dioxide removal; and
- RO treatment at elevated pH.

This type of RO treatment is relatively new and has not been used for water reuse applications, it has only been applied in the power station and mining industries.

The advantages of the process over conventional RO include; reduction in scaling, elimination/reduction of biological and organic fouling due to high pH and recoveries of up to 95%.

The disadvantages of the HERO process is the high chemical usage (due to lime softening process and ion exchange), higher capital costs than conventional RO and the disposal of waste streams generated from the lime softening process (solids) and ion exchange (waste brine).

Mechanical Evaporation

The mechanical evaporation process is driven by heat transfer where condensing steam is used to the lower the temperature of membrane reject. The absorbed heat causes vaporisation of water and an increase in the reject salt concentration. The vapour is then condensed becoming distillate for reuse.

Evaporators can be categorised according to the arrangement of their heat transfer surface and the method used to impart heat to the feed solution. Common types of evaporators include the following:

- single effect;
- multiple effect;
- vapour compression;
- vertical tube falling film;
- horizontal tube spray film; and
- forced circulation.

The most common combination of evaporators to accomplish full evaporation of membrane reject streams is vertical tube falling film vapour compression evaporation followed by a crystallisation/landfill step. A further detailed description of this process is outlined in the CH2M HILL 2007a.

Evaporation Ponds/Misters

Evaporation ponds rely on solar energy to evaporate water from the brine/concentrate, leaving behind precipitated salts, which are ultimately disposed of in landfills.

In the most common case, brine/concentrate is conveyed to the evaporation ponds where it is spread out over a large area and allowed to evaporate. Multiple ponds are normally provided to enable them to operate as a batch process. Once full, the ponds are taken offline to enable the salt to dry to a firm consistency. Once the precipitated salts have reached a satisfactory consistency, the ponds are cleaned by removing and transporting the precipitated salts to a landfill for ultimate disposal. The evaporation ponds must be appropriately lined to prevent percolation of reject water down to the groundwater table. Liner material and thickness must also be selected appropriately, since increased salt content may cause deterioration of the liners.

An option for decreasing the pond area required is to include mechanical misting equipment that sprays the brine/concentrate into the atmosphere in tiny droplets substantially increasing evaporation. The increased exposed surface area corresponds to a very high evaporation rate. Depending on the atmospheric conditions, large amounts of water can be evaporated leaving only precipitated salts.

Evaporation ponds generally require some form of perimeter buffer to be managed to protect the surrounding environment and improve the visual impact. This is particularly important when misters are used. The possibility of wind drift generally requires location of the misters at the upwind end(s) of the ponds for the prevailing wind(s) and a high wind switch from an anemometer to turn off the misters and minimise impact on the surroundings. If misters are not used, the impact is usually only visual and only screening is required.

Forced Circulation Crystalliser (FCC)

A FCC is a mechanical evaporation process that uses heat and pressure differentials to flash boil water, generating distilled liquid and solid salts. Some suppliers integrate the crystalliser with the mechanical vapour compression falling film exchanger vessel. A further detailed description of this process is outlined in CH2M HILL2007a.

4.2.4 Water Purification Process Brine Disposal Options

The brine or RO concentrate rejected by RO membranes includes ionised salts, organic molecules of relatively low molecular weight, viruses, oocysts, pathogens and trace compounds and this liquid reject stream must be disposed of.

A detailed assessment of options for the disposal of brine is provided in CH2M HILL 2007b and its associated sub-reports CH2M HILL 2007c-i.

Two options are seen as available for management of the brine stream from an RO plant in Canberra. They are:

- co disposal of the brine with LMWQCC effluent back to the Molonglo River; and
- removal of brine from the process stream and either on site or off site concentration and off site concentrate disposal.

These options and associated technologies are discussed in detail below.

Discharge of Brine with LMWQCC Effluent to River

One option for management of brine is to reintroduce the brine from the RO plant back into the effluent stream from LMWQCC. This option does not result in an increase in the total mass of salts being discharged from the plant to the river. However, there would be an increase in the concentration of dissolved salts in the effluent stream and an increase in the concentration of dissolved salts in the downstream river due to the decreased flow.

Ocean Disposal

A large number of water purification plants using RO processes (including desalination plants) are located close to the ocean. This is due to the complexity of treatment and energy required to concentrate the brine waste from RO plants so the most feasible option is to pipe the brine waste to the ocean, provided a suitable site for disposal to the ocean can be identified. The disposal scheme is relatively simple and only involves a pump station and pipeline from the WPP to the coast and minimal treatment is required.

The issue for this project is the distance to the coast (in excess of 170 km) and the elevation required to pump over the Great Dividing Range (greater than 300 m lift). Preliminary consideration of this option has raised additional issues apart from the economics. The pipeline would be located for the majority of its route in NSW, a different regulatory jurisdiction, requiring land acquisition or approvals for easements and in addition there would be a need for detailed environmental investigation and approvals for any outfall.

Near Site Evaporation Ponds

Natural evaporation is an alternative to thermal and mechanical evaporation, both of which require significant capital and operating costs. Evaporation from ponds is practiced at numerous inland RO facilities overseas, with multiple lined lagoons receiving brine solution, eventually to be allowed to dry out in turn with the salt removed to landfill.

For this option brine produced by the primary RO process would be further concentrated (dewatered) using secondary RO with precipitative softening. The concentrated salt slurry (approximately 18,000 mg/L TDS) is then delivered by pipeline and distributed to a number of evaporation ponds.

Using historical evaporation data from the Bureau of Meteorology for the Canberra region, the evaporation pond area required is calculated as 55 ha for a 25 ML/d water purification plant including; berms and roadways on a level site. An additional buffer area, estimated at approximately 45 ha, is required with the final sizing of the buffer area depending on the location and topography selected for the ponds. The pond area could be reduced by including mechanical devices such as Turbomisters™, which spray the brine solution up into the air above the pond and increase the evaporation rate (somewhat similar to a snow machine but with a different purpose). These can create additional environmental impacts arising from mist drift and are not proposed for this project.

Near site refers to the location of the ponds being somewhere within the ACT. For this project, a pipeline would be relatively short and the approval process would be relatively straightforward, although the local terrain makes it difficult to find a suitable location. Conceptually, an area near the Uriarra settlement and Tarpaulin Creek appears suitable and is near where the proposed pipeline from the Water Purification Plant to the Cotter Reservoir is expected to pass (Uriarra Road), which would mean that the two pipes could be laid together for most of their length. Acquisition of suitable land for construction of evaporation ponds is seen as a difficulty and the potential environmental impact of the ponds and their operation is seen as significant.

Ultimately the dry salt needs to be harvested and disposed of, potentially to a market if some beneficial use can be found for the salt, or to a suitable receiving facility such as a landfill. Evaporation ponds with the final salt product transported to a suitable landfill site (the specific site has not been determined) by truck, represent a balance between the environmental impact of high energy consumption and social and visual impact on the surroundings.

Fees for landfilling of dried salt have been estimated at approximately $500/t (dry mass); this is substantially more than typical costs for disposal of sewage sludge. For the facilities to accept salt they have to ensure containment to prevent mobilisation of the salt and permeation into groundwater.

Operating costs of the ponds are expected to be low; $100,000/yr is estimated, allowing for inspection and maintenance of the ponds and buffer areas.

Offsite Evaporation Ponds

If evaporation ponds were to be used, but a suitable site could not be found in the ACT, additional complications arise. The length of the pipeline to deliver the brine increases, probably requiring multiple pump stations and the jurisdiction changes into NSW so that the approval process becomes more complex. A secondary RO concentration step with pre softening at LMWQCC is proposed to reduce the volume for disposal and transport.

The old Woodlawn open cut mine site between Lake Bathurst and Lake George has been identified as a possible location. The pit is now operated by Veolia Environmental Systems as a landfill for Sydney's garbage, with a sophisticated irrigation system to control site runoff and leachate and collect methane gas from the waste for power generation which is referred to as a Bioreactor. Veolia's site covers a total of about 6000 hectares, including the old mine tailings dams, evaporation ponds and surrounding areas and is licenced and operated purely as a waste facility.

Preliminary discussions have been held with the management of the Woodlawn site and acceptance of the brine stream would require a change to the site operating licence. Discharge of brine to the Bioreactor would not be suitable as the brine would affect the biological processes and could create safety issues by inducing release of hydrogen sulphide gas from the landfill. However, Veolia are in the business of waste management and see no problem with developing appropriate facilities on their site for acceptance of brine solution. There is also the possibility of using the brine stream to neutralise acid mine drainage water resulting from sulfate exposed at the mine, or in maintaining a liquid cover on the tailings dams.

A complication that could possibly affect this option is that there is an active mineral exploration licence on the site to investigate further exploitation of the ore body. The current market for base metals and improved technologies has made metal extraction from lower concentrations of ore economically viable and the mining activities on the site may be resumed. This would not affect the bioreactor, but the tailings dams and evaporation ponds may be recommissioned. However, Veolia expect that separate, dedicated ponds and landfill facility could be approved and developed. The boundary of the Sydney Water Catchment passes through the existing evaporation ponds on the site; any new ponds or landfill would have to be to the west of this boundary.

The Bioreactor is licenced to accept waste for another 20 years and will continue to operate to generate power from methane, apparently for another 20 or 30 years after it stops accepting waste. Veolia have applied to double the license limit on the loading rate to the Bioreactor, so that it may stop receiving waste after 10 years, but the site would still be active thereafter. The site has approval to install 50 MW of wind power generation also, which could affect the operational status of the site.

An assessment of the possible pipeline routes shows that the energy consumption to reach the Woodlawn site is still comparatively modest, around 80 kW for the 25 ML/d plant capacity. Including the power consumed at LMWQCC for concentration with PS and RO, this gives a total of 750 kW. The price for disposal at Woodlawn is uncertain, but would be on commercial terms. Management at the Woodlawn site see some potential benefits of having such a continuous flow stream, but do not have any similar customers at the moment and costs are uncertain; $500/t (dry mass) is assumed. The ability to obtain modification to the current site licencing arrangements is seen as a risk to this concept.

Deep Well Injection

Deep well injection (DWI) is a disposal alternative that ultimately stores the liquid waste in subsurface geologic formations that are not used for beneficial use. A well is used to convey the liquid waste some distance below the ground surface where it is released into a geologic formation; well depth is typically less than 2,500 m. The well depth depends on; the class of well used, the existing geologic strata and the depth to groundwater aquifers. In the US, deep well injection is the most frequently used method for disposal of brackish water when options for disposal to surface water or the sewer are not available.

Implementation issues for brine/concentrate disposal by deep well injection include; site availability, well classification, brine/concentrate compatibility and public perception.

The site must have favourable underground geology conducive to deep well injection, with a porous injection zone capable of sustaining adequate injection rates over the life of the membrane facility. In addition, an impermeable layer is required to prevent the migration of the injected brine/concentrate into any water source.

The site also needs to be a sufficient distance from any wells penetrating the impermeable layer that may serve as a pathway through the impermeable layer into a potable water source. Another important consideration is proximity to faults, as injecting brine/concentrate could increase water pressure on fault lines resulting in earth movement.

Preliminary review of the regional geology indicates that the underlying formation is granite and opportunities for locating suitable aquifers would be very limited. Further review of the regional geology is recommended to see if there are any opportunities for deep well injection.

Natural Treatment Systems

Natural Treatment Systems (NTS) are another potential approach for disposal/reduction of wastewater effluent or brine/concentrate. Wetland treatment systems use naturally occurring physical, chemical and biological processes.

There is very limited information on the effective operation of natural treatment systems for concentration and management of brine in inland areas and the suitability of this process for the Canberra region has not been assessed.

Crystallise and Truck to Landfill / Market / Stockpile

Over the past 20 years, zero liquid discharge (ZLD) has become quite common on industrial plants overseas (including USA and South Korea) for the management of brine, driven by environmental regulation or cost of land and to avoid evaporation ponds. A crystallised salt product produced by the associated technologies (refer to Section 4.2.3) allows it to be transported by road to the ultimate disposal site, avoiding all the issues with pipeline construction and operation.

The disadvantage from an environmental perspective of ZLD is the high energy consumption and associated greenhouse gas emissions. Conventional MF/RO water purification plants with no further brine concentration use in the order of about 1 to 1.5 kWh/kL of water produced while estimates for an equivalent plant using a ZLD process for brine management are in the order of 30 kWh/kL of water produced.

Multi Criteria Analysis (MCA) has been used to assess the most appropriate option for management of brine residuals from the WPP and a summary of this process is provided in Section 4.4. For the purposes of Multi Criteria Analysis (MCA), three distinct options have been identified for the offsite disposal of crystallised salt, which have different outcomes in terms of the criteria and are discussed in further detail below.

The landfill option would comprise a load based fee for disposal at the site (yet to be determined, but Veolia's Woodlawn site is a possibility, see above). The assessment covers the possibility that the salt may have some value for beneficial use for rehabilitation of acid affected sites or as chemical feedstock, for example and therefore attract reduced fees and positive environmental effects.

Stockpile was identified as a short term option which could allow for time lag in developing the ultimate landfill if this could not happen in the timeframe for delivering the water to Canberra. The alternative of storing the crystallised salt on site at LMWQCC in a purpose built facility before distribution could have some benefit. This could buy time to allow the WPP to continue to operate in the event that the market ceases to take the salt. This option is similar to other crystalliser options in respect of technical issues. The required building to keep rainwater away from the salt and to allow front end loader access for 6 months storage is estimated at $5M, with a decommissioning and rehabilitation cost of $180,000.

Transport to Sydney or Wollongong

Another possible disposal route for crystallised salt is to transport it to an existing sewage treatment plant with a deep ocean outfall and dispose of the salt as trade waste. Some preliminary discussion with Sydney Water has indicated that this is feasible. Possible sites would be Malabar or North Head (less likely) in Sydney or the Wollongong plant which already has a MF/RO facility to supply Bluescope Steel. This is seen as duplication (or a sub option) of the Crystallise and Truck to Landfill option and is included as an alternative ultimate disposal route. It could still be a viable alternative for the ultimate disposal from an evaporation pond system as well. A cost of about $500/t for discharge licence fees and transport is anticipated.

Landfill

For a majority of the brine/concentrate reduction alternatives, the end disposal mechanism is to landfill either the liquid/slurry or solid brine/concentrate. The amount of material disposed into a landfill depends upon which reduction/disposal alternative is used as well as its efficacy. There are a number of considerations that must be taken into account when identifying potential disposal sites including:

- disposal of liquid waste may not be permitted at every facility and can be significantly more expensive if disposal of liquid waste is required to be done in drums;
- many landfills have a requirement that at least 50 percent of the material to be placed in the landfill must be in solid form;
- there are high transport and permit costs associated with disposing industrial material in landfills; and
- disposal fees can vary dramatically by landfill facility.

Beneficial Reuse

Initially it was thought that some commercial use could be found for the salt components of the brine, for example, chemical feedstock, which might cover the costs of dewatering.

However, the composition of the salts present and the contamination with soluble organics mean that the salt is of limited commercial value. It is recognised that there still may be some value in the salt for remediation or other purposes and that this could become the ultimate disposal route for the dry product from a number of dewatering options.

Transport of water by road is expensive and dewatering of the brine stream on site is expected if this option is selected. This option for disposal is therefore incorporated by differentiating between landfill and market for ultimate disposal of the dry, dewatered salt from other treatment processes. This avoids the estimated $500/t for ultimate disposal to landfill.

Using the costs developed for the dewatering processes, it is possible to estimate a break even price for the salt over the 25 year project life, not including transport costs from the final dewatering step (evaporation ponds or crystalliser). These are:

- a 25 ML/d plant with crystalliser at LMWQCC, break even price is approximately $1140/t (dry mass);
- a 25 ML/d plant with onsite evaporation ponds, break even price is approximately $1,240/t (dry mass); and
- a 25 ML/d plant with pipeline to evaporation ponds at Woodlawn mine site, break even price is approximately $1,430/t (dry mass).

An issue for the disposal to a market is that the market may not be reliable, or may not want to accept all of the approximately 10 t/d. Another, alternative disposal route would then be required.

4.2.5 Water Purification Plant Pretreatment Options

One of the finished water quality target requirements for any water purification plant for the ACT is to ensure water quality meets both human health and environmental requirements for release into the Cotter Reservoir. This requirement extends to ensuring that nutrient concentrations (total nitrogen and phosphorus) in the water returned to the Cotter Reservoir are at levels that do not impact on the aquatic life in the reservoir or trigger algal growth blooms.

The water treatment processes proposed do not effectively reduce nutrient (total nitrogen and phosphorus) levels to a sufficiently low level, therefore, additional pre or post treatment must be added to effectively manage the reduction of nutrients.

Biological denitrification is the most effective process to target nitrogen in association with the WPP. This is best achieved prior to the WPP through the use of purpose designed anoxic reactors within the existing LMWQCC facility (treating all or part of the plant flow) or can be achieved in purpose designed denitrifying units (filters or reactors) located immediately upstream of the WPP.

For the two alternative WPP process options, the following nitrate guidelines are seen as applicable:

- a WPP with dual membrane (RO) technology would require an additional upstream denitrification facility to reduce nitrate feed concentration from the anticipated WWTP upgrade concentration of 12 to 15 mg/L to less than 5 to 7 mg/L. This would achieve a less than 0.7 mg/L nitrate after the WPP (RO membranes can reject 80 to 90% of nitrate); and
- a WPP with ozone/BAC technology would require an additional upstream denitrification facility to reduce nitrate feed concentration from 12 to 15mg/L to 1mg/L or less as there is no removal of nitrate in the ozone/BAC process.

With these guidelines in mind the following are the options for further biological denitrification at LMWQCC. A detailed assessment of these options is outlined in CH2M HILL 2007b.

- recommissioning of the existing denitrifying columns on the full plant flow with new methanol dosing facilities. Solids generated in the columns would be captured in the existing downstream tertiary filters and feed to the WPP would be from upstream of the chlorine contact tank;
- recommissioning part of the existing denitrifying columns to treat a side stream flow with new methanol dosing facilities. This would require flow splitting arrangements at the inlet to the columns and tapping into and modifying the transverse effluent channel running underneath the columns to keep the denitrified flow isolated from the main plant flow. A new solids separation stage, for example, DAFF or cloth filter would likely be required to avoid overloading of the WPP;
- reconfiguring the operation of the LMWQCC treatment plant to increase carbon load to the secondary process, increasing mixed liquor return (MLR) flows and potentially dosing methanol to the process;
- construction of new purpose built secondary denitrification reactor and methanol dosing facilities to treat the full LMWQCC plant flow, connected to the existing reactors and feeding mixed liquor back to the mixed liquor channel for settling in the existing clarifiers;
- Construction of new purpose built denitrifying reactor and methanol dosing facilities for treatment of a side stream only as part of a new membrane bioreactor (MBR) tank. There are two configurations for this option; firstly take mixed liquor from zone 8 or the mixed liquor channel and return activated sludge (RAS) back to the new anoxic tank.

Secondly take clarified effluent and pump it to a new anoxic MBR facility, which could be located at the proposed site for the WPP;

- construction of new purpose built denitrifying filter with incorporated backwashing facilities and methanol dosing for the WPP. This could be fed with clarified effluent to reduce energy requirements to pump feed water to the denitrifying filter. This would also reduce flow to the existing tertiary filters; and
- construction of new purpose built moving bed biological reactor (MBBR) with associated facilities and methanol dosing for the WPP. This could be fed with clarified effluent to reduce energy requirements to pump feed water to the denitrifying filter. This would also reduce flow to the existing tertiary filters.

Selected Denitrification Treatment Processes

Based on the evaluation of the alternatives the preferred option for upstream nitrate reduction at this stage of planning for both alterative process trains is the inclusion of denitrifying filters, treating secondary clarified or filtered effluent upstream of the WPP process train.

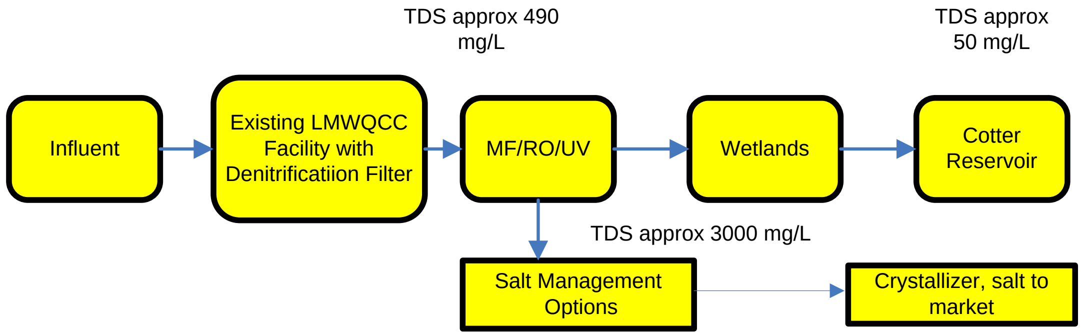
Issues such as the current site constraints, flexibility in operation and cost effectiveness were considered, as was the location of the denitrification filters adjacent to the proposed WPP plant site.

4.3 Water Purification Plant Process Selection

Four main process options for the WPP were selected for further evaluation, two utilising MF/RO and two ozone/BAC. All options incorporate WPP Pretreatment (denitrification facilities) and wetlands.

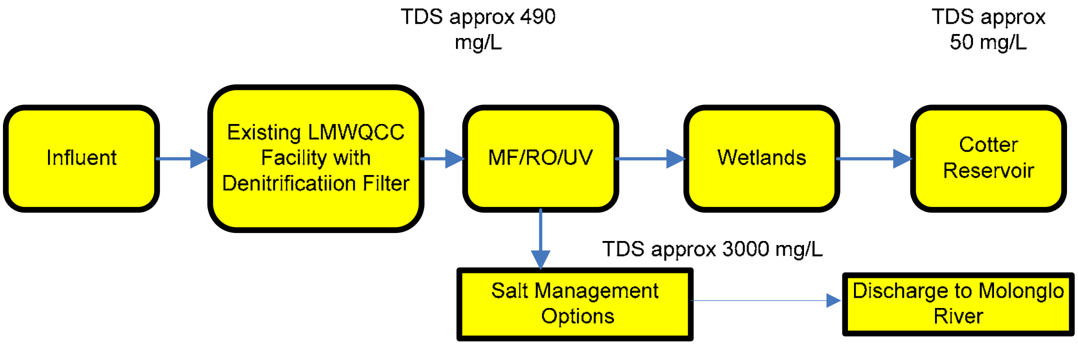
The Dual Membrane Option 1A treatment process is depicted in the simplified process flow diagram in Figure 4-5.

Figure 4-5 - Option 1A – Dual Membrane - Simplified Process Flow Diagram



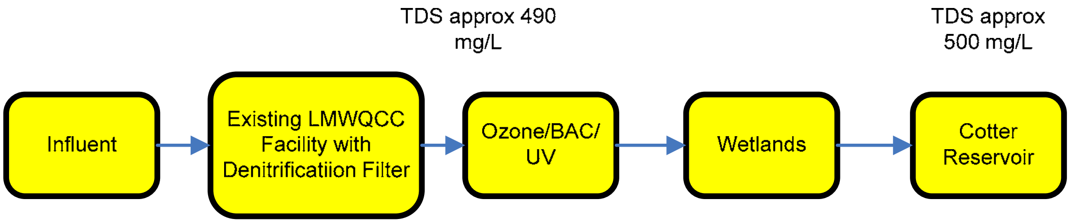
The dual membrane option 1B treatment process is depicted in the simplified process flow diagram in Figure 4-6 below. The difference between this option and option 1A is the method used for disposal of the brine waste from the RO.

Figure 4-6 - Option 1B – Dual Membrane - Simplified Process Flow Diagram



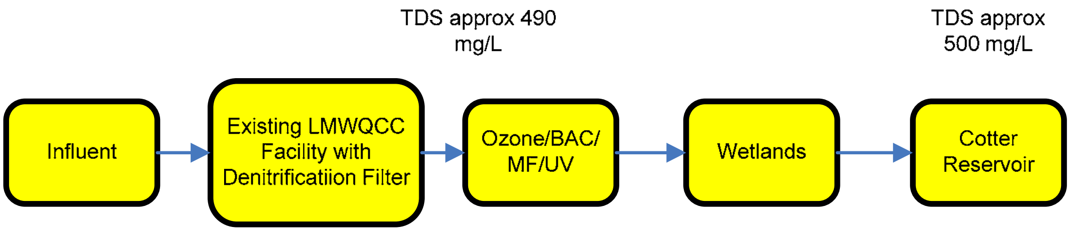
An alternative to dual membrane, option 2A treatment process, is depicted in the simplified process flow diagram in Figure 4-7.

Figure 4-7 - Option 2A – Ozone/BAC - Simplified Process Flow Diagram



An alternative to dual membrane, option 2B treatment process, is depicted in the simplified process flow diagram in Figure 4-8 below. This option has MF included.

Figure 4-8 - Option 2B – Ozone/BAC - Simplified Process Flow Diagram



Both the dual membrane and ozone/BAC process options employ technologies that have been proven worldwide for indirect potable use using the multiple barrier approach.

When examining indicative pathogen removal from the treatment processes and comparing water quality produced by the different process streams. It can be seen that MF/RO options have marginally better performance than the ozone/BAC options (CH2M HILL 2007b). However, both perform well above minimal requirements for supply of water to the Canberra water supply system.

The RO membrane can reject nitrogen from 80 to 90% and it is therefore possible for the MF/RO option to achieve the water quality objectives in the Cotter Reservoir without further treatment. The wetlands for the dual membrane option should be sized for temperature reduction only.

For the ozone/BAC options nitrogen reduction would be achieved using denitrifying filters, as the denitrifying filters would reduce the nitrate nitrogen to approximately 1.0 mg/L as against the target 0.7 mg/L, the wetland has been designed to remove the remaining 0.3 mg/L.

4.3.1 Multi Criteria Analysis for the Selection of Water Purification Plant Processes

To assist in comparing process options for this scheme, a Multi Criteria Analysis (MCA) was undertaken. Assessment of the options has been carried out by MCA because of the complexity of the information to consider. MCA is a decision making tool that enables comparison of items of different units and content, on quantitative and qualitative, objective and subjective items and is a means to assess the relative merits of nominated options against a specified range of criteria. This is discussed further in CH2M HILL 2007b.

Two levels of MCA have been undertaken with the first focused specifically on salt management options (described in detail in Section 4.2.4) associated with the management of brine from an RO plant. The second considered differing water treatment process trains together with salt management options as discussed in Section 4.2.2.

The MCA of water purification treatment processes and salt management options captures expected performance of the above four water treatment process options (Table 4-2) against the following criteria:

- technical;
- community;
- environmental;
- regulatory;
- estimated time required; and
- cost.

The result of the assessment is a relative ranking of options from preferred to least preferred.

Table 4-2 - Options Selected for Evaluation

Option Number	Process	Wetlands	Salt Disposal
1A	MF/RO/AOP	Temperature adjustment only	Crystallise on site and dispose of salt to market
1B	MF/RO/AOP	Temperature adjustment only	Brine discharge to River
2A	Ozone/BAC/AOP	Nutrient Polishing	Not required
2B	Ozone/BAC/MF/AOP	Nutrient Polishing	Not required

The MCA results show strongest performance in the two options 1A and 1B involving MF/RO (salt crystallised and reused commercially, or brine discharged to river). Option 1A's weaknesses lie in the Technical criteria, while Option 1B's weaknesses are visible in the Environment criteria.

These two MF/RO water treatment options 1A and 1B are stronger performers primarily due to the reliability of water treatment process and perceived drinking water quality criteria. These criteria are considered key to decision making due to health requirements, and lead to relatively better performance in the Estimate Time Required criteria. A consistent supplementary source of high quality drinking water delivered in a short timeframe is imperative. The relative reliability and performance of the treatment system noted in similar water treatment approaches elsewhere sets the MF/RO options ahead in this area. While Option 1B may appear technically simpler to implement, Option 1A performs relatively better in the Receiving Water Quality criteria, likely to be important to environmental regulators, non government organisations and the community. Both Options 1A and 1B have minimal impact on Cotter Reservoir and drinking water supply quality.

4.3.1.1 Dual Membrane

The dual membrane option (option 1B), with discharge of brine waste to the river ranked the highest and therefore preferred option for water purification plant up to a 25 ML/d capacity.

The ACT Government would have to confirm that discharge of salt waste to river is an acceptable option if this is to be considered further.

If a plant of larger capacity is required, continued discharge to the river may be possible for the MF/RO option. However, the resulting increase in salt concentration in low river flow periods may make this option non viable for environmental reasons. Crystallisation and disposal to a market off site (option 1B) would be the preferred option if this was the case. The higher greenhouse gas emissions generated from the MF/RO options may be offset if the Government were to link this project to a green energy scheme or other carbon offsetting schemes.

The dual membrane option ranked higher than ozone/BAC primarily due the following factors:

- the operational reliability of the water treatment process;
- the minimal impact on water quality (salinity) in the Cotter Reservoir and water supply from salt recirculation; and
- the perceived higher drinking water quality.

These criteria were considered key to decision making due to health requirements and community perceptions. The dual membrane option would both provide a higher level of public confidence in the overall concept because of publicity surrounding the Singapore NEWater plants, the Orange County Water District Ground Water Replenishment Project and the Western Corridor Project in Queensland (currently under construction).

Other points to consider with the results are:

- the MF/RO system is relatively readily upgraded to allow the replacement old membranes with newly developed versions; and the physical barriers of the membranes which lead to greater removal of inorganic compounds and biological particles.
- option 1A (the MF/RO based water treatment with salt crystallised and reused commercially) is the strongest performer within the MCA Community and Environment criteria groups;

- option 1A performs well by meeting all of the four Receiving Water quality criteria. Option 1A scored highly within the Receiving Water Quality criteria because salt and additional components, potentially toxic to aquatic organisms removed from the river are not discharged back into it in brine solution (as it is in Option 1B). Salt that is removed is reused commercially (identifying and pursuing a viable commercial reuse opportunity);
- option 1A shows mid range performance in the Estimated Time Required criteria covering salt management. This is due to the fact that a commercial reuse of salt has been identified, however, confirmation of feasibility remains unknown at this stage in the options selection process;
- option 1A is the relatively weakest performing option within the Technical criteria group. This is due to relatively higher amounts of energy are used in both MF/RO and crystallisation equipment, leading to increased costs and greenhouse gas emissions;
- costs may be recouped to a degree if a commercially viable reuse is identified for the salt, but if partial or total climate neutrality is a desired outcome from the public's perspective, further study into credible offset opportunities and costs would be required;
- process and construction complexity score poorly for both MF/RO options due to greater complexity in dual membrane technology when compared to ozone/BAC systems;
- option 1B (MF/RO based water treatment with brine discharge to river) performs well in areas similar to Option 1A due to the reliability of the water treatment system. It also performs relatively higher in the Regulatory criteria group, as a tested and proven water treatment system is more likely to satisfy the requirements of health authorities.
- within the salt management study the simplicity of a relatively short pipeline reduces energy use, contract, construction and process complexity, has fewer regulatory requirements exist, it is relatively quick to design and construct and it is the relatively less expensive salt management option; and
- option 1B showed poorest performance in the Environmental grouping. Whilst the option scores well for Cotter Reservoir Receiving Water Quality criteria, the remaining Murrumbidgee River, Murrumbidgee Salt Load and Molonglo River criteria receive the lowest scores. This is related to increases in electrical conductivity (EC) in these water bodies as a result of the treatment process and brine discharge to river.

4.3.1.2 Ozone/BAC

The ozone/BAC Options (options 2A and 2B) were the lowest ranking options. Key areas are:

- whilst ozone/BAC does not require an extra salt or brine management steps, they are considered the poorer performing options due to key decision making criteria;
- ozone/BAC showed weaker scores in the Perceived Drinking Water Quality and Perceived Risk criteria; key indicators of likely health authority and community level of concern. Due to this likely resistance, Estimated Time Required for approvals performs poorly. This combined performance does not meet the imperative of a consistent supplementary source of high quality drinking water delivered in a short timeframe.
- The ozone/BAC option also showed weaker scores in the Cotter Reservoir Receiving Water Quality criteria. It is important to stress that the ozone/BAC option would increase salinity in the Cotter Reservoir and the City water supply;

- if the ozone/BAC option is to be considered further, the impact of increased salinity in the Cotter Reservoir would need further investigation before it can be established the acceptability of such increases. The impact on customer confidence of supplying water of increased and varying salinity would also need to be assessed;
- increasing the plant capacity above 25 ML/d increases the salinity changes likely in both the Cotter Reservoir and the Canberra water supply system and this may make this option untenable much above a capacity of 25 ML/d; and
- This option is however, considerably lower in energy use (operating cost) and capital cost than the dual membrane option.

A summary of capital, operating costs and power usage for the options are shown in tables; 4.3, 4.4 and 4.5.

Table 4-3 - Capital Cost Estimates for Options

Treatment Capacity, ML/d	Capital Cost (AU$M)			
	Option 1A	Option 1B	Option 2A	Option 2B
25	206.3	168.2	133.3	156.2
50	296.8	226.3	181.8	216.7
75	386.6	286.5	234.9	281.4

Notes: See CH2M HILL 2007b Appendix D for full cost breakdown. Estimates in this table are for construction of water purification plant at stated capacity with no allowance for expansion using a single brine disposal option. Estimates include allowance for power supply upgrade, pump station and pipelines for transfer of purified water to Cotter catchment, wetland and denitrification facility.

Table 4-4 - Operation and Maintenance Cost Estimates for Options

Treatment Capacity, ML/d	Operation and Maintenance Cost (AU$M/yr)			
	Option 1A	Option 1B	Option 2A	Option 2B
25	13.9	9.7	6.7	7.1
50	23.3	15.6	10.4	11.7
75	33.1	21.5	15.3	16.4

Notes: See CH2M HILL 2007b Appendix D for full cost breakdown. Estimates in this table include allowance for operation and maintenance for the pump station and pipelines for transfer of purified water to Cotter catchment, wetland and denitrification facility

Table 4-5 - Power Requirements for Options

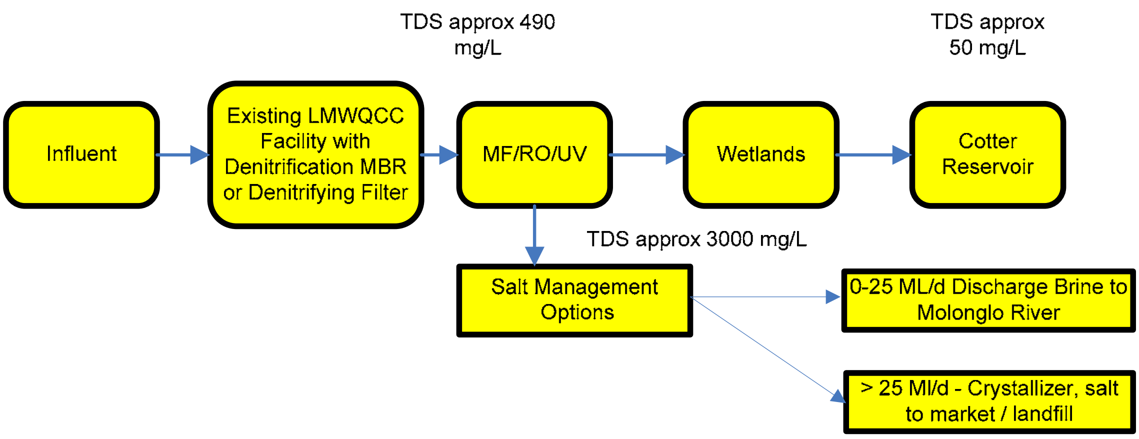
Treatment Capacity, ML/d	Total Power Requirements (MW) Option 1A	Option 1B	Option 2A	Option 2B
25	6.1	4.5	2.6	3.1
50	11.0	7.8	5.0	5.6
75	15.9	11.1	7.4	8.2

Notes: See CH2M HILL 2007b Table 9 2 for water purification plant power supply requirements. Estimates in this table include allowance for pumping of purified water to Cotter catchment.

4.3.2 Preferred Water Purification Plant Process Option

Based on the above analysis of options for both water purification plant treatment processes and brine management options, the preferred water purification plant treatment process and brine management options is a combination of Options 1A and 1B; both of which use dual membrane processes. Outline process flow diagrams for these options are provided in Figure 4-5 and Figure 4-6 and combined in Figure 4-9.

Figure 4-9 - Outline Preferred Water Purification Plant Process Flow Diagram



A detailed description of the proposed process for the water purification plant is provided in Section 4.2.2

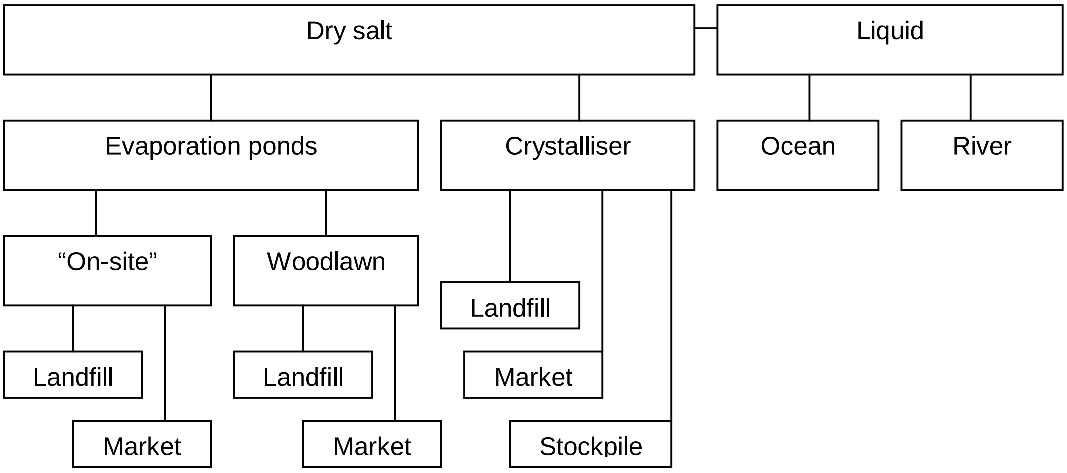
4.4 Brine Management Process Selection

The options identified as feasible for managing the brine stream can be broken down on several levels. The most obvious distinction, at the top level, is whether the final product for disposal is a liquid or is converted to a dry solid.

The next level of distinction is separated according to whether evaporation ponds or a crystalliser are used.

The distinction has become more unclear because of the combination of transport mode and market opportunities. Where evaporation ponds are used, it is feasible to transport the liquid stream a long distance by pipeline and subsequently use road transport to dispose of the final salt. Figure 4-10 illustrates this break down.

Figure 4-10 - Brine Management Options for RO



Nine Options were analysed as using a MCA:

- option 1 - concentration on site, pumping of brine to nearby salt evaporation lagoons, harvested salt transported to landfill;
- option 2 - concentration on site, pumping of brine to nearby salt evaporation lagoons, harvested salt transported to market destination;
- option 3 - brine transported via pipeline to purpose built evaporation pond at Woodlawn Bioreactor, salt remains at Woodlawn;
- option 4 - brine transported via pipeline to purpose built evaporation pond at Woodlawn Bioreactor, harvested salt transported to market;
- option 5 - concentration on site, crystallisation of salt, salt transported to landfill;
- option 6 - concentration on site, crystallisation of salt, salt trucked to market;
- option 7 - concentration on site, crystallisation of salt, salt stockpiled onsite or off site;
- option 8 - concentration on site, brine transported via purpose built pipeline to ocean outfall; and
- option 9 - brine discharge to river.

4.4.1 Multi Criteria Analysis for Brine Management

Figure 4-11 presents the relative total performance of each salt management option according to the MCA scoring system. Good performance within a particular criterion is indicated by a lower score, therefore the shorter columns in the graph indicate better performance.

Figure 4-11 - Brine Management MCA Option Scoring

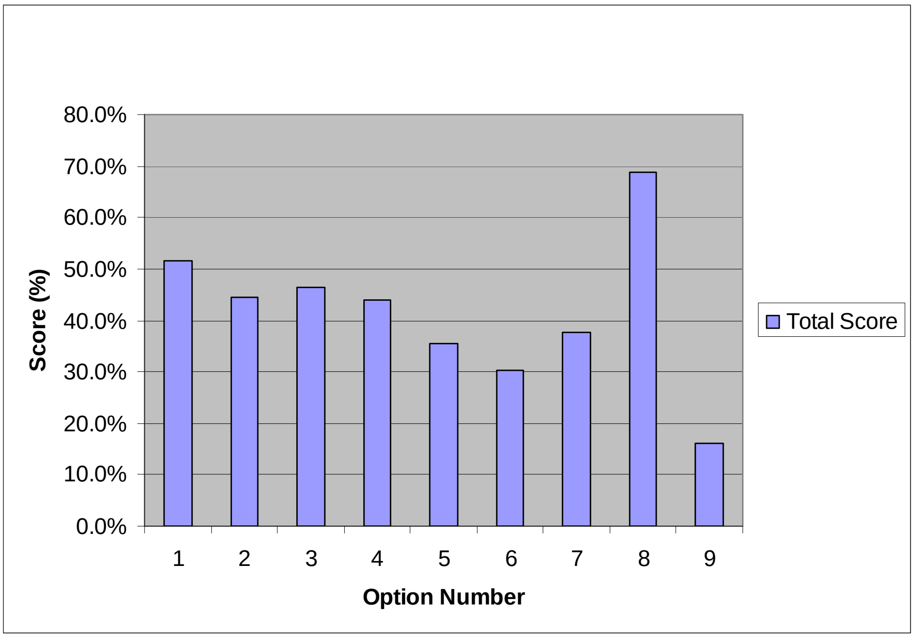
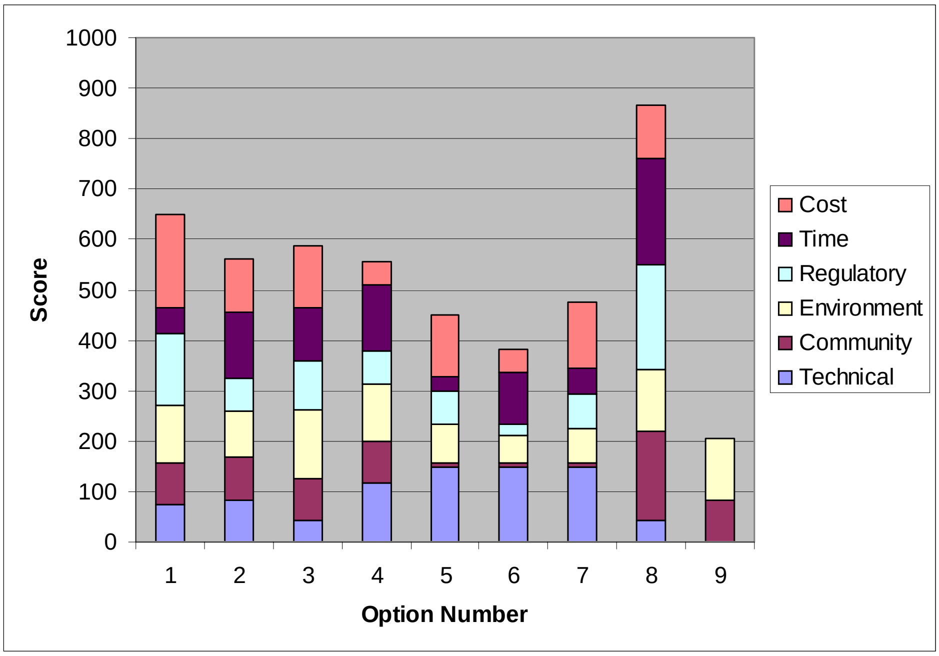


Figure 4-12 presents the relative contribution of each criteria group to an option's score. For example, Option 9 (discharge to river) only received high scores within the Community and Environment criteria groupings. Option 8 (brine transport via pipeline to ocean outfall) received high scores within each criteria grouping and therefore shows the worst result when compared to all other options.

Figure 4-12 - Relative Contribution of each criteria group to brine management option total scores



4.4.2 Preferred Brine Management Option

Discharge to Molonglo River (Option 9)

The option of discharging brine to the river was identified as the preferred option for brine management for a water purification plant up to a 25 ML/d capacity. Technically this is the simplest option to build.

The brine from the primary RO would be directed to a pipeline leading to the de chlorination point for the LMWQCC effluent. With the slope of the site and proposed location of the WPP, no pumping is required.

It should be noted that the affect on salinity of the LMWQCC discharge, which can represent the great majority of the flow in the Molonglo and Murrumbidgee Rivers during dry periods, for a 50 ML/d plant is thought to be excessive and therefore this option is likely only to be implemented for a plant up to 25 ML/d capacity.

A variation of the environmental authorisation for LMWQCC would be required for the 25 ML/d due to the change in the effluent salinity.

On Site Dewatering including Crystallisation and Truck to Market (Option 6)

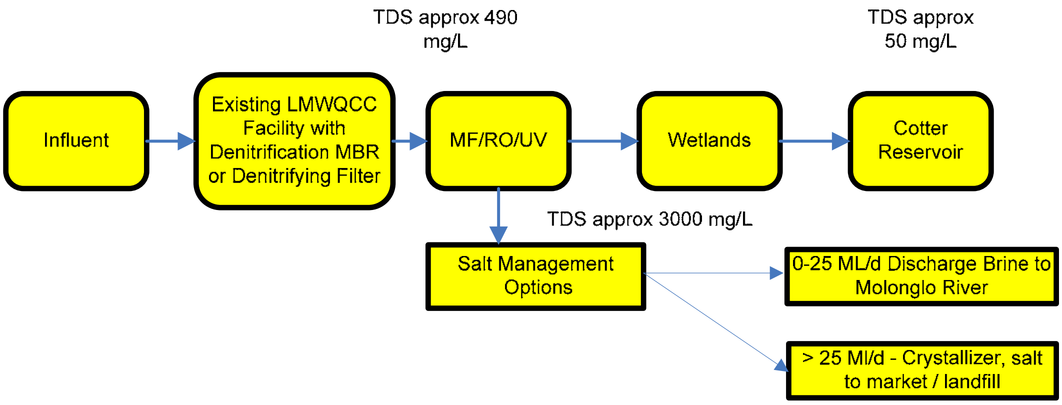
For Water Purification Plant capacities greater than 25 ML/d the preferred process is the dewatering of the primary RO brine stream at the LMWQCC. This process includes a secondary RO train with precipitative softening, followed by a mechanical vapour compression brine concentrator and a crystalliser. For a 50 ML/d water purification plant the brine stream from 25 ML/d would be discharged to river with the brine from the other 25 ML/d being crystallised.

5 Proposed Water Purification Scheme Process

This Section gives a detailed description of the proposed water purification process. The proposed unit processes for the water purification plant are shown in Figure 5-1.

A description of the unit processes and the process which has been used for the selection of these preferred processes, is provided in Section 4.

Figure 5-1 - Proposed Unit Processes for the Water Purification Plant



5.1 Dual Membrane Water Purification Plant Process Description

The following sections summarise the main process units in the proposed Water Purification Plant System as outlined in CH2M HILL 2007a and CH2M HILL2007b. As detailed in Section 4, the proposed treatment process is based on the use of a dual membrane (MF/RO) process.

5.1.1 Equalisation Tank

The wastewater flow to the LMWQCC has seasonal variations as well as with the day of the week. To operate the water purification plant at 25 ML/d output, a flow equalisation storage tank may be required. For plants with a capacity of 50 ML/d or higher, an equalisation tank is required.

Tertiary effluent from LMWQCC filters would be taken from the inlet of the chlorine contact tank, prior to chlorination and diverted to the equalisation tank. Alternatively secondary clarified water may be taken before the filters and diverted to the equalisation tank. Stored water would be pumped to the inlet of the denitrifying filters.

5.1.2 Denitrifying Filters

The feed water to the Water Purification Plant must receive additional denitrification prior to the reverse osmosis process in order to achieve the target total nitrogen levels for discharge to the Cotter catchment. This would be achieved using a denitrifying filter.

The denitrifying filter comprises of a deep bed of uniformly graded filter media (sand). Water flows through the filter bed and is dosed with methanol (a carbon source for micro organisms). Denitrifying micro organisms are seeded into this process and grow on the filter media converting dissolved nitrates in the water to nitrogen gas. The filter is regularly backwashed to remove excess biological growth. Backwash water is returned to the LMWQCC plant for reprocessing.

The filters would be deep bed sand filters with a media effective size of approximately 2.0 mm. The media would meet tight standards for uniformity and sphericity to allow more rolling and contact with other media grains during backwashing. Media depth would be approximately 2.0m. Six filters, each approximately 4.5 m x 6.7 m, are proposed for the 25 ML/d plant giving a total surface area of 179 m^2. This area is based on an assumed surface loading rate of 7.3 m/hr. The requirements for a 50 ML/d plant are approximately double that of the above.

Water and air backwashing for the filter would be provided and backwash water would be sourced from the membrane filtration feed tank. Backwash pump rates would be approximately 450 L/s for each filter. The design is based on backwashing each filter about once every 24 hours at peak solids loading conditions. The backwash volume per wash has been based on three times the bed volume, which is typically what is required to remove the bulk of the filtered solids and sloughed biomass. The backwash water volume has been estimated to be about 5% of the feed flow rate. Air scour at the rate of 55 $m^3/m^2/hr$ is proposed. Backwash water would be discharged to the backwash return line to the head of the LMWQCC from the membrane filtration process. Methanol dosing would also be provided.

The denitrified water then passes to the micro strainers. Water leaving the denitrifying filter is dosed with pre mixed aqueous ammonia and sodium hypochlorite to form chloramines. Chloramination prevents biological growth in the microfiltration feed tank and on the surface of downstream process equipment.

5.1.3 Micro strainers

The tertiary effluent pumps would deliver to self cleaning micro strainers. There are four strainers, with three duty strainers and one standby. The micro strainers are required to protect the downstream membranes from fouling by foreign materials such as hair, fibre and other particles that impair their performance or damage membrane fibres. Each micro strainer comes complete with its own integral backwash system that uses a motor driven wiper mechanism and the feed pressure to backwash a small section of the filter screen at a time and directs the waste to the existing filter waste backwash storage tank. Cleaning is initiated by either increased pressure drop across the strainer or after a preset time without a cleaning cycle.

5.1.4 Membrane Filtration Feed Tank

The membrane filtration feed tank is located immediately before the membrane filtration system. Its main function is to provide buffering storage capacity between systems to even out flow variations and to allow maintenance to be carried out without interrupting the downstream processes.

5.1.5 Membrane Filtration Feed Pumps

The use of membrane filtration feed pumps is subject to selection of the membrane filtration system supplier. For this project, a submerged membrane filtration system is proposed, whereby tertiary effluent is delivered to a tank containing exposed membranes submerged in the feed and filtrate pumps operate under negative (gauge) pressure to pull the filtrate through the membrane. For such a system, the intent is to allow flow by gravity from the feed tank to a distribution channel, from where a control valve regulates the delivery to each tank.

For a pressurised membrane filtration system, pumps are required to deliver the feed through pipe work and valving to the individual membrane elements, contained within pressure vessels.

Feed pressure is required to force the filtrate through the membrane and deliver to the RO feed tank. In this situation, the micro strainers would be relocated to the discharge of these pumps. The features of submerged and pressurised systems are discussed in more detail below.

For the design of the membrane filtration feed pumps, the intent would be to allocate one dedicated feed pump per train, with three trains for each 25 ML/d of final treated water capacity (six in total for a 50 ML/d plant capacity). One standby train and pump allows downtime for pump maintenance.

5.1.6 Membrane Filtration (MF) System

The purpose of the MF system is to remove sub micron particles including bacteria, large colloids and other suspended solids from the tertiary effluent to improve the performance of the downstream RO process, by reducing fouling and minimising the chemical cleaning requirements. The MF system is made up of microporous membranes that are used to pre treat the effluent before the reverse osmosis system. Typical pore, or opening, sizes stated by manufacturers, range from about 0.2 down to 0.04 microns.

Design fluxes for the preliminary concept have been chosen based on the most recent performance data from similar operating plants in Singapore (Bedok, Kranji, Seletar and the NEWater Factory Demonstration Project) and pilot studies at the Orange County Water District's Water Factory 21 facility in California. Pilot testing is proposed to confirm acceptable flux rates prior to finalising the design.

The proposed MF system is based on submerged membranes installed in tanks. Whilst either pressure or submerged membranes could be used, submerged membranes offer some economic advantage. These systems are fed by gravity with the filtrate being removed by pumps on the discharge or outlet side of the membrane. The MF filtrate pumps would be fitted with variable speed drives and located adjacent to the membrane tanks.

Membrane systems require regular cleaning to maintain economic performance. Clean in place (CIP) systems would be provided. These are automated to safeguard the membranes and simplify plant operation. The CIP cycle is usually initiated manually after a prompt from the SCADA system.

Extra process units are to be provided to allow downtime for regular CIP procedures.

5.1.7 RO Feed Tank

A storage tank to store MF filtrate is provided to balance flows between the multiple batch MF process and the continuous RO process. Oxidation Reduction Potential (ORP) of the influent is monitored and sodium bisulphite or sulphur dioxide is dosed to ensure that no free chlorine can be introduced to the RO membranes. The storage volume required would be a function of the time the MF systems are off line for cleaning and backwashing and the plant capacity.

5.1.8 Reverse Osmosis

The primary RO plant includes pre treatment chemical addition, high pressure pump stations, pressure vessel arrays, RO flush system and separate RO CIP systems.

The RO system would be a three stage system with the concentrate from the first stage being processed by a second set of RO membranes and the concentrate from the second stage being processed by a third set of RO membranes. Brackish water membrane elements would be used, which would produce a permeate with a TDS concentration of less than 50 mg/L. The final concentrate would then be passed to a secondary treatment process where the salts would be concentrated in preparation for offsite disposal.

Each individual RO train would have a dedicated feed pump; with a flow of approximately 107 L/s at 140 m head and a 250 kW motor.

The recovery of the RO system would be designed to suit either case of brine discharge, to the river or brine concentration treatment. Recovery is expected to be greater than 80% in either case.

5.1.9 Advanced Oxidation

For this plant it is proposed to use an advanced oxidation process utilising UV irradiation and hydrogen peroxide.

Generally, total organic carbon (TOC) levels in RO permeate from tertiary treated effluent are less than 0.1 mg/L. The final value would depend on the composition of the LMWQCC effluent, which can be affected by the level of industrial waste in the raw wastewater. Design parameters would be subject to water quality analysis and pilot testing to ensure suitable pre treatment is provided and that there is sufficient capacity and storage in the dosing systems.

The system would be designed to achieve a minimum 1.2 log removal (93.7%) of N-nitrosodimethylamine (NDMA) and 0.5 log removal (68.4%) of 1,4-dioxane, targets set in California for groundwater recharge reuse (California Department of Health Services, 2004). These criteria relate specifically to water intended to supplement potable supply and require treatment by reverse osmosis.

UV doses in the order of 500 to 600 mJ/cm^2 are anticipated and must be achieved at all times. The UV system design for each train assumes the use of closed inline reactors, each vessel being fitted with either low pressure high output (LPHO) or medium pressure lamps. UV dose, lamp selection and hydrogen peroxide dose requirements are still to be resolved.

5.1.10 Carbon Dioxide Stripper

After advanced oxidation, the water would be passed through a packed tower with counter current air flow to strip dissolved carbon dioxide from the water. Carbon dioxide that is in equilibrium with the bicarbonate alkalinity can permeate RO membranes and provides pH buffering capacity. Removal in a degassing tower reduces the quantity of caustic soda required for pH correction and gives a better final quality of water in terms of aggressiveness or corrosion indices. Filters are used on the air fans to minimise contamination of the water from air borne matter. The stripper is located downstream of the UV units so that any particulates introduced through the air stream do not affect the UV transmissivity of the water and thereby reduce the efficiency of disinfection and oxidation.

Depending on the final effluent quality requirements determined from environmental issues and the point of discharge to the catchment, it may be necessary to revisit this selection. If additional hardness and alkalinity is required, CO_2 addition and lime may be necessary.

5.1.11 Product Water Storage

Product water storage would be provided to enable on line monitoring of water quality and flow balancing prior to pumping to the Cotter catchment. It is proposed that two tanks are operated in batch mode, to allow for diversion of any off spec water during operation or unforeseen equipment failure. Sizing of these tanks is yet to be resolved.

5.1.12 Chemical Systems

Chemicals required for the water purification plant would consist of:

- aqueous ammonia and sodium hypochlorite for control of microbial growth on the MF and RO membranes and to provide a residual for the transfer system;
- sodium metabisulphite to ensure that no free chlorine can reach the RO membranes;
- sulphuric acid to adjust pH of the RO feed and of the secondary concentrate stream;
- anti scalant to prevent the precipitation of sparingly soluble salts;
- hydrogen peroxide for advanced oxidation;
- sodium hydroxide for MF and RO CIP and pH correction; and
- citric and hydrochloric acids would also be used for CIP membrane cleaning.

Lime, soda ash, proprietary surfactant and antiscalant are anticipated for the brine concentration stream. Some chemicals may be deleted or added, subject to further testing of the effluent and design refinement. Chemicals and chemical dosing systems would be matched to existing systems in use at LMWQCC where appropriate. The quality of all chemicals used would be suitable for use in potable water systems.

5.1.13 Power Supply Upgrade

The proposed Water Purification Plant (WPP) would require a substantial electrical power supply and would necessitate an upgrade of the power supply to the LMWQCC site. Although the new WPP would be a separate, standalone facility, its power supply planning would be integrated with the existing LMWQCC facility.

The power supply upgrade would need to accommodate additional loads of approximately 10 MW for the dual membrane plant, which includes the power demand for the pump station to deliver water to the Wetlands/Cotter reservoir.

New high voltage (HV) feeders from ActewAGL's Latham zone substation appear to be the most effective method for getting additional power supply to the Water Purification Plant facility. Based on discussions with ActewAGL Energy Networks, these new HV feeders would most likely be at 11 kV and be run as underground cables over their full length (see Pace Consulting Engineers 2007).

New high voltage and low voltage substations and switchboards would be required on site for power supply to the new facilities. Further details on the preliminary planning for power supply augmentation are provided in CH2M HILL 2007a and CH2M HILL 2007b.

5.1.14 Redundancy and fail safe operation

The MF/RO plant would be designed with a 33% redundancy for the MF and RO membranes (i.e. four 33 % process trains would be provided with three required for full capacity). Redundancy would also be provided in the UV system (i.e. redundant UV reactor/lamps)

The plant would be provided with appropriate on line monitoring and alarms to ensure that appropriate actions were implemented for any malfunction or out of spec water. Typical on line instrumentation used at other facilities and that would be considered for the water purification plant includes;

- inlet feed water to MF/UF membranes; turbidity is typically measured to monitor the quality of the water being feed to the membranes;

- on each MF/UF skid; a programme of membrane integrity testing (such as pressure decay testing) is used to regularly check the integrity of the membranes and the trans membrane pressure (TMP) is monitored to indicate the need for initiation of membrane cleaning cycles;
- Permeate from each MF/UF skid; depending on the membrane configuration, turbidity can be used on the permeate line from each skid. Similarly, particle counters can be used on each train to detect any particulate material although this is less common;
- main MF/UF permeate stream (RO feed water); turbidity is monitored continuously with the permeate expected to be less than 0.1 NTU. Particle counters can also be employed to detect any particulate breakthrough. Online electrical conductivity (EC) is often measured to represent the dissolved salts being applied to the RO membranes. Since most RO membranes have a very low tolerance to free chlorine, oxidation/reduction potential (ORP) is typically monitored to indicate the absence of free chlorine to ensure that the RO membranes are not damaged;
- on each RO skid; feed pressure is measured to indicate fouling on the membranes and the pressure required to pass permeate across the membrane;
- permeate from each RO skid; electrical conductivity is often measured to determine the dissolved salts rejection across the RO membranes; and
- combined RO permeate – As for individual skids, electrical conductivity is used to reflects the remaining dissolved salts. On line total organic carbon (TOC) can be used to detect the combined remaining carbonaceous material in the RO permeate. On line UV transmissivity can also be used as an indication of how well the organic material has been removed from the water.

Whilst all of this online instrumentation contributes to the overall confidence in the integrity of the membrane performance, the concentration of impurities in the RO permeate is so low that most on line instruments do not have the range and provide the necessary degree of accuracy to measure changes in the effluent quality. However, a TOC analyser on the RO permeate can accurately measure very low concentrations of organic compounds and as such the on line TOC can be used as an indicator as to whether the product water would meet specification.

At the NEWater plants in Singapore, online TOC is continuously monitored and if the TOC rises above a pre determined limit (typically around 100 µg/L), product water discharge off site is discontinued immediately and the permeate is recycled back to the head of the plant until the cause of the high reading has been determined and remedied and the permeate is back within the required specification. A similar approach would be adopted for the water purification plant at LMWQCC. The design incorporates two parallel product water tanks, with one tank filling while the contents of the other tank are being pumped to the catchment. If the TOC analyser measures a concentration in the permeate exceeding the pre determined limit, the contents of the product tank currently being filled would be emptied back to the head of the plant and permeate recycled until the problem is rectified.

State of the art instrumentation would be used at the Water Purification Plant to continuously measure the integrity of the process and ensure that only product water that meets specification would be transferred to the catchment.

On line monitoring of water quality would be supplemented by a very detailed water quality sampling, analysis and monitoring program which would form part of the HACCP plan for the project. Sampling, analysis and monitoring would be undertaken at identified critical control points in the water supply and sewerage systems and more intensely at inter process stages within the water purification plant. Details of the proposed water quality monitoring program are provided in Ecowise Environmental 2007b.

Any out of specification water would be returned to the inlet of the WPP or to LMWQCC. Diversion points would be installed at each of the key process monitoring location to ensure diversion takes place immediately any out of specification performance is identified.

5.2 Transfer of Purified Water to the Cotter Catchment

Purified water from the product water storage would be pumped to the Cotter catchment via a buried pipeline (nominal diameter 750 mm).

An engineering study considering the preliminary pipe alignments, sizes and costs of pumping, has been undertaken (ActewAGL, 2007). A number of potential pipeline routes were estimated in length and pumping power requirement.

The pump station would be constructed adjacent to the WPP and would be designed to accommodate the ultimate flow capacity of the water purification plant. For the first stage two variable speed pumps would be installed to meet the initial capacity of 25 ML/d, with provision to add two additional pumps to give maximum capacity of 50 ML/d.

Based on economic comparison for pipe size and pumping costs for various flow scenarios (25 and 50 ML/d) it has been determined that 750 mm diameter steel pipeline be laid over the 10 km route to the wetlands area.

The pipeline, approximately 10 km in length, would cross the Molonglo River to the west of LMWQCC and then approximately follow the alignment of Uriarra Road to the Cotter catchment boundary near Bullock Paddock Flat. The route selection is based on physical reconnaissance and the apparent constructability of the route, a detailed survey is yet to be undertaken. This route has been selected to minimise construction access difficulties, environmental disturbances and river crossings.

A study has been completed (KMR Consulting, 2007) to assess the preferred pipeline route between LMWQCC and the Cotter reservoir. The report highlights a number of possible land related issues which would need to be addressed should the project proceed.

Water would discharge from the pipeline to a proposed wetland facility.

5.3 Wetland and Discharge to the Cotter Reservoir

The key objective of the proposed wetland would be to equalise the temperature of the purified water with that of the surface waters in the Cotter Reservoir. Minor polishing of water quality and reduction of nitrate concentrations are also anticipated.

Surveys of potential sites for the construction of the wetland have established that the most suitable site is along the upper parts of Indecision Creek, just off Brindabella Road, in the Cotter catchment area. The design of the wetland has been considered in CH2M HILL 2007b and Ecowise Environmental 2007a. The site is drains to the reservoir by Indecision Creek. This area was previously covered with pine plantation, all of which was destroyed in the 2003 bushfires.

The identified site could accommodate up to approximately 65 ha of wetlands (Ecowise Environmental, 2007a), however the area required is likely to be in the range of 10 to 20 ha (maximum). Final determination of the wetlands area requirements is still being assessed.

The cost of wetland construction is estimated to be in the order of $1 M per 5 ha of water surface area.

Water would exit the wetland and flow to the Cotter Reservoir via Indecision Creek. The hydraulic capacity of this creek has been assessed and it is considered that flows up to 50 ML/d would not result in erosion.

5.4 Water Purification Plant Residual Streams

5.4.1 Dual Membrane Brine Treatment

The residual brine stream for the initial 25 ML/d water purification plant facility would be discharged to the Molonglo River via the existing LMWQCC outfall after mixing with effluent from the LMWQCC.

The proposed treatment for the brine from the second stage of the plant, i.e. when capacity is increased to 50 ML/d, is to consist of the following components;

- Solids Contact Clarifier (precipitative softening process);
- Secondary Reverse Osmosis System;
- Mechanical Vapour Compression Brine Concentrator; and
- Forced Circulation Crystalliser.

The component description is as follows.

5.4.1.1 Solids Contact Clarifier and Secondary Reverse Osmosis System

A combined process involving precipitative softening and secondary RO would be the initial treatment step for the concentration of brine from the primary RO system.

The solids from the clarifier would be sent to the existing LMWQCC solids handling system. Further investigations would be required to ascertain the impact on the LMWQCC solids handling system from this additional solids load and in particular:

- the need to re commission the second furnace;
- the need for any additional feed pumps; and
- the need for an additional centrifuge.

Preliminary calculations based on a limited set of data indicate that the sludge from the clarifier would contain approximately 9 t/d (dry) for a 25 ML/d plant. The remaining salt load in the concentrate is reduced from about 13.8 t/d to approximately 10.5 t/d.

The solids contact clarifier would be 14 m in diameter. Lime and soda ash would be dosed in a 6 m^3 flash mixing tank prior to the clarifier. Expected dose rates are 400 to 500 mg/L for both lime and soda ash. (See CH2M HILL 2007a for further detailed description of this process.)

Following the Solids Contact Clarifier the softened, neutralised, decarbonated brine then passes to a three stage reverse osmosis unit with seawater membranes. Overflow from the clarifier would be treated by cartridge filters or by microfiltration prior to the secondary RO process.

RO projection software indicates that this stream can be operated at 85% recovery, thereby achieving a 6 fold increase in TDS concentration to about 15,100 mg/L. The permeate can be added to the primary RO permeate stream or directed back to the feed to the primary RO, subject to pilot testing.

5.4.1.2 Mechanical Vapour Compression Brine Concentrator

A vertical tube falling film vapour compression evaporation is proposed for this stage of the process. (See CH2M HILL 2007a for further detailed description of this process.)

5.4.1.3 Forced Circulation Crystalliser (FCC)

The concentrated brine would be further treated in the forced circulation crystalliser (FCC) which would process 0.044 ML/d. The water recovery from this process is expected to be 80% and the product salt stream would be 10.5 t/d of crystallised solid. The FCC footprint would be approximately 12 m by 10 m with a height of about 9 m.

Forced circulation crystalliser (FCC) is a mechanical evaporation process that uses heat and pressure differentials to flash boil water, generating distilled liquid and solid salts. (See CH2M HILL 2007a for further detailed description of this process.)

No redundancy of this equipment is proposed, because the materials of construction are expensive. Intermediate storage tanks and equipment turndown would be provided to allow operation at reduced throughput for short periods. In case of a major failure of the crystalliser, the water purification plant may have to be shut down, or the brine could be diverted the Molonglo River in an emergency.

The high cost of this process warrants further detailed to ascertain if other salt management options could be adopted.

6 Water Purification Scheme Delivery and Operations

This section outlines the procurement of the water purification plant and key aspects relating to its management and operation.

The proposed water purification plant would have a maximum capacity of 50 ML/d, delivered in two 25 ML/d stages. The selected site has space for a future expansion of the plant to 75 ML/d, however, this is not currently anticipated.

Stage 1 of the water purification plant would have a delivery capacity of 25 ML/d and would include all key common infrastructure required for a final plant capacity of 50 ML/d, however without the facility for brine concentration and crystallisation. Stage 2 would add additional membrane processing units and systems for brine concentration and crystallisation.

6.1 Infrastructure Delivery Program

The proposed water purification plant can be programmed to produce first purified water into the Cotter reservoir via a constructed wetland at the earliest by March 2010, allowing for a 12 month planning approvals period.

This assumes a number of activities would be complete to achieve this milestone and that staging of the works suits the availability of specialist long lead delivery equipment, such as membranes.

The earliest achievable design, construction and commissioning program also assumes:

- the WPP is located at the LMWQCC (eastern side of the existing maintenance building) and is without any serious permit, building or environmental constraints;
- the WPP membrane building is sized for 2 x 25 ML/d trains with site provision for future expansion of another 25 ML/d (ultimate capacity 75 ML/d);
- a construction start date of September 2008;
- the initial Stage 1 installed capacity would be 25ML/d and could produce 'first' water by March 2010, with brine waste discharge directly to the Molonglo River;
- Stage 2 could be complete by January 2011. Stage 2 includes installation and commissioning of the second 25 ML/d membrane plant with associated brine concentration and crystallisation equipment;
- Stage 3 (expanding the plant to a 75 ML/d capacity) is not considered at this time due to the uncertainty of future influent flows;
- the pilot plant is developed and operated for a minimum 6 months prior to construction of the water purification plant so process design can be validated. This would include pilot testing of brine management processes;
- an Equalisation Tank would be constructed upstream of the WPP to even out any diurnal flows from the LMWQCC at the full flow of 50 ML/d;
- a denitrification facility would be a part of the capital works for this project and built immediately adjacent to the WPP;

- a new Power Supply would be installed as part of the project with HV feeders (11 kV) laid underground from the Latham zone substation, HV switchboard, ring mains, substations and LV switchboards;
- a pump station and 750 mm pipeline would be laid between the WPP and proposed Cotter Dam Wetlands along a route generally following the eastern and western sections of the Uriarra and Brindabella Road;
- wetlands would be constructed. The sizing of the wetlands would essentially provide temperature adjustment from the incoming purified water, but is also expected to provide some minor nitrate polishing;
- it is not expected that there would be major construction issues for the construction of the wetland as the catchment is already a highly disturbed area. It would be important that plant selection and sourcing is done with care so that only plants endemic to the catchment are used. A detailed investigation of types and sources of wetland plants within the catchment would be undertaken; and
- a draft EIS could be completed and approval obtained in approximately 12 months at which time onsite construction can occur.

6.2 Infrastructure Procurement Strategy

To meet the time frame for delivery of first water, and achieve all environmental approvals, an innovative procurement delivery strategy would need to be developed.

It is noted that the Australian engineering and construction market, which is involved with similar major water projects is very extended at present. A strategy which acknowledges the potential resource and materials constraints in the market would be required for successful delivery of the project (including specialist membranes and brine concentration equipment).

The current Australian trend in work on major water supply infrastructure projects is the delivery of these projects under co operative contracting arrangements, such as Alliance contracts. Alliance arrangements generally allow for more flexibility in the development of projects, particularly where there are tight delivery time frames and not all inputs are known. Currently there are many engineering and construction companies that would only work under an alliance style contracting arrangement as they generally lower costs and are less time consuming to bid.

The procurement strategy for the water purification plant in particular should ensure that an integrated solution is achieved for the denitrification facility and the membrane plant, so necessary nitrate removal can be achieved and appropriate risk transfer arrangements can be put in place.

The procurement strategy would include providing contractors with access to Pilot Plant operational data and responsibility for operation of the Pilot Plant for design validation.

It is anticipated that early engagement of the market and a contractor(s) to develop the water purification plant project would ensure better outcomes. Consideration would be given to staging of the works so that pilot studies, concept designs and detailed project plans can be developed prior to commencement of procurement and construction activities.

6.3 Operations

Prior to commissioning the water purification plant ACTEW would develop and have approved by ACT Health and the Environmental Protection Authority an Operations, Maintenance and Monitoring Plan for the Water Purification Scheme – including the overall management of the sewerage network, sewage treatment facilities. A separate plan would also cover the commissioning of the water purification plant.

It is anticipated these plans would be required as part of the licencing of the Water Purification Scheme.

6.3.1 Commissioning and Handover

As part of the preparation of the water infrastructure for operation there would be commissioning activities on all individual plant, including:

- HV and LV power supply equipment;
- denitrification facility;
- water purification plant; and
- pump station and pipeline.

Activities during commissioning would include testing of each individual component, system commissioning and performance testing of each discreet plant. It is anticipated that a minimum 30 day continuous performance test period would be necessary to achieve practical completion of the denitrification facility and the WPP. The requirements for commissioning would be fully documented.

Once the pipeline to the wetlands is hydrostatically tested and the water treatment facilities are performance tested and approved, the overall system can then be operated and proven over a longer period.

It is anticipated that the contractor(s) delivering the infrastructure may operate the system for a period to optimise and fine tune the processes. This period may extend for up to 1 to 2 years beyond the initial commissioning. This period would allow for performance warranties relating to power and chemical usage, membrane performance and plant water production to be more accurately measured and contractually delivered.

6.3.2 Operations Protocols and Hazard Analysis and Critical Control Point (HACCP)

It is essential that the treatment facilities are operated and maintained to ensure optimum removal of contaminants. As part of the Operations, Maintenance and Monitoring Plan, ACTEW would address a number of areas that are considered key to meet ongoing quality objectives. They include establishing;

- appropriate staffing levels for the new WPP (including the denitrification facility and wetlands),
- full training program for plant operators, maintainers and managers to undergo prior to and during plant commissioning and performance testing/proving (as referred above);
- the means by which the operation of each of the stages of treatment is monitored and maintained at the optimum level, e.g. where relevant, details of membrane integrity testing, specialised on line instruments etc (see below for more details); and

- a preliminary outline HACCP Plan that shows the likely critical control points (CCPs) for the various stages and barriers in the water purification plant, together with action and shutdown values.

After the outline plan is agreed by all stakeholders, a fully developed HACCP Plan would be implemented and accredited for the new WPP.

Whilst HACCP analysis is an integral part of the '***Framework for Management of Recycled Water Quality and Use***' as outlined in the AGWR (NRMMC, EPHC and AHMC, 2007), LMWQCC does not currently have HACCP certification. ACTEW would seek to attain HACCP certification for LMWQCC and the sewer network prior to commissioning of the new WPP.

6.3.3 Ongoing Monitoring and Reporting

In accordance with the AGWR (NRMMC, EPHC and AHMC, 2007) ACTEW intends to follow the 12 step framework for the management of recycled water quality and use (refer to Section 2.8 of this report).

To ensure a continuous supply of high quality purified water it would be necessary for this scheme to have robust and stringent management framework with operational, monitoring and process controls as key components

As monitoring plays a key role in risk management systems operational monitoring of processes would be targeted;

Operational monitoring would include a high degree of immediate on site and field testing and, in the case of this scheme, a high degree of on line continuous measurements with 24 hour alarm systems;

A continuous monitoring program would include;

- upstream monitoring of flows coming into LMWQCC;
- inter stage monitoring within LMWQCC (primary, secondary and tertiary treatment stages); and
- LMWQCC discharge (WPP Feedwater) monitoring, including TOC, conductivity and turbidity).

Detailed procedures (process control programs) would be provided for the operation of all processes and activities (both ongoing and periodic) from sewer or storm water source through to the wetlands. Appropriate inter stage on line monitoring for the WPP is covered in Section 5.1.14 of this report.

Operators would be trained and be proficient, able to interpret the significance of changes in water quality and treatment and be able to respond appropriately in accordance with established procedures. As these procedures would be developed in association with the operators they are expected to be effective due to early awareness and commitment to operational and process control.

The procedures would include analysis of results, responses to alarms and implementation of corrective actions.

6.3.4 Documented Procedures

Process control programs would be documented in operations manuals, with controlled copies readily accessible to all appropriate personnel. Operation manual material would be organised into sections dealing with individual components of the purified water system.

6.3.5 Operational Monitoring

Operational monitoring would assess and confirm the performance of preventive measures through a planned sequence of observations and measurements. It would provide proof and ongoing assurance that the water quality criteria are being met.

In this context, operational monitoring would include parameters monitored at critical control points. Data from operational monitoring would be used as triggers for immediate short term corrective actions to protect recycled water quality and to prevent unacceptable risk to human or environmental health.

Key elements of operational monitoring to be adopted include:

- identification of the parameters and criteria to be used;
- on going review and interpretation of results to confirm operational performance; and
- documentation of protocols and results.

6.3.5.1 Selection of operational parameters to be adopted

Operational parameters reflect the effectiveness of each process or activity and provide an immediate indication of performance. Parameters would be readily measured and enable responses to be implemented in a timely fashion.

On line testing would be established to include monitoring of activity (e.g. disinfectant residual, flow rates) and surrogates but does not include direct measurement of hazards themselves because of practical difficulties (such as time factors, cost, laboratory analyses rather than field measurement etc).

Surrogates should behave in a similar fashion to the hazard that they are representing and be sensitive to accurate measurement (preferably on line). Surrogates include parameters such as turbidity (for microbial hazards) and total organic carbon (for chemical hazards). Where surrogates are used, the relationship between the surrogate and removal or inactivation of the targeted hazard(s) would be established, validated and documented.

6.3.5.2 Monitoring of Membranes

As the key barriers in the planned water purification plant relate to membranes, specific attention would be paid to ensuring membrane integrity testing protocols are established which detect breaches of membrane integrity. As high level performance is required direct integrity testing would be instigated.

Direct integrity testing involves a physical measurement that correlates directly to process integrity. Examples include pressure decay and bubble point tests (USEPA, 2005). These tests are more sensitive than on line tests but require the membrane unit to be taken off-line. Examples include; pressure decay test, water displacement tests, vacuum decay tests, and diffused air flow. These tests typically have a relative sensitivity of 4-5 log compared to on line tests such as turbidity monitoring, particle monitoring and particle counting which have relative sensitivity of 1-3 log.

Direct off-line test methods would also be considered for other high performance process units.

6.3.5.3 Sampling locations

Sampling locations would chosen to ensure that operational monitoring is both effective and reliable.

6.3.5.4 Automatic monitoring and alarms

Outputs from continuous on line testing would be monitored automatically with excursions leading to alarms being activated. Systems would be established to ensure that alarms are received immediately, 24 hours a day. Every alarm is to be investigated without fail.

On line monitoring systems would be calibrated regularly. Calibration records would alert operators to instrument drift and procedures may need to be altered accordingly.

Where critical limits are exceeded automatic shut off of supply or flow diversion back to the inlet of the plant. Supply or flow is only to resume after an operator has ensured that any faults have been corrected and acceptable performance has been restored.

Automatic monitoring equipment would include the capacity to record and store results. Excursions to be logged and responses documented. Critical excursions would be reported using agreed incident or emergency reporting protocols.

6.3.6 Analysis of results

Results would be reviewed frequently to confirm compliance with operational criteria and critical limits. Reviews would also include an assessment of compliance with monitoring protocols including frequency of testing.

The system developed would include regular reporting of operational monitoring results to relevant stakeholders, using methods such as graphs or trend charts to facilitate interpretation.

6.3.7 Monitoring Protocol Documentation

Operational monitoring protocols would be documented in a monitoring plan. The plan would include sampling and monitoring procedures, parameters, testing frequencies, limits, criteria and reporting requirements.

Procedures would be developed to re establish process control immediately in situations where target criteria or critical limits are not met. The procedures would include instructions on required adjustments, process control changes and additional monitoring. Where non compliance leads to cessation of supply, procedures need to be established to deal with storage or discharge of substandard water.

6.3.8 Event Communication

Rapid communication systems would be established to deal with any unanticipated events. Responses would be prepared for the worst case scenario when corrective actions do not re establish operational performance quickly enough to prevent recycled water of unacceptable quality from reaching consumers. These would include ***boil water*** and ***avoid use*** notices.

6.3.9 Equipment Capability and Maintenance

Equipment and infrastructure would be adequately designed and of sufficient capacity (size, volume, detention times) to handle all flow rates (peak and otherwise), without limiting performance. Hydraulic overload of processes would be considered in the design phase.

Design features would be considered to improve performance and process control, such as:

- online measuring devices that monitor operational parameters continuously;
- automated responses to changes in water quality;
- backup equipment, including power generators;
- variable control of pump rates and chemical dosing; and
- effective mixing facilities.

Design of equipment and processes would to be validated. Equipment used to monitor process performance would be selected carefully and be appropriate for the required tasks. Monitoring equipment would be selected ensure it is sufficiently accurate and sensitive within required measurement ranges. Systems would be designed such that monitoring equipment failures do not compromise the plant's processes. Backup systems would be provided at critical control points.

6.3.10 Equipment Inspection and Maintenance

Operators would be required to understand the operation of monitoring equipment so that causes of spurious results can be recognised and rectified. Regular inspection and maintenance of all equipment, from source to point of use, would to be undertaken to ensure continuing process capability. A maintenance program would be established and documented, detailing:

- operational procedures and records for the maintenance of equipment, including the calibration of monitoring equipment;
- schedules and timelines;
- responsibilities; and
- resource requirements.

The maintenance management program would be linked to the established maintenance management system at LMWQCC

6.3.11 Material and Chemicals

As chemicals and materials used in LMWQCC and the water purification plant have the potential to adversely affect water quality or the environment they are applied to, any selected for this scheme would be evaluated for potential contamination, chemical and physical properties, maximum dosages, behavior in water, migration and concentration build up. In addition, the potential impact of such chemicals on materials used in treatment plants or on the environment would be considered. Chemicals used in treatment processes would be securely stored to avoid spills or leakage.

Chemical suppliers would be evaluated and selected on their ability to supply product in accordance with required specifications. Documented procedures for the control of chemicals, including purchasing, verification, handling, storage and maintenance would be established, to assure their quality at the point of application. Responsibilities for testing and quality assurance of chemicals (supplier, purchaser or both) would be clearly defined in purchase contracts. These would build upon existing ActewAGL quality procedures in place for chemical procurement.

Contaminants may also be introduced when purified water comes into contact with materials such as filter media, protective coatings, linings and liners, jointing and sealing products, pipes and fittings, valves, meters and other components installed in the water supply and sewerage networks, but more particularly in LMWQCC and the proposed water purification plant.

Products and materials used in water infrastructure and plumbing systems would be authorised or approved to ensure compliance with:

- Australian and New Zealand Standard AS/NZS 3500 (Plumbing and Drainage Code; Standards Australia 1996–2003);
- AS/NZS 4020 (Testing of products for use in contact with drinking water; Standards Australia 1999);
- WSAA Sewerage Code Version 2.1 (WSAA 2002a);
- WSAA Water Supply Code (Dual Water Supply Supplement Version 1.1) (WSAA 2002b);
- WSAA Water Supply Code; And
- Other appropriate standards and codes of practice.

6.3.12 Verification of water quality and environmental performance

Verification of the effectiveness of the water purification system in delivering safe drinking water to consumers and the environment would be undertaken using an agreed water quality sampling and monitoring program.

Verification would be conducted at elevated frequencies during the first weeks and months of operation, to demonstrate that water quality targets are being achieved and to provide confidence to operators and consumers that target criteria for water quality can be reliably achieved.

The planned water quality monitoring program for the Water Purification Scheme is outlined in Section 3.4 of this report.

6.3.13 Licensing

ACT Health would be responsible for licencing and ACTEW would co operate with the implementation and operation of any licencing arrangements.

6.3.14 Internal/ External Expert Audit Panels

ACTEW plans to establish an Expert Auditing and Advisory Panel for the Water Purification Plant along similar lines with those established by the Singapore Public Utilities Board for the audit and review of NEWater factory performance and the Orange County Water District and the Western Corridor project in Queensland.

The membership of the Panel would be established from external process engineering and water quality and health experts, both nationally and internationally (membership of approximately five to six persons).

The Panel would be established at the commencement of the project prior to commencement of detailed design and would have the following key roles:

- to advise ACTEW on key process design selection issues, including water quality objectives, process selection, etc;
- to review design and construction develop and pilot/demonstration plant performance information, including commenting on key design modifications;

- to review commissioning plans and sampling programs, including results from these programs;
- to advise on acceptance of the plant at the end of the commissioning period.
- to undertake regular three to six monthly reviews of the plants' performance, including operations and maintenance plans and non conformance reports and monitoring program data and independently report on these to the ACTEW Managing Director, Chairman and the Chief Health Officer; and
- to provide a source of expert advice and information on the international development of indirect potable use water technologies and of key issues arising in the use of indirect potable use water technologies from a public health perspective.

7 Environmental Assessment

7.1 Background Studies

Specific studies would be commissioned to answer the many technical questions that need to be addressed during the planning approval process. These studies would provide the necessary supporting documentation.

Background studies needed to support the approval of the water purification scheme have not yet been completed. The scope of the studies cannot be completed until the concept design for the plant and pipeline is agreed upon.

Two key background documents are:

- ***Lower Molonglo Water Quality Control Centre Preliminary Assessment,*** (CMPS&F Pty Ltd, 1992); and
- ***Habitat mapping and regional conservation considerations for the Pink-tailed Worm Lizard (Aprasia parapulchella) population at the Lower Molonglo Water Quality Control Centre,*** (Osborne W.S., 2006).

Details of work that would be required to support the Water Purification Scheme proposal is discussed below.

7.2 Cultural Heritage

The archaeological survey of the LMWQCC site (Paul Packard 1992) was conducted as part of the 1992 Preliminary Assessment Study. Several sites of indigenous archaeological interest were located but all were limited to the northern area, remote from the proposed location of the Water Purification Plant. The research covered the entire site and provides a sound basis for decision making with regard to the Water Purification Plant. There are no apparent cultural heritage impediments to the construction of the plant.

A ground survey for aboriginal artifacts or sites would be necessary to identify any that may be impacted by either the pipeline or wetlands. The subsequent report would identify appropriate management plans for any sites found and whether there may be a major constraint or impediment to the implementation of the Water Purification Scheme and its associated infrastructures.

Research and a report, would also be required on European heritage matters, although for the pipeline alignment and the wetlands this is unlikely to uncover anything of significance.

The scope of this work cannot be resolved until the project is more precisely defined and areas of likely impact are identified. The necessary field surveys and consultation with indigenous groups would be undertaken in accordance with procedures that are endorsed by the ACT Heritage Unit.

7.3 Aquatic Flora and Fauna

The input of additional water from the proposed Water Purification Plant to the Cotter reservoir has the potential to impact on endangered fish species. A Fish Impact Study (Environment ACT 2005) has been completed for the Cotter Dam enlargement project. That report identifies a series of knowledge gaps relating to the project that need to be addressed to ensure the project can proceed without undue risk to the fish species. Much of this work would be undertaken as part of the Cotter Dam enlargement evaluation. Additional specific study would be required to assess possible impacts of the introduction of water from the purification plant into the reservoir, whether or not it is enlarged. This additional water may have impacts due to its temperature, composition and flow rates.

Potential impacts on aquatic flora and fauna in the Murrumbidgee River would also need to be researched and reported on. Impacts may stem from altered river flow regimes and alterations in salt concentrations and load.

Research areas would include:

- riverine habitat;
- endangered or vulnerable Fish species;
- aquatic ecology; and
- impacts on aquatic environment.

7.4 Terrestrial Flora and Fauna

The Pink-tailed Worm Lizard ***(Aprasia parapulchella)*** has Special Protection Status in the ACT under section 16 of the Nature Conservation Act 1980. The species is listed as vulnerable under the ***Environment Protection and Biodiversity Conservation Act 1999*** (Cwlth) (EPBCA). The Lower Molonglo site is a known habitat for the lizard. The special protection status means that the lizard is considered to be either endangered or threatened with extinction.

The site investigation report discusses the ***Aprasia*** as detailed below (Osborne W.S., 2006):

"***The Pink-tailed Worm Lizard (or Granite Worm Lizard) (Aprasia parapulchella) (Figures 1 & 2) is reasonably common in the ACT and region where it is has a patchy distribution along the slopes the of the Molonglo and Murrumbidgee River corridors and on adjacent outlying hills such as Mt Taylor and Googong Hill (Osborne et al. 1991; Osborne and Jones 1995; NPWS 1999) (Figure 3). Although the species was once thought to be largely restricted to the ACT (Kluge 1976; Osborne et al. 1991), surveys in recent years have revealed that it has a wider distribution. Specimens reported to be A. parapulchella have been found near Bendigo in Victoria and in New South Wales outlying populations have been found near Tarcutta, Cootamundra, Cooma, Queanbeyan and Bathurst (Osborne et al. 1991; Jones 1999). Although most of these records are of specimens from single locations, this broad distribution indicates that the Pink-tailed Worm Lizard may be much more widespread than current knowledge indicates. Because of its restricted distribution, low abundance and threats to habitat sites with lizards, the species has been given formal conservation status in each state or territory in which it occurs. It is listed as Vulnerable nationally (Environment Protection and Biodiversity Conservation EPBC Act 1999), as Endangered in Victoria (Flora and Fauna Guarantee Act 1988) and as Vulnerable in NSW (Threatened Species Conservation Act 1995). In the ACT it is not listed as a threatened species – but instead has been assigned Special Protection Status (SPS species) recognising the importance of the ACT populations in a regional and national context. The species is not currently in danger of extinction in the ACT because it is reasonably common and occurs in many small reserves (Osborne et al. 1991; Osborne and McKergow 1992). Despite this formal level of protection, weed invasion, livestock grazing, cultivation, tree***

planting and removal of rocks have contributed to habitat deterioration at many sites, including in the Molonglo Valley (Osborne and Coghlan 2004).

A large and regionally important, population of Pink-tailed Worm lizards (A. parapulchella) was studied by Jones (1999) at the Lower Molonglo Water Quality Control Centre (LMWQCC). Funding and other support for the study by Jones was provided by ACT Electricity and Water as a research consultancy with the Applied Ecology Research Group at the University of Canberra. At the time that this study was undertaken it was thought that the population at the LMWQCC represented more than 10 percent of the total known population (Scott and Furphy Pty Ltd 1992). This population was subsequently used by Jones (1999) in an experimental translocation that involved moving 114 individual lizards (and suitable stones) from the site of then proposed excess flow storage dam to a rocky hillside on the south eastern side of the LMWQCC. Only 15 of these lizards were ever recaptured and the long term success of this translocation was not tested because the enclosures designed to hold the animals were damaged in strong winds".

This work was undertaken prior to a major upgrade of the LMWQCC secondary treatment infrastructure that is scheduled for construction in 2007. The LMWQCC Secondary Treatment Augmentation Project would involve construction of several large tanks and associated pipe work adjacent to the existing plant. Due to the proposed construction project as well as the expectation of ongoing maintenance and future construction activities, ActewAGL considered it important that a more detailed assessment of the distribution of potential habitat be undertaken. Although the population of ***A. parapulchella*** at LMWQCC has been the subject of previous study, the earlier work at the LMWQCC by Jones (1999) did not include a detailed assessment of the extent of suitable habitat within the site boundary. This 2007 report provides background information that sets the LMWQCC population in a regional context and provides a detailed map of the extent of potential habitat within the site boundary.

Habitat areas within the site are rated as either of high or moderate value. A small isolated patch of moderate value habitat is located in the vicinity of the water purification plant site.

This small isolated patch represents a very small proportion, approximately 5%, of the total habitat area on the LMWQCC site, which in turn is now known to be only a small portion of the total regional population. This together with the fact that this small patch has been identified as being of only moderate value means that its loss may not be considered significant.

Further studies of the pipeline alignment and wetland site which would need to be addressed:

- terrestrial fauna;
- soils;
- terrestrial flora;
- catchment management;
- stormwater; and
- surface water.

7.5 Catchment and Landscape Analysis

A Landscape assessment of the water purification scheme would be required. Significant elements would be the plant facility itself, the pipeline wherever it may be above ground and the wetland. The likely impacts are considered to be manageable, but would require careful evaluation. This would include reference to the National Capital Authority for advice regarding the pipeline crossing of the Murrumbidgee River Corridor and Cotter wetlands which may impinge on areas of national landscape significance.

7.6 Social Impacts

The social impacts of providing or not providing a new water source was discussed as part of the FWO project, in An overview of the social impact of the Future Water Options Project, Stage 1 Social Impact Appraisal, (ACTEW, 2005a).

The assessment highlighted the critical social importance of a reliable water supply for the city and district. It considered that the three options under consideration at the time (Cotter, Tennant and Tantangara) were not greatly different from a social perspective.

The important social factors that any option would be measured against include:

- value for money, as government expenditure on water competes with other essential services such as health, education and transport;
- intergenerational equity, considering long term impacts;
- reliability of supply, to provide business and social confidence;
- environmental impact, due to social expectations for conservation of high value environments;
- extent of direct impacts, such as business or farm operation disruption and the need for compensation; and
- power consumption and greenhouse gas emissions, which are a topical issue and of increasing social concern (it is noted that the water purification scheme would be relatively energy intensive).

While FWO Stage 1 considered these issues for the Cotter Dam and concluded that the benefits associated with a reliable water supply would outweigh social concerns, these issues were not considered for a Water Purification Plant at that time.

During the three month community consultation program on the Water2WATER proposal in early 2007, community concerns were identified and included:

- health with a focus on removal of drugs and hormones;
- investigation and communication of all water supply/security options;
- environmental factors, particularly energy usage;
- cost to the end user;
- quality assurance/monitoring; and
- community confidence in ACT Government and ACTEW.

Given these issues of community concern, primarily health, an environmental assessment would be likely called for by the Minister for Planning and the Minister for Health. Environmental assessments in the ACT are usually overseen in the main by the Minister for Planning but the legislation (***Land (Planning and Environment) Act*** 1998) makes special provision for the involvement of the Minister for Health where a public health issue is under discussion.

The pipeline would traverse leased land generally adjacent to the Uriarra Road alignment. This is discussed further in KBR Consulting 2007. All the relevant rural leases include pipeline clauses that provide for the installation of pipelines for public purposes. Consequently there are no land tenure impediments to the installation of the pipeline. There would be some disruption to agricultural activities during construction but this is likely to be minimal. The pipeline would be buried so long term impacts would be negligible, however assess for pipeline inspection and access to valves and other installations would be required over the long term.

Investigative research would be required to address:

- public health;
- cultural heritage;
- recreation;
- stakeholder engagement;
- leaseholders;
- community;
- traffic;
- noise;
- odour;
- dust;
- visual amenity;
- hazards; chemical, physical; and
- waste management.

8 Water Purification Scheme Costs

8.1 Overall Costs

The estimated overall Water Purification Scheme capital costs are described in Table 8-1.

Table 8-1 - Estimated Capital Costs

Water Purification Plant Capacity	25 ML/d	50 ML/d
Estimated Capital Cost (AU$M 2007)	181	274*

Notes

* Brine from the initial stage of 25ML/d discharged to River. Brine treatment for additional 25 ML/d flow only in stage 2.

The overall costs include a number of components which a make up the Water Purification Scheme. Those components include:

- denitrification facility;
- water purification plant;
- pump station and pipeline to transfer purified water to the Cotter catchment; and
- wetlands and associated inlet and discharge structures.

This section outlines the basis of capital and operating costs for a 25 ML/d and 50 ML/d Water Purification Plant and associated components as specified above.

The costs are based on using dual membrane (MF/RO) with advanced oxidation for the liquid treatment process as detailed in this report. The costs assume that there are two stages of introducing water into the system described below.

Stage 1. Water Purification Plant capacity - 25 ML/d

- Denitrification facility;
- Water Purification Plant and associated equipment and infrastructure;
- High voltage power supply and power supply upgrade to the LMWQCC site;
- Flow equalisation tank;
- Pump station and 750mm diameter pipeline (approx. 10km), and
- wetlands sized for temperature equalisation for initial 25 ML/d plant capacity.

Stage 1 could to be operational by the end March 2010.

Stage 2. Water Purification Plant capacity - 50 ML/d (additional 25 ML/d)

- Water Purification Plant (extra equipment and membranes for extra 25 ML/d);
- brine concentration equipment to suit 25 ML/d plant capacity only; and
- wetlands increased in size to suit additional 25 ML/d.

Stage 2 could be operational by January 2011.

8.2 Basis of Estimate

The estimate is based on cost estimates, technologies, labour rates and equipment rates used on local alliance projects of similar nature; and budget prices from suppliers for process equipment, piping, chemicals and other miscellaneous items.

Capital and operations and maintenance cost estimates were based on the conceptual design, preliminary drawings and equipment lists.

Direct cost estimates for large equipment items such as the MF, RO, UV and evaporators were provided by suppliers and vendors. Indirect costs such as approvals, engineering, commissioning and start up were estimated as a percentage of the total construction cost estimates.

Cost estimates for 25 ML/d facility assume it would be expanded to 50 ML/d and non process equipment including piping, tankage, chemical facilities and other services are therefore sized for 50 ML/d.

Both capital and operating costs were based on the assumption that a 25ML/d or 50ML/d plant would be programmed for construction by mid 2008. On this basis a 10% escalation factor has been included in the estimate to accommodate potential volatility in raw material and high demand for construction resources over this period. The makeup of the capital cost estimates is provided in Table 8-2. The makeup of the operating and maintenance cost estimates is provided in Table 8-3.

Table 8-2 - Capital Cost Estimate Makeup

Treatment Capacity	Capital costs (AU$M)		
	Water Purification Plant	Pump Station and Pipeline	TOTAL
Stage 1 - 25 ML/d	161.3*	19.7***	181.0
Stage 2 - Additional 25 ML/d	92**	0.70#	92.7
Total - 50 ML/d	253.3	20.4	273.7

Notes:

* The WPP price includes costs for the Denitrification Facility, Power Supply and Wetlands. The direct costs of those components are;

- denitrification facility - $4.8 M;
- power supply upgrade to LMWCC - $10 M; and
- wetlands - $1.8 M.

** Includes extra $48.3 M for liquid stream equipment, $43.6 M for brine treatment (25 ML/d) and increase in wetlands for extra 25 ML/d of $1.5 M.

*** The transfer pump station facility and pipeline is sized for transfer of 50 ML/d (750 mm dia). Initially pumps only installed for 25 ML/d capacity.

Includes extra pumps and surge equipment for the additional 25 ML/d.

Table 8-3 - Operation and Maintenance Cost Estimate Makeup

Treatment Capacity	Operating costs (AU$M)		
	Water Purification Plant	Pump Station and Pipeline*	TOTAL
Stage 1 - 25 ML/d	8.5	1.20	9.7
Stage 2 - Additional 25 ML/d	12.4**	1.10	13.5
Total - 50 ML/d	20.9	2.30	23.2

Notes:

* Includes pump power costs of $115.00/ML and maintenance costs at 1% of capital.

** Includes brine treatment operation and maintenance costs for additional stage 2 25 ML/d stream only.

A detailed breakdown of the capital and operation and maintenance cost estimates for the Water Purification Plant is provided in CH2M HILL 2007b Appendix D.

During any further planning for the Water Purification Plant additional analysis will be undertaken on how to reduce these costs, with a particular focus on options for salt management.

9 Conclusions and Recommendations

This report is a summary of a range of other reports and discusses a proposal to augment the Canberra water supply system with additional supply derived from a water purification plant to be located at the LMWQCC, pumping and pipeline infrastructure to carry the purified water to a constructed wetland above the Cotter Reservoir and utilisation of the reservoir for storage prior to use.

The assessment in this report is based on information currently available which includes:

- a comprehensive review, including site visits, of interstate and international practice;
- a technical feasibility assessment of the proposed WPP;
- preliminary technical studies on possible pipeline alignments and wetland design and impacts of the discharge of water into the Cotter catchment;
- a review of available environmental research studies;
- the outcomes of a three month intensive public consultation program;
- previous investigations by ACTEW related to water supply and the ***Think water, act water*** suite of studies;
- concurrent investigations being undertaken related to the construction of an enlarged Cotter Dam;
- a technical review of water quality monitoring programs and preliminary monitoring program development;
- a range of advice from the Expert Panel on Public Health and the eWater CRC;
- a review by ACTEW on the performance of a range of future water options in the drought recovery period and beyond;
- a study of salt management options for the WPP waste brine stream; and
- a study of power supply options for the WPP.

Whilst this information is not fully comprehensive it provides a sound basis for the development of the conclusions and recommendations set out below and for further more detailed analysis.

It is important to place this proposal in the context of the overall Canberra water supply situation. Whilst its local environmental impact appears to be minimal the WPP is an expensive option in both financial and energy (and therefore greenhouse gas production) terms. It would not normally be a preferred option when considered against the various alternatives. It is being considered because of a high degree of uncertainty that now surrounds the future rainfall pattern in Canberra. Because of this uncertainty it must now be considered possible that the local climate has undergone a major and catastrophic change that would result in much lower overall rainfall in future, lower even than the reductions that are already factored into projections to account for the forecast climate change scenarios. If such a change has indeed occurred, and this would only be able to be judged over the next few years, then the WPP would become an important consideration as many other options which rely on rainfall, would not perform adequately. The conclusions and recommendation below should be seen in this light.

The conclusions are that:

- a water purification scheme consisting of a water purification plant at LMWQCC and pump, pipeline and wetland infrastructure to carry the water to storage in Cotter reservoir is considered to be feasible at a sufficient confidence level to warrant the commitment of the substantial further funds necessary to advance to detail design and final assessment;
- the facility should be sized to produce 25 ML/d, with optional expansion to 50 ML/d. The sizing of the facility greater then 50 ML/d is not considered viable at this stage due to the lack of flow entering LMWQCC, particularly during periods of water restrictions and greater household recycling of water; and
- discharge of brine effluent from the 25 ML/d facility should be to the Murrumbidgee River, noting that the impact of this would be nil increase in total salt load and a marginal increase in salt concentration. Brine disposal from the additional 25 ML/d facility, if built, should be further examined.

The recommendations are that:

- work should proceed on detailed investigation, design and analysis to confirm the feasibility of a WPP;
- design work should be accompanied by a comprehensive environmental assessment;
- a public health assessment should be included in the environmental assessment and build from the recently released Expert Panel on Health report and qualitative health risk evaluation being undertaken by ACT Health;
- environmental investigations related to the establishment of the facility at LMWQCC and impacts on the Cotter reservoir is already well advanced. Further work is required on the pipeline alignment and wetland proposals as well as on brine disposal aspects; and
- a potential construction commencement date of September 2008 could be achieved.

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