Appendix D

Land capability assessment

Googong Township water cycle project

Environmental Assesment

November 2010

GOOGONG RESIDENTIAL COMMUNITY

RECYCLED WATER IRRIGATION LAND CAPABILITY ASSESSMENT

PREPARED BY AGSOL PTY LTD

ON BEHALF OF CANBERRA INVESTMENT CORPORATION

FINAL REPORT

AUGUST 2010

DOCUMENT AMENDMENT AND APPROVAL RECORD

Issue	Description of Amendment	Prepared by (date)	Approved by
1	Preliminary	Catherine Hird April 09	Alison West Manidis Roberts
2	Draft	Catherine Hird July 09	As above
3	Draft 2	Catherine Hird August 09	As above
4	Draft Final	Catherine Hird 30 November	Jessica Eastwell Manidis Roberts
5	Final	Catherine Hird 9 December	Jessica Eastwell Manidis Roberts
6	Revision 1	Catherine Hird 19 May	Paul Keighley Manidis Roberts
7	Revision 2	Catherine Hird 6 August	Paul Keighley Manidis Roberts

PURPOSE OF THIS REVISION

The following report has been revised as a result of changes to scheme design that occurred after the final report was submitted to Manidis Roberts by Agsol in December 2009. Agsol has been provided with updated information on the recycled water scheme performance and potential sewage treatment processes by MWH and proposed storm water management by Browns Consulting. This information was not available at the time the original report was prepared.

Catherine Hird 6/8/ 2010

1 EXECUTIVE SUMMARY

Canberra Investment Corporation (CIC) is proposing a new town development at Googong, located south of Queanbeyan in NSW. The new town will be developed in specific stages in respect to both the subdivision of the land and the associated infrastructure.

A Water Recycling Plant (WRP) is proposed to supply high quality recycled water suitable for some household uses. The wastewater loading on the plant is expected to be around 0.7 ML at the completion of Stage 1a. Ultimately a population of around 16000 persons generating an expected average dry weather flow (ADWF) of around 3.0 ML/day will be serviced by the proposed recycled water plant (Source MWH 2010).

This report explores in detail the environmental performance of potential water saving solutions proposed for the development. Data generated from water and salt budgets detailed in this report is used to assess the catchment wide impacts of the various water saving solutions. These latter assessments have lead to the preferred water saving solution to be outlined in the Environmental Assessment.

The water saving solutions proposed include the use of rainwater collected in household tanks and recycling treated effluent from the WRP for toilet flushing, garden and landscape irrigation and laundry use. Household water supply will be ensured by topping up the recycled water system with potable sources when necessary.

1.1 OBJECTIVES OF THIS REPORT

The broad objectives of the land capability study were to:

- compile and review available soil and groundwater information;
- identify soil and groundwater constraints for the installation of infrastructure
- identify soil and groundwater constraints for the application of recycled water
- identify potential impacts for the application of recycled water in a residential setting
- identify high risk areas that may not be suitable for recycled water application; and
- develop recommendations for future investigations, including monitoring and mitigation measures

1.2 POTENTIAL RISKS ASSOCIATED WITH THE USE OF RECYCLED WATER

The recycled water will be more saline than the current potable water supply sources from Googong or Stromlo. The total dissolved solids (TDS) of the potable water supply generated from the Stromlo Reservoir are currently around 60 mg/l and from the Googong Reservoir 120 mg/l (source ACTEW). It is possible that the salinity of potable supplies could increase, if for example, re-chlorination is needed when pumping potable water supplies to the new town.

Recycled water also contains significant concentrations of nitrogen and phosphorus and other substances such as chlorine, sodium and chloride that could be potentially harmful to garden plants, surface waters and built infrastructure. The potential risks of using recycled water have been identified as:

- increases in soil sodicity or salinity within the development area as a result of irrigating with recycled water;
- damage to pipelines and other infrastructure due to burial in unsuitable soil materials or groundwater conditions;
- over-watering or introducing irrigation into a rain fed environment, which may raise the water table and cause salt to rise into surface soil and add to existing problem areas
- changes in catchment hydrology as a result of irrigation of gardens and the subsequent introduction of more salt and nutrients into the landscape, potentially leading to:
    - mobilisation of salt in already salt affected soils;
    - salinisation of home gardens;
    - eutrophication of ground and/or surface waters from excessive applications of nitrogen and phosphorus;
    - accelerated deterioration of any future built environment;
    - other potentially toxic effects such as increased cadmium uptake by plants grown for food, and contamination of soils with boron and chlorine; and
    - structural collapse (piping) associated with sodic subsoils when fresh water tables rise into the sodic/saline layer after significant rainfall events and/or disturbanceThese risks are investigated in this report.

1.3 POPULATION, MIX OF DEVELOPMENTS AND LIKELY AREA OF IRRIGATION

The garden and turf areas that could be irrigated with recycled water will be dependent on the size of residential housing blocks, the use of irrigation systems by home gardeners, the size of proposed irrigated playing fields and the need to irrigate landscaped areas within town centres. Based on lot layouts provided by Manidis Roberts, the potential irrigation area was estimated to be 27.3 ha in Stage NH1a and 115.3 ha when the New Town is completed (ultimate). The proposed development site is some 700 ha.

1.4 RECYCLED WATER MANAGEMENT

1.4.1 PREDICTED VOLUMES

The water balance discussed below and in more detail in Section 8 is based on an average dry weather flow (ADWF) of 0.628 ML/d in the neighbourhood 1A (NH1A) stage of development and 2.988 ML/d in the ultimate stage. In wet periods the recycled water production will increase due to storm water infiltration into the gravity sewerage system. Due to the relatively dry climate, the impact of storm water infiltration will only increase the average yearly flow rate by around 3% (AWM 2009).

MWH have advised that losses of waters will occur within the recycled water distribution system. These losses typically average 10% of the total flow but unlike wet weather infiltration effects cannot be modelled based on historical rainfall or evaporation patterns.

1.4.2 RECYCLED WATER TREATMENT AND DELIVERY

MWH (pers comm.) have provided Agsol with the predicted total dissolved solids in recycled water to be generated from their proposed 'Bio-P' water recycling plant (WRP). The average TDS is expected to be 660 mg/l with a 90th percentile of 720 mg/l. The average total nitrogen content is expected to be 5 mg/l and the phosphorus content to be between 0.2 and 0.5 mg/l. The low phosphorus level will be achieved by the addition of various chemicals in the sewage treatment process. To minimise salt impacts, the use of chlorides will be limited by using sulphate compounds where possible.

Distribution storage (or storages also known as reservoirs) will receive the daily flow of recycled water from the proposed WRP.

1.4.3 REUSE OF RECYCLED WATER

All houses will be provided with rainwater tanks and use rainwater as the primary source of water for laundry use and garden watering. Recycled water will be used as a backup supply. It will also used for toilet flushing and for irrigation of playing fields and landscaped areas.

MWH provided Agsol with estimates of non irrigation usages (59 l/EP/day). The amount used for irrigation will vary according to seasonal conditions and was estimated by AWM (2009) using a water balance as described below. In home gardens irrigation strategies used in the water balance were selected based on analysis of real data in Sydney's Rouse Hill development. Irrigation strategies in playing fields and landscaping represented typical strategies used by most green keepers.

1.4.4 POTABLE TOP-UP OF RECYCLED WATER SYSTEM

The seasonality of irrigation demand and the lack of a substantial recycled water storage means that potable water is needed to supplement the recycled water/tank water supply at certain times of the year. The water balance analyses undertaken in this report by AWM (2009) assumed that there were 'no water restrictions' and that homeowners/green-keepers would always irrigate to meet soil moisture demand. This resulted in a relatively high level of potable water demand. Agsol considers it unrealistic to assume that home irrigators would not restrict their use of water in hot dry periods either because of the costs or simply because of lack of suitable irrigation infrastructure. Hence we consider the estimates of potable top-up described in this report to be too high.

1.4.5 DISCHARGE OF RECYCLED WATER

Any recycled water that is not used within the day will be discharged to a constructed storm water system unless the stored recycled water continues to meet recycled water quality guidelines for a longer period. In our analyses we have taken a 'worst case' scenario i.e. that any unused recycled water will need to be discharged from these reservoirs on a daily basis.

Storm water and catchment water will be captured in a 50ML catchment dam as shown on Figure 1 (your Figure ES.2). Following significant rainfall events the captured water will be discharged to Googong Creek. Browns Consulting (using recycled water discharge data from MWH 2010) have modelled the likely dilution achieved when recycled water is mixed with storm water as well as the volume and frequency of discharges from the aforesaid dam into Googong Creek.

1.5 WATER BALANCE RESULTS

A series of water balance analyses were undertaken by AWM (2010) to estimate the reuse, discharge (to the storm water system) volumes and irrigation volumes under various water saving scenarios being considered for the Googong Development. Analyses were done for two stages of development being Stage NH1A and at the expected completion of the entire development (ultimate).

Table S3 summarises the findings of the water balance for NH1A.

Table S3 Summary of the mean reuse and irrigation for the two scenarios

Component	Class	Scenario	
		NH1A	Ultimate
Reuse (%)	Recycled water	67	68
Discharge (ML/yr)	Recycled water	78	362
Irrigation (ML/yr)	Rain water	24	122
	Recycled water	57	234
	Potable water	52	205
	Total	133	561

In the NH1A Stage the level of reuse of recycled water was estimated to be 67%. Recycled water provided 43% of the irrigation water needs.

MWH (2010) used different models (but with the same assumptions) to determine the level of reuse and achieved a slightly lower level of reuse (65% with rainwater tanks). These differences are considered insignificant.

In the ultimate Stage, the level of reuse measured by AWM was similar to NH1A stage being 68%. The volumes of discharges were much greater reflecting the increased effluent production. MWH (2010) using different model achieved a lower level of reuse (62%).

1.6 SUITABILITY OF THE SOIL LANDSCAPE FOR RECYCLED WATER IRRIGATION

Most of the proposed new urban developments are likely to be located on the Burra soil landscape. This landscape consists of undulating to rolling low hills and alluvial fans on Silurian Volcanics. Higher parts of the proposed development occur on Campbell soil landscape. Here rock outcrop is common and some areas exhibit tombstone sized and shaped rows of vertically dipping tuffaceous material.

Parts of Neighbourhoods 3 and 4 (refer to Map 1) are characterised by the Williamsdale Soil Landscape typified by undulating rises fans, valley flats and depressions on Silurian Volcanics. This landscape includes a significant area of pediplain. Soils here are typically moderately deep.

An electromagnetic (EM) survey (see Appendix 1) showed low readings over the site consistent with non saline and well drained soils. The lowest readings are in areas dominated by rocky soil. Very small areas within drainage lines showed high readings that suggest slightly saline conditions at depths between 2 and 4 metres.

Agsol's soil survey confirmed the dominance of moderately deep red and yellow chromosols and shallow rudosols in the rocky areas. The typical soils are not saline or sodic and the soils have good water and nutrient holding capacity to about 50 cm. The soils have a high capacity to absorb phosphorus. Cation exchange capacity is relatively high and is dominated by calcium and magnesium ions.

Agsol notes that within the area to be urbanised, it is likely that garden soils and playing fields may be filled with local soil materials and subsequently topsoiled and mulched, ensuring a sufficient 'soil' layer to protect any vulnerable groundwater features.

Poorly drained soils increase the risks of concentrating salts within or near irrigation areas. In turn this may adversely impact on the built environment and plant growth. The typically well drained and non-saline soils over much of the area lower this potential risk.

1.7 GROUNDWATER AND SURFACE WATERS

1.7.1 ENVIRONMENTAL PROTECTION AREAS

The study area adjoins large areas of environmentally sensitive land zoned Environmental Protection which corresponds with part of the Googong Dam and Foreshores. An area of 40 hectares in the south-west of the study area drains directly to Googong Dam. This area has been excluded from any urban or active recreation uses (see Map 1). In addition a 20 metre buffer zone along the edge of the dam catchment has been put in place to avoid having development occurring on the cusp of the catchment boundary.

1.7.2 SURFACE WATER IMPACTS

The area proposed for housing development is traversed by a number of small ephemeral and semi-permanent creeks, farm dams and depressions. The majority of this land drains to the catchment below the Googong Dam. Approximately 287 hectares of land within the study area's western portion drains to Jerrabomberra Creek. The proposed subdivision layouts have located open space and parklands adjacent to most creek lines. These will act as buffers.

The pre-development site is badly eroded. Hence heavy rain showers falling on the site would generate run-off. AWM (2010) has estimated that runoff would average 26 mm/year.

The proposed development is likely to increase the amount of runoff because of the increase in hard surfaces. Some of this runoff will be captured in rainwater tanks and reused. The remainder will be collected in the constructed storm water system and holding dam. When the holding dam is full it will discharge to an unnamed tributary of the Queanbeyan River (known in this report as Googong Creek).

Browns and Associates have modelled the impact of discharges of recycled water into the creek using recycled water with a concentration of 650 ppm. The analysis showed that the storm water significantly diluted the recycled water in the proposed storm water holding dam producing an average discharge TDS of less than 250 mg/l during discharge events. This means that the ANZECC guideline of 350 uS/cm for 'upper streams' is likely to be met.

The analyses also showed that salt concentrations were highest during the winter months (and more likely to exceed ANZECC guidelines) because this is the most likely time that recycled water would discharge into the storm water system. Using stored storm water for irrigation of landscaping, thereby minimising the likelihood of discharge would reduce this impact.

Runoff generated from the small area of recycled water irrigation is likely to be slightly more saline than the pre-development runoff water. However because of the small area involved and the existence of preventative buffers around creek lines and depressions the impacts are expected to be insignificant.

1.7.3 GROUNDWATER IMPACTS

Water that enters the soil and is not removed by evapo-transpiration (estimated to average 86 mm/year) is likely to move laterally above clay subsoils or hard rock. A relatively small proportion of the 86 mm would enter any deeper groundwater resource through cracks in the bedrock.

Most groundwater flows through the study area also trend towards the study area's north-eastern corner and the Queanbeyan River. There are no existing licenced bores within the proposed development site. Data close to the site suggest useable groundwater aquifers are likely to be below 10 metres and therefore according to DEC (2004) should not be a constraint to any recycled water irrigation unless the groundwater is considered vulnerable.

The proposed development is likely to reduce the amount of groundwater recharge. AWM (2010) identified the change in recharge conditions within the irrigated landscape. The analyses found little change from the pre-irrigated state (average 86 mm/yr) compared with the irrigated rate of 96 mm/yr. However, given that a substantial part of the catchment will now be paved or essentially impervious (estimated to be around 70%-pers. comm. Browns Consulting) the overall recharge within existing sub-catchments is likely to be less (a normal consequence of changing from a rural to an urban landscape). This means that the volume of recharge within the landscape is reduced by more than 60% but the recharges will be much more saline.

Agsol has estimated that after the development is fully completed the extra load of salt entering the landscape will amount to 21.4 tonnes/ha over a 100 year time span. Chris Jewell and Associates (2010) conclude the impacts of this increased salinity are unlikely to be significant.

High yielding bores are found close to the south-western corner. Groundwater in the south-western corner is considered as having a "moderately high" vulnerability due the presence of shallow rocky soil in the vicinity. It is understood that no recycled water irrigation will occur within or near this area.

1.8 IMPACTS ON THE IRRIGATED GARDEN

The use of household detergents and chemicals in the sewage treatment process means that recycled water has a much higher salt load (TDS average 660 ppm) than the potable water supply (TDS average 100 ppm).

AWM (2010) undertook salt budgets to assess the degree of risk to the irrigated landscape. The salt budget examined the effect of recycled water with an average total dissolved salt concentration (TDS) of 660 ppm.

The salt budget showed that the use of collected rainwater for irrigation (when it was available) and the dilution effects of topping up with the potable water supply during periods of peak irrigation demand significantly reduced potential impacts of foliar injury and reduced plant growth during periods of the highest expected salt concentration (i.e. when the only source of water is recycled water).

It is noted that the estimated small risk of foliar injury can be further mitigated by using less sensitive species and/or using drip or subsurface irrigation, and taking precautions such as avoiding watering during the heat of the day.

The expected soil salinity never exceeded 1.6 dS/m and hence there was no soil-salinity risk to most plant species. However, this was predicated on the assumption that natural rainfall events would leach excess salt out of the plant root zone. In this regard Agsol notes that the natural subsoils are well drained and the use of sulphates in the sewage treatment process will favour the development of gypsum in the soil which will act to maintain good drainage conditions.

1.9 IMPACTS ON THE FUTURE BUILT ENVIRONMENT

Continued use of slightly saline recycled water for irrigation of home gardens can predispose the built environment to potential impacts such as

- Decreased life of bricks and concrete structures
- Increased road and pavement failure
- Water logging of soils
- Decreased water quality in the local environment

The site has no existing soil salinity issues. Future issues which could occur as a result of irrigation with slightly saline recycled water can be readily addressed with preventative measures such as:

- Building design/drainage systems to avoid water ponding within individual house blocks
- Damp Proof membrane installed under slab (according to the Building Code of Australia for saline environments)
- Damp Proof Courses properly installed, and maintained throughout construction, landscaping, and finishing.
- Reduce the exposure of materials to potentially salty soils, e.g. raised slab or pier and beam designs.
- Susceptible construction materials avoided, e.g. Seconds, porous material
- Use appropriate salt resistant bricks and construction materials

1.10 OTHER SALT IMPACTS

Other effects which can occur as a result of irrigating with recycled such as increased cadmium uptake by plants grown for food and chlorine damage to sensitive plants are unlikely to occur unless the chloride concentration in recycled water is greater than 350 ppm and the chlorine residual is consistently greater than 2mg/l. A review of typical recycled water qualities in other parts of NSW suggest that this is unlikely, but monitoring of the recycled water product is re recommended.

1.11 POTENTIAL NUTRIENT IMPACTS

Browns Consulting have undertaken modelling of the discharges from the WRP to the storm water system and thence to the wider catchment using the proposed concentrations of N and P. The results show that at the upper creek quality is unlikely to breach ANZECC guidelines for N and P.

Chemical removal of phosphorus from the recycled water ensures there are no risks of phosphorus leaching to the wider environment through irrigation. The proposed recycled water is likely to have an average phosphorus concentration of 0.2-0.5 mg/l, however, much higher levels could be tolerated if it can be demonstrated that there is no impact on discharges to receiving waters. The advantage of higher P concentrations (apart from providing some fertiliser) is that less salt will be needed during the recycled water treatment process.

1.12 CONCLUSIONS

The only significant risk identified from this investigation relates to the introduction of salt into the landscape and receiving waters as a result of garden and landscape irrigation and discharges from the RWP. More salt will be added to the soil (and potentially the groundwater) from recycled water irrigation than is currently the case (in the rain fed environment) or if conventional potable water supplies were used. However irrigation with recycled water reduces the salt, nutrients and other potential toxins delivered to streams and waterways from direct discharges from a sewage treatment plant.

During prolonged rainfall events, salt accumulated from recycled water irrigation will leach below the plant root zone and start to move to lower lying parts of the landscape. Unless most of the salt is directed to the storm water system and/or leaches below plant root zones; soil salt levels downhill could increase harming the growth of existing or future vegetation stands. At worst, salt scalds could develop in lower lying areas and soil erosion may subsequently occur where plant growth is impaired.

Salt stored in the landscape may also find its way via interflow or groundwater to streams in the catchment of the Queanbeyan River and Jerrabomberra Creek. Discharges from these sources are likely to be generated in pulses following heavy and/or prolonged rain and/or erosion events.

The above potential impacts may take many years to develop; hence there is a need for preventative actions to be taken during the design and implementation of the Town. Long term monitoring of soil and water quality is required to ascertain the effectiveness of preventative actions and the need (if any) to undertake refinements.

Existing salinity and other adverse soil/groundwater conditions (such as elevated levels of chloride, sulphur and magnesium) were not apparent from the soil survey and hence pose no special risks to installation of underground services and other infrastructure. However irrigation with recycled water will increase salinity (either in soil water or from irrigation sprays) around infrastructure, homes and other buildings. Hence salt sensitive construction techniques should be adopted. These are outlined in various publications distributed by DECCW (Appendix 3).

Risks are also associated with a recycled water product where salinity levels significantly exceed 500 mg/l because of the potential to damage highly sensitive garden plants. This risk can be overcome reducing the salt load in recycled water as much as possible and by selecting tolerant plant species, of which there are many suited to the Queanbeyan climate. Dilution with rain water and potable water that is also used for irrigation will also reduce the expected salt concentration.

The recycled water will supply only a small portion of home garden nitrogen and phosphorus requirements. Agsol concludes that the risks (to the landscape) of nitrogen and phosphorus in recycled water are low and hence a special response to address nutrient impacts from irrigation of gardens is not warranted. There is scope to increase nutrient concentrations in recycled water that is irrigated (but not discharged). This would benefit irrigated areas by supplying a free nutrient source and by reducing the need to add salts during the recycled water treatment process. The risks of nutrients in recycled water will only be of significance where recycled water will be discharged. Hence there is scope to investigate whether nutrient removal treatments can be switched off during periods of high irrigation demand.

1.13 GENERAL RECOMMENDATIONS

The management of the potential impacts of the proposal should focus on the use of preventative measures. Generally, these would include, but may not be limited to:

- Reducing the salt and sodium load in influent. For example, conducting publicity campaigns to encourage the use of low salt detergents, consultation with manufacturers of detergents to investigate the use of potassium instead of sodium in detergents.
- Reduce the salt load in effluent as far as practicable. The proposed Bio-P process will minimise the use of salts (particularly sodium and/or chloride) in sewage treatment processes;
- Reduce damage to residential gardens caused by toxic levels of chlorine by ensuring residual chlorine levels do not exceed 2 mg/L. ;
- Instigate campaigns to educate the community on:
    - Water wise garden management, as less water irrigated will lead to less salt applied;
    - The risks associated with irrigation of recycled water; and
    - Garden plant species most suited to the salt/chlorine levels likely to occur.

1.13.1 CONSIDERATION OF THE STORM WATER SYSTEM

A storm water system should be developed to ensure that the increased salt load being applied to the landscape is managed to avoid adverse impacts on downslope vegetation communities and receiving waters.

1.13.2 INFRASTRUCTURE AND INDIVIDUAL BUILDINGS

The placement and design of any infrastructure including buildings, roads and pipe works, should take into account that salt levels could rise in the soil materials surrounding the infrastructure and hence building methods and codes designed for use in saline environments should as far as practicable be adopted.

1.13.3 HOME GARDENS AND LANDSCAPING

Home gardeners should be encouraged to grow plants with some level of salt tolerance. Salt tolerant plants should be used in landscaping areas, particularly within the low lying parts of the landscape. Landscapes should favour plants with high early spring growth to minimise the need for discharges of recycled water.

1.13.4 RISK ASSESSMENT

Notwithstanding the above specific recommendations, before the detailed design of the scheme, a HACCP style risk assessment (as promoted in the Australian Recycled water Guidelines 2006 and DWE 2007/8) should be undertaken to quantity identified risks and to design preventative measures, monitoring programs and emergency procedures to minimise the identified risks.

1.13.5 MONITORING

Prior to development piezometers should be located and installed upstream, within and below proposed key developments (as advised by groundwater specialists)to enable monitoring and mitigation of any adverse impacts associated with irrigation with recycled water. A monitoring program of water quality in streams that drain the proposed subdivisions should also be initiated.

This monitoring program will guide how recycled water is managed for future stages.

At the instigation of NH1A Stage, a program should be established to allow an assessment of the usage patterns of recycled water in home gardens, the impacts of recycled water on soil salinity and plant growth.

1.13.6 WATER QUALITY

The proposed WRP should be designed to minimise the need for additions of chemicals for phosphorus removal such as ferrous chloride. Ferrous sulphate is likely to have less impact on the irrigated plants as sulphate is a plant nutrient. It may be possible to switch off the phosphorus removal processes during peak irrigation demand periods. This may be achieved if irrigation occurred from the 50 Ml storm water dam during the summer months.

The use of low phosphorus, low sodium and salt detergents by householders should be encouraged and if possible mandated.

1.13.7 OPERATIONAL ENVIRONMENTAL MANAGEMENT PLAN

Once the scheme commences an operational environmental management plan (OEMP) which describes the operational and maintenance procedures and activities of the recycled water irrigation scheme needs to be put in place to minimise the environmental impacts.

2 INTRODUCTION

2.1 BACKGROUND

Canberra Investment Corporation Limited (CIC) is proposing a new residential community at Googong, south of Queanbeyan in NSW and west of the Googong Reservoir for 15,000 to 18,000 residents. The study area is shown in Map 1.

The area to be developed comprises about 700 hectares of land located 8 kilometres south of the Queanbeyan central business district on Old Cooma Road. Old Cooma Road extends north-south along the western border of the study area, while Googong Dam Road forms the northern boundary for the core site. The Commonwealth-owned Googong Dam Area (including the dam and the foreshores) limits any further development to the east.

It is proposed that the Googong residential community is developed in specific stages in respect to both the subdivision of the land and the associated infrastructure. The first stage (known as NH1A) lies to the immediate south of Googong Dam Road as indicated on Map 1. The NH1A development area comprises 112 hectares and is anticipated to support development of dwellings and a population of around 3750. The final stage of the development is expected to have a population of around 16000 persons. Supporting services will include retail and commercial services located in a village centre together with schools and active and passive open space areas.

The proposed community will use contemporary environmental and social sustainability processes, incorporating a host of major initiatives ranging from walkable neighbourhoods and energy efficiency to water reuse and savings that will target significant reductions in potable water use compared with traditional developments.

Water is a particularly important element in the planning of this project because of the relatively low regional rainfall, increasingly constrained water resources, and the identified need to move toward more sustainable communities. The Googong project vision aims to achieve high levels of water sensitive urban planning and design. The development of an integrated water cycle management strategy for Googong is intended to ensure more sustainable urban use of the region's water resources. This will be achieved through reducing potable water demand, maximising water reuse and minimising environmental impacts of the new development.

The water cycle management strategy incorporates stormwater (roof water and potentially overland stormwater) capture and reuse, wastewater (recycled water) reuse, potable water supply and water sensitive urban design.

A preliminary environmental assessment of the project has been undertaken by Manidis Roberts based on the results of early studies. This assessment has allowed for the identification of the environmental risks posed by the project, a range of broad environmental management measures for the project, and proposed further studies to ensure that key environmental issues are addressed.

The ensuing environmental studies will focus on overall water cycle management, resulting in the development of a water cycle management plan that addresses potential construction and operational environmental impacts of the proposal on water quality, hydrology, aquatic ecology and human health. This plan will guide the activities related to the design and development of water cycle infrastructure for the stage NH1A.

2.2 NEW URBAN SUBDIVISIONS

As a result of the Building Sustainability Index (BASIX) introduced by the state government, new housing in NSW will be required to be designed and built to use less mains supply water and produce lower greenhouse gas emissions than average housing of the same type.

A typical development will meet appropriate targets for water conservation if it includes:

- showerheads and tap fittings with at least a 3A rating;
- dual flush toilets; and
- a rainwater tank or equivalent communal system of a minimum specified volume or a connection to an appropriate recycled water supply for outdoor water use and toilet flushing and/or laundry.

New urban subdivisions allow the option of using reclaimed (or recycled) water from water recycling plants (WRPs) for toilet flushing and garden watering and for use in washing machines. In a dual reticulation scheme, each dwelling is supplied with two sources of water (drinking water and recycled water) through separate reticulation systems.

2.3 THE GOOGONG DUAL RETICULATION SCHEME

Drinking (or potable) water will be supplied from potentially two sources, Stromlo and Googong. High quality recycled water for the approved uses described above would be supplied to each house via a separate water reticulation system. The preferred option is for some non-potable water uses to be supplied using rain water tanks. In this report the option of using water stored in rainwater tanks for garden irrigation and laundry use is examined on the assumption that when this supply is exhausted water needs can then be met with recycled water from the WRP as described below.

A WRP is to be constructed at the north eastern end of the proposed development area as shown on Map 1 and detailed on Figure 1 (ES.2). Recycled water will be pumped to dedicated recycled water reservoirs to balance flows. These reservoirs will have a back-up drinking water feed connection to ensure continuity of supply.

The recycled water will be piped to individual properties for toilet flushing and outdoor use (irrigation, car washing, hosing, etc.). Recycled water will also be provided for laundry use (i.e.

direct connection to washing machines), subject to risk assessment and community and regulatory authority support.

The playing fields and other open space areas incorporated in the development (see Map 1) will also be irrigated with recycled water. Recycled water irrigation will also occur in the proposed unencumbered open space areas.

Any recycled water not used or irrigation will be discharged to a storm water system as shown on Figure 1. The option also exists for an open storage to be constructed to allow unused recycled water from the residential areas to be stored for later use on playing fields parks and landscaped areas. A 50 ML dam will be located at the boundary of the residential community above Googong Creek (as shown on Figure 1). This will allow recycled water to be mixed with storm water so as to a chive a water quality acceptable (according to ANZECC guidelines) for discharge charge into the Creek.

2.4 ISSUES EXAMINED IN THIS REPORT

This report provides the results of investigations into the role of recycled water in terms of:

- Its role in meeting non-potable water demand in conjunction with storm water collected in rainwater tanks.
- The likely volumes of necessary discharges of recycled water to the wider environment.
- The potential for salt impacts on the landscape and local hydrology.
- Other potential environmental impacts typically associated with the reuse of recycled water.
- Identification (and where possible quantification of) risks and preventive measures associated with reuse of recycled water.

2.5 OBJECTIVE AND STRUCTURE OF THIS REPORT

The purpose of this land capability assessment is to assess the sustainability of the proposed Googong dual reticulation scheme and identify measures to mitigate any potential adverse environmental impacts from the end use of recycled water for garden/turf irrigation. The report has been prepared on the basis of:

- A review of existing information;
- Identification of potential irrigation areas;
- Soil survey of potential irrigation areas and laboratory analysis of 'typical' soil samples;
- Available ground and surface water data;
- Estimates of recycled water quantity and quality;
- A daily water balance irrigation model; and
- Salt balances and consideration of nutrient impacts.

Planning and regulatory requirements relating to the reuse of recycled water for irrigation are discussed in section 3 of this report. The assumptions relating to the amount of recycled water that will be available and the likely areas of irrigation need are discussed in Section 4.

Section 5 details the risks and management issues associated with recycled water irrigation as outlined by the Australian Guidelines (2006). Soil conditions and the physical suitability of land within the proposed irrigation area are discussed in section 6 and Section 7 identifies potential impacts on surface and ground waters.

In Section 8, water budgets are used to determine the likely seasonal patterns use of recycled water for garden irrigation. In Section 10 salt budgets are used to identify the fate salt under the proposed recycled water management system. Potential environmental impacts and recommended mitigation measures are outlined in Section 11. Requirements for operation and monitoring of the irrigation scheme are also provided.

3 PLANNING AND REGULATORY REQUIREMENTS AND GUIDELINES ASSOCIATED WITH REUSE OF RECYCLED WATER

The following sections are relevant to planning and regulatory requirements specifically associated with the environmental impacts of irrigation of recycled water in home gardens and other landscaped areas. The general planning and regulatory requirements associated with the Googong residential community development are the subject of an environmental assessment by Manidis Roberts as required by the Environment and Planning Assessment Act 1979.The public health issues associated with the use of recycled water are addressed separately by MWH as part of the design of the sewerage system, recycled water plant and distribution infrastructure.

The use of recycled water for irrigation is governed by State legislation. However, wastewater plant operators and end-users may be liable under common law and under the Trade Practices Act for use of a wastewater product that causes harm.

The Department of Environment and Climate Change and Water (DECCW) and NSW Health have agreed to the circumstances and conditions under which approval for recycled water reuse in new urban estates.

3.1 DEPARTMENT OF ENVIRONMENT AND CLIMATE CHANGE AND WATER (DECCW)

DECCW supports the use of recycled water particularly where it replaces existing or potential use of drinking water resources as would be the case in this scheme.

Recycled water irrigation is not specifically listed in the schedule of DECCW licence activities. However as the recycled water scheme is ancillary to the scheduled activity associated with the proposed Googong sewage treatment plant (STP), DECCW will evaluate the recycled water management system proposed by CIC. In particular it will evaluate the wastewater discharges that may impact the water quality of NSW streams, rivers or groundwater.

In order to assess the scheme it is anticipated that DECCW will require:

- How the recycled water will be used (e.g. via garden irrigation, toilet flushing etc)
- Topography of the irrigation area, as well as its soil depth and type;
- A water balance which includes on a monthly basis (as a minimum) average rainfall, proposed patterns of use of recycled water and average evapo-transpiration and percolation rates;
- Proximity of the irrigation area and its potential impact on groundwater tables, water courses or other surface waters, sensitive ecosystems, dwellings, public areas and public roads as may be applicable;
- Any current use of groundwater and surface waters within the impacted area;
- Potential for the irrigation area to be flooded;
- Types of vegetation and their ultimate use, if applicable;

- Proposed irrigation application rates and associated resting periods; and
- Proposed system controls including timers, alarms, distribution safeguards, runoff collection provisions and maintenance programs.

The former Department of Environment and Conservation (DEC) now the Department of Environment, Climate Change and Water (DECCW) has produced 'Environmental Guidelines: Use of Effluent by Irrigation (2004).

This guideline covers the broad framework, principles, objectives and best management practices that should be considered when establishing an irrigation system that uses effluent. This information can be used in the design and operation of effluent irrigation systems and can also be relevant and useful for meeting environmental requirements under the Protection of the Environment Operations Act 1997 and in negotiations for premises-specific environment protection licences.

In addition to the above, DECCW has overall responsibility for the management of NSW's freshwater resources and administers the key natural resources legislation that governs water, namely the Water Management Act 2000 and Water Act 1912. The NSW Groundwater Quality Protection Policy (1998) is aimed at preventing the degradation of the State's aquifers, where each aquifer system is evaluated by its beneficial use.

The design and operation of the recycled water irrigation scheme should take into account the risk of contamination or degradation of surface waters and groundwater aquifers.

DECCW have adopted the Australian Guidelines (2006) as the framework for assessing Section 60 applications for approval to treat and supply recycled water under the Local Government Act 1993 and Section 292 applications for approval to treat and discharge recycled water under the Water Management Act 2000.

The then Department of Water Energy (DWE) have produced 'Interim NSW Guidelines for Management of Private Recycled Water Schemes' (2008). This guideline aligns the principles outlined in the Australian Guidelines to the approvals process for private recycled water schemes (requiring section 68 approvals) in NSW. The guideline replaces the NSW Health Interim Guidance for Grey water and Sewage Recycling for Multi-Unit Dwellings and Commercial Premises (previously Circular 2004/71).

3.2 MURRUMBIDGEE CATCHMENT BLUEPRINT

The Murrumbidgee catchment covers an area of approximately 84,000 square kilometres. The ACT and surrounding region, including the Googong Study Area, are located within the upper catchment area.

The Blueprint seeks to implement the principles of "integrated catchment management" in the management of land and water resources by government agencies and local councils. The Blueprint contains targets and actions to address water quality and flow, salinity, soil health, biodiversity and community building. Management targets of particular relevance to land use change within the Googong Study Area include:

- WMT6 – Ensure development and progressive implementation of stormwater management plans for all major urban areas;
- WMT7 – Reduce the water quality impacts of urban and rural residential development

3.3 NSW HEALTH

NSW Health is the NSW state government agency responsible for monitoring and managing public health and improving public health through regulation and promotion.

NSW Health has limited regulatory authority in relation to recycled water; however it is important to obtain their endorsement at an early stage. In the planning stage its major role is to provide public health guidance and advice to other state and local government authorities. NSW Health has endorsed the use of the Australian Guidelines (2006). Further discussion of NSW Health's role in this scheme will be addressed by MWH and is outside the scope of this report.

3.4 DEPARTMENT OF PLANNING

3.4.1 PROPOSALS WHICH INCLUDE RECYCLING OF TREATED EFFLUENT

The Department of Planning administers the EP&A Act (1979). The then NSW Department of Urban Affairs and Planning has produced an Environmental Impact Statement (EIS) guideline for proposals which include sewage effluent management by irrigation (DUAP 1996). Issues identified in this guideline that should be included in any environmental assessment are as follows:

- Objectives of the proposal;
- Existing and predicted population to be served by the proposal including a strategy for serving that population;
- The estimated sewage and effluent volumes to be serviced by the proposal under normal and wet weather conditions;
- Level of demand and evidence of uptake of treated effluent;
- Estimates of potable water volumes to be saved as part of the proposal;
- Impact of treated effluent as reuse on land uses including impact on groundwater and soil quality and long term sustainability of such sites;
- Management responsibility;
- Health impacts resulting from effluent reuse;

- Likely acceptance of residential/reuse schemes;
- Means of differentiating between and ensuring separation of recycled and potable water in residential areas;
- Alternatives considered in developing the preferred strategy and their evaluation;
- Water demand strategies implemented or proposed by Council;
- Construction and operation costs and means of funding including cost to residential use of recycled water;
- Measures proposed to be taken to manage treated recycled water that is stored;
- The proposal's benefits;

3.4.2 DIRECTOR GENERAL'S REQUIREMENT

The Director General as issued a number of requirements which are specific to the Googong Residential Proposal. Those relevant to this report are as follows:

Soil and Groundwater:

'The EA shall include consideration of existing soil conditions, the suitability and sustainability of long term recycled water application, including measures to avoid soil degradation and inappropriate nutrient loading

An assessment of groundwater impacts must be provided, focusing specifically on the potential for accessions to groundwater of recycled water and salinity / sodicity impacts.

Consideration must also be given to the impact of trenching and other and other underground work on groundwater and subsurface flows'.

These issues will also be addressed in separate groundwater reports prepared by Chris Jewell and Associates and site development reports by Browns Consulting.

Environmental Risk analysis

... The EA shall include an environmental risk analysis to identify potential environmental impacts associated with the construction and operation of the project, proposed mitigation measures and potentially significant residual environmental impacts after the application of the proposed measures.

These issues will be primarily addressed by Manidis Roberts and MWH- the lead consultants. Information provided in this report will assist with the analysis.

3.4.3 ADDITIONAL COMMENTS BY THE DIRECTOR GENERAL

In March 2010, additional comments were received on the first version of the EA provided by Manidis Roberts in 2010. Those of some relevance to this report are described below.

- *The EA should demonstrate how the proposal is consistent with any agreement or statement for the Healthy River systems, flows or water quality in the Queanbeyan and Molonglo Rivers*
- *The quality and quantity of water released from the water treatment plant into the environment, particularly for the operation of the Stage 1 works where all effluent is being discharged into the local water course including the 90th and 100th percentile discharge limits.*
- *Consider the impacts on water quality and flows/hydrological impacts in the Queanbeyan River catchment of the proposed discharge of recycled water to the receiving environment from the WRP. A model based on measured site characteristics to quantify the potential impacts of irrigation such as water-logging, soil salinity, quality and quantity of groundwater/subsurface flow and contributions to stream flow.*
- *The proposed uses of recycled water and impacts of storm water discharge and the need for buffer zones should be discussed.*
- *The potential for salt levels to reduce the beneficial use of water resources and to impact on ecological function should be discussed*
- *The salt in the groundwater and surface water systems and associated impacts needs further investigation.*
- *The wet weather effluent storage, the location of infrastructure within riparian zones and the details of dry and wet overflows needs to be described. The frequency of overflows or contingency measures to minimise infiltration need to be identified*
- *How the development will impact on the water balance for the site. Groundwater recharge and surface water inputs from the proposed irrigation of recycled water and modification of the existing site water balance need to be quantified.*
- *The potential impact on any groundwater dependant ecosystems down gradient of the site needs to be identified. The EA should address the NSW State Groundwater Dependant Ecosystem policy. An assessment of the impact of the development on the flow regime and associated ecological impacts of the surface water system pre and post development should be provided to address on-site impacts in addition to upstream and downstream impacts on the environment, groundwater dependant ecosystems, and existing users where relevant.*
- *Need for engineered drainage structures if salt levels are and alternative methods to reduce the level of TDS in recycled water.*
- *Measures at the WRP to manage salt levels before it goes back to the household or is discharged*

3.5 QUEANBEYAN CITY COUNCIL

Queanbeyan City Council will have responsibility for ensuring appropriate planning and compliance instruments for residential subdivisions using recycled water. These may need to include, (but not be limited to):

- Soil landscape and groundwater assessments to ensure suitability for recycled water use.
- The need for CIC to provide appropriate information about the use of recycled water to householders occupying houses receiving recycled water.
- The need for CIC to implement appropriate controls over installation method (e.g. colour coding of pipes, ensuring cross connections do not occur).
- The potential impact of slightly saline garden irrigation water on building methods and materials.
- The impact of recycled water irrigation on storm water management within residential subdivisions.

It is understood that the above issues will need to be addressed by Queanbeyan City Council in conjunction with CIC during the development approval process for individual subdivisions.

3.6 SCHEME MANAGEMENT ISSUES

Developers of new subdivisions and those responsible for the building of individual houses need to be aware of the specific issues related to irrigation with recycled water compared with irrigation with conventional drinking water supplies. It is likely that Queanbeyan City Council will need to impose special conditions of consent on new subdivisions and building approvals to ensure that salt does not build up in inappropriate locations. As detailed later in this report, the Western Sydney Salinity Code of Practice (WSROC 2004) and other documents produced by DECCW as well as recent Australian Building Codes provide specific advice regarding this issue.

4 SCHEME DESIGN ASSUMPTIONS

4.1 VOLUME OF RECYCLED WATER

The volume of recycled water available will depend on the population at any one time, the types of household infrastructure and the influence of rainfall events in infiltrating the sewerage system. MWH (pers comm.) have undertaken a detailed evaluation of the likely effluent production per person taking into account the adoption of water efficient toilets, showers, wash basins and washing machines. These figures are used by AWM in its water balance (see Section 8).

The total flow at the end of NH1A is approximately 0.7 ML/day and at the completion of the development 3.0 ML/day. The estimates are based on an effluent production rate per 'equivalent person (EP)' of 154.1 l/EP/day.

In wet periods the recycled water production will increase due to stormwater infiltration into the gravity sewerage system. This was estimated using the Anderson Ruge algorithm Anderson and Ruge 1994) assuming that the entire system has a relatively 'low' propensity for stormwater infiltration. MWH have also advised there will be losses of around 10% from the sewage treatment train and distribution infrastructure.

4.2 MIX OF DEVELOPMENTS

The likely mix of housing and other developments for the completed Googong New town scheme Stage NH1a are shown in Table 5.1.

Table 4.1 Number of dwellings and Non residential land areas for NH1a (source MWH 2010)

Customer Category	Number of dwellings	Irrigated area per dwelling (m^2)	Total irrigated area (Ha)
Apartments	26	11.3	0.03
Townhouse/Terrace	51	17.1	0.09
Small Courtyard	211	40.2	0.85
Large Courtyard	293	67.8	1.99
Single Lot	452	98.5	4.45
Large Lot	243	156	3.79
Estate homes	0	360	0
Rural	0	720	0
Total	1276		11.2
Non residential land areas			
Customer category	Gross Areas (Ha)		Total Irrigated area (Ha
Schools	5		2.5
Open Spaces	13.5		13.5
Commercial Use	1		0.1
Total	19.5		16.1

The likely mix of housing and other developments for the completed Googong New town scheme Total development are shown in Table 4.2.

Table 4.2 Number of dwellings and Non residential land areas for the total development (source MWH 2010)

Customer Category	Number of dwellings	Irrigated area per dwelling (m^2)	Total irrigated area (Ha)
Apartments	566	11.3	0.64
Townhouse/Terrace	477	17.1	0.82
Small Courtyard	852	40.2	3.43
Large Courtyard	1311	67.8	8.89
Single Lot	1833	98.5	18.05
Large Lot	818	156	12.76
Estate homes	281	360	10.12
Rural	58	720	4.18
Total	6196		58.9
Non residential land areas			
Customer category	Gross Areas (Ha)		Total Irrigated area (Ha
Schools	21		10.5
Open Spaces	45		45
Commercial Use	14		1
Total	80		56.4

4.3 USE OF RAINWATER TANKS

If rainwater tanks are used for garden irrigation and/or for some non-potable uses then the amount of recycled water used will be less. The potential reduction in recycled water use will depend on:

- The size of the rainwater tank on each household type.
- The size of the roof area on each household type.
- The uses to which the rainwater tank will service.
- The prevailing rainfall characteristics (amount, frequency and intensity).

MWH have identified the roof area and volume of tank for each of the dwelling types described in the above tables (See Section 8). Water held in the rainwater tanks will be used in preference to recycled water for garden irrigation and in washing machines. When these empty, water for these uses will be sourced from the recycled water system. Once the rainwater tank is 10% full again, recycled water will cease to be used for the garden and washing machines, and rainwater will be used in preference. Recycled water will be the only source for toilet flushing.

4.4 ESTIMATED IRRIGATION AREA AND LANDSCAPING

The estimated irrigation area has been calculated for the entire Googong development and NH1A as shown in Tables 4.1 and 4.2. To undertake the water balance described in section 8 it is also important to know the type of plants that will be used as they have different water use characteristics.

With regard to turf it is assumed that the turf will be summer couch and winter ryegrass. Shrubs will incorporate a range of types including native shrubs and ornamental grasses (which typify the open landscaped areas) and commonly grown European garden plants including roses, lavenders, and camellias. The shrub classification will also include tree species, including deciduous and non-deciduous types. It is also assumed that where deciduous plants are used it is likely that there will be an understory of winter flowering plants such as bulbs.

4.5 CLIMATIC DATA

The climatic data used in the modelling will be rainfall, (Queanbeyan Bowling Club station no. 070072) and evaporation (Canberra Airport station no. 070014). These are the closest stations with records held by the Bureau of Meteorology. The modelled years are from 1966 (when records began at Canberra airport) to 2007. This data set includes the second driest year on record, 1967 when only 285 mm of rain fell at the Queanbeyan Bowling Club.

5 RECYCLED WATER IRRIGATION RISKS

This report has canvassed the sustainable use of recycled water for non potable household use. This type of use is desirable because it:

- replaces other forms of water such as town, storm water or river water for non potable urban uses; and
- reduces the risk that the water quality at the WRP release point adversely impacts on local water quality and flow regimes.

There are, however, risks associated with recycled water schemes including human health and risks to the environment. The environmental risks are discussed in general in this section. The risks will be analysed for this scheme in later sections of this report.

Recycled water generally differs from typical drinking water supplies in that it is slightly more saline and contains a range of 'nutrients' suitable for plant growth. In addition, depending on the level of treatment applied before reuse, the recycled water may contain a range of pathogens that can cause damage to human health. Agsol notes that the pathogen issue will be addressed by MWH and therefore this report does not include detailed discussions of pathogen risks.

5.1 NUTRIENTS

Typically, recycled water contains significantly greater concentrations of nitrogen and phosphorus than potable supplies. These nutrients, if applied to the landscape in excess, have the potential to impact on the wider environment if they are not absorbed into the growing garden or underlying soil. To assess the risk of nutrient impacts on the environment, it is usual to carry out nutrient budgets. However in this case the average concentrations of nitrogen and phosphorus in the recycled water are low (5mg/l and 0.2 mg/l) respectively, well below measured sustainable levels from many other reuse schemes analysed by Agsol. Typically nitrogen levels of up to 15 mg/l and phosphorus levels up to 2 mg/l can be sustained in urban settings, even if the soil materials have a poor capacity to 'sorb' excess phosphorus'.

5.2 SODIUM

Recycled water can contain significant levels of sodium. If sodium levels are high relative to cations such as calcium and magnesium, there is a risk that application of recycled water would impact on the structural stability of clay soils through the process of dispersion. Calcium has the opposite effect of improving structure in clay soils by coagulation. The potential impact of sodicity is assessed by measuring the sodium absorption ratio (SAR) of recycled water. In general if SAR levels are less than 6, no significant impacts are expected. In soils sodicity is measured by comparing the relative levels of sodium to other cations in the soil. A soil with an exchangeable sodium percentage of more than 5 is considered sodic.

It should be noted that where soils are very sandy, sodicity is not an issue except where it contributes to salinity as discussed in Section 5.1.4 below.

5.3 SALT

Recycled water, and to a lesser extent rainfall, will apply salt to the soil. The slightly saline recycled water irrigated onto gardens has the potential to adversely impact on garden soils, garden plants, soil landscapes, native vegetation communities, stream quality and built structures. An analysis of these risks will be provided using salt budgets.

5.4 SALT AND SODICITY

As described above recycled water has the potential to make the soil more saline and more sodic. In clay soils, soil structure can be affected by the relative concentrations of salt and sodium in the soil. An already saline soil with a high level of sodium will be better structured than a similar low salinity soil with a high level of sodium. When a dry sodic and saline soil is suddenly saturated by non saline rainfall the previous soil structure may be destroyed making the soil less permeable. This process would be exacerbated if the soil structure has already been disturbed through cut and fill operations. This risk can be mitigated by applications of gypsum or lime when disturbing clayey soils during cut and fill operations. Gypsum and lime supply calcium to the soil thereby reducing the soils sodicity consequently improving the soil structure.

5.5 ORGANIC MATTER

Organic matter, oil and grease in recycled water applied to soil can clog pore spaces, creating anaerobic conditions and consequently odours. However, the high level of treatment associated with recycled water production to meet Australian guidelines (2006) and DWE (2007/08) for irrigation of home gardens, ensures that these potential contaminants are removed to negligible levels. Consequently, this risk is not considered further in this report.

5.6 OTHER POTENTIAL CONTAMINANTS

The Australian guidelines (2006) nominate nine likely water quality hazards associated with recycled water use. In addition to the above, these also include boron, cadmium, chlorine disinfection residuals and chloride.

A summary of the potential impacts of these is shown in Table 5.1

Table 5.1 Hazards associated with various constituents in recycled water (after NRMMC et al 2006)

Hazard	Environmental end point	Effect or impact on the environment
Boron	Accumulation in soil	Plant toxicity
Chlorine disinfection residuals	Plants Surface waters	Toxicity to plants Toxicity to aquatic plants
Chloride	Plants Soils Surface water	Direct toxicity to plants when sprayed on leaves Plant toxicity via uptake through root Toxicity to aquatic biota

The Australian Guidelines (2006) also suggest that a further nine hazards be screened (i.e. measured in recycled water as part of a monitoring program) — ammonia, aluminium, arsenic, copper, lead, mercury, nickel, surfactants (i.e. linear alkyl benzene sulphonates) and alcohol ethoxylated surfactants) and zinc.

6 IDENTIFICATION OF LAND PHYSICALLY SUITABLE FOR IRRIGATION

The selection of suitable lands involves identifying lands that are physically capable of being irrigated. It also involves ensuring that the proposed land uses can sustain the irrigated activity and that the proposed recycled water and its chemical and organic constituents will essentially be immobilized within the irrigated area. This section of the report discusses the identification of lands that are physically capable of being irrigated. Soil and topographical guidelines for identification of physically suitable lands for recycled water irrigation are documented in Hardie and Hird (1998). These guidelines have been adopted by DECCW in their latest guideline (2004) and follow the principles outlined in the Australian guidelines (2006).

Section 7 of this report investigates potential impacts of recycled water irrigation on surface and ground waters. In the final report water budgets will be used to determine the seasonal demand of recycled water for garden irrigation. The water budget also forms the basis for nutrient and salt budgets which identify the fate of nitrogen, phosphorus and salt under the proposed recycled water management systems. Organic budgets will not be undertaken, because the level of organic material (represented by BOD) in recycled water is typically at levels that would not impact on the local environment (DEC 2004).

6.1 TOPOGRAPHY

Most of the project area is part of a dissected undulating plateau known as the Mt Campbell uplands (Coffey 2004) standing at a general elevation of about 750m and some 100m above the entrenched Queanbeyan River. The topography is generally undulating. The steepest slopes occur along the side of streams that flow to the river and the most rugged topography is in the lower reach of Montgomery Creek where it passes through the Googong adamellite (a granite-like rock).

The micro-topography strongly reflects the different rock types present plus a valley wide blanket of Quaternary alluvium along the upper reaches of Montgomery Creek.

Sheet erosion is common but gully erosion is limited as in most places rock outcrops prevent the stream channels from incising.

6.2 GEOLOGY

At least twelve different rock types belonging to five different geological groups over the entire 662 ha site (Map 2).

The oldest rocks are Ordovician shale and radiolarian chert. These are overlain by Silurian shallow marine volcanic rocks known as the Colinton volcanics (which characterise NH1A and to a lesser extent re-crystallised limestone and dolomite. All of the rocks have been subject to a moderate degree of metamorphism and are strongly deformed with North-North-East (NNE) trending tight folds, close jointing, shear zones, and some faulting.

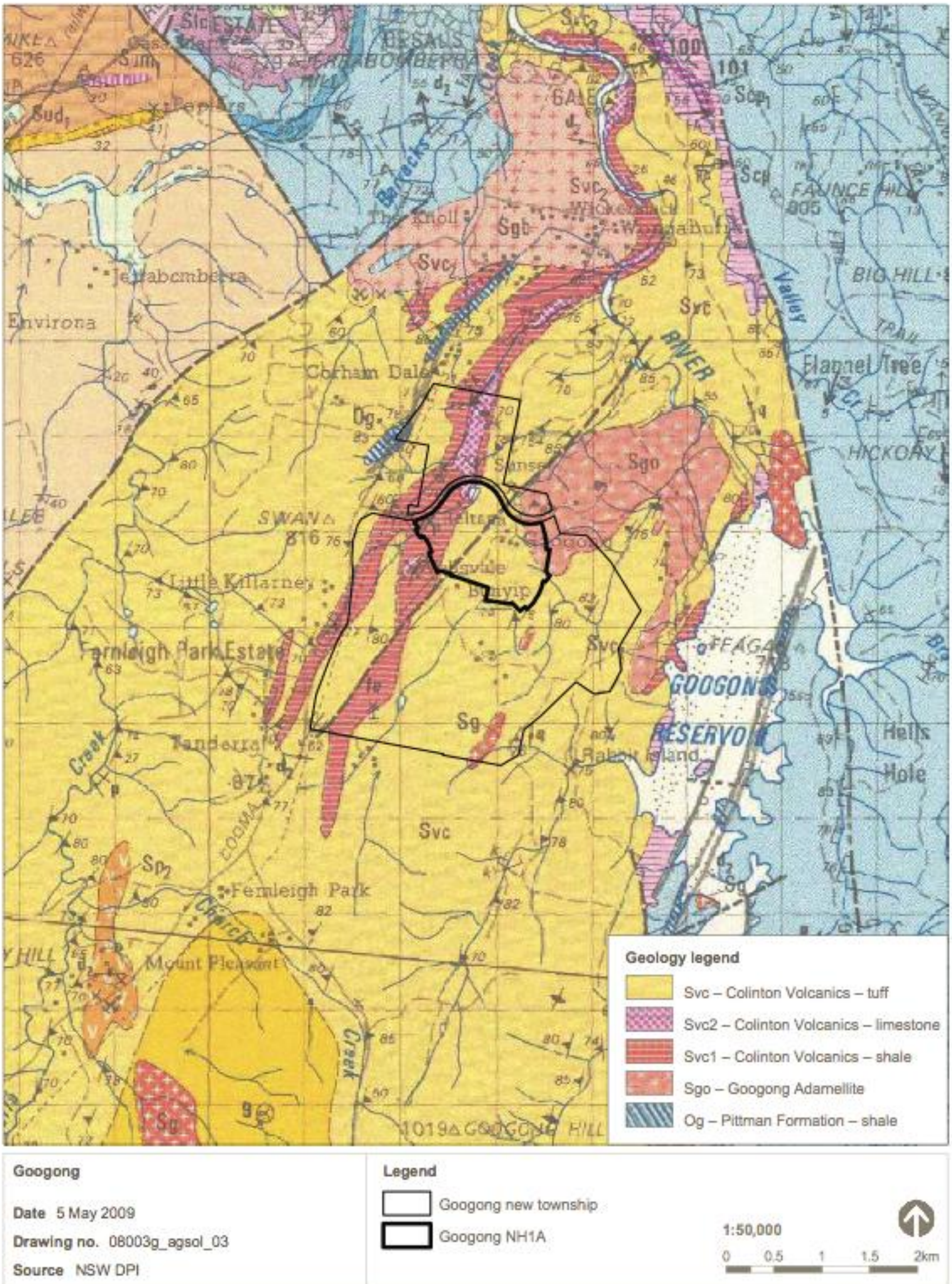


Figure 2 Googong New Township – regional geology

Map 2 Geology of the Googong Residential Area

At least one major fault, which has been infilled by quartz veins, runs through the property along the crest of Twin Hills.

The youngest rock is an intrusive granitic material known as the Googong adamellite that occurs in the central and eastern parts of NH1A. The boundaries appear to be faulted.

Rocky outcrop is common over most of the project site and in part dominates the landscape. Most areas of the volcanics have10-30% rock outcrop occurring as vertical sheets of more durable facies outcropping in linear ridges up to 1m high oriented approximately NNE.

The Silurian marine rocks were deposited as shallow marine volcanic ash fall events and some lava flows. All outcrops are strongly foliated and crenulated, close jointed, steep dipping and penetrated by quartz veins along major fractures (Mitchell 2007).

6.3 SOIL LANDSCAPES

According to the Soil Landscapes of the Canberra Queanbeyan, Lake George, Hoskinstown (Jenkins 2000), most of the proposed new urban developments are likely to be located on the Burra soil landscape. This landscape consists of undulating to rolling low hills and alluvial fans on Silurian Volcanics, The soils are described as shallow well drained rudosols (lithosols) and tenosols (earthy sands) on crests and upper slopes with red kurosols (red podsolic soils); red kandosols (red earths) on midslopes and most lower slopes. Moderately deep slow to moderately well drained brown chromosols (yellow podsolic soils) and kandosols (yellow earths) occur along minor drainage lines.

Higher parts of the proposed development occur on Campbell soil landscape. Here rock outcrop is common and some areas exhibit tombstone sized and shaped rows of vertically dipping tuffaceous material. Shallow rudosols dominate (<70 cm) with some areas of red and yellow chromosols. Drainage areas in this landscape are characterised imperfectly drained sodosols and chromosols. The Twin Hills Reserve occurs within this landscape.

Parts of Neighbourhoods 3 and 4 are characterised by the Williamsdale Soil Landscape which is characterised by undulating rises fans, valley flats and depressions on Silurian Volcanics. This landscape includes significant area of pediplain. Soils are typically moderately deep and moderately well drained yellow chromosols and red and brown kandosols.

Minor outcrops of the Celey's Creek soil landscape also occur. This landscape occurs on rolling low hills of granitic rock. Rocky outcrop as large tors is a feature. The soils are typically well to rapidly drained Tenosols and Rudosols on crests. Shallow to moderately deep Tenosols occur on upper slopes. Lower slopes are characterised by shallow to moderately deep well drained red and yellow chromosols.

6.4 PREVIOUS SOIL INVESTIGATIONS

Soil investigations were previously undertaken by Sydney Environmental Laboratory (SEL). Results of soil tests are shown in Table 6.1.

Table 6.1 Previously soil laboratory results for the site (source SEL 2003)

Sample Number	Depth (mm)	Texture	pH (CaCo3)	EC	Sodicity	Ca	Mg	eCEC	Cu	Zn
1	Topsoil?	Clay loam weakly structured	Slight acid	Very low	Not sodic	741 mg/kg	321 mg/kg	low	1.9 mg/kg	1.3 g/k
2 (Hole 1)	500-700 (A2)	Silty clay loam	6.3	0.05 (ECse (0.5)						
3 (Hole 1)	800	Medium clay	6.5	0.08 (ECse 0.6)	6.7%	7.62	723	16.4		
4 (Hole 2)	0-250	Sandy loam	Strong acid	Low	2.3			4.4	1.1	21
5 (Hole 2)	250-300	Medium clay	5	0.12 (ECse 0.84)	2.8	5.7	7.3	13.6		
6 (Hole 3)	0-200	Loam	4.5	0.07 (1.0 ECse)	0.7	5.3	1.3	7.4	2.3	6.3
7 (Hole 3)	200-400	Clay loam	5.2	.04 (ECse 0.4)						
8 (Hole 3)	450	Sandy clay	5.4	0.02 (ECse 0.2)	0.9	4.7	2.2	7.4		
9 (Hole 3)	700	Sandy clay	5.7	0.02 (ECse 0.2)	0.3	6.3	2.9	9.6		
10 (Hole 4)	0-200	Silty clay loam	4.5	0.06	1.4	4.4	1.7	6.4	1.9	2.4

Whilst the location of these samples is not known they suggest the typical soil is not saline or sodic. The soils have low to moderate cation exchange capacity and are generally acid. The results are consistent with tenosols and chromosols described for the Burra, Campbells Creek and Williamsdale soil landscapes.

6.5 EM SURVEY

On behalf of CIC, Agsol undertook a more detailed soil survey of the site in early 2009. The survey involved the use of electromagnetic (EM) survey as described below, followed by field soil sampling and laboratory analyses of selected soil sites.

Electromagnetic (EM) surveying is a technology routinely used to identify the variability in soil characteristics by measuring the soils apparent conductivity. Influenced by soil porosity, soil moisture, the concentration of dissolved salts and the amount and type of clay within the soil profile, apparent conductivity has been proven to be a useful indicator of soil trends and for the determination of appropriate locations for targeted soil investigations.

Under normal conditions, the highest conductivity readings will represent soils with the highest overall clay content and lowest drainage, with greatly elevated readings indicating potentially saline conditions. The lowest conductivity readings indicate relatively coarse textured soils with lower electrolyte levels and typically having increased relative drainage characteristics.

EM31 and 38 sensors were used for this survey providing a total sensor depth up to 6.0m. The EM 31 predicts soil/rock conditions in the two to three metre depth range and the likely presence of saline subsoils or ground waters at depth. The EM 38 results predict soil conditions in the top one metre.

The location of individual measurements is recorded using a Global Positioning System (GPS). The position is differentially corrected in real time resulting in location variation of between 80 and120 cm.

According to Hird and Foreman (2010), existing detailed salinity studies in Western Sydney have demonstrated a fairly robust relationship between the salt load in the top 3 metres of soils in western Sydney and EM 31 readings. For example all existing studies conclude that EM31 readings <50 mS/cm represent non saline, usually coarse textured or shallow soils; EM31 readings of 50-100 mS/cm are well developed soils usually with significant clay content but without significant salinity whereas soils with EM31 readings >100 mS/cm usually have salt in the top three metres, the salt load increasing with increasing EM31 values above 100 mS/cm.

6.5.1 EM SURVEY RESULTS AND DISCUSSION

The results of the EM 31 surveys are shown in Map 3. EM 38 results are shown in Appendix 1. Generally the EM31 conductivity readings were low to very low (i.e. <50 mS/cm). This probably indicates that shallow non-saline soils dominate the site.

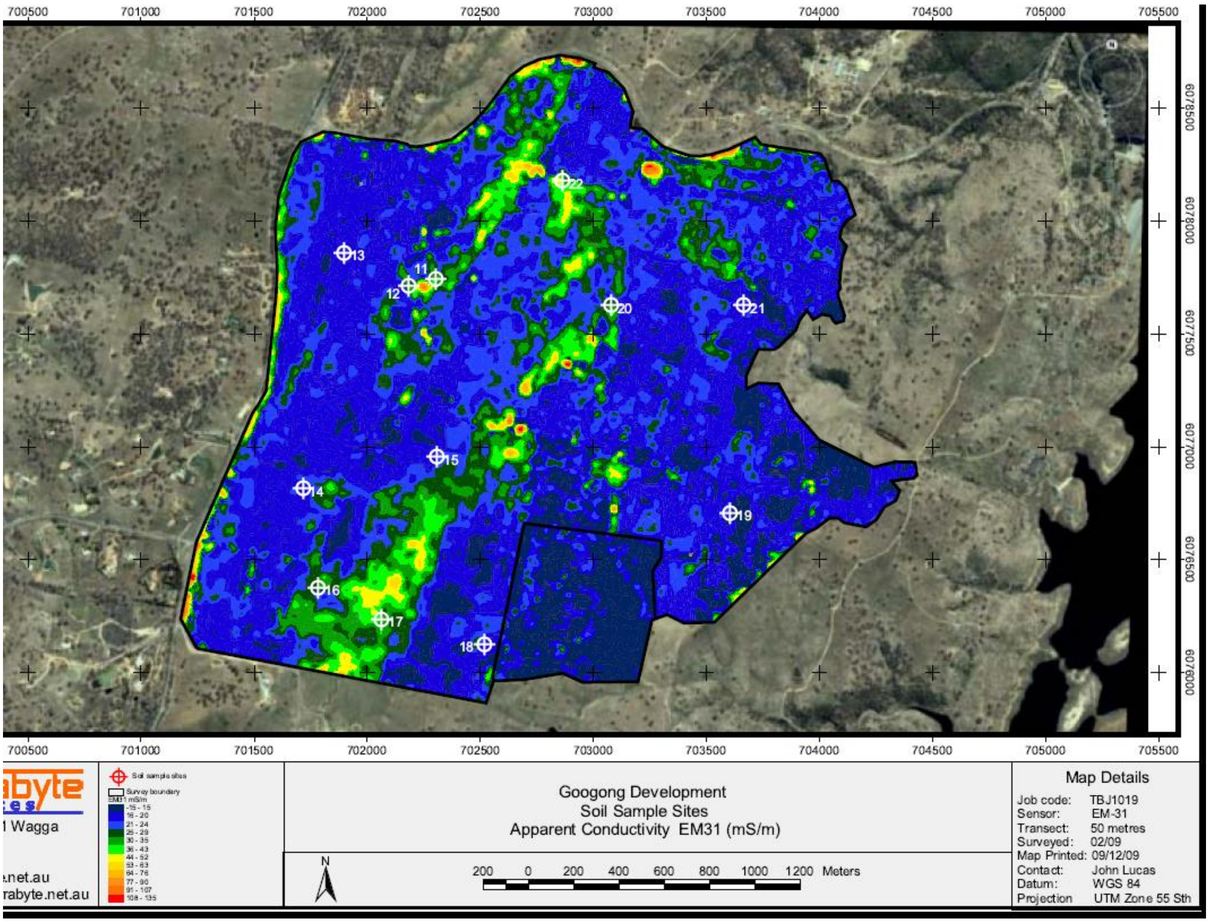
Higher readings generally occur along the drainage lines and may be an indicator of deeper or damp soil. The small areas of highest conductivity (i.e. 100-135 mS/cm) generally occur in drainage lines and may be an indicator of shallow ground water with some level of salinity.

The higher conductivity readings found adjacent to the two roads could be due to runoff from the roads or localised poor drainage leading to some salt accumulation.

There was a large area of negative conductivity readings recorded using the shallow sensing EM38 instrument. This has been mapped separately and is investigated in the soil survey. The soils survey identified these as iron rich heavy clays and it is thought that the result was related to a high level of magnetism.

Both sensors showed anomalous readings in the south east of the survey area. It is unclear whether it is a magnetic feature or an external influence which has affected the readings, but the fact that both sensors where affected is extremely unusual.

Map 3 Summary of EM31 survey results and location of field soil sample sites



6.6 FIELD SOIL SURVEY

On Monday and Tuesday 16/17 March 2009 Catherine and Lew Hird of Agsol undertook a soil survey using a backhoe to excavate sites up to one metre. Soil survey locations are shown on

Map 3. They noted that the site had been extensively cleared primarily for sheep grazing (for wool). Results are shown in Table 6.2.

Table 6.2 Field description of soil sites

Site ref.	Location	EM38	EM 31	Site description/remarks	Soil description	Likely soil classification
11	55 H N 6077744 E0702301	-6.1	35	Upper hill slope (<2%) naturalised grass Near abandoned farm house	0-20 cm pale reddish brown weakly structured clay loam sharp to 20-60 cm red structured heavy clay clear to: 60-100 cm yellow brown mottled red clay (no gravel or rock)	Red kurosol
12	N 6077710 E 0702184	-1.3	32	Upper hill slope (<2%) naturalised grass	0-20 cm red clay loam (stony) gradual to: 20-50 cm red clay plus volcanic rock incisions 50-100 cm gradually weathered volcanic rock	Red kurosol
13	N 6077860 E 0701896	4.1	16	Hillcrest naturalised grass 5-10% slope). Local rock	0-10 cm brown fine sandy loam a1) clear to 10-20 cm bleached A2 (fsl) Sharp to: 20-80 cm red/yellow/pale yellow mottled medium structured clay 80 cm slaty parent material	Yellow chromosol
14	N 6076815 E 0701715	8.4	19	Mid hill slope (5-10% slope). Localised vertical rock outcrop	0-20 cm brown stony fine sandy loam sharp to: 20-40 cm pale A2 (rocky) fine sandy loam Clear to rocky regolith showing vertical bedding (excavatable)	Rudosol

Table 6.2 (cont) Field description of soil sites

Site ref.	Location	EM38	EM 31	Site description/remarks	Soil description	Likely soil classification
15	N 6076957 E 0702308	10.1	22	Lower foot slope (<2%) above dam	0-10 cm brown fine sandy loam clear to 10-40 cm white A2 (Fine sandy loam) clear to 40-60 yellow grey mottled clay 60-85 cm weathering slaty rock Excavator refusal at 85 cm	Yellow chromosol
16	N 6076377 E 0701785	31.8	37	Upper hill slope (5-10%) in previously cultivated area. Stony surface	0-10 cm pale grey brown sandy loam clear to 10-40 cm fin sandy loam A2 sharp to: 40-60 cm Red yellow grey mottled medium clay gradual to: 60-80 cm weathering shale and yellow clay. Excavator refusal due to rock at 80 cm.	Yellow chromosol
17	N 6076239 E 0702064	22	33	Alluvial Flat (<2%) naturalised grass gully erosion dams	0-20 cm brown fine sandy loam sharp to 20-40 cm white A2 sharp to 40-100 cm yellow weakly structured silty clay some grey mottles	Yellow kandosol
18	N 6076128 E 0702520	7.2	16.3	Upper hill slope (7-15% rocky-vertically bedded)	0-10 cm brown sandy loam gradual to: 10—50 cm pale sandy loam Excavator refusal at 50 cm due to solid rock	Rudosol

Table 6.2(cont) Field description of soil sites

Site ref.	Location	EM38	EM 31	Site description/remarks	Soil description	Likely soil classification
19	N 6076708 E0703606	12	14.3	Lower hill slope (rocky) Note quarried dark volcanic material just to the east of here	0-5 cm brown fine sandy loam topsoil sharp to 5-25 c bleached fine sandy loam A2 diffuse to: 25- Yellow mottled fine sandy clay loam becoming yellower with depth and rockier. Excavator refusal at 80cm	Tenosol
20	N 6077626 E 0703077	27.8	31	Lower hill slope near road	0-5 cm brown fine sandy loam sharp to: 5-30 cm Bleached A2 (fine sandy loam –gradual to 30-50 c (A3/B1) mottled orange and white silty loam gradual to B2 mottled yellow orange fine sandy loam with manganese charcoal at depth (old swamp?)	Yellow chromosol
21	N 6077625 E 0703665	14.5	19	Mid hill slope near AE3 (No surface rock outcrop)	0-10 cm grey brown fine sandy loam gradual to 10-40 cm bleached A2 (fine sandy clay loam) clear to 40-60 cm Mottled white orange sandy clay gradual to 60-100 cm Red yellow mottled clay and regolith	Yellow chromosol
22	N 6078177 E0702862	25.9	33	Flood plain	0-40 cm Dark grey silty clay gradual to: 40-100 cm r yellow/dark grey mottled sandy clay)	Tenosol

6.7 SOIL TESTING AND ANALYSIS

Soil samples from soils where EM31 values were greater than 50 mS/cm were sent to the Department of Lands Soil Testing Laboratory at Scone for testing and analysis of soil properties related to the sustainability of recycled water reuse. Summaries of the results are shown in Table 6.3

Table 6.3 Soil laboratory results (Source Dept of Lands Soil Testing Laboratory Scone)

Site #	Depth (cm)	pH	ECse (dS/m)	CEC (me/100g)	%Na	P sorb mg/kg	EAT	Texture
11	0-20	5.0	0.4	7.4	1.3	168	8/3(1)	Light sandy clay loam
	20-40	7.0	0.2	25.6	3.1	497	3(2)	Medium clay
	40-100	7.7	0.4	34.3	3.8	793	3(1)	Heavy clay
16	0-20	5.3	0.3	9.2	4.3	243	3(1)	Sandy clay loam
	20-40	5.9	0.1	8.5	4.7	233	3(2)	Clay loam
	40-100	6.0	0.2	23.9	6.7	680	5	Medium clay
22	0-20	7.8	0.6	24.7	2.0	198	8/3(1)	Silty loam
	20-40	8.5	0.7	31.1	4.8	487	7/5	Medium clay
	40-100	8.3	3.4	22.2	6.3	453	4	Sandy clay

The soils tested are not saline or sodic. They generally have high cation exchange capacities in the subsoil which indicates good water and nutrient holding capacity. These soils would also be an effective barrier to any potential contaminants accessing any sensitive groundwater table. The soils are typically acid at the surface and neutral at depth. However Site 22 found in a low lying area is alkaline. This soil is slightly saline at depth but the salinity appears to be caused by calcium and magnesium salts, not sodium salts. (See Appendix 2).

6.8 SUITABILITY OF SOILS LANDSCAPES FOR IRRIGATION WITH RECYCLED WATER

The suitability of soils for irrigation can be determined using Tables 2.1 and 2.2 of DEC 2004 (see Appendix 4). It should be noted that these tables were originally developed for agricultural irrigation and hence some of the criteria may not be appropriate for home gardens

A topographic suitability analysis as described in Table shows there are no significant topographical limitations to irrigation within the proposed housing developments.

Table 6.4 Topographic suitability assessments for recycled water irrigation (after DEC 2004)

Feature	Details of this scheme	Limitation rating	Recommended management response
Slope gradient (%)	<10% Areas where slopes exceed 10% have generally been excluded from proposed housing development and irrigated open space areas	Slight (for spray irrigation)	n/a
Flooding	Areas affected by flooding have been excluded from the proposed housing development. However they may be included in proposed irrigated landscape areas.	Slight	n/a
Landform element	Hill slopes and ridges. Home sites and some active playing fields will be modified to make them more suitable for irrigation.	Slight	n/a
Surface rock outcrop	Significant in some locations, however surface rock outcrop need not necessarily be a concern for irrigated home gardens or passive recreational areas. Rocks will be removed or covered in playing fields.	Moderate	n/a

Willana and Associates (2007) recommended that areas with a slope of greater than 20% should be excluded from development. Development on slopes greater than 15% should be suitably designed to ensure slope stability and avoid long-term erosion impacts.

Table 6.5 Soil suitability assessments for recycled water irrigation (after DEC 2004)

Soil characteristic	Typical Soil Result	Limitation rating	Comment/management response
pH Topsoil	5.0-7.8	slight	Many native plants prefer an acid environment. Garden soils will probably be top dressed and fertilised to meet plant requirements
ESP (%) 0-40 cm	<5	slight	Recycled water may increase sodicity. Applications of gypsum and lime may be advised in some situations.
ESP (%) 40-100 cm	<10	slight	No special management practices required
Elec. Cond (EcE) dS/m 0-20cm	<1	slight	Recycled water likely to increase soil salinity
Elec. Cond. (EcE) dS/m (20-100 mm)	<4	slight	Recycled water likely to increase soil salinity
Cation exchange capacity (0-40 cm)	<12	Slight to moderate	Organic matter will increase cation exchange capacity as will lime additions.
Depth to seasonal water table	>3 m on hill slopes and crests. May rise to within 1 metre in low lying areas	Slight	Low lying areas unlikely to be irrigated
Depth to hardpan or bedrock	50 cm to >1 metre	Slight to moderate	Areas with shallow soils likely to be ameliorated by adding extra topsoil
Hydraulic Cond. Surface	80 mm/hr	slight	Assumes gardens playing fields and landscaped areas will be topsoiled with suitable material and therefore no special management response required.
Hydraulic Cond. Subsoil	<5 mm/hr	moderate	Care must be taken not to over-irrigate areas with poor drainage

Table 6.5 (cont) Soil suitability assessments for recycled water irrigation (after DEC 2004)

Available water holding capacity mm/mm)	100	slight	Available water holding capacity will be examined in detail to dtremine appropriate scheduling rates as part of any irrigation design.
EAT(0-100cm)	3(1)	slight	No special management response required
P sorption	good		No special management response required

1. Results estimated from field appearance and an interpretation of other laboratory results.

The analysis of the suitability of the soil landscape for irrigation as shown in the above tables suggests that there are no significant limitations to recycled water irrigation.

6.9 SUITABILITY OF SOILS FOR UNDERGROUND INFRASTRUCTURE

The soil survey has highlighted that some soils are relatively shallow and trenching may involve rock excavation in some locations. The survey has also shown that the soils are not sodic. Sodic soils may become unstable after trenching and subsequent replacement of soils. This in turn leads to the development of subsurface piping ultimately leading to the development of gully erosion.

Careful soil excavation and replacement is good management for installing subsurface infrastructure. However the soil types within the project area are suitable for trenching without the need for special management.

The EM31 survey results are very low. This suggests that the soils in general have a high resistivity. This may need to be taken into consideration in the design of any electrical infrastructure or infrastructure that is affected by lightning strikes.

7 SURFACE AND GROUND WATERS

7.1 BUFFERS ALREADY INCORPORATED INTO PROJECT DESIGN

Willana and Associates (2007) identified that the study area adjoins large areas of environmentally sensitive land zoned Environmental Protection or forming part of the Googong Dam and Foreshores. Their key recommendations were:

- Future land use should incorporate suitable buffers and development intensities to avoid long-term impacts on the adjoining sensitive areas.
- An area of 39.9 hectares in the south-west of the study area drains directly to Googong Dam. This area is unsuitable for development and has been excluded from any urban or active recreation uses (see Map 1). The Johnstone Centre Environmental Consulting group (2004) recommended the inclusion of a 20 metre buffer zone along the edge of the dam catchment to avoid having development occurring on the cusp of the catchment boundary.
- Major drainage lines and creeks should generally be integrated with the open space and park network to preserve natural drainage over the study area. These will also act as buffers. Agsol recommends that landscaped or natural buffers surrounding defined creek lines should be at least 50 metres.

7.2 SURFACE WATERS

7.2.1 DECCW GUIDELINES RELATING TO SURFACE WATERS

The quality of streams and rivers in the catchment of an effluent (recycled water) irrigation scheme must not be downgraded. There is a risk that surface waters may be degraded by poorly designed or managed effluent irrigation schemes, particularly where effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated. Runoff events into streams are a common cause of fish kills. Fish are particularly sensitive to oxygen depletion, ammonia, nitrate, nitrite, sulphur dioxide and organochlorine pesticides.

Potential impacts on current and future downstream water users and resources need to be considered, e.g. downstream aquaculture and fishery industries.

DECCW advise that these risks can be minimised by ensuring that:

- Irrigation of moderate to high strength effluents in close proximity to surface waters is well designed and managed. In this case the recycled water is classified as 'low strength' further reducing this potential risk.
- The plant/soil mantle within and down-gradient of the effluent irrigation area is capable of immobilising any potential contaminants in the effluent.
- There is an adequate buffer zone between the irrigation area and the surface water body (Section 7.3).

- Runoff control structures within the irrigation area are adequate. In this scheme all runoff will be controlled through a designed stormwater system.

DECCW further advise that on sites with identified risks to surface waters, baseline surface water chemistry may need to be established. Regular surface water monitoring is required for effluent irrigation systems that operate in a location where they pose a threat to surface waters.

7.2.2 SURFACE WATER FEATURES WITHIN THE GOOGONG STUDY AREA

The Googong Study Area is traversed by a number of small ephemeral and semi-permanent creeks, farm dams and depressions. The majority of land within the project area drains to the river below the Googong Dam wall.

Jerrabomberra Creek flows through the western portion of the study area. Approximately 287 ha of land within the study area's western portion drain to Jerrabomberra Creek upstream of Jerrabomberra Lake and the existing residential areas of Jerrabomberra Park. From Jerrabomberra Park, Jerrabomberra Creek flows into the ACT at Hume and eventually to Lake Burley Griffin. The sections of Jerrabomberra Creek located immediately downstream of the Googong Study Area adjoin or flow through potential future urban land

7.3 FLOOD HAZARD AND DRAINAGE

The study area is generally free of potential flood hazard. Localised flooding related to increased volume of flows within Jerrabomberra Creek and the Queanbeyan River may occur within the low-lying western and north-eastern margins of the study area. These areas are inaccessible and will not be directly impacted upon by urban development.

Large portions of the study area display gradients of less than 2%. These areas are likely to experience localised drainage constraints (and would be sites where salt may accumulate) and appropriate solutions will need to be incorporated into any future development. Control of storm water discharge from the study area has been developed to avoid any downstream flood impacts for land adjoining Jerrabomberra Creek and the Queanbeyan River.

7.4 GROUNDWATER

7.4.1 DECCW GUIDELINES RELATING TO GROUND WATERS

The quality of the underlying groundwater must not be downgraded to the extent that the resource is not able to support its most sensitive beneficial use. There is a risk that underlying groundwater may be downgraded as a result of irrigation with effluent. These risks are greatest when effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated and/or where the groundwater has a current or potential beneficial use (e.g. used for drinking water or flows to a groundwater dependent ecosystem).

These risks can be minimised by:

- Avoiding areas where the groundwater has a current or potential beneficial use, is close to the soil surface or where there is evidence of dryland salinity
- Ensuring that the plant/soil mantle above the groundwater table is capable of immobilising any potential contaminants in the effluent.

Environmental impact assessment for groundwaters should be based on the principles set out in the National Water Quality Management Strategy: Guidelines for Groundwater Protection in Australia (ARMCANZ & ANZECC 1995) and the NSW State Groundwater Policy (1998).

The Department of Infrastructure, Planning and Natural Resources (DIPNR) (now part of DECCW) have published groundwater availability/vulnerability maps that highlight areas that are at risk due to effluent irrigation. Groundwater investigations should take into account current groundwater chemistry and condition and the quality and quantity of the effluent to be irrigated; for example, the quality of the irrigation water should not exacerbate rising salinity in the water table.

Where supporting technical advice has not been obtained, effluent should not be applied to land where the depth to groundwater table is considered to be less than 10 metres or where the irrigation area is located less than 1000 metres from a town water supply bore.

In areas subject to existing or potential problems, such as rising groundwater tables or dry land salinity, (or where groundwater is a direct conduit discharging to surface waters), appropriate measures must be taken to ensure that the effluent irrigation system does not exacerbate these problems.

The following are appropriate ways to protect groundwater from impacts of effluent irrigation.

- Careful selection of suitable sites for irrigation.
- Implementation of a well-structured management plan that includes,
- details of deficit irrigation scheduling,
- monitoring soil moisture content and strategies to suspend irrigation when soil moisture content is high,
- Selection of areas where the presence of one or more impervious geological strata (for example, a thick layer of compacted clay) above the groundwater aquifer can prevent deep percolation from reaching the aquifer.

In the absence of protective geological strata, an adequate depth to the normal water table at or near the irrigation site will usually be needed for groundwater with current or potential beneficial uses. On some moderately permeable soils, a minimum depth of 15 metres may be required.

On sites with identified risks to groundwater, baseline groundwater chemistry should be established as a basis for assessing the extent of potential impacts and to develop a monitoring program, if required. Regular groundwater monitoring is required for effluent irrigation systems that operate in a location where they pose a threat to groundwater.

Water quality objectives for the groundwater (i.e. water quality needed to protect beneficial uses of groundwater) also should be considered.

7.4.2 GROUNDWATER FEATURES WITHIN THE GOOGONG STUDY AREA

Groundwater conditions have been investigated by C.M Jewell and Associates in 2004 and revised in 2009 and 2010. Agsol has reviewed these documents to determine whether recycled water irrigation poses risks to these resources.

Rocks within the area have undergone significant folding and faulting. The predominant structural trend is oriented approximately north-east south west. Other fracture trends include diagenetic (cooling of volcanic joints), orogenic, epiorogenic and weathering phase each of which may enhance or reduce the rock's permeability.

Characteristics of existing bores are shown in Table 7.1.

Table 7.1 Details of bores near the proposed development area (Source NSW Groundwater data base)

Bore Number	Location with regard to development	Northing	Easting	SWL	Yield (L/sec)	Salinity	Use
GW047361	> 1 km to north	6080249	702141	* (hole depth 6 metres)	*	Unknown	Industrial
GW050004	> 1km to north	6080576	703126	14.2	0.15	'fresh'	Domestic
GW061449	> 1 km to north	6080576	703126	* (Hole depth 80 metres)	1.26	'hard'	Domestic
GW063668	150 m to the west	607640	700650	4.9	4.54	Unknown	Domestic
GW064429	150 m west	6076750	700875	(Hole depth 45.7 metres)	0.44	Unknown	Domestic

Table 7.1 Details of bores near the proposed development area (Source NSW Groundwater data base)

Bore Number	Location with regard to development	Northing	Easting	SWL	Yield (L/sec)	Salinity	Use
GW400206	150 m to the west	6076580	700820	4.6	0.76	good	Domestic and stock
GW400534	> 1 km to the north	6080175	701990	2	2.25	good	Domestic and stock
GW400651	> 1 km to the west	6077650	699185	18	0.63	good	Domestic
GW400940	500 metres to north	6078950	703700	31	0.22	unknown	Domestic/stock
GW40148	500 metres to west	607757	699611	9	0,19	0.10 mg/l	Stock
GW402109	10 metres west	6076104	700995	11	12.5 l/s	370 mg/l	Domestic and stock
GW402157	20 metres north	6078291	701728	20	0.5	unknown	Domestic and stock
GW402348	>250 metres west	6076645	700319	*hole depth 45 m	0.44	unknown	Domestic/stock
GW402383	>500 m North East	607591	704515	* hole depth 122 m	0.33 l/s	unknown	Test
GW402384	> 500 m nor	6080095	703336	*Hole depth 100 m	0.51 l/s	unknown	Test

There are no existing bores within the proposed development. As shown in Table 7.1 above, water yields reported for all wells surrounding the study area generally range between 0.15L/s and 4.54L/s, (with one exceptional result of 12.5L/s reported for a well located within Fernleigh Park immediately west of Old Cooma Road). This latter well originates from a "large cavity within a volcanic rock" at a depth of 18 metres to 23 metres. The second highest yield is 4.54 L/s.

Generally groundwater is found below 15 metres although there are exceptions to this.

7.4.3 CONCEPTUAL GROUNDWATER MODEL

Jewell (2010) identifies that rainfall recharge of low permeability fractured rock aquifers occurs through areas of open fracturing, either at the surface or through superficial unconsolidated material. In the latter case, there may be a delay between a rainfall event and the entry of water into the aquifer due to storage in the unconsolidated material of the recharge zone.

Groundwater is also hosted within the discontinuities of the Googong Adamellite (and accompanying Devonian stocks and intrusion), and within the alluvial aquifers located along the alignments of locally significant waterways. These are expected to have minimal storage, and not of significance to this assessment.

Shallow groundwater flow direction is expected to be heavily influenced by the local topography, with local and regionally significant peaks and ridges' delineating local groundwater divides. There is a groundwater divide beneath the study area, located somewhat further to the west than of the surface catchment boundary, with groundwater beneath the south-eastern part of the proposed development area flows towards Googong Dam.

7.4.4 GROUNDWATER VULNERABILITY

The majority of the Googong Study Area is located within an area of "moderate" vulnerability characteristic of much of the surrounding region, including the existing urban area of Queanbeyan. The central portion of the site is mapped as "low moderate" vulnerability.

Two areas within the study area are mapped as having a "moderately high" vulnerability. These comprise steep land in the vicinity of Jerrabomberra Creek and land within the south-western corner of the study area immediately east of Old Cooma Road. It is understood that no recycled water irrigation will occur in his area.

7.5 EXPECTED CHANGES TO SURFACE AND GROUNDWATER CONDITIONS AS A RESULT OF THE DEVELOPMENT

7.5.1 SURFACE WATERS

The proposed development has the potential to significantly alter the local surface and groundwater conditions through through levelling, construction and paving. A stormwater system (which also captures any recycled water that is not used) is to be developed with the following key objectives (source Browns Consulting):

- A reduction of one-in three month storm water peak runoff flow to existing levels. Captured flow will be released over 1 to three days
- A reduction of five year ARI and 100-year ARI storm water peak flows to predevelopment levels

- Maintaining the existing hydrogeological regime for stream forming flows with respect to peak and duration.

Strategies for achieving the objectives include (but are not limited to):

- Roof water run-off harvesting and reuse
- Storm water treatment (gross pollutant traps etc)
- 50 ML storm water detention basin
- Maximising the area of infiltration
- Potential for reuse of stored storm water

Browns and Associates have modelled the impact of discharges of recycled water (Table 7.2) into the storm water system using recycled water will a concentration of 650 mg/l and daily discharge patterns from an analysis undertaken by MWH (2010). The analysis showed that the storm water significantly diluted the recycled water in the proposed storm water holding dam shown on Map 1. Recycled water with a TDS of 650 mg/l mixed with storm water when it discharges to Googong Creek produces an average discharge TDS of less than 250 mg/l and therefore likely to be within the ANZECC guideline of 350 uS/cm for 'upper streams'.

The analyses also showed that salt concentrations were highest during the winter months (and more likely to exceed ANZECC guidelines) because this is the most likely time that recycled water would discharge. Using stored storm water for irrigation of landscaping, thereby minimising the likelihood of discharge would reduce this impact.

Table 7.2 Modelled basin outflow salt concentrations (recycled water TDS of 650 ppm)-Source Browns Consulting

Yearly (TDS mg/l)		Seasonal average (TDS mg/l)	
Average	234.1	Summer	155
Maximum	648.3	Autumn	254.6
90^{th} percentile	345.7	Winter	287.1
75^{th} percentile	327.4	Spring	220.7

7.5.2 GROUNDWATER

AWM (2010) identified the change recharge conditions within the irrigated landscape (see Section 8). The analyses found little change from the pre-irrigated state (average 86 mm/yr) compared with the irrigated rate of 96 mm/yr. This was due to the likely increase in the soil infiltration and water holding capacity within garden and irrigated landscape areas. Given that a substantial part of the catchment will now be paved or essentially impervious (estimated to be around 70%-pers. comm. Browns Consulting) the overall recharge within existing sub-catchments is likely to be less (a normal consequence of changing from a rural to an urban landscape). This means that the volume of recharge within the landscape is reduced by more than 60% but the recharges will be much more saline.

Chris Jewell and Associates conclude that the significant decline in the amount of water available for groundwater recharge – both across the site and throughout the local area will lead to the following consequences:

- the drying of perched water tables beneath developed portions of the site;
- the lowering of the water table and the possible drying-up of shallow bores in the area;
- reduced groundwater discharge to each of the ephemeral waterways in the north and east of the site; migration of the groundwater divide in the south-eastern corner of the site to the west; and
- a likely increase in the total dissolved solids content of the groundwater

7.5.3 RECOMMENDATIONS

Jewell (2010) recommends that salt levels in the waterways be regularly monitored during and after the development of Neighbourhood 1A. Groundwater samples should be collected from both the shallow and regional aquifers, and soil conductivity (i.e. EM survey) mapping carried in areas of inferred impact.

8 WATER BALANCE

The modelling analyses described here form part of a wider investigation into total water cycle management of the proposed development. MWH and Browns Consulting have been retained by CIC for the total water cycle management issues. The investigations undertaken by AWM (Appendix 4) on behalf of Agsol address the impact of recycled water use on soil salinity and groundwater. Water budgets are constructed to enable these impacts to be quantified where possible.

MWH and Browns Consulting have separately investigated:

- The existing quantities/quality of water in the Queanbeyan River;
- The water quality/quantity impacts of discharges from the Googong development.

8.1 SUITABLE STORMWATER MANAGEMENT.

The proposed Googong residential community is designed to maximise the use of recycled water and rainwater. For human health reasons, potable water will be used for all internal household uses other than toilet flushing and laundry. However, for these uses it is recognised that potable water supply will also be needed to top up recycled water supply during periods of peak water demand. In turn 'peak demand' can be impacted by government imposed water restrictions or water pricing policies.

Potable water, recycled water and rainwater differ in their concentrations of salts, nitrogen and phosphorus content. These differences arise from variations in the untreated effluent arriving at the WRP as well as through sewage treatment processes such as aeration to remove nitrogen and additions of salts to remove phosphorus.

Consequently, the investigations and analyses described below are complex as they need to take into account the mix of water sources and the recycling that occurs through the sewage treatment process.

The analyses described in Sections 8 and 9 were repeated for two stages of development:

- NH1A.
- Ultimate development.

8.2 LOCAL ENVIRONMENT

Local monthly rainfall and evapotranspiration are summarised in Table 8.1 and were based on daily records from the Bureau of Meteorology. Rainfall records were taken at the Queanbeyan Bowling Club (station no. 070072) and pan evaporation at Canberra Airport (station no. 070014). The climate data set covered 41 years from 1967 to 2007.

Pan evaporation was converted to potential rates of evapotranspiration from the irrigated plants by multiplying by appropriate pan and crop coefficients.

Table 8.1 Mean monthly rainfall and potential evapotranspiration from the three types of vegetation (Source AWM 2009).

Month	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Rain (mm/mth)	56	58	48	45	38	40	40	48	52	58	66	49	598
Evapotranspiration gardens (mm/mth)	167	134	113	72	42	23	22	34	60	106	128	165	1065
Evapotranspiration playing fields (mm/mth)	163	130	110	70	38	21	20	31	55	103	125	161	1027
Evapotranspiration landscaping (mm/mth)	173	139	117	74	43	24	25	38	66	110	133	171	1112

The annual rainfall distribution varied as follows:

Driest	1/10-dry	Median	1/10-wet	Wettest
260mm	414mm	618mm	758mm	976mm

Points of note are:

- The area receives a low rainfall that averages 598 mm/yr;
- The balance between the mean monthly rainfall and evapotranspiration was:
  - Gardens and landscaped areas: rainfall deficit from September to May;
  - Playing fields: Rainfall deficit from September to April.

The rainfall/evapotranspiration balance indicates those months when irrigation will be most needed, but the daily variation in rainfall can also create an irrigation demand in any month.

8.3 THE PROPOSED REUSE SYSTEM

The recycling plant will produce a continuous supply of recycled water and as much as possible will be reused for specified internal household use and for irrigation. Household rainwater in tanks will be used to provide an additional source of water for household use and irrigation. Potable water will be used to make up any shortfall in the water supply.

The following figure (8.1) provides a general flow chart for the scheme and processes at relevant reference points.

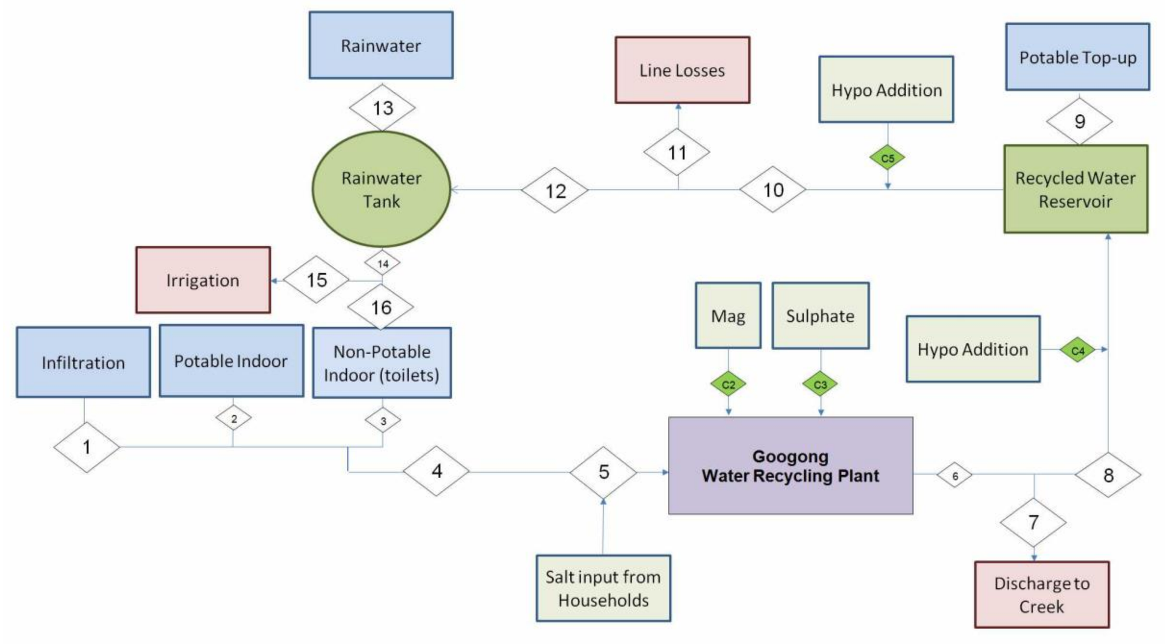


Figure 8.1 Flow chart of showing the processes applied to water supplies between the water recycling plant, households, and irrigation sites.

The critical points in Figure 8.1 are described below.

SEWAGE FLOW (POINT 4)

Sewage is reticulated to the WRP, which according to MWH (2009) will have an average dry weather flow rate of:

- 0.628 ML/d in the NH1A stage of development
- 2.988 ML/d in the ultimate stage.

WET WEATHER INFILTRATION (POINT 1)

During and immediately following wet weather, water will infiltrate from soil into the sewerage pipes. The Anderson-Ruge algorithm (Anderson and Ruge 1994) was used to estimate the amount for a reticulation system with a low level of leakiness. The wet weather effect increased the annual flow by an average of 3%.

SALT INPUT (POINT 5)

Household use added a quantity of salt to the sewage, and because a proportion of the total water supply was cycled through households more than once, there will be a gradual accumulation of salt in recycled water. The mean equilibrium total dissolved salt (TDS) concentration in recycled water, after taking the accumulation effect into account, was 660 mg/L (pers comm. MWH 2010).

RECYCLED WATER RESERVOIR (POINT 8)

Recycled water is piped to the recycled water reservoir, which is used to buffer diurnal differences between the supply and demand for recycled water, but not to provide a between-day buffer.

A detailed study (MWH 2008) estimated the "design peak day recycled water demands" during different stages of development. These set the minimum volume of recycled water that must be held in the distribution storage each day. In order to avoid any deterioration in the quality of the recycled water during storage, any surplus above the daily demand needs to be discharged. The consequence of this is that even a small disruption to irrigation demand due to light rain will give an immediate and substantial increase in the quantity of surplus recycled water to be discharged. However it was recognised that buffering within the distribution system was available and this was estimated in the water budget described below to be twice the average dry weather flow.

DISCHARGES TO CREEK (POINT 7)

Recycled water that was not required for immediate use was discharged to the storm water system (Map 1).

POTABLE TOP-UPS (POINT 9)

When the daily demand for tank and recycled water exceeded the supply, potable water made up the shortfall. It was introduced to the system at the recycled water reservoir. Potable water has an estimated average TDS concentration of 100 mg/L (source MWH 2010).

LINE LOSSES (POINT 11)

A 10% loss rate was applied during reticulation of recycled and potable water (source MWH 2009).

RAINWATER COLLECTION AND STORAGE (POINT 13)

Inflows to the rainwater tanks were calculated from the daily rainfall records, less the first millimetre of daily rainfall. Total roof catchment areas and tank capacities were estimated for each household type by MWH. The sum of the entire development was:

- 18ha catchment and 5.5ML tank capacity (NH1A)
- 85ha catchment and 30ML capacity (Ultimate).
- Based on the distance from the coast, the estimate TDS concentration in rainwater was 13 mg/L (AWM 2009).

INTERNAL USE (POINT 16)

When available, rainwater was used in laundries, with recycled water as the default supply. The sums of these were:

- 0.037 ML/d (NH1A); 0.197 ML/d (Ultimate).

Recycled water was also used for other internal uses including toilet flushing at rates of:

- 0.183 ML/d (NH1A); 0.983 ML/d (Ultimate).

Internal leakage (pers comm.– MWH 2009) of recycled water accounted for:

- 0.022255 ML/d (NH1A); 0.104785 ML/d (Ultimate).

When the tanks were drawn down to 5% of capacity, a switching mechanism caused recycled water to replace tank water for laundry and garden use. This replacement continued until subsequent rain caused the tanks to fill to more than 10%.

IRRIGATION (POINT 15)

The water use and salt loading were calculated for four general types of irrigation sites. The general characteristics of these sites are summarised in Table 8.2, and their total areas are given in Table 8.3.

Table 8.2 Characteristics of the four general types of irrigation sites.

Type	Vegetation	Exposure	Advected energy [a]	Irrigation system	Level of watering [b]
Household gardens	Turf/shrubs	Protected	Mod.-high	Sprinkler	Moderate
Playing fields	Turf	Open	Nil	Sprinkler	Well-watered
Parks & open spaces	Turf (65%) / shrubs (35%) + some trees	Open	Nil	Sprinkler	Restricted
Streetscapes	Turf (65%) / shrubs (35%) + some trees	Open	High	Subsurface	Restricted

a. Advected energy refers to the additional flux from immediate surrounds.
b. Level of watering:
   - Moderate. Irrigation scheduling restricted applications so some stress developed in plants but not to the extent that caused their death
   - Well-watered. Irrigation scheduled so as to avoid any plant stress

Table 8.3 Irrigated areas in the two stages of development.

Type	Irrigated area (ha)	
	NH1A	Ultimate
Household gardens	11.2	58.9
Playing fields	8.8	31.8
Parks & open spaces	5.8	18.0
Streetscapes	1.4	6.6

Three classes of water were used for irrigation:

- Rainwater from tanks was used as the first preference to water household gardens. It was not available to water landscaping features.
- Recycled water was used to irrigate all areas.
- Potable water was used to make up any demand shortfall when other supplies were exhausted for all areas.

The degree of irrigation was also varied between types according to their needs from the aesthetic and wear point of view. The effects of the water-use characteristics of the different vegetation types and their exposure were assessed separately and the irrigation volumes represent the sum of these mixed effects.

- Household gardens: Medium level of watering.
- Playing fields: Well-watered to address the high level of wear.
- Landscaping (parks, open spaces & streetscapes): Restricted level that was sufficient to maintain aesthetics without using liberal amounts of water.

The model included a set of water stress factors which varied according to the level of watering (see Table 8.2 note b).

Losses associated with the irrigation equipment were accounted for within the irrigation efficiency factors. These were set at 85% for sprinkler systems and 95% for subsurface irrigation.

NON-IRRIGATION EXTERNAL USES

Other external use covered miscellaneous factors including use of a non potable garden hose for washing (50%) and external leakage (50%). This leakage allowance was separate to line losses (Point 11). The allowance was 0.017612 ML/d (NH1A) and 0.091439 ML/d (Ultimate).

This usage was applied to tank-water when supplies permitted, otherwise recycled water was used.

8.4 WATER BALANCE ANALYSES

The calculations were based on the H2OB daily water balance model. The model estimated daily changes in the soil moisture content from the day to day changes in rainfall and evapotranspiration, and irrigation was scheduled according to a deficit irrigation strategy that ensured no more water was applied than the soil could absorb. An outline of the H2OB model is described in Appendix 3 of AWM 2009.

The irrigation volumes were largely determined by the interaction of:

- The evaporative demand and its seasonal trend from low in winter to high in summer;
- The rainfall pattern and the extent to which it satisfied the evaporative demand. The variation in rainfall between years gave rise to the differences in irrigation volumes between dry and wet years. Not all the rain was effective because some was lost through runoff and deep percolation;
- The water-use characteristics of the vegetation;
- The irrigation efficiency. The irrigation volumes are gross values that include the net volume that reaches plants plus irrigation losses.

Separate analyses were calculated for each stage of development NH1A and Ultimate

8.5 RESULTS – NH1A STAGE

The mean water balances for the three classes of water are given in Table 8.4, and for the three types of irrigation areas in Table 8.5.

Table 8.4. The mean water-supply balance for the three classes of water, with rainwater tanks in the NH1A stage (source AWM 2009).

Component	Rainwater	Recycled water	Potable water
	Rate (ML/yr)		
Inflow	95	237	57
Outflow			
Irrigation (gross)	24	57	52
Toilet	0	67	0
Laundry	11	3	0
Miscellaneous	2	1	0
Leakage (all allowances)	3	31	5
Discharge	55	78	0
Total outflow	95	237	57

The mean potential rainwater harvest was 95 ML/yr but 55 ML/yr was lost through overtopping from the rainwater tanks. About 33% of the collected rainwater was used in laundries or for miscellaneous use, and the remainder was used for garden watering or was lost through leakage.

Of the mean annual flow of recycled water, 24% was used for irrigation and 30% for internal household use. Potable water top-ups accounted for 39% of the total water use for irrigation.

Table 8.4 The mean irrigation water-balance for the three types of irrigation areas with rainwater tanks in the NH1A stage.

Component	Gardens	Playing fields	Landscaping
	Rate (ML/yr)		
Supplied for irrigation			
Rainwater	24	0	0
Recycled water	10	30	17
Potable water	18	20	14
Total	52	50	31
Used			
Irrigation (net)	44	43	27
Irrigation losses	8	7	4
Total irrigation	52	50	31

On average, the garden watering used 46% rainwater, 19% recycled water and 35% potable water. On the other areas, more recycled water than potable water was used for irrigation. These relative proportions determined the average salt content of the irrigation water and hence the extent of salt accumulation in the soil (see Section 9).

The irrigation volumes in Table 8.5 are annual means, but the volume varied considerably between years depending on the degree of dryness (Table 8.6). The proportion of each class of water also varied.

Table 8.6 The irrigation volumes in years of varying dryness (source AWM 2009)

Site	Irrigation volume (ML/yr)		
	1/10-dry	Median	1/10-wet
Gardens	73	54	33
Playing fields	67	51	34
Landscaping	44	31	18
Total	184	136	85

Less rainwater was collected from houses in dry years (64 ML/yr in the 1/10-dry year increasing to 122 ML/yr in the 1/10-wet year). The higher level of irrigation on gardens in dry years largely came from an increased use of recycled and potable water.

In addition, there were large differences in the irrigation volumes between months. This is illustrated in Figure 8.2 where the values are means for each month of the year.

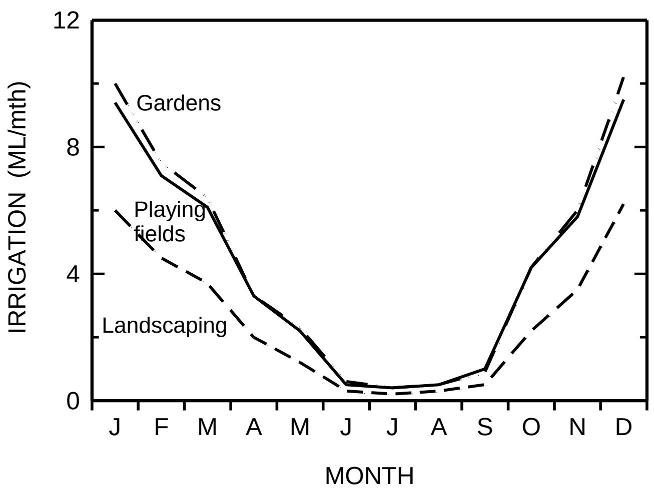


Figure 8.1 The mean monthly irrigation volume on the three irrigation areas in the NH1A stage.

As expected, most irrigation was used during the warmer months. Although the gardens occupied a larger area than the playing fields, their irrigation volumes were very similar because the playing fields were well watered whereas the gardens received a moderate level of watering (Table 8.6).

8.6 RESULTS – ULTIMATE STAGE

As shown in the following tables, the mean potential rainwater harvest was 449 ML/yr but 242 ML/yr (54%) was lost through overtopping from the rainwater tanks. About 35% of the harvested rainwater was used in laundries or for miscellaneous uses, and the remainder was used for garden watering or was lost through leakage.

Of the mean annual flow of recycled water, 21% was used for irrigation and 33% for household use. Potable water top-ups provided 37% of the total water use for irrigation.

Table 8.7 The mean water-supply balance for the three classes of water for the ultimate stage, with rainwater tanks in the ultimate stage (Source AWM 2009).

Component	Rainwater	Recycled water	Potable water
	Rate (ML/yr)		
Inflow	449	1126	226
Outflow			
Irrigation (gross)	122	234	205
Toilet	0	359	0
Laundry	58	14	0
Miscellaneous	14	3	0
Leakage (all allowances)	13	154	21
Discharge	242	362	0
Total outflow	449	1126	226

Table 8.8 The mean irrigation water-balance for the three types of irrigation areas with rainwater tanks in the ultimate stage (Source AWM 2009).

Component	Gardens	Playing fields	Landscaping
	Rate (ML/yr)		
Supplied for irrigation			
Rainwater	122	0	0
Recycled water	54	117	63
Potable water	99	64	42
Total	275	181	105
Used			
Irrigation (net)	234	154	92
Irrigation losses	41	27	13
Total irrigation	275	181	105

On average, the garden watering used 44% rainwater, 20% recycled water and 36% potable water. On the other areas, more recycled water than potable water was used for irrigation.

As in the NH1A stage, the irrigation volume varied considerably between years depending on the degree of dryness (Table 8.9).

Table 8.9 The irrigation volumes in years of varying dryness (Source AWM 2009).

Site	Irrigation volume (ML/yr)		
	1/10-dry	Median	1/10-wet
Gardens	382	284	176
Playing fields	242	183	122
Landscaping	151	107	63

In the 1/10 dry year the irrigation volume increased by about one third relative to the median volume, and it decreased by about the same proportion in the 1/10 wet year.

le water was used on the other sites.

8.7 REUSE AND DISCHARGES

The level of reuse and discharge of recycled water are presented in Table 8.10 for dry, median and wet years for the ultimate scheme.

Table 8.20 The percent reuse and discharge volume of recycled water in years of varying dryness, in the ultimate stage (Source AWM 2009).

Scenario	Reuse (%)			Discharge (ML/yr)		
	1/10-dry	Median	1/10-wet	1/10-dry	Median	1/10-wet
1	79	68	60	230	362	457

The levels of reuse were very similar in the NH1A and ultimate stages of development.

9 POTENTIAL IMPACTS OF SALT IN IRRIGATION WATER

9.1 EXISTING SALINITY

Dry land salinity hazard areas have been mapped by the NSW Department of Planning. The portions of the Googong study area known to be subject to dry land salinity hazard are restricted to low lying areas at the margins of the study area in the vicinity of Jerrabomberra Creek and Queanbeyan River. These areas are inaccessible and will not be directly impacted upon by any future urban development. No surface evidence of salinity has been identified elsewhere within the study area.

9.2 SALT IN IRRIGATION WATER SUPPLIES

Irrigation with recycled or potable water will apply salt to the soil. The varying amounts that will be retained will vary with the applied volumes and hence application amounts, and also with the rate of removal which is affected by the amount of percolation through the plant root zone. Salt budgets were used to examine these issues for the different mixes of rain, recycled and potable water.

Two factors must be addressed when considering the possible consequences of salt in irrigation water on plant growth. The first is the scorching effect of salty water on plant leaves, and secondly the potential to increase soil salinity as determined by the salt budgets.

9.2.1 SALINITY OF IRRIGATION WATER

The TDS concentrations in the irrigation water varied with the proportion of each class of water that was used on the various sites, and the TDS concentrations in the raw supplies. The latter were set as follows:

- Rainwater TDS 13 mg/L, EC 0.02 dS/m;
- Recycled water TDS 660 mg/L, EC 1.03 dS/m;
- Potable water TDS 100 mg/L, EC 0.16 dS/m.

Water balance analyses were used to estimate the irrigation volumes on the various sites within the scheme, and the proportions of the three sources of water that were used to make up the irrigation volumes. The results were provided in detail in a report dated November 2009. The relative proportions for the two stages of development for systems with rainwater tanks are detailed in Table 9.1, and the mean salinities in Table 9.2. The salinity of water used on the landscaped areas differed slightly between the parks-open spaces and the streetscapes because of differences in their irrigation volumes.

Table 9.3 The relative proportions of rainwater, recycled water and potable water that were used for irrigation on three irrigation sites.

Stage	Water class	Relative proportion (%)		
		Gardens	Playing fields	Landscaping
NH1A	Rainwater	46	0	0
	Recycled water	19	60	55
	Potable water	35	40	45
Ultimate	Rainwater	44	0	0
	Recycled water	20	65	60
	Potable water	36	35	40

Table 9.4 The mean salinity of irrigation water on four irrigation sites.

Stage		Salinity (dS/m)		
	Gardens	Playing fields	Parks & open spaces	Streetscapes
NH1A	0.26	0.69	0.62	0.65
Ultimate	0.26	0.71	0.65	0.67

The average salinity of the water used on the residential gardens was considerably less than on other areas because of the partial use of rainwater collected in tanks on the gardens.

9.3 SALT AND FOLIAR INJURY

Salty water can damage foliage and since the effect depends on the salinity of water used on each day it represents a day to day risk that can be assessed through the EC of the irrigation water that is used on that day. Hence the separate salinity of each source of water is important in this context.

Highly salt sensitive species

A West Australian Farmnote (Agric-WA 1999) listed the following species as being highly sensitive to salt with their tolerance to salty water being limited to the 0-0.9 dS/m EC range, and recommended that irrigation water should not wet the leaves of these species on hot dry days:

- Fruit: Almond, apples, avocado, citrus fruit, loquot, passionfruit, pears, persimmon, raspberry, stone fruit, strawberry;
- Vegetables: Carrot, celery, green beans, onion, parsnip, peas, radish, squash;
- Ornamentals: Azalea, begonia, camellia, fuchsia, gardenia, ivy, magnolia, primula, rose, star jasmine.

While there is no risk that the highly-sensitive species will suffer foliage burn from irrigation with rainwater or potable water, the recycled water (EC = 1.03 dS/m) presents some risk. Precautions that will lessen or eliminate that risk are:

- Subsurface or surface drip irrigation will eliminate the risk because the recycled water will not touch the foliage;
- Avoiding watering during hot, daylight hours will lessen the risk;
- Rinsing the foliage with potable water at the conclusion of watering will considerably lessen the risk.

Mildly salt sensitive species

The second group was mildly sensitive and were tolerant to an EC within the 0.9-2.7 dS/m range.

Mildly-sensitive plants were:

- Fruit: Grape, mulberry;
- Vegetables: Broccoli, cabbage, capsicum, cauliflower, cucumber, lettuce, potatoes, pumpkin, rock melon, sweet corn, tomato, water melon;
- Ornamentals: Aster, banana (*Musa* spp.), bauhina, *Callistemon viminalis*, emu bush (*Podocarpus*), geranium, gladiolus, hibiscus, hop bush (*Dodonea attenuata*), *Juniperus chinensis*, lantana, pointsettia, *Thuja orientalis*, zinnia.

None of the three water sources pose a risk to the mildly sensitive species. By extension, there is no risk of foliar damage to the more tolerant species, and for completeness they are listed below.

Slightly salt sensitive species

The third group was slightly salt-sensitive and had a tolerance within the EC range of 2.7 – 6.35 dS/m.

Slightly salt-sensitive plants were:

- Turf grasses: Buffalo grass, couch grass, kikuyu grass, ryegrass;
- Fruit: Fig, pomegranate, olive;
- Vegetables: Asparagus, garden beets, kale, spinach;;
- Ornamentals: *Acacia longifolia*, Bangalay (*Eucalyptus botryoides*), bamboo, boobyally (*Myoporum acuminatum*), boungainvillea, carnation, chrysanthemum, coprosma, false acacia (*Robinia pseudoacacia*), *Ficus* spp., Kondinin blackbutt (*E. kondininensis*), mesembryanthemum, morrel (*E. oleosa*), native pine (*Actinostrobus pyrimidalis*), New Zealand christmas bush (*Metrosideros tomentosa*), oleander, portulaca, Queensland pyramid tree (*Lagunaria patersonii*), river red gum (*E. camaldulensis*), rosemary, Rottnest syprus (*Callitris robusta*), Rottnest teatree (*Melaleuca cupressiformis*), stock, swamp mallet (*E.* spathulata), swamp yate (*E. occidentalis*), vinca, York gum (*E. loxophleba*).

Salt tolerant species

The fourth group was salt tolerant with a tolerance within the EC range of 6.35 – 23.65 dS/m.

Salt tolerant plants were:

- Turf grasses: saltwater couch (*Paspalum vaginatum*), sand couch (*Sporobolus virginicus*);
- Fruit: Date palm;
- Ornamentals: Canary palm (*Phoenix canariensis*), *Melaleuca thyoides*, saltbushes, salt sheoaks (*Allocasuarina cristata* and *A. glauca*), salt river gum (*E. sargentii*), tamarisks.

The above classification of plants according to their sensitivity to salt in irrigation water also provides a general guide to their sensitivity to soil salinity. However, note that such a classification is based on the EC of the irrigation water, which is an indirect indicator and as such is more general than relating the risk to soil salinity.

9.4 SOIL SALINITY AND PLANT GROWTH

The second effect of salt in irrigation water is the potential for salt to accumulate in the soil, leading to retarded growth and even the death of some plants. Soil salinity is generally in expressed in terms of the electrical conductivity of a soil extract (ECE). Note that whilst the same measure of electrical conductivity is used to quantify both water and soil salinities, the two measures are on different scales and cannot be directly compared. Hence in the following discussion the electrical conductivity of a solution is abbreviated as EC, whereas ECE is used for soil salinity.

In general, critical ECE values are:

- Negligible for the majority of plants when less than 2 dS/m;
- Sensitive plants affected at 2-4 dS/m;
- Many plants affected at 4-8 dS/m;
- Only salt-tolerant plants grow satisfactorily at greater than 8 dS/m.

The Australian Guidelines for Water Recycling (NWQMS 2006) provide detailed lists of the tolerance of a wide range of species to soil salinity. Examples of some highly sensitive and sensitive plants that are affected by soil salinity in the 1-2 dS/m and 2-4 dS/m ranges respectively are listed below. For each group, the effect will be relatively small provided the soil salinity does not exceed 2.0 dS/m and 4.0 dS/m respectively.

Highly sensitive species

- Fruit: Apple, apricot, blackberry, boysenberry, pear, pepper, plum, strawberry;
- Vegetables: Bean, cabbage, carrot, celery, egg plant, lettuce, onion, potato, radish, spinach, sweet potato, turnip,
- Ornamentals: Bear's breeches, begonia, barberry, boxwood, camellia, blue atlas cedar, Pyrenees cotoneaster, broom, dahlia, euonymus, fuchsia, gardenia,

Algerian ivy, privet, lily, Japanese spurge, photinia, blue spruce, primula, Douglas fir, rhododendron, rose, blue willow, linden, violet;

Sensitive species

- Fruit: Almond, grape, grapefruit, lemon, olive, orange, peach;
- Vegetables: Beet, broccoli, cauliflower, cucumber;
- Ornamentals: Glossy abelia, aster, deodar cedar, Kaffir lily, jade plant, blue daisy, Carolina jasmine, geranium, gladiolus, sea lavender, honeysuckle, stock, plum, pepper tree, dwarf running myrtle, zinnia;

Turf grasses

Most turf species are tolerant of soil salinity, and the sensitivity of a number of species is as follows:

- Highly sensitive (ECE <1.5 dS/m): Annual bluegrass, rough bluegrass, colonial bentgrass.
- Moderately sensitive (ECE 1.6-3.0 dS/m): Kentucky bluegrass.
- Moderately tolerant (ECE 3.1-6.0 dS/m): Hard fescue, strong creeping red fescue, creeping bentgrass.
- Tolerant (ECE 6.0-10.0 dS/m): Fairway wheatgrass, tall fescue, perennial ryegrass, slender creeping red fescue.

For purposes of the present study, the risk of soil salinity affecting some plants was quantified by calculating the proportion of years when the soil salinity was expected to exceed thresholds of 2.0 and 3.0 dS/m. The 2.0 dS/m threshold was taken as an indication that highly sensitive species will be affected by soil salinities above this value. Similarly, values above the 3.0 dS/m threshold indicated an effect on sensitive species. The soil salinity must be greater than 4.0 dS/m to affect moderately-tolerant and tolerant species.

9.4.1 EXPECTED CHANGE IN SOIL SALINITY

Because the rainfall particularly affects salt accumulation, separate estimates of soil salinity were calculated for the ten deciles of rainfall at Googong. Results are given as the weighted root-zone salinity expressed as the ECE in a saturated soil extract. Annual estimates of soil salinity were calculated on the assumption that the equilibrium salinity with the prevailing rainfall and salt inputs was reached within a year. Results are given for the NH1A stage of development (Figure 9.1) and the ultimate stage (Figure 9.2).

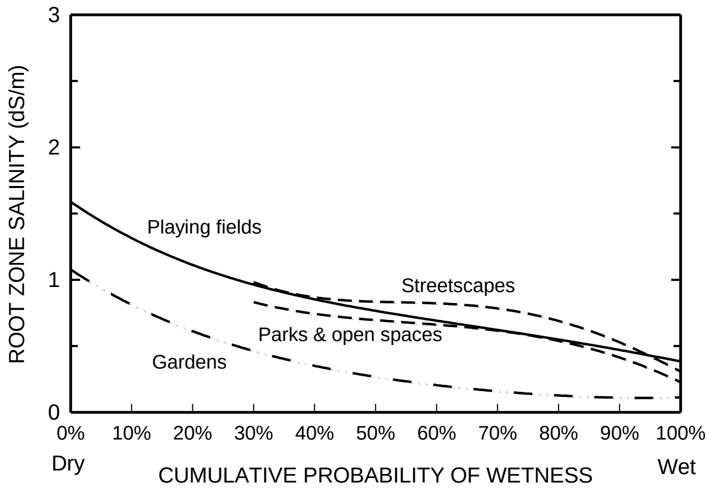


Figure 9.2 The estimated root-zone salinity on the four types of irrigation areas in the NH1A stage.

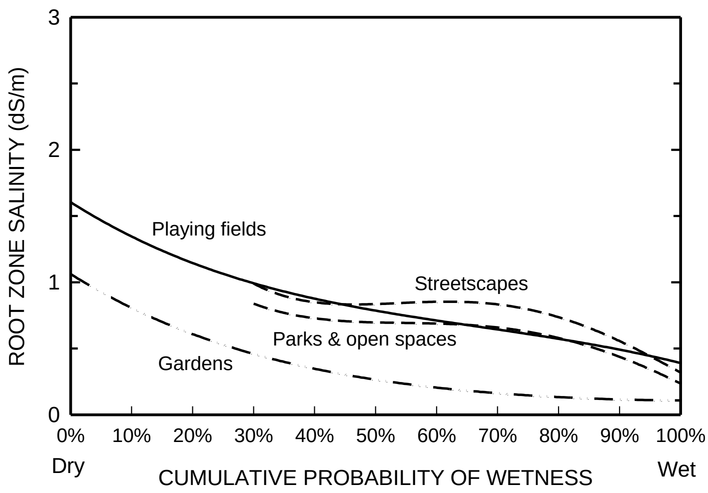


Figure 9.3 The estimated root-zone salinity on the four types of irrigation areas in the ultimate stage.

Salt accumulation was greatest with a low rainfall because there was less percolation of rainwater down the soil profile and hence less leaching of salt beyond the root zone. The other dominant effect on soil salinity was the volume of recycled water that was used for irrigation. Since the recycled water had the highest salt concentration, the volume of recycled water largely determined the salt load.

The soil salinity was least with the household gardens because rainwater contributed a significant proportion of the total water use for irrigation. The higher salinity on the playing fields reflected the greater irrigation rate per hectare which gave a greater salt load.

No estimates of soil salinity were obtained for the driest 30% of years on the two classes of landscaping (as the water budget showed that there was insufficient recycled water available for these activities during these years), but the streetscapes broadly followed the salinity on the playing fields, and the parks and open spaces tended to be a little less in those years with estimates.

Importantly, the estimated soil salinities never exceeded 2 dS/m, and hence there was no risk of soil salinity increasing to a level that would affect most plant growth.

9.5 SALT LOADS

The salt loads to the households, irrigation and discharges varied with the various water mixtures and TDS concentrations, and the mean annual loads are detailed in Table 9.3. The irrigation loads were based on the net irrigation volumes.

Table 9.5 The mean annual salt loads (t/yr) for internal household use, irrigation and in discharges.

Stage	Household - internal	Irrigation	Discharge
NH1A	47	37	52
Ultimate	249	150	239

In both stages, the total salt load was divided approximately as 36% household use, 26% irrigation, and 38% in discharges.

In the ultimate scheme 150 tonnes per year are applied to some 700 ha of land or 0.21 tonnes/ha/yr. In 100 years each hectare of land will have received an average salt load of 21.4 tonnes of salt.

10 IDENTIFICATION AND MITIGATION OF ENVIRONMENTAL IMPACTS

10.1 SOIL

Target: No change or an improvement in soil quality, no additional water logging of soil or increase in average height of water table.

Potential risks: In home gardens, the risks to soil include adverse physical and/or chemical changes, which could lead to a reduction in fertility and the soils' potential to grow turf or garden. The principal risk would be from irrigation leading to extra water logging, a rise in water tables and/or soil salinity increases.

The local area has generally well drained soils and water tables recharge is expected to be less. Hence the only significant impact is expected from increases in soil salinity. These impacts are also expected to be minor.

This low risk can be mitigated by careful selection of plant species and by simple management practices, including minimising leaf wetting especially during hot weather and during daylight.

Education can help users to reduce these small risks.

10.2 LANDSCAPES AND CATCHMENT HYDROLOGY

Target: No change in catchment conditions (including soil erosion risk) as a result of irrigating with recycled water.

Potential risks: There is a risk that irrigation will generate significantly more runoff and/or percolation, leading to a change in catchment hydrology and/or soil erosion.

The risk of physical erosion would be the same as if drinking water had been used instead of recycled water. These erosion risks would normally be addressed by a soil and water management plan during the detailed design of any subdivision.

If the soil were to become more salty as a result of salt accumulating in areas with poor drainage, death of plants could occur increasing the risk of erosion.

Salt applied to irrigation areas leaches below the plant root zone as a result of natural rainfall. This salt is likely to move though the landscape as 'interflow' or subsurface flow. Significant 'vertical' movement to the groundwater table is unlikely as the only pathways are through fractures in the generally impermeable rocks. (Chris Jewell and Associates 2010)

Salt in the interflow will move to the lower lying parts of the land and probably to those areas with the highest current electrical conductivity measured by the Electro-magnetic (EM) survey (Appendix 1).

Unless salt can be discharged, the potentially salt affected areas could increase in size and move upslope leading to salt scalds or saline seepage areas.

Monitoring (using EM survey) of low lying areas where salt is likely to accumulate should be undertaken. If salt levels are shown to be increasing, engineered drainage structures to nearby creek lines may need to be constructed.

As a preventative measure to avoid future bare soil patches and erosion, salt tolerant landscaping should be planted in low lying areas.

Opportunities exist to use the NH1A stage to better understand movement of salt in the landscape. This would involve the installation of carefully located piezometers and monitoring the effectiveness of any pre-emptive measures.

10.3 THE BUILT ENVIRONMENT

There is potential for salt to accumulate in the landscape by poor construction techniques and possibly through lateral flow of groundwater but it would take many years before the impacts that are specific to recycled water use could be measured. Hence preventative measures are required to ensure that salt does not accumulate upslope of built infrastructure ultimately leading to degradation of that infrastructure. Preventative measures would follow the principle that any accumulated salt is able drain during natural rainfall events to a safe outlet.

Any construction has the potential to alter the subsurface drainage. For example, on a residential building site, the house plus paving could reduce the permeable area (garden) by up to 80% or even more. This will have the effect of considerably reducing the opportunity for pre-development interflow to move from the hillside to low lying areas. If the soil under the paved areas remains wet, the water moving beyond the plant root zone from the garden will continue to move down the slope at a slower rate. If the soil under the paving dries the interflow will be slowed even more. At the extreme, if interflow stops the added salt will accumulate under the building or paved area. Furthermore, on a duplex soil where interflow is concentrated in the upper soil horizon the salt accumulation will be at a shallow depth. These effects will be most pronounced near crests where run-on interflow will be least.

Salt in soil can have negative impacts on built infrastructure such as bricks, metal pipes, and concrete and road pavements leading to premature decay. It is understood that there is no particular correlation with soil EC level and potential salt impacts on buildings (pers. com Sian McGhie-DECCW). Some of the tests for corrosivity, and the aggressiveness of various parameters on concrete, are described in the German Standard DIN 4030.

10.1 Extract from the German Standard DIN 4030 "Corrosivity Assessment for Concrete"

Parameter	Degree of aggressiveness		
	Low	High	Extremely high
pH	5.5 - 6.5	4.5 - 5.5	< 4.5
Carbonic acid (CO_2) (mg/L)	15 - 40	40 - 100	> 100
Ammonium (mg/L)	15 - 30	40 – 100	> 100
Magnesium (mg/L)	300 - 1000	1000 – 3000	> 3000
Sulphate (mg/L)	200 - 600	600 - 3000	> 3000

Values of ammonium and sulphate anticipated in the recycled water at Googong are expected to be much lower than the numbers shown in Table 10.1. However, it is not a simple matter to relate the above concentrations to the composition of the recycled water because of the many modifying processes between irrigation and accumulation in the soil solution. The modifiers include gaseous losses, plant absorption, soil adsorption and concentrating effects of evapo-transpiration.

SEL's soil tests suggest that there are no significant concerns with regard to magnesium and sulphate. However it would be prudent to undertake soil testing and/or seek advice from concrete manufacturers in areas where concrete is to be laid.

10.3.1 BUILDING CODES AND OTHER GUIDELINES

Because of the risk of salt accumulation in this area, Queanbeyan City Council may require developers to implement salt sensitive storm water management and building techniques. A number of Australian building codes have been developed for construction in saline areas. Whilst the Googong area is not saline the risks associated with applying slightly saline water to the landscape via irrigation, suggested that these codes should be adopted at Googong. The Department of Environment and Climate Change and Water have a number of publications describing these techniques and these are listed in Appendix 4.

10.4 SURFACE AND GROUND WATERS

Target: Surface and ground waters must not degrade as a result of organic, nutrient or chemical loadings applied.

Potential risks: Water, nutrients, salt, organics and chemicals not immobilised by a healthy plant/soil system in urban gardens could leak to the wider environment including surface and groundwater resources.

The amount of nutrients and organic matter for optimum sustainable production of any given land management system will be a function of the crop, tree, pasture or garden grown, the way the garden is managed and site specific factors such as climate, topography and soil and proximity of ground and surface waters. It is unlikely that the expected low concentrations of nitrogen and phosphorus in recycled will have an impact on surface and ground waters. However, home gardeners should be made aware of the nutrient content of the recycled water to avoid potential impacts of applying too much fertiliser.

The recycled water will add up to 21 tonne/irrigated ha of salt over a 100 year period. This compares with negligible salt load in the pre-development landscape. The added salt is expected to leach below the plant root zone and ultimately to swamps and streams below the built area. The potential for impacts on these water bodies is not expected to be significant but should be considered during the detailed design of individual subdivisions.

11 REQUIREMENTS AND RECOMMENDATIONS FOR OPERATION AND MONITORING

This section of the report demonstrates how the proposed recycled water irrigation scheme and its environmental safeguards should be implemented and managed in an integrated and feasible manner.

11.1 ENVIRONMENTAL MANAGEMENT PLAN

An environment management plan (EMP) should be developed that incorporates the irrigation activity. In accordance with the NSW DEC Environmental Guidelines 2004 (the Use of Treated Effluent for Irrigation), the EMP should facilitate the following aims:

- Improve resource utilisation (e.g. use of recycled water for irrigation);
- Protect land resources (e.g. soils);
- Protect ground water;
- Protect surface waters;
- Maintain community amenity (e.g. odours, public health, noise, etc.);

In order to minimise environmental health risks, the EMP should address the following issues.

11.1.1 RECYCLED WATER QUALITY AND QUANTITY

The operator of the WRP will be responsible for ensuring that recycled water delivered to individual households is suitable for its intended uses according to State and National guidelines. The multiple barrier risk management plan adopted by the operator will include protocols for dealing with any significant variation in recycled water quality that could potentially impact on the environment as a result of garden/lawn irrigation. In addition to the volume of recycled water used, WRP should monitor at least the following recycled water quality parameters:

- pH
- Salt content (EC or TDS concentration)
- Total nitrogen, total phosphorus, potassium and other trace fertilisers
- Sodium, calcium and magnesium leading to a calculation of sodium absorption ratio (SAR)
- Biological Oxygen Demand
- Suspended solids
- Turbidity
- Faecal coliforms and other pathogen requirements of the Australian guidelines (2006) and/or DWE 2008
- Residual chlorine

- Heavy metals, pesticides and herbicides and other potential contaminants should be monitored in accordance with the intent or requirements of the Australian Guidelines (2006).

11.1.2 SHALLOW GROUNDWATER CONDITIONS

At least three shallow groundwater points should be established within each sub-catchment of the development area (one above the irrigation area, one within the irrigation area and one below the irrigation area). The monitoring should focus on increases in salt and nutrient concentrations in the groundwater. Baseline conditions should be established on the advice of a specialist groundwater consultant representing dry, average and wet conditions, prior to subdivision development.

11.1.3 SURFACE WATER CONDITIONS

The point(s) at which surface and subsurface drainage meets a perennially flowing water body should be identified. Baseline monitoring should commence as soon as possible at this point as well as one point upstream. The monitoring should focus on increases in salt and nutrient concentrations in the surface water(s). Baseline conditions should be established representing wet, medium and dry periods based on the advice of a specialist surface water specialist.

12 REFERENCES

Agric-WA (1999) *Tolerance of plants to salty water*. Farmnote 71/99. Agriculture Western Australia and the Chemistry Centre of Western Australia.

Anderson, J.M. and Ruge, T.J. (1994) *Effluent Reuse: Land and Wet Weather Storage Requirements.* Urban Water Research Association of Australia. Research Report no. 80.

Browns and Associates 2010: Model of salt concentration in stormwater

AWM 2009 *Googong Water Cycle Management, Water and Salt Balance Revised Analyses*

C.M Jewell and Associates 2004 –*Desk Top review of Potential Hydrogeological Impact* Googong Water Cycle Strategy on behalf of MWH

C. M Jewell and Associates 2009 *Groundwater Assessment Googong, NSW*

C. M Jewell and Associates 2010 *Groundwater Assessment Googong, NSW*

DEC 2004 Environmental Guideline. *The Use of Effluent for Irrigation*

DWE 2008 *NSW Guidelines for management of private recycled water schemes*

Hardie A and Hird C (1998) *Landform and soil requirements for biosolids and effluent reuse (NSW Agriculture Advisory Bulletin July 1998.*

Hird C and Foreman I (2010) *Salt-Pinpointing the problem Urban Salt Conference 2010*

Jenkins B.R. (2000) *Soil Landscapes of the Canberra (Canberra, Queanbeyan, Lake George, Hoskinstown) 1:100 000*

Manidis Roberts 2008 *Googong Water Cycle Preliminary Environmental Assessment*

Mitchell PB (2007) *Geology of the Googong development area*

MWH Pty Ltd 2009. *Googong New Town Concept Design - Site Water Balance Assessment*

MWH 2010 *Googong New Town Concept Design - Site Water Balance Assessment*

MWH 2010 a *Salt balance with and without biological phosphorus removal*

NRMMC and EPHC 2006 *National (Australian) Guidelines for Water Recycling Managing Health and Environmental Risks*

NHMRC &ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and marine water Quality*. Volume 4. Agricultural water use –rationale and detailed discussions (Draft) Commonwealth of Australia

Willana Associates, 2007. *Googong urban investigation area – Local Environmental Study.*

APPENDIX 1 –EM SURVEY RESULTS

APPENDIX 2 SOIL LABORATORY TEST RESULTS

APPENDIX 3 GUIDELINES FOR BUILDING IN SALT AFFECTED AREAS

The following publications can be downloaded from the internet.

City of Wagga Wagga (undated): Building in a saline environment Active print phone 0269212233

Department of Infrastructure, Planning and Natural Resources (2002) Broad Scale Resources for Urban Salinity assessment

Department of Infrastructure, Planning and Natural Resources (2002) Site Investigations for Urban Salinity

Department of Infrastructure, Planning and Natural Resources (2003) Building in a Saline Environment

Department of Infrastructure, Planning and Natural Resources (2003) Roads and Salinity Local Government Salinity Initiative-

Department of Infrastructure, Planning and Natural Resources (2005) Salinity Indicator Plants Local Government Salinity Initiative- Booklet Number 8

Department of Infrastructure, Planning and Natural Resources (2005) Groundwater basics for Understanding Urban Salinity- Booklet Number 9

Department of Infrastructure, Planning and Natural Resources (2005) Costs of Urban Salinity Local Government Salinity Initiative-Booklet Number 10

Department of Infrastructure, Planning and Natural Resources (2005) Landuse Planning and Urban Salinity. Local Government Salinity Initiative-Booklet Number 11

Fairfield City December 2004 Building in Saline Environments

McGhie S 2003 Local Government Salinity Initiative Booklet No 6 Local Government Salinity Initiative

WSROC 2004 Western Sydney Salinity Code of Practice

Table 2.1: Landform requirements for effluent irrigation systems

	Limitation			
Property 1	**Nil or Slight**	**Moderate**	**Severe[2]**	**Restrictive Feature**
Slope (%) (for following irrigation methods)				
– flood/surface/ underground	< 1	1–3	> 3	excess runoff and erosion risk
– sprinkler	< 6	6–12[3]	> 12[3]	
– trickle/microspray	< 10	10–20[3]	> 20[3]	
Flooding	none or rare	Occasional	frequent	limited irrigation opportunities
Landform	crests, convex slopes and plains	concave slopes and foot-slopes	drainage lines and incised channels	erosion and seasonal water- logging risk
Surface rock outcrop (%)	Nil	0–5	> 5	interferes with irrigation and/or cultivation equipment; risk of runoff

Source: Based on Hardie and Hird (1998), NSW Agriculture, Organic Waste Recycling Unit

Notes: 1. Careful consideration should also be given to potential impacts on groundwater (see 2.6 Groundwater).

2. Sites with these properties are generally not suitable for irrigation.

3. Slopes over 12% may be acceptable provided runoff and erosion risks are identified in the site selection process.

Table 2.2: Typical soil characteristics for effluent irrigation systems

Property	Limitation			Restrictive Feature
	Nil or Slight	Moderate	Severe[1]	
Exchangeable sodium percentage (0–40 cm)	0–5	5–10[2]	> 10	structural degradation and waterlogging
Exchangeable sodium percentage (40–100 cm)	< 10	>10	–	structural degradation and waterlogging
Salinity measured as electrical conductivity (EC_e) (dS/m at 0–70 cm)	< 2	2–4	> 4[3]	excess salt may restrict plant growth
Salinity measured as electrical conductivity (EC_e) (dS/m at 70–100 cm)	< 4	4–8	> 8[3]	excess salt may restrict plant growth, potential seasonal groundwater rise
Depth to top of seasonal high water table (metres)	> 3[4]	0.5–3[4]	< 0.5	poor aeration, restricts plant growth, risk to groundwater[5]
Depth to bedrock or hardpan (metres)	> 1	0.5–1	< 0.5	restricts plant growth, excess runoff, waterlogging
Saturated hydraulic conductivity (Ks, mm/h, 0-100 cm)	20–80	5–20[6] or >80[6]	<5	excess runoff, waterlogging, poor infiltration
Available water capacity (AWC, mm/m)	> 100	< 100 [6]	–	little plant-available water in reserve, risk to groundwater
Soil pH_{CaCl_2} (surface layer)	> 6–7.5	3.5[7]–6.0 > 7.5	< 3.5	reduces optimum plant growth
Effective cation exchange capacity (ECEC, cmol (+)/kg, average 0–40 cm)	> 15	3–15[8]	< 3	unable to hold plant nutrients
Emerson aggregate test (0–100cm)	4, 5, 6, 7, 8	2, 3	1	Poor structure
Phosphorus (P) sorption (kg/ha at total 0–100 cm)	high[9]	moderate[9]	Low	unable to immobilise any excess phosphorus

Source: Based on Hardie and Hird (1998), See also NSW Department of Primary Industries (2004)

Notes: 1. Sites with these properties are unlikely to be suitable for irrigation of some or all effluent products.

2. Application of gypsum or lime may be required to maintain long-term site sustainability.

3. Some high EC soils containing calcium 'salts' are not necessarily considered 'severe'.

4. Where unable to excavate to 3m, local knowledge and absence of indications of water table to the depth of sampling (1m) should be used.

5. Criteria are set primarily for assessing site suitability for plant growth. Presence of a shallow soil water table may indicate soil conditions that favour movement of nutrients and contaminants into groundwater. In such cases, careful consideration should be given to quality and potential impacts on groundwater (see 2.6 Groundwater).

6. Careful irrigation scheduling and good irrigatin practices will be required to maintain site sustainability.

7. Soil pH may need to be increased to improve plant growth. Where effluent is alkaline or lime is availble, opportunities exist to raise pH. If acid sulfate soil is present, site-specific specialist advice should be obtained.

8. Soil may become more sodic with effluent irrigation. In some cases, however, this soil property may be ameliorated with addition of a calcium source.

9. Soils with medium to high phosphorus sorption capacity can adsorb excess phosphorus not taken up by plants. The effectiveness of this depends not only on the sorption capacity but also, the depth and permeability of the soil. A nutrient budget must be undertaken (see Section 4.3).

GOOGONG WATER CYCLE MANAGEMENT

REVISED SALT BUDGETS

3 August 2010

1. POTENTIAL IMPACTS OF SALT IN IRRIGATION WATER

Irrigation with recycled or potable water will apply salt to the soil. The varying amounts that will be retained will vary with the applied volumes and hence application amounts, and also with the rate of removal which is affected by the amount of percolation. Salt budgets were used to examine these issues for the different mixes of rain, recycled and potable water that applied to two scenarios.

Two factors must be addressed when considering the possible consequences of salt in irrigation water on plant growth. The first is the scorching effect of salty water on plant leaves, and secondly the potential to increase soil salinity as determined by the salt budgets.

1.1 Salinity of irrigation water

The TDS concentrations in the irrigation water varied with the proportion of each class of water that was used on the various sites, and the TDS concentrations in the raw supplies. The latter were set as follows:

- Rainwater TDS 13 mg/L, EC 0.02 dS/m;
- Recycled water TDS 660 mg/L, EC 1.03 dS/m;
- Potable water TDS 100 mg/L, EC 0.16 dS/m.

Water balance analyses were used to estimate the irrigation volumes on the various sites within the scheme, and the proportions of the three sources of water that were used to make up the irrigation volumes. The results were provided in detail in a report dated November 2009. The relative proportions for the two stages of development for systems with rainwater tanks are detailed in Table 1, and the mean salinities in Table 2. The salinity of water used on the landscaped areas differed slightly between the parks-open spaces and the streetscapes because of differences in their irrigation volumes.

Table 1 The relative proportions of rainwater, recycled water and potable water that were used for irrigation on three irrigation sites.

Stage	Water class	Relative proportion (%)		
		Gardens	Playing fields	Landscaping
NH1A	Rainwater	46	0	0
	Recycled water	19	60	55
	Potable water	35	40	45
Ultimate	Rainwater	44	0	0
	Recycled water	20	65	60
	Potable water	36	35	40

Table 2 The mean salinity of irrigation water on four irrigation sites.

Stage	Salinity (dS/m)			
	Gardens	Playing fields	Parks & open spaces	Streetscapes
NH1A	0.26	0.69	0.62	0.65
Ultimate	0.26	0.71	0.65	0.67

The average salinity of the water used on the residential gardens was considerably less than on other areas because of the partial use of rainwater on the gardens.

1.2 Salt and foliar injury

Salty water can damage foliage and since the effect depends on the salinity of water used on each day it represents a day to day risk that can be assessed through the EC of the irrigation water that is used on that day. Hence the separate salinity of each source of water is important in this context.

Highly salt sensitive species

A West Australian Farmnote (Agric-WA 1999) listed the following species as being highly sensitive to salt with their tolerance to salty water being limited to the 0-0.9 dS/m EC range, and recommended that irrigation water should not wet the leaves of these species on hot dry days:

- Fruit: Almond, apples, avocado, citrus fruit, loquot, passionfruit, pears, persimmon, raspberry, stone fruit, strawberry;
- Vegetables: Carrot, celery, green beans, onion, parsnip, peas, radish, squash;
- Ornamentals: Azalea, begonia, camellia, fuchsia, gardenia, ivy, magnolia, primula, rose, star jasmine.

While there is no risk that the highly-sensitive species will suffer foliage burn from irrigation with rainwater or potable water, the recycled water (EC = 1.03 dS/m) presents some risk. Precautions that will lessen or eliminate that risk are:

- Subsurface or surface drip irrigation will eliminate the risk because the recycled water will not touch the foliage;
- Avoiding watering during hot, daylight hours will lessen the risk;
- Rinsing the foliage with potable water at the conclusion of watering will considerably lessen the risk.

Mildly salt sensitive species

The second group was mildly sensitive and were tolerant to an EC within the 0.9-2.7 dS/m range.

Mildly-sensitive plants were:

- Fruit: Grape, mulberry;
- Vegetables: Broccoli, cabbage, capsicum, cauliflower, cucumber, lettuce, potatoes, pumpkin, rock melon, sweet corn, tomato, water melon;
- Ornamentals: Aster, banana (*Musa* spp.), bauhina, *Callistemon viminalis*, emu bush (*Podocarpus*), geranium, gladiolus, hibiscus, hop bush (*Dodonea attenuata*), *Juniperus chinensis*, lantana, pointsettia, *Thuja orientalis*, zinnia.

None of the three water sources pose a risk to the mildly sensitive species.

By extension, there is no risk of foliar damage to the more tolerant species, and for completeness they are listed below.

Slightly salt sensitive species

The third group was slightly salt-sensitive and had a tolerance within the EC range of 2.7 – 6.35 dS/m.

Slightly salt-sensitive plants were:

- Turf grasses: Buffalo grass, couch grass, kikuyu grass, ryegrass;
- Fruit: Fig, pomegranate, olive;
- Vegetables: Asparagus, garden beets, kale, spinach;;
- Ornamentals: *Acacia longifolia*, Bangalay (*Eucalyptus botryoides*), bamboo, boobyally (*Myoporum acuminatum*), boungainvillea, carnation, chrysanthemum, coprosma, false acacia (*Robinia pseudoacacia*), *Ficus* spp., Kondinin blackbutt (*E. kondininensis*), mesembryanthemum, morrel (*E. oleosa*), native pine (*Actinostrobus pyrimidalis*), New Zealand christmas bush (*Metrosideros tomentosa*), oleander, portulaca, Queensland pyramid tree (*Lagunaria patersonii*), river red gum (*E. camaldulensis*), rosemary, Rottnest syprus (*Callitris robusta*), Rottnest teatree (*Melaleuca cupressiformis*), stock, swamp mallet (*E.* spathulata), swamp yate (*E. occidentalis*), vinca, York gum (*E. loxophleba*).

Salt tolerant species

The fourth group was salt tolerant with a tolerance within the EC range of 6.35 – 23.65 dS/m.

Salt tolerant plants were:

- Turf grasses: saltwater couch (*Paspalum vaginatum*), sand couch (*Sporobolus virginicus*);
- Fruit: Date palm;
- Ornamentals: Canary palm (*Phoenix canariensis*), *Melaleuca thyoides*, saltbushes, salt sheoaks (*Allocasuarina cristata* and *A. glauca*), salt river gum (*E. sargentii*), tamarisks.

The above classification of plants according to their sensitivity to salt in irrigation water also provides a general guide to their sensitivity to soil salinity. However, note that such a classification is based on the EC of the irrigation water, which is an indirect indicator and as such is more general than relating the risk to soil salinity.

1.3 Soil salinity and plant growth

The second effect of salt in irrigation water is the potential for salt to accumulate in the soil, leading to retarded growth and even the death of some plants. Soil salinity is generally in expressed in terms of the electrical conductivity of a soil extract (ECE). Note that whilst the same measure of electrical conductivity is used to quantify both water and soil salinities, the two measures are on different scales and cannot be directly compared. Hence in the following discussion the electrical conductivity of a solution is abbreviated as EC, whereas ECE is used for soil salinity.

In general, critical ECE values are:
- Negligible for the majority of plants when less than 2 dS/m;
- Sensitive plants affected at 2-4 dS/m;
- Many plants affected at 4-8 dS/m;
- Only salt-tolerant plants grow satisfactorily at greater than 8 dS/m.

The Australian Guidelines for Water Recycling (NWQMS 2006) provide detailed lists of the tolerance of a wide range of species to soil salinity. Examples of some highly sensitive and sensitive plants that are affected by soil salinity in the 1-2 dS/m and 2-4 dS/m ranges respectively are listed below. For each group, the effect will be relatively small provided the soil salinity does not exceed 2.0 dS/m and 4.0 dS/m respectively.

Highly sensitive species
- Fruit: Apple, apricot, blackberry, boysenberry, pear, pepper, plum, strawberry;
- Vegetables: Bean, cabbage, carrot, celery, egg plant, lettuce, onion, potato, radish, spinach, sweet potato, turnip,
- Ornamentals: Bear's breeches, begonia, barberry, boxwood, camellia, blue atlas cedar, Pyrenees cotoneaster, broom, dahlia, euonymus, fuchsia, gardenia, Algerian ivy, privet, lily, Japanese spurge, photinia, blue spruce, primula, Douglas fir, rhododendron, rose, blue willow, linden, violet;

Sensitive species
- Fruit: Almond, grape, grapefruit, lemon, olive, orange, peach;
- Vegetables: Beet, broccoli, cauliflower, cucumber;
- Ornamentals: Glossy abelia, aster, deodar cedar, Kaffir lily, jade plant, blue daisy, Carolina jasmine, geranium, gladiolus, sea lavender, honeysuckle, stock, plum, pepper tree, dwarf running myrtle, zinnia;

Turf grasses
Most turf species are tolerant of soil salinity, and the sensitivity of a number of species is as follows:
- Highly sensitive (ECE <1.5 dS/m): Annual bluegrass, rough bluegrass, colonial bentgrass.
- Moderately sensitive (ECE 1.6-3.0 dS/m): Kentucky bluegrass.
- Moderately tolerant (ECE 3.1-6.0 dS/m): Hard fescue, strong creeping red fescue, creeping bentgrass.
- Tolerant (ECE 6.0-10.0 dS/m): Fairway wheatgrass, tall fescue, perennial ryegrass, slender creeping red fescue.

For purposes of the present study, the risk of soil salinity affecting some plants was quantified by calculating the proportion of years when the soil salinity was expected to exceed thresholds of 2.0 and 3.0 dS/m. The 2.0 dS/m threshold was taken as an indication that highly sensitive species will be affected by soil salinities above this value. Similarly, values above the 3.0 dS/m threshold indicated an effect on sensitive species. The soil salinity must be greater than 4.0 dS/m to affect moderately-tolerant and tolerant species.

1.3.1 Expected soil salinity

Because the rainfall particularly affects salt accumulation, separate estimates of soil salinity were calculated for the ten deciles of rainfall at Googong. Results are given as the weighted root-zone salinity expressed as the ECE in a saturated soil extract. Annual estimates of soil salinity were calculated on the assumption that the equilibrium salinity with the prevailing rainfall and salt inputs was reached within a year. Results are given for the NH1A stage of development (Figure 1) and the ultimate stage (Figure 2).

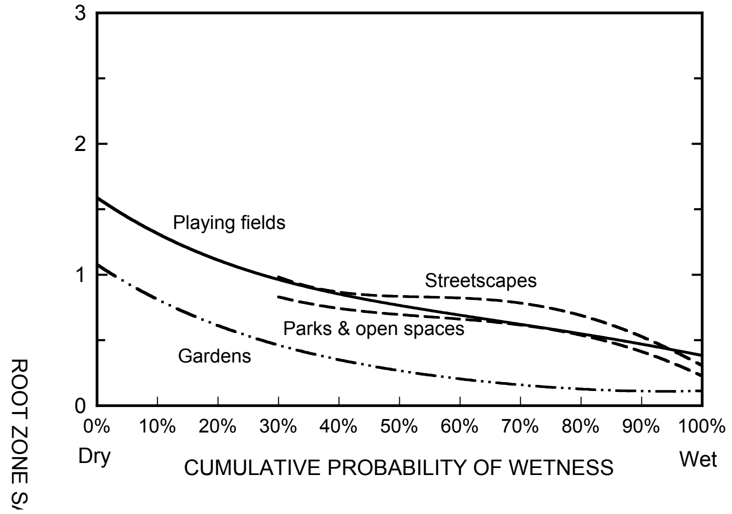


Figure 1 The estimated root-zone salinity on the four types of irrigation areas in the NH1A stage.

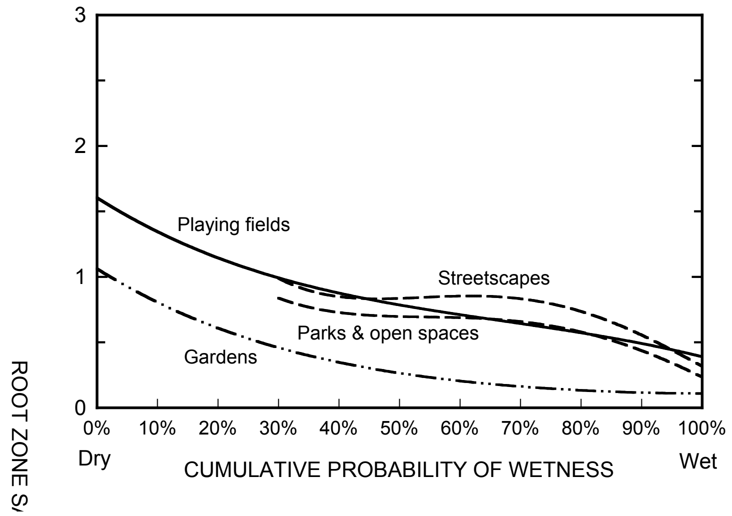


Figure 2 The estimated root-zone salinity on the four types of irrigation areas in the ultimate stage.

Salt accumulation was greatest with a low rainfall because there was less percolation of rainwater down the soil profile and hence less leaching of salt beyond the root zone. The other dominant effect on soil salinity was the volume of recycled water that was used for irrigation. Since the recycled water had the highest salt concentration, the volume of recycled water largely determined the salt load.

The soil salinity was least with the household gardens because rainwater contributed a significant proportion of the total water use for irrigation. The higher salinity on the playing fields reflected the greater irrigation rate per hectare which gave a greater salt load.

No estimates of soil salinity were obtained for the driest 30% of years on the two classes of landscaping, but the streetscapes broadly followed the salinity on the playing fields, and the parks and open spaces tended to be a little less in those years with estimates.

Importantly, the estimated soil salinities never exceeded 2 dS/m, and hence there was no risk of soil salinity increasing to a level that would affect plant growth.

1.3.2 Salt loads

The salt loads to the households, irrigation and discharges varied with the various water mixtures and TDS concentrations, and the mean annual loads are detailed in Table 3. The irrigation loads were based on the net irrigation volumes.

Table 3 The mean annual salt loads (t/yr) for internal household use, irrigation and in discharges.

Stage	Household - internal	Irrigation	Discharge
NH1A	47	37	52
Ultimate	249	150	239

In both stages, the total salt load was divided approximately as 36% household use, 26% irrigation, and 38% in discharges.

2. REFERENCES

Agric-WA (1999) Tolerance of plants to salty water. Farmnote 71/99. Agriculture Western Australia and the Chemistry Centre of Western Australia.

NWQMS (2006) Australian Guidelines for Water Recycling: Managing Health and Environmental Risk (Phase 1). National Water Quality Management Strategy, vol 21.