




University of South Australia

Division of IT, Engineering and the Environment

An Investigation into the Tolerance and Sensitivity of the Adelaide Parklands' Landscape Plants to the Glenelg Recycled Wastewater

Associate Professor Ali Morad Hassanli
(Chief investigator)

Doctor Fatemeh Kazemi

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Authors	Ali Morad Hassanli[1] (Chief investigator) Fatemeh Kazemi[2]

1 Adjunct Associate Professor of University of South Australia (CWMR) and Associate Professor of University of Shiraz, Iran

2 Research Fellow of University of South Australia (CWMR) and Associate Member of Ferdowsi University of Mashhad, Iran

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An Investigation into the Tolerance and Sensitivity of Adelaide Parklands' Landscape Plants to Glenelg Recycled Wastewater

University of South Australia
Division of IT, Engineering and the Environment, (ITEE)
School of Natural and Built Environments (NBE)
Centre for Water Management and Reuse (CWMR)

SA Water
Adelaide, Australia

University of
South Australia

Associate Professor Ali Morad Hassanli
(Chief investigator)

Doctor Fatemeh Kazemi

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Authors, 2012

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Executive Summary

Urban green spaces impact on the microclimate (moderate temperature), hydrological cycle (increased water infiltration rate and evapotranspiration, slow down runoff), biodiversity (source of habitat for many fauna species), improve water quality and reduce air pollution, remove significant amounts of pollutants such as nitrogen, phosphorus and fine sediments and in general have environmental, social and economic benefits. Adelaide Park Lands, with an area of 720 ha around the City of Adelaide bring environmental, social, cultural and financial benefits for the people of Adelaide. The Adelaide Park Lands provide habitat and green space connectivity for a diverse range of flora and fauna species. Although these green spaces are of great benefit to the community and environment, they require substantial amounts of water to maintain their health and beauty. The use of water for irrigation is often problematic in Australia, particularly in South Australia which is the driest state in Australia. Securing Australia's water requires a diversity of water sources to ensure the country will be prepared for future water scarcity (droughts) as the population grows. Recycled water is one of the main water resources which can make a substantial contribution to increasing the security of future water supplies. Scientific and technical studies are required to maximize this contribution through developing water recycling opportunities and reuses, particularly for green space irrigation, to provide environmentally, socially and economically sustainable environments.

The use of municipal recycled water for green space plants is a valuable attempt to use the easily available water resources but it requires a monitoring system to mitigate the possible adverse impacts on the soil, plants and groundwater. Variables such as climate, weather, irrigation methods and frequency, plant genetic variations and plant species, soil health and soil physical and chemical characteristics can have a profound effect on the sensitivities of plants to salts and various toxic elements. Soil drainage, irrigation application rate, irrigation water quality, rainfall characteristics (volume, intensity and frequency), and plant canopy shade can influence the long-term effects of salinity, and toxic effects of chemical compounds on the vegetation health. It is, therefore, important to have information specific to each individual plant species, as well as information on all the above-variables, specific to each locality, in order to properly plan and manage water requirements of specific landscapes. There is currently a lack of adequate information specific to the Adelaide Park Lands vegetation, their tolerance to salinity and toxicity and their threshold levels. There has been little research to investigate water requirements of mixed vegetation in urban landscapes such as plantings in the parkland systems. In addition, research is required to examine the methods to remove pollutants from the recycled water.

This report is part of a larger investigation of the response and sensitivity of landscape plants within the Adelaide Park Lands to the use of Glenelg recycled water for irrigation. The scope of this report includes: a review of the current literature on possible impacts of the use of treated wastewater on native plants in the Adelaide Park Lands, detailing potential toxic effects of salinity, sodium, chloride and boron; an introduction to the major plant species reported in the Adelaide Park Lands as well as their characteristics and functions within the Australian landscape; a summary of water logging, salinity, sodium, chloride and boron tolerance of the selected species (provided in Appendix 2); recommendations for the planting design within the parklands and watering methods and regimes for the same area and also the research gaps that are required to be investigated for a more sustainable use of Glenelg recycled water for Adelaide Park Land irrigation.

This study uses plant species found on the lists reported (Long, 2003), with the main focus on plants available in the largest number of parks within the parklands. The major aim was to provide specific information on their botanical characteristics and tolerance to salinity and to certain toxic elements, focussing on sodium, chloride and boron.

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South Australia

The annual average salt concentration in the Glenelg recycled wastewater is 1190-1200 mg/l or 1.8dS/m. Although the salinity variation in usual irrigation water is expected to vary up to 3 dS/m, irrigation with Glenelg recycled wastewater with an irrigation application rate of 4.5ML/year-ha would cause annual accumulation of nearly 9 tonne/ha salts to the soil. In the absence of an efficient irrigation management strategy, salinity build up hazard would be problematic in the long term.

The average sodium and chloride level in the Glenelg recycled wastewater is 231 and 389 mg/l, respectively. However the sodium and chloride concentration levels in usual irrigation water are expected to be 0-920 and 0-1065 mg/l , respectively. This shows that the sodium and chloride concentration in the Glenelg recycled wastewater is below the maximum allowable level. However, it does not mean that accumulation of these two toxic ions in the long term, without considerable attention to sustainable irrigation management, would not be a hazard for the Adelaide Park Land plants particularly those that are sensitive to toxicity of these elements.

The findings suggest that further research would be needed to clarify the benefits of the irrigation of urban green spaces by recycled water and improve irrigation management to mitigate the possible inverse impacts of recycled water for a sustainable environment to ensure having a healthy plant, soil and water system across the Adelaide Park Lands.

Contents

University of
South Australia

List of Figures

List of Tables

List of Appendices

To authors

I have read the report and have sent it to our research, development and innovation manager (Mike Burch), and we have the following comments:

- The report was excllent, well written, informative and sets the scene for the next steps
- We felt there was nothing in the report which could be viewed as being detrimental to SA Water, Adelaide City Council and the operation of this irrigation scheme
- SA Water does have the copyright permission for the two REM reports that you mentioned below, and hereby give you permission to reproduce these in your report

We look forward to continuing to work with you on these parkland related projects, and appreciate the quality of the work produced by your team.

Thanks,

Greg Ingleton
Principal EIA Advisor - Recycled Water

SA Water Corporation

Friday March 02, 2012

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1. Introduction

Adelaide is recorded as one of the best planned cities in the world. One of the reasons behind this statement is its distinctive design of a central business and commerce core surrounded by parklands (Williams, 1966). The parklands were set aside for public recreation and relaxation. Designed in 1837, Adelaide has a metropolitan open space system (MOSS) connecting the city, suburbs, coast and hills of Adelaide and adding unique value in open space planning for the metropolitan area (Williams, 1966). The Adelaide Park Lands, with an area of 720 ha around the Adelaide CBD, are a core component of MOSS. MOSS brings environmental, social, cultural and financial benefits for the people of Adelaide.

Although the Adelaide Park Lands have been altered considerably since settlement, they are still considered a valuable natural asset for Adelaide (Long, 2003). Despite little of the original pre-settlement biodiversity remaining, the Park Lands continue to provide habitat and connectivity of green space for a diverse range of flora and fauna species. Some of these species are rare or endangered (species of conservation significance) and rely on the uninterrupted nature of the Park Lands to provide for their habitat requirements. The Park Lands are also used frequently throughout the year by the community to host cultural events and on a daily basis for relaxation and recreation. These aspects are some of the unique characteristics of this network of green spaces that add more value to this environment.

Although these green spaces are of great benefit to the community and environment, they also require substantial amounts of water to maintain their health and beauty. The use of water for irrigation is often problematic in Australia which has the distinction of being one of the driest countries on earth (Stevens, 2006). Australian soils are also very old and depleted, with little organic matter to trap runoff and maintain soil moisture (Stevens, 2006). In South Australia, large-scale water abstraction from the Murray has proven to be unsustainable and this potable water has been prioritised to fulfil domestic requirements and maintain the health of the river system (Girardet, 2003).

With the increased focus on 'waterproofing' Adelaide and initiating sustainable practices, it has been suggested (Girardet, 2003) that the use of recycled wastewater and storm water become the centrepiece of a proposed water policy in Adelaide. South Australia is seen as a national leader in recycled water use. This water is primarily used for the irrigation of crops and town parklands (Allen and Cunliffe, 2007).

Commissioned in 1999, the Virginia Pipeline Scheme (VPS) began supplying Class A recycled water (the highest quality recycled wastewater) to several commercial food growers on the Northern Adelaide Plains (Laurenson et al., 2010). This successful example of the use of recycled wastewater prompted other recycled water schemes such as Mawson Lakes, the Willunga Basin Pipeline and the Adelaide Airport pipeline (Allen and Cunliffe, 2007). In line with these successful schemes, the Glenelg to Adelaide Parklands recycled water project, commissioned in 2008 and completed in 2010, also became part of the Waterproofing Adelaide initiative (South Australian Water Corporation, 2009).

Monitoring and ensuring the safety of recycled water for the public and the environment falls to the water departments within local government, which include SA Department of Health, the EPA and SA Water. In order to understand and monitor the impacts of recycled wastewater on the public and the environment, several reports have been commissioned over the years. These reports have investigated the possible environmental impacts of treated wastewater on the specific plants found in the Adelaide Park Lands.

1.1 Possible environmental impacts of recycled wastewater on native vegetation in the Adelaide Park Lands

Literature on the effects of salinity on various crops and American landscape plants is extensive, as shown by the lengthy bibliography in this report; it is not however helpful in determining possible impacts on specific native South Australian landscape plant species. Alan Blaylock (1994), from the University of Wyoming's College of Agriculture, investigated the effects of salt tolerance on a number of Wyoming native landscape plants as well as various fruit trees and vegetables; Wu, et al. (1998) carried out experiments on Californian landscape plants; and Kotuby-Amacher et al, (2000) explored the salinity tolerance of various crops such as barley, corn and sunflowers. Some of the data currently available on the effects of specific salts, such as sodium, chloride and boron, on various landscape plants has been obtained under controlled testing (van der Moezel et al., 1991) which does not present the wide gambit of difficulties associated with field testing (Niknam and McComb, 2000). Variables such as climate (Niu and Rodriguez, 2006), weather, genetic variation; soil health (Stevens et al., 2008), soil physical and chemical characteristics (Hassanli et al., 2007), soil texture and soil structure; irrigation methods (Hassanli et al., 2009, Hassanli et al., 2010) and frequency (Wu et al., 2001), can have a profound effect on the sensitivities of plants to various salts. It is therefore important to have information specific to each individual plant species, as well as information on all the above-mentioned variables, specific to each locality, in order to properly plan and manage specific landscapes (Pedrero et al., 2010). Hassanli and Javan (2005a) evaluated the impacts of the quality of municipal secondary recycled water on the green space plants grown in the arid and semi-arid regions. They believe the use of municipal recycled water for green space plants is a good attempt to use the easily available waters within the park lands area but it requires a monitoring system to mitigate the possible inverse impacts on the soil and groundwater. As Pedrero and Kalavrouziotis et al. (2010), Hassanli et al. (2008) and Hassanli, et al. (2007) further explain, soils, drainage, irrigation methods and the amount of shade all influence the long-term effects of salinity and toxicity of chemical compounds on vegetation. It is also important to note that the effects of excess salts continue long after the source of that excess is removed (Handreck and Black, 2002).There is currently a paucity of information specific to the Adelaide Park Lands vegetation, soil types and drainage characteristics.

A wide range of results were found in various studies (Wu et al., 2001, Sun and Dickinson, 1993, Dunn et al., 1994), highlighting the importance of specific study for all plant species of concern as well as the influence of many other factors as mentioned above. Field studies of the effects of treated wastewater on plant growth other than crops are rarely carried out (Pedrero et al., 2010). The use of wastewater for irrigation requires good management and planning with the understanding that not all local situations can be predicted when preparing guidelines (Pedrero et al., 2010). The use of a large variety of plant species is not widely practiced (Niu and Rodriguez, 2006) and presents unique challenges when irrigating landscaped areas. There is currently limited information on the salt tolerance of ornamental plants and the small number of studies that have been conducted show substantial differences in tolerance to various salts between species. Different species also exhibit a variety of methods to counter high salt concentrations, further complicating the management and planning of irrigation (Niu and Rodriguez, 2006). This lack of information suggests extensive and specific further study is required on the tolerance of various native Australian landscape plants to increased salt levels and toxicity levels in recycled waste water used for irrigation.

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Figure 1: Aerial view of the Adelaide Park Lands (Google - Imagery, 2011)

2. Problem Statement

The water scarcity and consequent need for the sustainable use of water resources in Adelaide has emphasised the need to explore alternative options of water for irrigation purposes. With this in mind, the use of recycled water from the Glenelg Wastewater Treatment Plant (WWTP) has been identified as one of the best resources to meet the irrigation requirements of the Adelaide Park Lands plants (REM et al., 2008). A requirement for the use of this water has been to explore possible environmental effects of this recycled wastewater on the vegetation of the Adelaide Park Lands.

In order to isolate which elements need to be managed in the recycled water, this investigation has looked at the specific detrimental levels of salinity; excess sodium, chloride, boron and at water logging. If these individual effects are known, appropriate management of the watering regimes can be more easily established.

3. Scope of this Work

This report is part of a larger investigation of the response and sensitivity of landscape plants within the Adelaide Park Lands to the use of Glenelg recycled water for their irrigation. The scope of work for this report included:

- a review of the current literature available on possible impacts of the use of treated wastewater on native plants in the Adelaide Park Lands, detailing potential toxic effects of salinity, sodium, chloride and boron.
- an introduction of the major plant species reported in the Adelaide Park Lands as well as their characteristics and function within the Australian landscape.
- a summary of water logging, salinity, sodium, chloride and boron tolerance of the selected species (provided in Appendix 2)
- management measures and recommendations for planting design within the Park Lands and watering methods and regimes for the same area.

This report will use plant species found on the list reported by Long (2003), with the main focus on plants available in larger number of parks within the parklands. The major aim is to provide specific information on their botanical characteristics and tolerance to certain toxic elements, focussing on salinity, sodium, chloride and boron.

4. The Study Area

The Adelaide Park Lands are the study area in this report. They are the arrangement of green spaces encircling the central business district of Adelaide and North Adelaide. This green space is bounded by a number of roads and the railway, including: Park Terrace, Fitzroy Terrace and Robe Terrace to the north; Hackney Road, Dequetteville Terrace and Fullarton Road to the east; Greenhill Road to the south and finally, the railway line and Port Road to the West (Long, 2003). The Adelaide Park Lands (Figure 1) cover 720 ha and comprise 45% of the area of the city of Adelaide (Long, 2003).

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5. Vegetation in the Adelaide Park Lands

During 2002 and 2003 a biodiversity survey of the flora and fauna within the Adelaide Park Lands was undertaken. At this time, Long (2003) compiled a comprehensive list of the vascular plant species found in each of the 27 parks. Our current information is limited to those plants on Long's (2003) list. A brief summary of this information is as follows:

1. 514 plant taxa were recorded of which 60% (309 species) are introduced and non-locally indigenous; 183 species are indigenous to the area (Long, 2003); at the time of the survey, 22 grass species remained unidentified.
2. There is no comprehensive record of the spatial arrangement of each listed species. The information lists the presence of each species within each park area. The complete list of these plant species and their presence within each park is available in Appendix 2.
3. The available vegetation information does not indicate the abundance of each species. Therefore, this data can only provide an indication of the richness of the plant species' within the Park Lands area.
4. Of the plant species indigenous to the locality (species that naturally occur in the area) the families listed in decreasing order of richness are: Gramineae (42 taxa); Leguminosae (22 taxa); Myrtaceae and Compositae (20 taxa each); Liliaceae, Cyperaceae, Chenopodiaceae (13 taxa each); Juncaceae (8 taxa) and Pittosporaceae (5 taxa).
5. The major plant species are identified as grasses, eucalypts and acacias. The dominant understorey species are chenopods, lilies and daisies.The dominant water course species are sedges and rushes.
6. Opportunistic surveys of specific areas within parks 6, 16, 17, 21 and 22 are shown in Long, (2003). This information may be less representative of the vegetation of the whole Adelaide Park Lands.

Priority has been given to plant species present in the greatest number of parks. Characteristics of the locally endemic species found in most of the parks in the Adelaide Park Lands are outlined in Sections 5.1 and 5.2.

5.1 Botanical characteristics of the dominant, locally endemic species in the Adelaide Park Lands

5.1.1 *Eucalyptus camaldulensis* (river red gum) (CSIRO n.d.)	
Present in 19 of the 21 parks of the Adelaide Park Lands.	
Family:	Myrtaceae
Origin:	All regions of mainland Australia and South Australia (SA) except the Nullarbor.
Botanical description:	*E. camaldulensis* (Figure 2) is a medium to tall tree with a single stem. It can reach heights of 30 to 45 m and could reach great ages of up to 1000 years. *E. camaldulensis* is large-boled with smooth white or grey bark. The tree is a perennial and has lance-shaped blue-grey leaves. Flowering occurs in late spring and summer.
Habitat and distribution:	Commonly found on riverine sites, in the channels of sandy watercourses and creeks. *E. camaldulensis* is widely spread over the Australian mainland with a few exceptions: southern Western Australia, south-western South Australia and coastal eastern Queensland, New South Wales and Victoria.
Application in landscaping:	Excellent large park tree, providing shade, a strong skyline feature and silhouette (Adelaide Advanced Trees Nursery, n.d.).

5.1.2 *Callitris gracilis* (slender cypress-pine) (Dept. of primary industries Victoria, 2009)	
Present in 14 of the 21 parks of the Adelaide Park Lands.	
Family:	Cupressaceae
Origin:	SA, New South Wales (NSW) and Victoria (Vic).
Botanical description:	*C. gracilis* (Figure 3) is a small to medium tree, up to 20 m in height, conical in shape with a single trunk. The bark is dark grey, fissured in an irregular way and continues onto the branches of the tree. The branches are erect to spreading and carry dark green foliage of fine thread-like leaves.
Habitat and distribution:	*C. gracilis* occurs most frequently in woodlands and mallee open scrub and is often found in association with eucalypts. The natural distribution of this small tree is across southern Australia and northern Victoria. C. gracilis prefers well drained, deep sandy to sandy loam soils and an annual rainfall of 250 – 500 mm.
Application in landscaping:	Best used in areas for windbreaks, roadside plantings and shade (Adelaide Advanced Trees Nursery, n.d.).

Figure 2: Eucalyptus camaldulensis (A, B: Australian National Botanic Gardens, Photographer: Murray Fagg)

Figure 3: Callitris gracilis (Photographer: Joan Gibbs, 2012)

5.1.3 *Acacia pycnantha* (golden wattle) (Australian Native Plant Society (Australia), Florabank)

Present in 13 of the 21 parks of the Adelaide Park Lands.	
Family:	Mimosaceae
Origin:	All states in Australia except WA and Tasmania (Tas).
Botanical description:	*A. Pycnantha* (Figure 4) is a small tree of between 5 and 8 m. Flowering occurs from winter to late spring, when bright yellow clusters of globular-shaped flowers appear.
Habitat and distribution:	*A. pycnantha* prefers a well-drained site with calcareous sands, clays or shallow stony loams. Occurs where annual rainfall is around 200 to 850 mm. *A. pycnantha* prefers open forest and woodland, or rocky ridge tops.
Application in landscaping:	*Acacias* grow very fast and are useful for revegetation of degraded areas (Gardening Australia, n.d.).

5.1.4 *Eucalyptus leucoxylon ssp.leucoxylon* (South Australian blue gum) (Holiday, 2005)

Present in 13 of the 21 parks of the Adelaide Park Lands.	
Family:	Myrtaceae
Origin:	SA and Vic
Botanical description:	*E. leucoxylon* (Figure 5) is a medium sized tree reaching 14 to 28 m in height. Bark is retained on lower trunk, but branches and upper trunk are smooth-barked and cream to grey in colour. Adult leaves are lance-shaped. Cream, pink or red flowers appear, usually in threes from autumn through to late spring.
Habitat and distribution:	Common in South Australia and western Victoria. *E. leucoxylon* prefers dry summers and is tolerant of a variety of soil types, but prefers heavy-textured clay soils.
Application in landscaping:	*E. leucoxylon* is fast growing and long flowering making it very suitable for areas requiring shade and interest (Flowers and Colmer, Adelaide Advanced Trees Nursery, n.d.).

Figure 4: Acacia pycnantha (PlantNET and the Royal Botanic Gardens and Domain Trust, photographer: Murray Fagg)

Figure 5: Eucalyptus leucoxylon (Australian Native Plant Society; Photographer: Brian Walters)

5.1.5 *Allocasuarina verticillata* (drooping she-oak) (Holiday 2005; Florabank)

Present in 12 of the 21 parks of the Adelaide Park Lands.

Family:	Casuarinaceae
Origin:	SA, NSW, Vic and Tas
Botanical description:	*A. verticillata* (Figure 6) is an evergreen tree growing 5 – 10 m tall. The tree has a single trunk with dark grey persistent bark. The dense needle-like branches droop and are dark green in colour. The leaves are reduced to insignificant whorls encircling the branches at regular intervals.
Habitat and distribution:	*A. verticillata* occurs along the south coast of Australia, from the Eyre Peninsula across to NSW. This tree grows in a variety of soils and in a wide range of habitats from Coastal plains to rocky inland outcrops. *A. verticillata* blooms during winter .
Application in landscaping:	The smaller stature of this tree makes it suitable for smaller parks (Adelaide Advanced Trees Nursery, n.d.).

5.1.6 *Chloris truncata* (windmill grass) (Bennett & Mitchell 2006; Dept of Primary industries)

Present in 12 of the 21 parks of the Adelaide Park Lands.

Family:	Poaceae
Origin:	All Australian states except Northern Territories (NT) and Tas.
Botanical description:	*C. truncata* (Figure 7) is a perennial, short-lived tufted grass, 16-45 cm tall. The plants have small fibrous leaves that are narrow and pale green in colour. The inflorescence has 5 – 13 radiating spikes resembling a windmill. Flowers appear from late winter till autumn.
Habitat and distribution:	Common to all but NT mainland states of Australia, *C. truncata* occurs in a variety of soils but prefers red earths and grey clays.
Application in landscaping:	Great for use in sunny rocky areas. It can be useful for stabilising eroded or scalded areas (SALTdeck Series, 2006).

Figure 6: Allocasuarina verticillata (Photographer Fatemah Kazemi, 2012)

Figure 7: Windmill Grass - Chloris truncata (© Geoff Sanity)

5.1.7 *Acacia ligulata* (sandhill wattle/"umbrella bush") (Holiday 2005; Florabank)	
Present in 9 of the 21 parks of the Adelaide Park Lands.	
Family:	Mimosaceae
Origin:	SA, parts of WA and NT.
Botanical description:	*A. ligulata* (Figure 8) is a shrubby species of native willow of up to 5 m tall with drooping willowy branches which provide abundant shade. *A. ligulata* flowers from August to November with massed orange-yellow flower balls surrounded by phyllodes which are very variable in length.
Habitat and distribution:	Widespread in the dry inland regions. *A. ligulata* favours alkaline soils on inland and coastal sand dunes. It can also be found on the banks of inland salt lakes and floodplains.
Application in landscaping:	*A. ligulata* can be used to revegetate disturbed soil.

5.1.8 *Atriplex semibaccata* (berry saltbush) (AWI & CRC Salinity 2006; Botanic Gardens Trust)	
Present in 9 of the 21 parks of the Adelaide Park Lands.	
Family:	Chenopodiaceae
Origin:	All Australian states except NT.
Botanical description:	*A. semibaccata* (Figure 9) is a prostrate perennial shrub up to 40 cm high, with diamond-shaped succulent leaves. The leaves provide food for the larva of *Theclinesthes serpentata serpentata*. Small flowers cluster at the axils of the grey green leaves in summer.
Habitat and distribution:	Native to most of Australia. It is usually found under trees in remnant grasslands and has a moderate tolerance to salinity.
Application in landscaping:	*A. semibaccata* does well in shady areas (Murray, 2007)

Figure 8: Acacia ligulata (PlantNET and the Royal Botanic Gardens and Domain Trust, photographer: T. M. Tame)

Figure 9: Atriplex semibaccata (A & B: Lotte Von Richter, The Australian Botanic Garden, Mount Annan)

5.1.9 Austrodanthonia sp. (wallaby grass) (Native Seeds Pty. Ltd.; Dept. of Primary Industries Victoria)	
Present in 9 of the 21 parks of the Adelaide Park Lands.	
Family:	Gramineae
Origin:	Various species from all over Australia
Botanical description:	Typically, *Austrodanthonia* (Figure 10) is a tussocky perennial grass with tall tufted stems, up to 90cm in height. The leaves are fine and flat or loosely in-rolled and can range from hairy to smooth. The variability depends on their specific localised environment. The flowers appear in spring or autumn.
Habitat and distribution:	There are about 30 species of wallaby grass in Australia. They occur commonly on roadsides in all states except NT. Most species have a low tolerance for water logging, and prefer medium clays to light sandy loams.
Application in landscaping:	*Austrodanthonia* is quick to establish making it useful for areas that need to be revegetated quickly (Florabank, n.d.).

5.1.10 Callistemon sp. (bottlebrush) (Australian Native Plants Society; Australian National Botanic Gardens Herbarium; FloraOnline; Holiday, I 2005)	
Present in 8 of the 21 parks of the Adelaide Park Lands.	
Family:	Myrtaceae
Origin:	SA, NSW, Vic and WA.
Botanical description:	*Callistemon* (Figure 11) are closely related to the paperbark melaleucas and are often easily confused for each other. Most Callistemon species are small to medium shrubs and some are prostrate. The showy bottlebrush shaped flowers appear from October to early December, and sometimes again in autumn. Each flower produces a small woody fruit containing hundreds of tiny seeds.
Habitat and distribution:	*Callistemon* occur in SE Australia, some in South West of Western Australia and some in New Caledonia. They are often found along watercourses and along swamp boundaries. *Callistemon* species prefer open forest or woodland in relatively high rainfall areas.
Application in landscaping:	Application in landscaping: All species of *Callistemon* are excellent for bird attracting and once established, require little watering. *Callistemon* are also able to withstand extended periods of water logging (Adelaide Advanced Trees Nursery, n.d.).

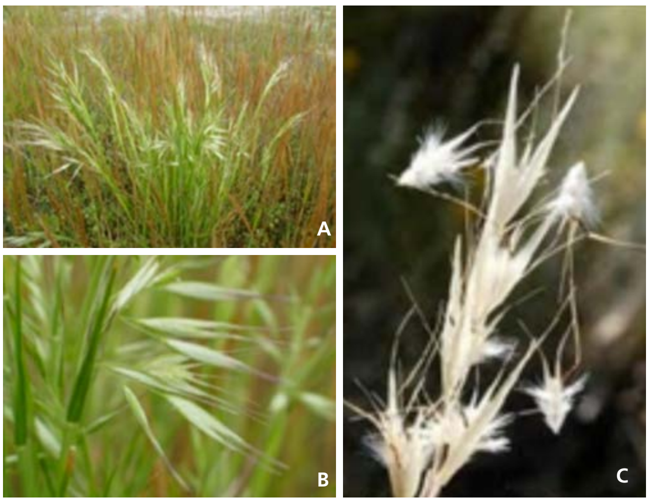

Figure 10: Austrodanthonia sp. (A & B: © State of Victoria, Dept. of Primary Industries, Victorian Resources online: www.dpi.vic.gov.au/vro, photographer: A.J. Brown. Reproduced with permission; C: © FloraPhoto)

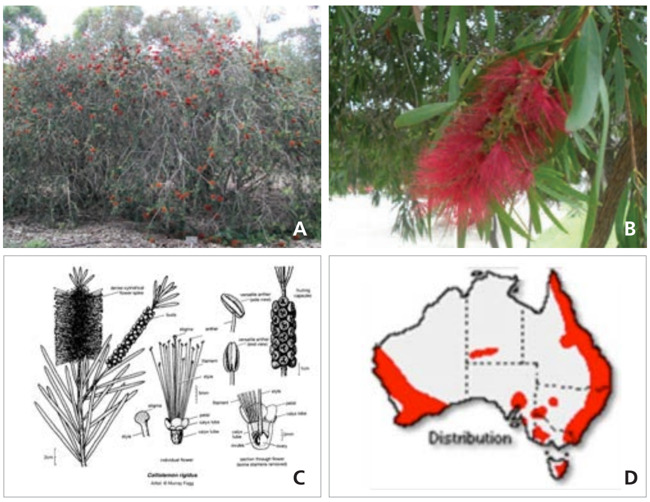

Figure 11: Callistemon sp. (A & B: Photographer: Fatemah Kazemi, 2012; C & D: Australian National Botanic Gardens, Photographer: Murray Fagg)

5.1.11 Maireana enchylaenoides (wingless bluebush) (Victorian Flora; PlantNET, FloraOnline)

Present in 8 of the 21 parks of the Adelaide Park Lands.

Family:	Chenopodiaceae
Origin:	All Australian states except NT and Tas.
Botanical description:	*Maireana enchylaenoides* (Figure 12) is a small (30-60 cm) perennial herb with narrow, oblong-shaped hairy leaves. *Maireana* flowers in summer and the fruits appear from September to March and are covered by crescent-shaped wings that overlap each other.
Habitat and distribution:	Usually found in box woodland, *M. enchylaenoides* is tolerant to dry and saline conditions.
Application in landscaping:	*M. enchylaenoides* is considered disturbance resistant, so may be useful in high traffic areas or areas of possible animal disturbance (Department of the Environment and Water Resources, 2007).

5.1.12 Oxalis perennans (native sorrel) (Hardin 1991; vonRichter; Botanic Gardens Trust; PlantNET)

Present in 8 of the 21 parks of the Adelaide Park Lands.

Family:	Oxalidaceae
Origin:	All states of Australia
Botanical description:	*Oxalis perennans* (Figure 13) is a herb with often upright and branches or sometimes creeping branches of up to 25 cm long. The branches are sparsely to densely hairy. Yellow flowers appear from February to December. Mature plants resprout after fire.
Habitat and distribution:	*O. perennans* is widespread, usually on heavy-textured soils. It is often found on woodland and disturbed sites.
Application in landscaping:	Excellent groundcover that spreads quickly. Monitor the spread though, it may become weedy. *O. perennans* is considered to be disturbance resistant, and is useful in high traffic areas where it may occasionally experience foot traffic and animal disturbance (Department of the Environment and Water Resources, 2007).

Figure 12: Maireana enchylaenoides (PlantNET and the Royal Botanic Gardens and Domain Trust)

Figure 13: Oxalis perennans (Hardin 1991; L. vonRichter; PlantNET and Royal Botanic Gardens and Domain Trust)

5.1.13 Typha domingensis (narrow-leaf Cumbungi)(Botanic Gardens Trust)

Present in 8 of the 21 parks of the Adelaide Park Lands.	
Family:	Typhaceae
Origin:	All states of Australia
Botanical description:	*T. domingensis* (Figure 14) is a robust aquatic herb growing up to 2 m high. The flowers appear from November to May and have the male and female flowers on one long spike. The fruit is a small one-seeded follicle surrounded by silky hairs. The leaves are long and narrow, erect and grass-like. *T. domingensis* provides habitat for the Eastern dwarf treefrog and the leaves and stems of the plants are eaten by the black swan and freckled duck.
Habitat and distribution:	*T. domingensis* is occasionally found in lakes and is a coloniser of wet muddy areas.
Application in landscaping:	Good for use around ponds and in lower areas wetter areas. *T. domingensis* could also be used in a teaching garden as it is used in bush tucker (South East Regional Centre for Urban Landcare, n.d.).

Figure 14: Typha domingensis (L. von Richter, PlantNET and Royal Botanic Gardens and Domain Trust)

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5.2 Characteristics of turf grasses

Large areas of the Adelaide Park Lands are dedicated to sports playing fields and golf courses. Approximately a third to a half of all irrigation water for an urban area is used on turf (Handreck and Black, 1986). Turf grasses prefer infrequent, deep watering which encourages deep root growth, thereby increasing water storage area (Handreck and Black, 1986). Shading by deep tap rooted trees or buildings is another method of reducing the need for excessive watering on turf park areas (Handreck and Black, 1986).

The predominant turf grasses in the Adelaide Park Lands are Kikuyu (*Pennisetum clandestinum*), Couch Grass (*Cynodon spp.*) and Bentgrass (*Agrostis tenuis*)(REM and SRHS, 2007).

As Handreck and Black (1986) and Neylan (Neylan, 2005) explain, warm-season turf grasses such as *P. clandestinum* and *Cynodon* are more efficient water users than cool-season turf grasses. It is however, important to complement the warm season grasses by over-seeding with a cool season grass such as *A. tenuis* in order to maintain a reasonable turf cover during the colder seasons (Neylan, 2005). All three of these grasses have a moderate tolerance to salinity (if not waterlogged). Their tolerance to water logging is also moderate (Moore, 2006). These characteristics make them a sustainable and durable option for turf grasses in the high traffic grassed areas of the Adelaide Park Lands where recycled wastewater will be used for irrigation.

5.2.1 Characteristics of Pennisetum clandestinum (Kikuyu grass)

Family:	Poaceae
Origin:	Central African highlands – Kenya & Ethiopia
Botanical description:	*P. clandestinum* (Figure 15) is a coarse textured, light green prostrate grass that forms a dense turf. The plant spreads easily via rhizomes and vigorous stolons. Flowering is inconspicuous with the seed heads concealed within a leaf sheath (Moore, 2006)
Habitat and distribution:	*P. clandestinum* prefers a high rainfall of 1,000 mm+. It tolerates occasional frost and occurs in sub-tropical areas with mild temperatures.
Application in landscaping:	Used for dairy cow pasture; is tolerant of heavy grazing; is highly sought after as playing field turf or golf courses (Moore, 2006).

Figure 15: Pennisetum clandestinum (© J Gibbs, 2005)

5.2.2 Characteristics of *Cynodon spp.* (Couch grass)

Family:	Poaceae
Origin:	Southern Africa and South East Asia
Botanical description:	*Cynodon* (Figure 16) is a prostrate creeping grass, which spreads via rhizomes and stolons. The leaves are fine and between 2-5 cm in length (Moore, 2006). The seed heads are finger-like and turn purple or red after flowering (Moore, 2006).
Habitat and distribution:	*Cynodon spp.* prefers warm temperate climates with a daily mean of about 24 °C. This grass particularly prefers well drained coarse-textured soils. *Cynodon* is widely used across the United States for grazing.
Application in landscaping:	Used widely as lawns and occasionally as grazing, although it appears less palatable with age (Moore, 2006).

5.2.3 Characteristics of *Agrostis palustris syn. A. stolonifera* (Creeping bentgrass)

Family:	Poaceae
Origin:	Eurasia and North Africa (Hannaway and Larson, 2004)
Botanical description:	*A. palustris* (Figure 17) is a cool season creeping bentgrass. This perennial grass spreads by above-ground stems that grow vigorously. *A. palustris* flowers occur in late spring or early summer. The flowers are compressed panicles that are purplish in colour and only have one floret each (Hannaway and Larson, 2004).
Habitat and distribution:	*A. palustris* prefers moist fertile and poorly drained soils. This grass is moderately tolerant to drought and can easily stand submergence and frequent flooding. *A. palustris* prefers cool slightly humid areas (Hannaway and Larson, 2004).
Application in landscaping:	*Agrostis* is used as a winter lawn and turf grass to compliment the warm season grasses. It should be cut frequently to a fairly short length in order to thrive (Hannaway and Larson, 2004).

Figure 16: Cynodon dactylon (PlantNET, Royal Botanic Gardens and Domain Trust)

Figure 17: Agrostis stolonifera (A: Photographer: Daniel Olsen. www.Better-Lawn-Care.com. B: PlantNET, Royal Botanic Gardens and Domain Trust)

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6. Key potential environmental effects of using glenelg recycled water in the Adelaide park lands

The average salinity of the Glenelg wastewater is reported to be 1200 mg/L which is lower than that of the current irrigation water used on the Southern Park Lands (salinity 1300 to 1500 mg/L) (REM et al., 2008). The 1200 mg/L is, however, higher than that of normal tap water and can potentially have negative environmental effects on the plants, soil and groundwater of the Adelaide Park Lands. These effects have been outlined by Resource and Environmental Management Pty Ltd (REM), Scholefield Robinson Horticultural Services (SRHS) and Sunraysia Environmental (SE) (REM et al., 2008). For ease of reference, selected sections have been attached as Appendix 1.

The investigations suggested by REM and SRHS (2007) supported the development of an adaptive management framework and a conceptual irrigation management plan. This framework was prepared by REM, SRHS & SE in 2008 and described as the preferred choice for natural resource management (Figure 18).

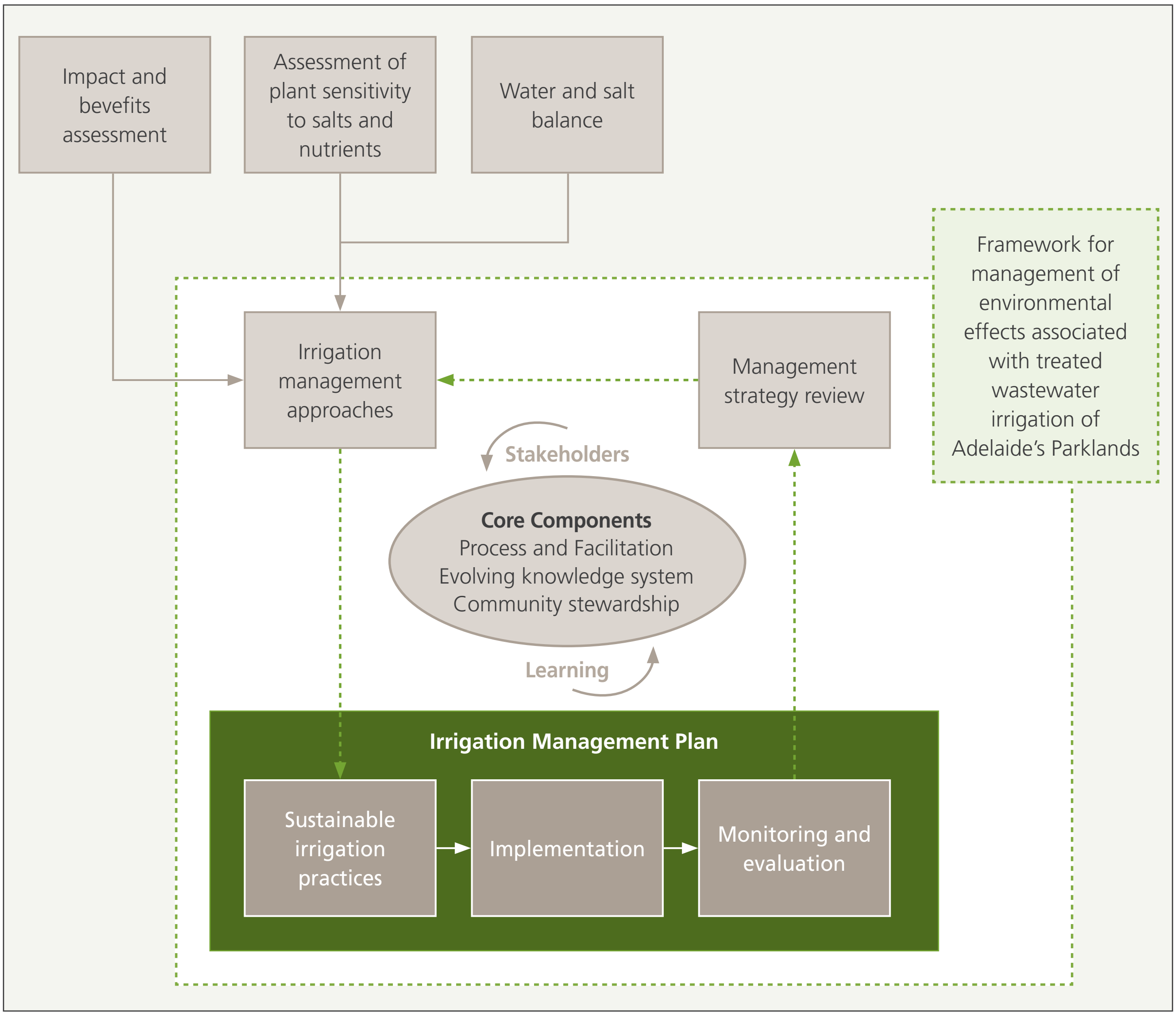

Figure 18: Adaptive management framework for the Adelaide Park Lands (REM et al., 2008)

A requirement of the adaptive management framework laid out above, is an assessment of the current available knowledge on the sensitivity and responses of the Adelaide Park Lands plant species to specific salts and nutrients in the treated wastewater. An informed understanding of any limitations should allow for the development of a sustainable irrigation management plan that will increase the probability of the survival and healthy development of the plants used in revegetation. The use of recycled wastewater has been identified as a potential sustainable irrigation practice, one of the management approaches identified in Figure 18.

6.1. Recycled wastewater

Recycled wastewater may potentially contain levels of chemicals deleterious to vegetation and the environment. It is important to set chemical parameters when preparing guidelines for the use of recycled water for irrigation purposes (Salgot et al., 2006). The South Australian Department of Health has approved treated wastewater from the Glenelg Waste Water Treatment Plant for unrestricted irrigation use (REM et al., 2008).

The most common toxic elements in wastewater are Sodium, Chloride and Boron. The variation of these elements in the Glenelg recycled wastewater is shown in Table 1.

Table 1: Summary of Glenelg recycled wastewater quality in 2005 (REM and SRHS, 2007)

	Sodium (mg/l)	**Chloride** (mg/l)	**Boron** (mg/l)
Maximum	299	437	0.61
Minimum	205	310	0.258
Median	231.5	353	0.3835
Average	242.08	363.83	0.40

For landscaping purposes, the waste characteristics of importance are those chemical elements and compounds that may have an effect on the growth of plants and the structure and permeability of the soil (Pedrero et al., 2010). Although low concentrations of certain chemicals may not have immediate and obvious toxic effects on vegetation or the structure of the soil, bioaccumulation may occur, causing long-term chronic effects (Salgot et al., 2006). Continued irrigation using recycled water, could over time exceed the soil's adsorption capacity for salts (Nable et al., 1997). Particularly during dry seasons when there are few rainfall events which could leach the salts from the soil.

Common laboratory determinations used for the evaluation of irrigation water quality are given in Table 2 (Pedrero et al., 2010). In the adaptive management report developed by REM et al. (2008) the effects of sodium, chloride and boron on certain fruit trees and vegetables is briefly discussed. Their findings suggest that turf grasses and native vegetation may be tolerant to these elements. This report focuses on the effects of salinity on specific plant species found within the Adelaide Park Lands, as well as their tolerance to sodium, chloride and boron.

It is important to note that not all conditions and situations specific to each locality can be covered in any given set of general guidelines (Pedrero et al., 2010). Different soils, drainage, irrigation methods and amount of shade will influence the long-term effects of salinity, chemical elements and chemical compounds on the vegetation.

Soil structure can be affected by excess sodium in irrigation water (Pedrero et al., 2010) which reduces soil aeration and water filtration rates. This, in turn, leads to water logging, excess runoff and restricted root growth (Stevens et al., 2008).

Table 2: Laboratory determinations used to evaluate common irrigation water quality problems (Pedrero et al., 2010)

Parameter	Symbol	Unit
Salinity		
Electrical conductivity	ECw	dS/m
Total dissolved solids	TDS	mg/l
Cations and anions		
Calcium	Ca^{2+}	mg/l
Magnesium	Mg^{2+}	mg/l
Sodium	**Na^{+}**	**mg/l**
Carbonate	$CO3^{2-}$	mg/l
Bicarbonate	$HCO3^{-}$	mg/l
Chloride	**Cl^{-}**	**mg/l**
Sulfate	$SO4^{-}$	mg/l
Miscellaneous		
Boron	**B**	**mg/l**
Hydrogen ion activity	pH	unit
Sodium adsorption ratio	SAR	dimensionless

Ongoing foliar irrigation can lead to toxic levels of sodium, chloride and boron in the leaves of plants. Although all species respond differently to foliar irrigation application, generally, the amount of foliar damage is in direct proportion to the frequency of sprinkler treatment (Devitt et al., 2003). An excess of any irrigation can cause water logging and secondary salinity (Stevens et al., 2008). Stevens et al. (2008) also note that excess groundwater recharge often results in a rise in the water table, causing salinity problems.

General toxic effects and symptoms of excessive salinity, chloride, sodium and boron are discussed below. The average main element concentrations in the Glenelg recycled wastewater are given in Table 3. The variation of concentration of these elements, coupled with irrigation application rate and the other management measures are important for long term sustainable irrigation.

Table 3: Annual average concentration of some main elements in Glenelg recycled wastewater (REM et al., 2008)

Parameter	Annual Average	Unit
Chloride	389	(mg/l)
Boron	0.281	(mg/l)
Sodium	261	(mg/l)
SAR	7.50	
Total N	15.8	(mg/l)
Total P	6.74	(mg/l)
EC	1.8	(dS/m)
Temp	23.4	(C°)

6.2 General toxic effects of salinity on plants

The level of salt accumulation within the soil depends on a number of different factors: physical and chemical characteristics of the soil; annual precipitation level; evapotranspiration; the quantity of annual water application and most importantly, the concentration of salts in the irrigation water (Lazarova and Bahri, 2005).

When the levels of dissolved salts are high in the soil, additional energy is required for plants to take up water from this medium. The increased osmotic pressure of salty soil water is the reason for this higher demand on the plant's energy resources. The follow on effect is an increase in plant respiration, thereby progressively reducing the growth and yield of the plant (Lazarova and Bahri, 2005).

Symptoms of salinity stress are similar in most plant species. These symptoms include leaf scorching, (Figures 19 & 20) mottling or shedding and twig dieback in angiosperms (Kozlowski, 1997, Azza, Mazher et al., 2007). In gymnosperms the symptoms are slightly different, including necrosis of the needle tips; needle shedding and shoot dieback (Kozlowski, 1997).

Each plant species has a specific salinity tolerance level above which the growth and productivity of the plant is affected (Niu and Rodriguez, 2006, Azza Mazher et al., 2007). Halophytes which occur naturally in saline conditions are often not as badly affected as non-halophytes which may die more readily under excessively saline conditions. Environmental conditions may also have an effect on each species' response to salinity (Niu and Rodriguez, 2006). In general excessive salinity inhibits vegetative and reproductive growth and sometimes induces changes to plant morphology and anatomy.

Figure 19: Salt toxicity symptoms include leaf chlorosis and necrosis of tips and margins in Celtis Australis (Costello et al., 2003 Source: Nelda Matheny, HortScience, Inc., Pleasanton, CA, USA)

6.3 Toxic effects of sodium on plants

Soil that has an excess of sodium may exhibit changes in soil structure. These changes could reduce the rate of water infiltration and aeration of the soil. This in turn reduces the water available for uptake by plants and could also (Pedrero et al., 2010) increase the amount of sodium taken up in the water by plants. Many plants are naturally able to exclude sodium uptake via their roots (Stevens et al., 2008), however these plants can still suffer from sodium toxicity as the leaves are able to absorb sodium from sprinkler irrigation water.

The toxic effects of sodium accumulation in plants are evidenced by leaf mottling and necrotic patches (Figure 21) on the leaves (Kozlowski, 1997, Stevens et al., 2008). High levels of sodium also cause damage to the root cells (Handreck and Black, 2002) and can interfere with the photosynthetic processes of the plant (Department of Agriculture and Food, 1999). Woody plants are particularly vulnerable to the toxic effects of sodium as the symptoms are not seen for some time (Stevens et al., 2008) since the excess sodium accumulates in the roots and trunk.

The uptake of essential macronutrients by the plant can also be affected when high levels of sodium are present in the soil (Stevens et al., 2008). These nutrients, such as potassium and calcium enable the plant to select which substances are absorbed through the roots.

6.4 Toxic effects of chloride on plants

Chloride is an essential micro-nutrient required in small quantities by all plants (Stevens et al., 2008). It is also one of the most common phytotoxins which is typically absorbed through the roots of the plant. However, it can also be absorbed through the plant leaves, and this speeds up the rate of toxic accumulation of the ion (Lazarova and Bahri, 2005). The toxicity level of chloride ions will be specific to each plant or plant group, and should be considered on an individual basis (Wu et al., 1995, Kozlowski, 1997, Lazarova and Bahri, 2005). Generally, woody plants are more susceptible to chloride toxicity (Stevens et al., 2008).

Figure 20: Toxic effects of salinity on leaves (Las Pilitas Nursery, n.d.) Used with permission of Laspilitas.com http://www.laspilitas.com/advanced/advsoils.htm

Figure 21: Necrotic patches caused by sodium toxicity on a grape vine (PIRSA, n.d.) Photo supplied by Joanne Pech, South Australian Research and Development Institute (SARDI)

Visible symptoms of chloride toxicity usually appear before those of sodium or boron (Kozlowski, 1997, Azza Mazher et al., 2007). These symptoms include marginal chlorosis of the older leaves, followed by extensive leaf scorching (Figure 22), wilting and eventually defoliation (Stevens et al., 2008).

An indirect effect of excessive chloride levels is the prevention of absorption of essential nutrients such as nitrate and phosphates. Deficiencies in these nutrients lead to growth problems in plants (Stevens et al., 2008).

6.5 Toxic effects of boron on plants

Boron is an element required for good plant growth (Lazarova and Bahri, 2005). The range between acceptable and toxic levels of boron is quite small (Stevens et al., 2008) and plants respond differently to specific levels of boron. These toxic levels of boron do not often occur in arable soil, making it necessary to ensure the water used has minimal levels of boron. Plants are able to withstand higher soil boron levels in soils with a pH range of 7.5-9.5 (Stevens et al., 2008). Another factor influencing increased uptake of boron is the method of irrigation. Ben-Gal (2007) observed elevated boron levels in plants that had received foliar water application.

Foliar feeding is an effective method for correcting deficiencies and overcoming the soil's inability to transfer nutrients to the plant. Availability of essential nutrients and trace minerals from the soil may be limited at times by root distribution, soil temperature, soil moisture, nutrient imbalances and other factors. Foliar feeding can help maintain a nutrient balance within the plant, which may not occur strictly with soil uptake.

A project conducted at Michigan State University, using radioactive tagged nutrients, proved that foliar feeding can be 8 to 10 times more effective than soil feeding. Foliar feeding stimulates an increase in chlorophyll production, cellular activity and respiration (U.S Ag, L L C. n.d).

The visible symptoms of toxic levels of boron are typically leaf burn and necrotic patches (Figure 23) on the margins and tips of older leaves (Nable et al., 1997, Stevens et al., 2008).

Figure 22: Evidence of chloride toxicity in an Aspen (Goodrich and Jacobi, 2007/2008)

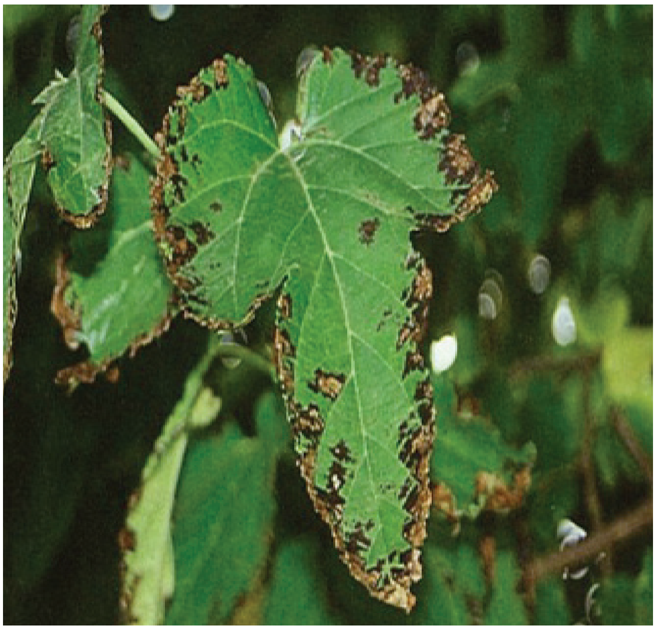

Figure 23: Boron toxicity causes dark, necrotic areas along the leaf margins in white mulbury (Morus alba) (Costello et al., 2003 Source: Nelda Matheny, HortScience, Inc., Pleasanton, CA, USA)

Other less typical symptoms are yield reductions (Stevens et al., 2008) bark necrosis and fruit disorders (Nable et al., 1997).

6.6 Effects of water logging on plants

Water logging has different effects on different plant species. The effects also vary depending on the salinity of the soil and water surrounding the plant. Kozlowski (1997) explains in great detail multiple physical and physiological effects of water logging on woody plants. Succinctly put, plant growth, reproduction and photosynthetic capabilities are all adversely affected by water logging. In addition, plants that have experienced water logging become more prone to drought because of their shallow and small roots (Kozlowski, 1997).

As Barrett-Lennard (2003) pointed out, the increased water uptake under waterlogged conditions also increases the salt ion uptake in the plant. These higher concentrations of ions have adverse effects on plant growth and reproduction, as discussed in the paragraphs above. Yet other plants suffer from leaf or needle dehydration as the stomata are closed in response to elevated water pressure on the root systems (Lewty, 1990). Water logging also affects plant aeration, root penetration and root distribution.

Visual evidence of water logging can be leaf tip burn, severe wilting and evidence of mildew. This discussion is evidence of the range of responses to water logging by different plant species. Once again, it is important to have information specific to the species found within the Adelaide Park Lands. The soils of most of the Park Lands are drained relatively freely, with the exception of a few areas where ponding occurs in low depressions and swales during severe storm events (REM and SRHS, 2007).

7. Management measures of salinity

7.1 Characteristics and physiology of salt-tolerant plants

Plants that naturally grow in salty conditions are known as halophytes. This group of plants have physical characteristics that allow them to thrive in saline conditions. These characteristics manifest themselves in a number of different ways (Seaman, Van Sengbusch 2003) depending on the genetics and physiology of the species. However, a few generalisations can be made. Most halophytes are succulents and often have vacuoles (Flowers and Colmer, 2008) or salt glands which are able to store sodium, isolating it from vital cellular functions (Hannink, 2005). These vacuoles then secrete the salt when it reaches unacceptable levels within the plant tissue. Leaf succulence allows the plant to store larger volumes of water, in order to dilute the salt concentrations within the plasma (Van Sengbusch, 2003). Other plants have very efficient root filtering mechanics, preventing the sodium from entering the vascular system of the plant (Flowers and Colmer, 2008). Examples of efficient root filtering plants are types of grasses (Van Sengbusch, 2003). One of the essentials required by a salt tolerant plant is the ability to maintain low cytosolic (fluid component of cytoplasm) sodium concentrations (Seaman, n.d.). In summary, homeostasis, detoxification and growth control are the three interconnected physiological mechanisms that facilitate salt tolerance in plants (Seaman, n.d.). Bernstein and Hayward (1958) also suggest that deeper-rooted species as well as those that use water efficiently during dry periods are more salt tolerant. Succulence is one of the few visible characteristic of salt tolerance, making it difficult to make suitable plant selections without a full understanding of the preferred habitat of all plant species available.

Table 4: Irrigation water quality guidelines (Ayers and Westcot, 1994)

Laboratory determinations needed to evaluate common irrigation water quality problems			
Water parameter	**Symbol**	**Usual range in irrigation water**	**Unit**
Salinity			
Salt Content			
Electrical Conductivity	EC_W	0 - 3	dS/m
(or)			
Total Dissolved Solids	TDS	0 - 2000	mg/1
Cations and Anions			
Calcium	Ca^{++}	0 - 20	me/1
Magnesium	Mg^{++}	0 - 5	me/1
Sodium	Na^{+}	0 - 40	me/1
Carbonate	CO^{--}_3	0 - 0.1	me/1
Bicarbonate	HCO_3	0 - 10	me/1
Chloride	Cl^{-}	0 - 30	me/1
Sulphate	SO_4^{--}	0 - 20	me/1
Nutrients[2]			
Nitrate-Nitrogen	NO_3-N	0 - 10	mg/1
Ammonium-Nitrogen	NH_4-N	0 - 5	mg/1
Phosphate-Phosphorus	PO_4-P	0 - 2	mg/1
Potassium	K^{+}	0 - 2	mg/1
Miscellaneous			
Boron	B	0 - 2	mg/1
Acid/Basicity	pH	6.0 - 8.5	
Sodium Adsorption Ratio	SAR	0 - 15	

7.2 Salinity control and management measures

The objective of salinity control is to maintain an acceptable crop yield or plant growth. Several management options are available for salinity control but in practice a combination may be used to solve the problem. Leaching salts out of the root zone before they build up to the levels that might affect yields, and maintaining adequate soil-water availability at all times are the two main solutions to overcome salinity problems. If drainage is adequate, the depth of water required for leaching depends on the salt sensitivity of the crop and the salinity level of the irrigated water. When salinity is high, the depth of the required leaching water may be too great, making it necessary to change planting to a more salt tolerant crop. Leaching is a basic step in production even for water of the best quality and must be practised when necessary to avoid salt accumulation that could ultimately affect plant growth. Leaching can only be done, however, if the drainage below the crop root zone is sufficient to prevent a rise in the water table so that it is not a source of salt by itself (Ayers and Westcot, 1994).

Drainage, leaching and changes to more salt tolerant crops are used to avoid the impact of long-term salinity build-up but other cultural practices may also be needed to deal with possible short-term or temporary increases in salinity which may be equally detrimental to crop yield and plant growth.

Many agricultural practices such as more frequent irrigation, land grading, timing of fertilization and methods of seeding make salinity management easier (Ayers and Westcot, 1994). In a few cases, an alternative water supply may be available for periodic use or can be blended with a poorer water supply to diminish a quality-related hazard. These alternatives, and drainage, leaching, cropping changes and other agricultural practices, are discussed in more detail in Ayers and Westcot (1994).

In most soils with a shallow water table, water rises into the active root zone by capillarity, and if the water table contains salts, it becomes a continual source of salts to the root zone as water is used by the plant or evaporates at the soil surface. The rate of soil salinity accumulation from an uncontrolled shallow water table will depend upon irrigation management, salt concentration and depth of the groundwater, soil type, and climatic conditions.

In arid and semi-arid climates, a salinity problem caused or complicated by poor drainage cannot be adequately controlled until the water table is stabilized and maintained at a safe depth, usually at least two metres. This requires open or tile drains or drainage wells to remove a part of the salty subsurface water and transport it to an acceptable salt-sink for safe disposal. When drainage is adequate, salinity related directly to water quality and irrigation management becomes a problem only if the salts applied with the irrigation water are allowed to accumulate to a concentration which reduces yield and plant growth. Effective salinity control, therefore, must include adequate drainage to control and stabilize the water table and leaching as needed to reduce the accumulated salts. A net downward flux of surface applied water to achieve the required leaching will then control the salinity (Ayers and Westcot, 1994). The annual average salt concentration in the Glenelg recycled wastewater is almost 1190-1200 mg/l or 1.8 dS/m. Although the salinity in normal irrigation water is expected to vary up to 3 dS/m, irrigation with Glenelg recycled wastewater with an irrigation application rate of 4.5ML/year-ha would cause annual accumulation of nearly 9 tonne/ha salts to the soil. In the absence of efficient irrigation management a salinity build up hazard would be problematic in the long term.

7.3 Salinity control by leaching

When the build-up of soluble salts in the soil is expected to become excessive, the salts can be leached by applying more water than that needed by the crop during the growing season. This extra water moves at least a portion of the salts below the root zone by deep percolation. Leaching is the key factor in controlling soluble salts brought in by the irrigation water. Over time, salt removal by leaching must equal or exceed the salt additions from the applied water or salts will build up and eventually reach damaging concentrations. The questions that arise are how much water should be used for leaching and when should leaching be applied?

To estimate the leaching requirement, both the irrigation water salinity (ECw) and the plant tolerance to soil salinity (ECe) must be known. The ECe or plant threshold should be estimated from appropriate plant tolerance data. For most agricultural plants the threshold data is identified but for most of the Park Land plants this has not yet been identified and more research work is needed.

The minimum leaching requirement needed to control salts within the tolerance (threshold level) of any particular plant is shown in Equation 1:

$$LR = \frac{Ecw}{5ECe - Ecw} \qquad (1)$$

Where LR is the minimum leaching requirement; ECw is the irrigation water salinity and ECe is the average soil salinity tolerated by the plant as measured on a soil saturation paste extract.

8. Toxicity problems and management measures

A toxicity problem is different from a salinity problem. It occurs within the plant itself and is not caused by a water shortage. Toxicity normally results when certain ions are taken up with the soil-water and accumulated in the leaves during water transpiration to an extent that results in damage to the plant. The degree of damage depends upon time, concentration, crop sensitivity and crop water use. The usual toxic ions in irrigation water are sodium, chloride, and boron. Damage can be caused by each, individually or in combination. Toxicity often accompanies or complicates a salinity or infiltration problem although it may appear even when salinity is low. The toxic ions sodium and chloride can also be absorbed directly into the plant through the leaves moistened during sprinkler irrigation. This occurs typically during periods of high temperature and low humidity. The leaf absorption speeds the rate of accumulation of a toxic ion and may be a primary source of the toxicity. Many trace elements, in addition to sodium, chloride and boron, are toxic to plants at very low concentrations (Ayers and Westcot, 1994). Absorption and toxicity occur mostly during periods of high temperature and low humidity (< 30 %), frequently aggravated by windy conditions. Obviously, the most effective method to prevent occurrence of a toxicity problem is to choose irrigation water that has no potential to develop a toxicity. Irrigation water quality guidelines are shown in Table 4. However, if such water is not available, or recycled wastewater is to be used for irrigation, there are often management options that can be adopted to reduce toxicity and improve yields. The potentially toxic ions sodium, chloride and boron can each be reduced by leaching in a manner similar to that for salinity, but the depth of water required varies with the toxic ion and may in some cases become excessive. Increasing the leaching or changing crops in an attempt to live with the higher levels of toxic ions may require extensive changes in the farming system. In cases where the toxicity problem is not too severe, relatively minor changes in cultural practices can minimize the impact. An alternative water supply may be available to blend with a poorer supply to lower the hazard from the low quality water (Ayers and Westcot, 1994).

8.1 Sodium toxicity

8.1.1 Characteristics and physiology of sodium-tolerant plants

Literature suggests no standard physiology or set of characteristics for sodium-tolerant plants. However, some features requiring laboratory analysis can be found in a number of plants that exhibit a tolerance to sodium. Although these features may be used as the possible suggestion of sodium-tolerance, plant-specific information should be obtained. Some of these features are described in the following paragraph.

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A higher proportion of root biomass could indicate higher sodium-tolerance in plants (Adrover et al., 2008). Plants exhibiting sodium tolerance are able to exclude ions at the point of uptake and/or reduce ion translocation to shoot apices (Adrover et al., 2008). Androver and Forss et al. (2008) cite further examples *(T. africana)* which have specialised ion excretion mechanisms, specifically selecting sodium for excretion.

A good indicator of sodium tolerance would be the presence of low sodium content in the plant leaves, in combination with high potassium content in the roots, stems and leaves (Adrover et al., 2008). Plant species that have high tissue calcium content in their leaves and stems would also be sodium-tolerant as calcium has been shown to neutralise the deleterious effects of various salts (Kozlowski, 1997).

8.1.2 Sodium toxicity management

Sodium toxicity is not as easily diagnosed as chloride toxicity, but clear cases of the former have been recorded as a result of relatively high sodium concentrations in the water (high Na or SAR). Typical toxicity symptoms are leaf burn, scorch and dead tissue along the outside edges of leaves in contrast to symptoms of chloride toxicity which normally occur initially at the extreme leaf tip. An extended period of time (many days or weeks) is normally required before accumulation reaches toxic concentrations. Symptoms appear first on the older leaves, starting at the outer edges and, as the severity increases, move progressively inward between the veins toward the leaf centre. Sensitive crops include deciduous fruits, nuts, citrus, avocados and beans, but there are many others. For tree crops, sodium in the leaf tissue in excess of 0.25 to 0.50 % (dry weight basis) is often associated with sodium toxicity. Leaf tissue analysis is commonly used to confirm or monitor sodium toxicity but a combination of soil, water and plant tissue analyses greatly increases the probability of a correct diagnosis. When using only leaf blade analysis to diagnose sodium toxicity, it is advisable to include analyses of leaf blades from damaged trees as well as separate analyses from nearby undamaged ones for comparative purposes. Sodium toxicity is often modified or reduced if sufficient calcium is available in the soil. Whether indicated sodium toxicity is a simple one or is more complicated involving a possible calcium deficiency or other interaction is presently being researched. Preliminary results indicate that for at least a few annual crops, calcium deficiency rather than sodium toxicity may be occurring. If confirmed, these crops should respond to calcium fertilization using material such as gypsum or calcium nitrate. Many crops do show sodium toxicity. The toxicity guidelines use SAR as the indicator of the potential for a sodium toxicity problem which is expected to develop following surface irrigation with a particular quality of water (Ayers and Westcot, 1994). The average sodium level in the Glenelg recycled wastewater is 261 mg/l and the amount of SAR is 7 (REM and SRHS, 2007). However, the sodium concentration in normal irrigation water is expected to be 0-920 mg/l. This shows that the sodium concentration in the Glenelg recycled wastewater is considerably below the maximum allowable level. However, it does not mean that accumulation of this toxic ion in the long term without considerable attention to sustainable irrigation management would not be a hazard for Adelaide Park Land plants, especially for those that are sensitive to sodium.

8.2 Chloride toxicity

8.2.1 Characteristics and physiology of chloride-tolerant plants

As with sodium-tolerance, there is no specific plant physiology that is typically chloride-tolerant. Rather, a number of characteristics have been found in plants exhibiting tolerance to chloride. Wu and Chen et al. (1995) gathered experimental evidence from a number of landscape plants in an attempt to discover differences in chloride tolerance and the reasons for these differences. Evidence of this testing on various landscape plants, suggests that plants with high concentrations of tissue calcium exhibit tolerance to chloride. Therefore, chloride-tolerance is positively correlated with tissue calcium percentages (Wu et al., 1995). The structural and functional integrity of plant and cell membranes depends in large part on the tissue calcium content of the plant (Wu et al., 1995).

Little research has been done on Australian landscape plants and it is important to have knowledge specific to each plant species, before assuming chloride tolerance.

8.2.2 Chloride toxicity management

The most common toxicity is from chloride in the irrigation water. Chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity), and progresses from the tip back along the edges as severity increases. Excessive necrosis (dead tissue) is often accompanied by early leaf drop or defoliation. With sensitive crops, these symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride on a dry weight basis. Many tree crops, for example, begin to show injury above 0.3 percent chloride (dry weight).Chemical analysis of plant tissue is commonly used to confirm a chloride toxicity. For irrigated areas, the chloride uptake depends not only on the water quality but also on the soil chloride, controlled by the amount of leaching that has taken place and the ability of the crop to exclude chloride. Crop tolerances to chloride are not nearly so well documented as crop tolerances to salinity. A chloride toxicity can occur by direct leaf absorption through leaves wet during overhead sprinkler irrigation. This occurs most frequently with the rotating type sprinkler heads (Ayers and Westcot, 1994). The average chloride level in the Glenelg recycled wastewater is 339 mg/l (REM and SRHS, 2007). While the chloride concentration in normal irrigation water is expected to be 0-1065 mg/l. This shows that the chloride concentration in the Glenelg recycled wastewater is considerably below the maximum allowable level. However, it does not mean that accumulation of this toxic ion in the long term without considerable attention to sustainable irrigation management would not be a hazard for the Adelaide Park Land plants, especially for those that are particularly sensitive to chloride.

8.3 Boron toxicity

8.3.1 Characteristics and physiology of boron-tolerant plants

Boron is seldom found in excess in most arable soils. Toxic levels of boron are usually related to soil types associated with low rainfall areas, amongst which are the dry lands of South Australia (Nable et al., 1997) as well as marine sediment soils (Muntean, Nable et al., 1997). The difference between required quantities and toxic quantities of boron for plants is very small. As with sodium and chloride, boron-tolerance is specific to individual species and to the water application method. A few predictors exist such as higher boron measurements in plant leaves as a result of foliar water application (Ben-Gal, 2007).

Research suggests that boron tolerance is at a genetic and cellular level (Nable et al., 1997). For example, differences in phloem mobility result in different accumulations of boron in the leaves, fruit and cambial tissue of a plant (Nable et al., 1997). It is therefore difficult to identify boron-tolerant plants from any physiological attribute.

8.3.2 Boron toxicity management

Boron, unlike sodium, is an essential element for plant growth. Chloride is also essential but in such small quantities that it is frequently classed non-essential. Boron is needed in relatively small amounts, however, and if present in amounts appreciably greater than needed, it becomes toxic. For some crops, if 0.2 mg/l boron in water is essential, 1 to 2 mg/l may be toxic. Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. Boron problems originating from the water are probably more frequent than those originating in the soil. Boron toxicity can affect nearly all crops but, like salinity, there is a wide range of tolerance among crops. Boron toxicity symptoms normally show first on older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges.

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Drying and chlorosis often progresses toward the centre between the veins (interveinal) as more and more boron accumulates with time. On seriously affected trees, such as almonds and other tree crops which do not show typical leaf symptoms, a gum or exudate on limbs or trunk is often noticeable. Most crop toxicity symptoms occur after boron concentrations in leaf blades exceed 250–300 mg/kg (dry weight) but not all sensitive crops accumulate boron in leaf blades. For example, stone fruits (peaches, plums, almonds, etc.), and pome fruits (apples, pears and others) are easily damaged by boron but they do not accumulate sufficient boron in the leaf tissue for leaf analysis to be a reliable diagnostic test. With these crops, boron excess must be confirmed from soil and water analyses, tree symptoms and growth characteristics (Ayers and Westcot, 1994). According to Table 4 the allowable level of boron in the irrigation water is between 0-2 mg/l. The level of boron in the class A Glenelg recycled wastewater is 0.4 mg/l (REM and SRHS, 2007). Boron therefore is not a concern in the Glenelg recycled wastewater at least in the short term.

8.4 Leaching as a practical way to reduce toxic ions

A parallel can be drawn between salinity and toxicity. The toxic ions (chloride, sodium and to a lesser extent boron) are an appreciable part of the normal salinity accumulation in the root zone and, as with salinity, leaching is the only practical way to reduce and control these toxic ions in the crop root zone. A toxicity can develop within a few irrigations or within one or more growing seasons, depending upon the toxic ion concentrations in the irrigation water and the leaching fraction accomplished (Ayers and Westcot, 1994).

Leaching can be used either to prevent a problem or to correct the problem after it has been recognized from plant symptoms or damage to the crop. Plant symptoms along with soil, plant and water analyses are very useful for monitoring for potential toxicity and the adequacy of present leaching practices and crop management. If the toxic ion is coming from the irrigation water, emphasis should be placed on prevention through adequate leaching. Chloride ions move readily in the applied irrigation water and make up an important part of water and soil salinity. Chloride can be leached and the leaching requirement equation is appropriate for calculating the leaching requirement for chloride if the chloride tolerance (Cle in saturation extract) and the chloride in the irrigation water (Clw) are known. The leaching requirement (LRCl) equation for chloride then becomes:

$$LRCl = \frac{CLw}{5CLe - CLw} \qquad (2)$$

Where LRCl = the minimum leaching requirement needed to control chloride with normal surface irrigation method

Clw = Chloride concentration in the applied water in me/l

Cle = Chloride concentration tolerated by plant as determined in the soil saturation extract in me/L.

Sodium ions cause toxicities to sodium sensitive crops (mostly tree crops and woody ornamentals) at a lower SAR value than would be expected to cause a permeability problem. The sodium ions move less readily with the soil-water than do chlorides. However, research indicates that high leaching fractions (LF) can be effective to maintain a low soil SAR but for SAR values in the water in excess of 9, without added amendments, a leaching fraction of 0.30 or greater may be required. Deliberately adding such large quantities of water in an attempt to control sodium toxicity may not be practical because this may cause problems with soil aeration and drainage. A preferred solution is to add moderate amounts of gypsum or calcium supplying fertilizer materials. If leaching plus amendments cannot control the sodium toxicity problem, a change to a more tolerant plant may be advisable (Ayers and Westcot, 1994).

Boron is much more difficult to leach than are chloride and sodium. Boron moves slowly with the soil-water and requires about three times as much leaching water as would be needed to reduce an equivalent amount of chloride or salinity. With good irrigation management, it should be possible to reduce and maintain the upper root zone soil at nearly the same boron concentration as in the applied water.

9. Conclusions and recommendations

9.1 Conclusions

The Adelaide Park Lands can potentially be developed as an example of sustainability by presenting a holistic approach to the management of the parklands (Pitman, 2006). It has become increasingly important to design and plant parklands and gardens that do not require extensive irrigation over and above the natural rainfall of the area. Varying rainfall and regular increases and unpredictability of temperatures require a change in the management strategy in order to adapt successfully to these changes (Pitman, 2006).

A wide variety of plants are used in the Adelaide Park Lands, each with a specific tolerance for high levels of salinity, sodium, chloride and boron. This further complicates the task of providing the correct amount of water without causing toxic levels of any of the abovementioned elements. It is important, therefore, to provide irrigation water that has salt concentrations suitable to a large number of plant species (Wu et al., 2001).

Using recycled wastewater is a sustainable option for irrigation of the Adelaide Park Lands. It is however important to maintain a healthy and diverse collection of plants within the parklands in order to achieve one of the goals of creating habitat for native fauna. To this end, it is important to understand the nutrient requirements and characteristics for each species found within the Park Lands and to manage their care accordingly. The amount of nutrient loadings using recycled water should be taken into consideration by monitoring the amount of nutrients that are loaded by recycled water and are taken up by the plants.

Previous reports have developed adaptive management frameworks designed to address the potential impacts of using recycled wastewater from Glenelg Wastewater Treatment Plant. This book has identified the physiological impacts of toxic levels of sodium, chloride, boron and salt, on some plants in the Park Lands and outlined the management measures. These sensitivities have been added to the spreadsheet (Appendix 2) originally complied by REM, SRHS & SE. It is still important to bear in mind that a lot of this data has been obtained under controlled testing conditions. A plant's salt tolerance is also variable depending on the climate, weather, genetic variation, soil health, texture and structure and irrigations methods and frequency (Wu et al., 2001). Investigations undertaken in this study indicates that the average level of three main plant toxic elements, sodium, chloride and boron is lower than the maximum allowable level recommended in the guidelines in Water Quality for Agriculture developed by the Food and Agriculture Organisation of the United Nations (FAO 29) (Ayers and Westcot, 1994) as shown in Table 4.

9.2 Recommendations and research gaps

It would be beneficial to Adelaide Park Lands irrigation with recycled wastewater and upkeep of the parklands to consider the following strategies::

1. Subsurface drip irrigation and onsite collection and reuse of water are the optimal practices in the parkland area;
2. Plantings should be grouped according to the sensitivities and watering requirements of the selected species (Pitman, 2006);
3. Water requirements of most Park Land plants are not known. Determining different plant water requirements would be essential to reduce over-irrigation and enhance the optimum plant growth.
4. Determining the mixed plant water requirement is another gap that is important for an efficient management practice in the Adelaide Park Lands.

5. Fertilizer application needs to be reconsidered based on the parkland plant nutrient uptake (required) and nutrient loading by Glenelg recycled water irrigation.
6. Foliar feeding is an effective method for correcting deficiencies and overcoming the soil's inability to transfer nutrients to the plant. This needs to be investigated for some park land plants.
7. Native Australian plants from more arid regions of South Australia should be considered as potential plantings (Pitman, 2006), it is important however, to ensure that there is no risk of these plants becoming invasive.
8. Maintenance of soil moisture should be ensured through mulching (Pitman, 2006) and natural shade provision.
9. If the management plan includes irrigation of all turf grass areas, replacement of the current areas covered by Bentgrass (*Agrostis tenuis)* with a more salt tolerant turf grass species such as a mix of Redgrass (*Bothriochloa macra*) and Wallaby grass (*Austrodanthonia spp.*) should be considered. *Bothriochloa macra* is a summer grass and has moderate tolerance to salinity and it is highly drought tolerant. *Austrodanthonia spp.* are winter grasses and several species are moderately tolerant to salinity.
10. Provision of a more precise irrigation framework for the Adelaide Park Lands, based on the correct grouping of plants, as mentioned in item 2 of these recommendations, is an approach for optimum irrigation in the Adelaide Park Lands.

Government of South Australia

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University of South Australia

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Example of the Adelaide Park Land environments (Photographer: Fatemeh Kazemi, 2011)

Appendix 1:
Key potential negative environmental effects of wastewater use for irrigation

Table A1.1: Key potential negative environmental effects of the use of treated waste water on plants of the Adelaide Park Lands (REM et al., 2008)

Hazard	Environmental endpoint	Effect or impact on the environment
Sodium	Plants, soil	Can be toxic to plants if it accumulates in soils from ongoing irrigation resulting in leaf burn and reduced growth. Also, a key component of salinity and sodicity.
Chloride	Plants, Soils, Groundwater & Surface water	Can be toxic to plants if sprayed directly on leaves or if accumulates in soils from ongoing irrigation resulting in leaf burn and reduced growth. Also a key component of salinity and sodicity.
Chlorine disinfection residuals	Plants Surface waters	Toxic to plants at high concentrations.
Salinity	Soils Infrastructure Surface water Groundwater	Soil and water salinity are problems which need to be managed in all irrigation systems. Whilst all fertilizers, gypsum and lime etc. are actually salts, the most common damaging form of salt is sodium chloride. Salinity may cause rising damp or corrosion of assets; this can also arise from excessive hydraulic loading. Salinity can cause damage to plants either through an osmotic effect or through direct toxicity effects of sodium and chloride ions. Salt affected plants have reduced growth and may show signs of leaf burn.
Sodicity and soil structural stability	Soils	Excess sodium in treated wastewater can make a soil more sodic which may make the soil structurally unstable. Structurally unstable soils can disperse resulting in reduced water infiltration and the formation of hard compacted soils.
Nutrient accumulation in the root zone	Soils Groundwater Surface water	Nutrients common in wastewater include nitrogen, phosphorus, Potassium, sulphur, calcium and magnesium. The wastewater may supply a surplus of nutrients, i.e., more is applied in the irrigation water than is removed from the area in plant and animal products or fixed in the soil (strongly bound to clay particles). If this occurs, then the surplus may become a risk to the environment through leaching into groundwater or surface waters. Runoff and discharge of nutrient rich water into surface water bodies increases the likelihood of eutrophication.
Water logging/ Hydraulic loading	Soil Groundwater	Applying too much irrigation can result in temporary water logging of the soil and plants. This increases the risk of salinity and sodicity effects as well as increasing the potential movement of nutrients into groundwater. The increased volumes of water infiltrating past the root zone can result in water logging where shallow water tables rise close to the surface or perched groundwater lenses develop on impervious sub-surface soil layers.
Boron	Accumulation in the soil	Specific boron toxicity can occur if boron rich treated wastewater is applied to sensitive plants or following build up of boron in soil with regular irrigation of wastewater.
Soil pH	Soils	If the treated wastewater has a high alkalinity, there is some risk of alkalisation of the soil following continued irrigation. In the experience of SRHS, acidification of the soil following irrigation with treated wastewater is unlikely but can be ameliorated with lime if required.

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Appendix 2:
Salinity and water logging tolerance of plant species within the Adelaide Park Lands and their tolerance to toxic levels of Chloride, Boron and Sodium elements (adapted from REM et al., 2008)

Reference list and classification of toxicity-salinity effects on plants

This reference list and classification of salinity and toxicity effects on plants should be reviewed along with the next table provided in this appendix. The numbers within the parentheses in the table refer to the reference number from which the salinity-toxicity range has been extracted.

References reviewed by (REM et al., 2008)

(1) Tolerances to salt spray are defined by the degree of salt stress symptoms developed in plant leaves and the salt concentrations in the irrigation water.

- Highly Tolerant (H): No apparent salt stress symptoms observed when plants are irrigated with water containing 600 mg/L OR 0.936 dS/m sodium and 900 mg/L OR 1.404 dS/m chloride
- Tolerant (T): No apparent salt stress symptoms observed when plants are irrigated with water containing 200 mg/L OR 0.312 dS/m sodium and 400 mg/L OR 0.624 dS/m chloride
- Moderately Tolerant (M): Symptoms observed on less than 10% of leaves when plants are irrigated with water containing 200 mg/L OR 0.312 dS/m sodium and 400 mg/L OR 0.624 dS/m chloride
- Sensitive (S): More than 20% of leaves develop symptoms when plants are irrigated with water containing 200 mg/L OR 0.312 dS/m sodium and 400 mg/L OR 0.624 dS/m chloride

(2) The definitions of soil salinity Tolerance are:
dS/m from: Cass et al, YEAR, vineyards soil degradation by salt accumulation and the effect on the performance

- Highly Tolerant (H): acceptable soil EC greater than 6 dS/m of the vine. 9th Australian Wine Industry Technical Conference, p153-160.
- Tolerant (T): acceptable soil EC greater than 4 and less than 6 dS/m 6 to 9 moderately saline to unspecified limit (8-16 very saline, >16 highly saline)
- Moderately Tolerant (M): acceptable soil EC greater than 2 and less than 4 dS/m 4 to 6 moderately saline
- Sensitive (S): acceptable soil EC less than 2 dS/m
  - 2 to 4 slightly saline
  - 0 to 2 non--saline

Reference: Wu L and Dodge L. 2005 Special report for the Elvenia J Sloson Endowment Fund (in press)

(3) Water salinity tolerance levels according to Ayers & Wescot, 1989. Water quality for Agriculture. Food and Agricutlure Orgnisation of the United Nations. Fig. 10, pp.36.

	ECe	ECw
Tolerant (T)	6-10	4-6.666
Moderately Tolerant (MT)	3-6	2-4
Moderately Sensitive (MS)	1-3	0.66-2
Sensitive (S)	0-1	0-0.666

Salinity tolerances of plant species using this criteria sourced from:

- Agriculture WA. 2003. Soil salinity tolerance of plants for Agriculture and revegetation. Department of Agriculture WA.

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- Anon. 2006. Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1). National Water Quality Management Strategy Document No. 21.
- Bonney, N. 2004. Common plants of the Coorong Region. Australian Plants Society (SA Region) Inc.
- Bulman, P. 1995. Farmtree$ for the Mt Lofty Ranges: A regional Agroforestry Handbook. PIRSA
- Elliot, R. 2003. Australian Plants for Mediterranean climate gardens. Rosenburg Publishing Pty Ltd.
- Marcar, N.E. and Crawford, D.F. 1995. Trees for salt land: a guide to selecting native species for Australia. CSIRO publishing
- Pettygrove, S. & Asano, T. 1985. Irrigation with reclaimed municipal wastewater = a guidence manual. Lewis publishers Inc.
- Wrigley & Fagg. 1983. Australian Native Plants 2nd Ed. Collins Press.

(3a) Soil Salinity tolerance from selected references listed above; Anon 2006, Agriculture WA, 2003; units mS/m

(4) Soil salinity tolerance levels according to Handreck, K. and Black, N. 1984. Growing media for ornamental plants and turf. NSW University Press.

- Very tolerant (VT): ECse of medium between 8 and 13dS/m
- Tolerant (T): ECse of medium between 5-6 and 8dS/m
- Moderately tolerant (MT): ECse of medium between 3-4 and 5-6dS/m
- Sensitive (S): ECse of medium between 1.8 and 3-4dS/m
- Very Sensitive (VS): ECse of medium below 1.8dS/m

(5) Suitability of plants for different sites according to Boomsma, C.D. 1983. Tree Planting Guide for South Australia. Woods and Forests Department, South Australia.

Wa = Plants for waterlogged sites
Ss = Plants for swampy and salty sites
Ds = Plants for dry, salty sites

According to Brief, the average salinity of the Class B effluent water is 1178mg/L OR 1.84dS/m. As such, this water would only be suitable for irrigating moderately tolerant ot tolerant plant species.

References reviewed in this report (Hassanli, Kazemi, 2011)

(6) Department of Agriculture (2005) Soil salinity tolerance of plants for agriculture and revegetation: moderately saline sites, Western Australia.

(7) Miyamoto, S, et al., Landscape Plant Lists for Salt Tolerance Assessment. 2004, Texas Agricultural Experimental Station.

- Sensitive: S (< 1 dS/m, Na and Cl < 150 ppm OR < 0.234 dS/m),
- Moderately sensitive: MS (1 – 2 dS/m, Na < 280 ppm OR < 0.4368 dS/m, Cl < 360 ppm OR < 0.5616 dS/m),
- Moderately tolerant: MT (2 – 3 dS/m, Na < 425 ppm OR < 0.663 dS/m, Cl < 590 ppm OR < 0.9204 dS/m),
- Tolerant: T (> 3 dS/m).

(8) Blaylock, AD (1994). Soil Salinity, Salt Tolerance, and Growth Potential of Horticultural and Landscape Plants, Department of Plant, Soil and Insect Sciences, College of Agriculture, University of Wyoming.

(9) Wu and Dodge, 2005. Salinity management guide; Choose salt-tolerant plants, applied to the root zone that may cause growth reduction or leaf injury.

» Sensitive (S): Plants may develop severe leaf burn (especially at the leaf tip) by irrigation with water containing 1 to 2 mg B L-1 OR between 0.00156 to 0.00312 dS/m B.
» Moderately tolerant (M): Irrigation with water containing 2 mg B L-1 OR 0.00312 dS/m B may not cause leaf injury, but plants may be severely injured by 4 to 6 mg B L-1 OR 0.00624 to 0.00936 dS/m B in irrigation water.
» Tolerant (T): Irrigation with water containing 4 to 6 mg B L-1 OR 0.00624 to 0.00936 dS/m B may not cause leaf injury, but plants may be severely injured by 6 to 10 mg B L-1 OR 0.00936 to 0.0156 dS/m B in irrigation water.
» Highly tolerant (H): Plants will not be injured by irrigation with water containing 6 to 10 mg B L-1 OR 0.00936 to 0.0156 dS/m B."

(10) Anonymous (2005). Chloride salt tolerance of Florida plants. Project Greenleaf. City of St. Petersburg.

» Plants which are highly tolerant of chloride salt levels up to and greater than 400 parts per million (ppm) OR 0.624 dS/m. Good tolerance of reclaimed water.
» Chloride salt concentrations for Tampa's reclaimed water range from 150 to 300 ppm OR 0.234 to 0.468 dS/m.
» Plants which may require extra maintenance if chloride salt concentrations exceed 200 (ppm) OR 0.312 dS/m. Avoid reclaimed water contact with plant leaves. Drip-irrigation may prevent leaf burn.

(11) Beckerman, J and Lerner, BR (2009). Salt damage in landscape plants. Purdue Extension, ID-412-W, Purdue University.

T = tolerant
M = intermediate
S = sensitive
— = No information available
* = invasive, not recommended in Indiana

(12) Costello, LR, Perry EJ, et al. (2003). Abiotic disorders of landscape plants: a diagnostic guide, Oakland, Calif. : University of California, Agriculture and Natural Resources.

(13) Stevens, DP, et al. (2008). Irrigation of amenity horticulture with recycled water. Aris Pty Ltd, Melbourne, Victoria.

Plant tolerance groups	Electrical conductivity of irrigation water
Sensitive	<0.65 dS/m
Mod. Sensitive	0.65 - 1.3 dS/m
Mod. tolerant	1.3 - 2.9 dS/m
Tolerant	2.9 - 5.2 dS/m
Very tolerant	5.2 - 8.1 dS/m
Generally too saline	> 8.1" dS/m

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Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008)

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Acacia acinacea 1	Wreath wattle	M	M(2)				L	
Acacia baileyana*	Cootamundra Wattle	M	M(2)				M	S(13)
Acacia brachybotrya	Grey Mulga-bush	M	M(2)				S	
Acacia cyclops	Western Coastal Wattle	H	H(2),VT(4)		>1600mS/m	Ds	L	
Acacia hakeoides	Hakea Wattle	M	M(2)				L	
Acacia iteaphylla*	Flinders Ranges Wattle	S	M(2)		200-400mS/m		L	
Acacia ligulata	Umbrella Bush	M	H(2)		800-1600mS/m			
Acacia melanoxylon *	Blackwood	S	L(2)	MS	200-400mS/m	Wa	S	
Acacia notabilis	Notable wattle	M	M(2)					
Acacia paradoxa	Kangaroo Thorn	M	M(2)					
Acacia pendula *	Weeping Myall	M	M(2),VT(6)		400-800mS/m		M	
Acacia pycnantha	Golden Wattle							
Acacia retinodes var. retinodes	Swamp wattle	M	H(2)		800-1600mS/m	Wa	H	
Acacia salicina	Willow Wattle	M	H(2)	T	800-1600mS/m	Wa,Ss	L	
Acacia saligna *	Golden Wreath Wattle	M	H(2)	MT-T	800-1600mS/m		M	
Acacia sp		M	H(2),VT(4)				M	
Acacia victoriae ssp. Victoriae	Elegant Wattle				400-800mS/m	Ds		
Acer pseudoplatanus *	Sycamore	S	S(2)					HS (13)
Acmena smithii *	Lillypilly							
Agapanthus s.*	Agapanthus		MT(4)	MT	400-600mS/m			S(13)
Agonis flexuosa *	Sweet peppermint	L	L(2)		<200mS/m	A. juniperina -Wa		
Allocasuarina verticillata	Drooping Sheoak	M	M(2), MT(4), T(6)	MT-T	400-800mS/m	Ds		
Anigozanthus sp. *	Kangaroo Paw							
Araucaria bidwillii *	Bunya Pine							
Araucaria excelsa *	Norfolk Island Pine (?)	H	T(2),VT(4)					
Araucaria sp. *	sp. heterphylla (NIP) is			T?	>800mS/m			
Artemisia sp. *	Wormwood							
Arthropodium fimbriatum	Nodding Vanilla-lily							
Arthropodium strictum	Common Vanilla-lily							
Arundo sp.*	Bamboo							
Asparagus declinatus *	Bridal Veil		T(8)					
Atriplex paludosa	Marsh saltbush	H	H(2),VT(4)	T	>1600mS/m	A.Cinerea -Ds		
Atriplex semibaccata	Berry saltbush	H	H(2),VT(4)	T	>1600mS/m	A. nummularia -Ds		
Atriplex suberecta	Lagoon saltbush	H	H(2),VT(4)	T				
Austrostipa puberula	Small rusty spear-grass	H	H(2)					
Austrostipa curticoma	Short-crest Spear-grass	H	H(2)					

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
				X		X											X	X						X	X	X			
S(13)																	X												
		X																										X	
						X																							
						X																							
					X				X							X		X	X	X	X	X	X	X				X	
				X	X	X											X				X			X	X			X	
	M (12)																							X	X				
						X																							
				X		X											X							X	X				
						X										X			X			X	X					X	X
			X	X	X	X				X							X	X		X	X	X		X					X
																											X	X	
																								X					
		X	X	X													X		X		X	X					X	X	X
											X			X															
																								X	X				
HS (13)	S (11)	X	X											X	X														
															X							X							
S(13)															X							X					X		
		X	X																			X							
					X	X											X	X		X	X	X		X	X			X	X
																											X		
						X					X																		
HT (5)																						X						X	
																		X		X	X							X	
																												X	
																		X						X					
							X											X						X					
																											X		
																								X					
																									X				
							X	X			X	X						X						X	X				X
							X																	X					
							X																						
																		X						X					

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Austrostipa drummondii	Cottony Spear-grass	H	M(2)					
Austrostipa eremophila	Rusty Spear-grass	H	M(2)					
Austrostipa flavescens	Coast Spear-grass	H	H(2)					
Austrostipa nitida	Balcarra Spear-grass	H	H(2)					
Austrostipa nodosa	Tall Spear-grass	H	H(2)					
Austrostipa puberula	Small rusty spear-grass	H	H(2)					
Austrostipa scabra ssp. scabra	Rough Spear-grass	H	H(2)					
Austrostipa sp.	Spear-grass	H	H(2)					
Banksia marginata	Silver Banksia		VT(4)					
Bauhinia sp. *	Hong Kong Orchid tree	L	L(2)	MT	400-600mS/m			
Boerhavia dominii	Tar-vine							
Brachychiton acerifolius *	Illawarra Flame Tree						Tolerant?	
Brachychiton discolor *	Lace tree/Lacebark Tree							
Brachychiton populneus *	Kurrajong			T?				
Brachychiton sp. *								
Buddleja davidii *	Butterfly Bush	L	L(2)					
Bursaria spinosa ssp. spinosa	Sweet Bursaria							
Callistemon phoenicius*	Bottlebrush	M	M(2), MT(4), T(6)		400-800mS/m		M	
Callistemon rugulosus var. rugulosus	Scarlet Bottlebrush	M	M(2)	T			none	
Callistemon sp.	Bottlebrush	T	M(2),T(4)	MT?		Wa		
Callitris gracilis	Southern Cypress Pine					C.Columellaris -Ds		
Calostemma purpureum	Pink-garland Lily							
Calothamnus sp. *								
Calystegia sepium	Large Bindweed							
Calytrix tetragona	Common Fringe-myrtle							
Casuarina glauca *	obesa similar tolerance	H	H(2), T(4)	T	>1600mS/m	Wa,Ss,Ds	Tolerant	
Ceratonia siliqua *	Carob		S(4)		200-400mS/m			
Chenopodium pumilio	Clammy Goosefoot							
Chloris truncata	Windmill Grass	M	H(2)		400-800mS/m		M	
Convolvulus erubescens	Australian Bindweed							
Convolvulus remotus	Grassy Bindweed							
Correa pulchella	Salmon Correa		C.Alba is VT(4)					
Correa reflexa	Common Correa							
Cotoneaster sp. *	Cotoneaster	L	L(2), VS(4)	S	<200mS/m			S (7)
Cotula australis	Common Cotula							
Cymbopogon ambiguus	Lemon-grass							
Cyperus sp.	Sedge							

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
																								X					
							X	X																X					
							X	X																X					
																								X					
							X	X										X						X					
								X																					
																								X					
			X		X	X	X	X									X	X		X	X	X	X						X
																									X				
	S(12)																											X	
							X				X	X												X					
					X										X					X								X	
																				X									
		X	X	X	X			X	X	X	X			X			X	X	X	X	X	X		X				X	
																											X		
																								X					
																								X	X				
	T (4)	X		X																									
						X																							
																X			X	X		X					X	X	
				X	X	X											X	X	X	X	X	X		X	X		X	X	X
																		X						X					
																												X	
		X																									X	X	
																	X												
		X	X	X	X		X							X							X	X	X	X	X	X	X	X	X
					X		X				X					X		X	X	X					X	X		X	
							X										X	X				X							X
			X			X	X	X				X					X	X		X	X	X	X						X
																								X					
																								X					
																											X		
																												X	
S (7)		X																				X							
								X										X											
																								X					
																X					X							X	

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Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Danthonia caespitosa	Common Wallaby-grass							
Danthonia carphoides var. carphoides	Short Wallaby-grass							
Danthonia racemosa var. racemosa	Slender Wallaby-grass							
Danthonia setacea var. setacea	Small Flower Wallaby-grass							
Danthonia sp.	Wallaby-grass							
Delonix sp. *	Poinciana							
Dianella revoluta var. revoluta	Black-anther Flax-lily							
Dichondra repens	Kidney Weed							
Dodonaea viscosa ssp. angustifolia	Narrow-leaf Hop-bush			MT	400-600mS/m			
Dodoneae viscosa	Sticky Hop-bush		MT(4) - T(4)	MT	400-600mS/m			
Einadia nutans ssp. nutans	Climbing Saltbush							
Elymus scaber var. scaber	Native Wheat-grass							
Enchylaena tomentosa var. tomentosa	Ruby Saltbush			T			none	
Enteropogon ramosus								
Epilobium hirtigerum	Hairy Willow-herb							
Eremophila maculata ssp. *				MT?				
Erythrina sp. *								
Eucalyptus camaldulensis var. camaldulensis	River Red Gum	M	M(2), VT(4)	T	400-800mS/m	Wa,Ss	L/tolerant	
Eucalyptus citriodora/ corymbia citriodora *	Lemon-scented Gum				200-400mS/m			
Eucalyptus cladocalyx *	Sugar Gum	S	S(2)		200-400mS/m		S	
Eucalyptus cornuta *	Yate	M	L(2)	T	200-400mS/m	Ds	M	
Eucalyptus erythrocorys *	Red Cap Mallee					Ds		
Eucalyptus ficifolia/corymbia ficifolia *	Red-flowering Gum				200-400mS/m			
Eucalyptus forrestiana *	Fuchsia Gum	S	S(2)		200-400mS/m		S	
Eucalyptus landsdowneana ssp. *	Red-flowered Mallee Box		MT(4),T(6)					
Eucalyptus leucoxylon rosea *	Red-flowering Blue Gum	M	M(2), MT(4), T(6)	T			M/none	
Eucalyptus leucoxylon ssp. leucoxylon	South Australian Blue Gum	M	M(2)	T	400-800mS/m		M/none	
Eucalyptus maculata/corymbia maculata *	Eyebane				200-400mS/m			
Eucalyptus megacornuta *	Warted Yale	S	S(2)		200-400mS/m			
Eucalyptus microcarpa	Grey Box	M	M(2), MT(4), T(6)		400-800mS/m			
Eucalyptus odorata	Peppermint Box							
Eucalyptus platypus *	Moort	M	M(2), MT(4), T(6)	T	400-800mS/m		S	
Eucalyptus porosa	Mallee Box	M	M(2)	T				

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
							X	X										X											
																		X											
								X										X											
							X																						
							X	X				X					X	X			X	X							X
																						X	X						
																	X	X			X			X					
							X	X	X									X											X
																	X	X							X				
						X																							
												X						X											
							X	X									X	X			X								
							X	X				X						X						X					
																							X						X
																	X												
									X																		X	X	
	S(12)																			X		X							
			X				X	X	X	X				X	X	X	X	X		X	X	X	X	X	X	X	X	X	
	T (12)	X					X			X	X			X		X		X		X	X	X	X		X	X	X	X	
	T (12)	X	X			X	X		X	X	X			X		X	X	X	X	X	X	X	X	X		X		X	X
		X																											
															X	X				X	X								
	M (12)	X																X											
							X									X								X	X				
																					X								
		X	X	X	X						X						X	X		X								X	X
						X				X							X		X	X		X	X	X	X	X		X	X
																X		X					X					X	
							X																						
						X																X			X				
					X															X									
			X	X																X									
																								X	X				

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Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Eucalyptus preissiana *	Bell-fruited Mallee							
Eucalyptus salmonophloia *	Salmon Gum	S	M(2)		200-400mS/m			
Eucalyptus salubris *	Gimlet							
Eucalyptus sideroxylon ssp. sideroxylon *	Red-flowering Ironbark	M	H(2),T(4)		800-1600mS/m		M	
Eucalyptus socialis	Beaked Red Mallee							
Eucalyptus sp.						ManySpecies -Wa,SsAndDs		
Eucalyptus spathulata *	Swamp Mallet		VT(4)	T	800-1600mS/m	Wa,Ss,Ds	none	
Eucalyptus stoatei *	Stoat Gum							
Eucalyptus torquata *	Coral Gum	S	S(2)		200-400mS/m			
Euphorbia drummondii	Caustic Weed		E. Pulcherrima is S(4)	MS?				
Eutaxia microphylla	Common Eutaxia							
Felicia sp. *	Rose	L	L(2)				L	
Ficus macrophylla *	Moreton Bay Fig	M	M(2), T(4) - VT(4)?	T??				
Fraxinus excelsior *	English Ash	M	M(2)	MT?				
Fraxinus raywoodii *	Claret Ash			MT?				MS (13)
Fraxinus sp. *	Ash	L	L(2), MT(4)	MT?				
Goodenia amplexans	Clasping Goodenia							
Grevillea banksii var. forsteri *								
Grevillea robusta *	Silky Oak	H	T(2)					
Hakea laurina *	Pincushion Hakea							
Hakea leucoptera ssp. leucoptera *	Silver Needlewood							
Hakea sp.			MT(4)?	MT?				
Hardenbergia violaceae								
Hedera helix ssp. helix *	Ivy		S(7)					MT (7)
Hibiscus sp. *	rosasinensis is		S(4)	MS?	600-800mS/m?			
Jacaranda mimosifolia *	Jacaranda	S	S(2)					
Juncus sp.	Rush							
Kniphofia sp. *	Red-Hot Poker							
Lagunaria patersonii *	Norfold Island Lagunaria		MT(4), T(6)	T	400-800mS/m			
Lagunaria sp. *	Pyramid Tree							
Lantana camara var. camara *	Common Lantana		MT(4)	MT	180-600mS/m			
Lavandula dentata *	Lavender							
Leptospermum laevigatum *	Coast Tea-tree		VT(4)	T	>800mS/m			
Leptospermum lanigerum *	Silky Tea-tree					Wa		
Leptospermum sp.	Tea-tree							
Livistona sp. *	Palm							
Maireana brevifolia	Short-leaf Bluebush	M	M(2), MT(4), T(6)		400-800mS/m			

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
		X			X		X				X									X					X				X
		X	X																					X					
																												X	
		X									X						X	X		X	X	X			X		X	X	X
																									X				
					X													X						X				X	
											X													X					
							X																	X	X				
		X		X	X		X											X		X					X				
							X					X												X					
																	X												
															X												X		
		X	X						X	X	X			X							X	X		X	X	X	X		
																		X		X		X						X	
MS (13)																		X											
	S (10)	X									X			X				X	X		X				X	X	X		
																		X											
																											X	X	
							X							X	X					X							X	X	
						X																X							
				X																									
		X		X		X																							
																								X	X				
MT (7)																								x					
	MS (13)																					X							
S (10)	T (13)																				X								
														X		X					X							X	
																											X		
																			X	X	X	X		X	X	X	X	X	X
		X	X		X		X			X	X			X		X							X						
	S (4);S(13)																					X					X		
																												X	
		X																											
																											X		
																												X	
																			X			X					X	X	
							X					X						X						X	X				

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Maireana enchylaenoides	Wingless Fissure-plant							
Malus sp. *	Kaffir Apple	S	S(2), S(7)	S				
Melaleuca decussata	Totem-Poles	H	H(2)	T	800-1600mS/m	Wa,Ss	H	
Melaleuca lanceolata	Dryland Tea-tree	M	H(2)	T	800-1600mS/m	Wa,Ss,Ds	M	
Melaleuca nesophila *		M	M(2), VT(4)	T	200-400mS/m	Ds	M	
Melaleuca sp.		H	H(2)				H	
Melalueca lanceolata ssp. lanceolata	Dryland Tea-tree	H	H(2)	T?	800-1600mS/m	Wa,Ss,Ds	H	
Melia azedarach var. australasica *	White Cedar			T?			Tolerant?	
Mesembryanthemum sp. *	Iceplant		T(8)					
Myoporum insulare	Common Boobialla	M	M(2) M yoporum Spp. Are T(4)	T	400-800mS/m	Ds	none	
Myoporum platycarpum ssp. platycarpum	False Sandalwood							
Myoporum viscosum *	Sticky Boobialla							
Myriophyllum sp.	Milfoil							
Nerium oleander *	Oleander		T(4)	MT	600-800mS/m			T (7);T(13)
Olea europaea ssp. europaea *	Olive	S	S(2), O. Europea is T(4)	MT	600-800mS/m			MT (13)
Olearia axillaris	Cost Daisy-bush							
Olearia ramulosa	Twiggy Daisy-bush							
Oxalis perennans	Native Sorrel							
Panicum effusum var. effusum	Hairy Panic							
Pennisetum clandestinum *	Kikuyu	M	T(2), VT(4)	T	200-400mS/m		L	
Persicaria decipiens	Slender Knotweed							
Phragmites australis	Common Reed							
Pinus halepensis *	Aleppo Pine	M	M(2), MS(7)	MT	600-800mS/m			T (13)
Pinus radiata *	Radiata Pine	M	M(2), MT(4), T(6)		400-800mS/m		M	
Pinus sp. *		M	M(2), MT(4)				M	T (13)
Pittosporum angustifolium	Native Apricot/ phylliraeoides T			MT?			Tolerant	
Pittosporum sp.			MT(4) -T(4)			P.Phylliraeoides -Ds		
Pittosporum undulatum *	Sweet Pitosporum							
Poinsettia sp. *	Euphorbia pulcherrima?				200-400mS/m			
Populus alba *	White Poplar		MS(7)					
Populus nigra *	Black Poplar							
Populus nigra italica *	Lombardy Poplar							
Populus sp. *	Poplar							S(13)
Prunus cerasifera *	Ornamental Cherry			MT	400-600mS/m			

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
							X	X										X				X	X	X					X
											X							X	X					X	X		X		
						X																							
				X		X																X		X	X	X			
																											X		
				X																		X							X
		X																											
		X					X				X			X	X		X					X					X		
															X														
																						X			X				
																									X				
																X	X												
																								X					
T (7);T(13)	T (4);T-MT(13)	X																						X			X	X	
MT (13)		X					X	X	X					X		X	X			X	X	X		X			X	X	X
																	X												
																								X	X				
							X	X									X	X			X		X	X					X
																								X					
		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
																											X	X	
		X																						X			X		
T (13)		X	X		X		X		X	X				X	X	X		X		X	X	X	X		X	X			X
		X					X		X		X					X		X		X		X	X	X	X	X	X	X	X
T (13)				X																		X							
						X														X				X				X	
																												X	
		X													X							X					X	X	
																											X		
															X		X	X	X									X	
																	X	X				X						X	
	S(11)	X													X			X	X			X						X	
S(13)		X					X							X		X				X	X				X	X			
	T(11)																										X	X	

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Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Species	Common Name	Tolerance to salt spray (1)	Tolerance to soil salinity	Water salinity (3)	Soil salinity tolerance	Suitability for sites (5)	Water-logging tolerance	Tolerance to Sodium
Prunus sp. *	Cherry Tree		S(7)	MT				S(13)
Pseudognaphalium luteoalbum *	Jersey Cudweed							
Quercus robur *	English Oak				200-400mS/m			
Quercus sp. *	Oak (several species)		S(7), MS(7)		200-400mS/m			S(13)
Rosa rubiginosa *	Briar Rose	L	L(2), Rosa Spp. Are VS(4)				L	
Salix babylonica *	Weeping Willow		S. Vitellina is MT(4)	MT?				MS (13)
Salsola kali	Buckbush							
Santalum acuminatum	Quandong							
Schinus areira *	Pepper-tree							
Senecio pterophorus var. pterophorus *	African Daisy							
Senecio quadridentatus	Cotton Groundsel							
Senecio sp.								
Senna artemisioides ssp. filifolia	Fine-leaf Desert Senna						none	
Solanum nigrum *	Black Nightshade		S. Tuberosum is MT(4)					
Tamarix aphylla *	Athel Pine				800-1600mS/m			
Teucrium recemosum *	Grey Germander							
Tristania sp. *								
Typha domingensis	Narrow-leaf Bulrush							
Ulmus procera *	English Elm	M	M(2)					
Veronica sp. *	Speedwell							
Vittadinia blackii	Narrow-leaf New Holland Daisy							
Vittadinia dissecta	Dissected New Holland Daisy							
Vittandinia gracilis	Wooly New Holland Daisy							
Vittandinia sp.	New Holland Daisy							
Westringia dampieri *			W. fruticosa is VT(4)					
Xanthorrhoea semiplana ssp. semiplana	Yacca							
Zantedeschia aethiopica *	White Arum Lily							

Table 5: Salinity, toxicity and water logging tolerance of plant species within the Adelaide Park Lands (REM et al., 2008) cont'd

Tolerance to Chloride	Tolerance to Boron	Park Number																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	21w
S(13)																			X			X							
																		X											
															X								X						
S (7);S(13)	T(11)	X																X				X						X	
																								X					
MS (13)	T(11)														X							X						X	
							X																	X					
																								X					
		X		X	X		X				X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
															X														
																								X					
																												X	
																								X	X				
																								X					
	T(11)	X					X			X	X			X								X		X			X		
																		X											
																						X							
		X												X		X					X	X		X			X	X	
		X												X	X												X		
																						X					X		
			X																										
							X																						
							X																		X				
							X											X											
									X													X						X	
																	X	X											
															X												X		

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Example of the Adelaide Park Land environments (photo by Fatemeh Kazemi, 2010)