City of South Perth

INTEGRATED CATCHMENT MANAGEMENT PLAN

VOLUME 1 STUDY REPORT

SEPTEMBER 2004

JDA Consultant Hydrologists

ecoscape

Executive Summary

The City of South Perth recognise that existing and historical land use, and drainage systems may pose a threat to water quality and ecological values.

As part of the Swan Canning Cleanup Program, a planning process was developed to provide a framework for catchment management. This process provides a mechanism to address urban stormwater management within established areas by local government in co-operation with State Government agencies and drainage utilities. The process aims to :

- Generate commitment to and awareness of best practice flood mitigation, land rationalisation, infrastructure asset management, and environmental management of stormwater and drainage.
- Identify priority issues using a risk based approach.
- Develop management strategies to address priority issues and risks.
- Establish a basis for ongoing cooperation and coordination between different sections of local government and different agencies.
- Ensure effective integration of any actions and use of investment by all partners.

In this context, to achieve a comprehensive approach to urban water management, the City of South Perth have undertaken the development of an integrated catchment management (ICM) plan with the aim of identifying land use and water quality issues within its catchments and to determine strategies for monitoring and, where necessary, improving ecological values.

The Existing Stormwater Management System

The existing stormwater management system comprises of a piped network of both local authority and Water Corporation Main Drainage, which discharges to a variety of receiving environments including the Canning and Swan Rivers, lakes, compensating basins, infiltration basins, swales, soakwells, and public open space reserves.

The system is largely fragmented, comprising of a large number of catchments (147), and a large number of drainage facilities, including a total of 80 infiltration or compensation basins, and 54 outlets to the Swan and Canning Rivers.

Infiltration of stormwater is the predominant method of stormwater disposal for the Study Area with approximately 65% of the area infiltrating stormwater. Of the remaining 35% of the Study Area which discharges to the Swan and Canning Rivers, 40% discharges to the rivers via compensating basins, while 60% of discharges are direct. Less than half of the existing outlets to the Swan or Canning Rivers have Gross Pollutant Traps installed.

Catchments which cross local authority boundaries with the Town of Victoria Park or City of Canning comprise a small overall proportion of the Study Area. To this extent the surface drainage system can be considered largely self contained and surface water quality within the Study Area predominately a result of land use and existing management practices of the City of South Perth.

The Study Area contains Conservation Category Wetlands and EPP lakes, all of which currently form part of the local authority drainage network or part of the Water Corporation's Main Drainage system.

Identifying Environmental Priority Catchments

Environmental priority catchments within the Study Area were determined on the basis of existing and historical land use impacts, and the environmental and social values of the receiving environment. In the absence of detailed water quality data for individual catchments within the Study Area, environmental priority catchments were determined using the process of map overlay techniques.

The top ten priority catchments are summarised in Table E1. Priority catchments are typically located in the southern region of the Study Area and mainly discharge to the Canning River. Only 2 catchments in the Northern Region are in the priority list, both of these discharging to basins in Sir James Mitchell Park.

Some of the priority areas identified correspond with areas previously identified by the City of South Perth to improve stormwater discharge quality and areas with existing environmental management plans. Some of the areas identified have already had stormwater quality improvement measures installed.

The Strategy

Recent developments in urban stormwater quality management have seen a shift of emphasis from attempts to trap or retard pollutants in their journey from land application to estuary discharge, to a more fundamental “Prevention is better than Cure” philosophy. Recent developments have also been toward total water cycle management, and considering urban stormwater and its quality within the wider context of the whole hydrological cycle.

The Department of Environment’s revised Urban Stormwater Management Manual for Western Australia provides a greater emphasis on strengthening use of non structural source controls and catchment management measures to reduce pollutant input, while still incorporating previously accepted water sensitive urban design (WSUD) measures and best management practice treatment trains.

The strategy recommends that the City of South Perth follows this approach and considers non structural water quality control techniques to be vital to achieving sustainable stormwater quality improvements. The proposed strategy is cognisant of the financial cost of stormwater quality management for its community and has been developed accordingly.

To this end the strategy recommends the use of education campaigns, native plantings, review of maintenance activities, and street sweeping as preferred comparatively low cost methods of reducing nutrients and pollutants and protecting receiving environments. Where possible, integration with existing programs (of state government agencies, catchment groups etc) is recommended.

In terms of the need for additional structural controls, these may be required in certain cases as part of applying a treatment train approach. The need for additional structural controls will require assessment on a case by case basis. Given the number of discharge locations, and the significant cost of installation and maintenance of new controls, it is recommended a water quality monitoring program be undertaken to establish baseline water quality data and more accurately determine the need for (and appropriateness of) structural controls. The integrated monitoring program should initially target environmental priority catchments.

The strategy has identified environmental priority catchments and it is recommended these priorities be used as a basis for targeting areas for improvement works within the Study Area.

In terms of the receiving environment for stormwater discharges the strategy recognises that environmental management plans already exist for some of the wetlands in the Study Area, and the specific details regarding recommendations contained within these management plans are not duplicated in this strategy. In this regard, this strategy is intended to provide an over-arching document to assist the City in the allocation of its resources to identified priority areas. The development of specific landscape plans for artificial wetlands in areas of high public access are recommended to maximise the environmental and aesthetic values of these assets.

With regard to infrastructure management, the fragmented nature of the drainage system and large number of infiltration and compensating basins provides some opportunity for consideration of infrastructure rationalisation. Further survey detail is required to enable existing level of service checks to be undertaken and the rationalisation opportunities to be investigated.

A number of priority catchments drain to Water Corporation Main Drainage. Negotiation with Water Corporation regarding any works for these catchments will be required on a case by case basis.

With regard to any new development, infiltration of stormwater on site should be encouraged.

Implementation and Review

Annual review of implementation is recommended. With regard to the ICM Strategy document itself, it is recommended the Strategy be reviewed after a period of 5 years. This review process would include :

- assessment of the success of measures implemented and programs undertaken.
- analysis of monitoring data and develop specific water quality criteria.
- integration of criteria and policy developments at the State Government level.
- review of new developments in stormwater quality management.
- further refinement of the strategy and reassess priority catchments for future works.

Table E1: Top Ten Priority Environmental Catchments

Priority. Catchment	Location / Description	Area (ha)	Nutrient Input TP kg/ha/yr	Major Roads (% of area)	Commercial (% of area)	Receiving Environment Social-Env Ranking
1. SP 136	Located south of Manning Rd, Waterford. The predominant land use is Residential (>=R20), also containing Bodkin Park and Manning Rd. Drainage via two Bodkin Park WC Compensating Basins, part of Collier Pines MD discharging to the Canning River.	41.0	34.2	6%	0%	High/High
2. SP 110	The catchment is located North of Manning Rd, Manning. Residential Area (<=R20) including Goss Avenue Bushland, and part Manning Rd drainage. Drainage to WC Manning MD compensating basin discharging to the Canning River.	28.0	32.1	9%	0%	High/High
3. SP 140	Clontarf, east of Clontarf College including catchment extending into City of Canning Predominantly a residential area (<=R20) including Clontarf EPP Lake and part Manning Rd drainage. Drainage compensated to Clontarf EPP Lake discharging to Canning River.	21.3	41.1	7%	0%	High/High
4. SP106	Located within the suburb of Manning and part of Como, including James Miller Oval. Catchment predominantly residential (mainly <=R20), includes Manning Primary School, Highway, Commercial and part Manning Rd drainage. Drainage into Open Bushland and Manning Primary School Oval.	47.3	25.3	4%	7%	High/High
5. SP139	Located South of Manning Rd, Waterford. Catchment drains to infiltration basin located within the park on Doneraile Ct. 78% of the catchment is residential (>=R20), remaining area is active park & recreation.	7.4	37.9	0%	0%	High/High
6. SP120	South of Manning Rd, Como. The catchment consists of Murlali Lodge (zoned R20) and Hogg Ave bushland. Drainage is via diffuse infiltration with depression located at bushland, Hogg Ave.	3.5	38.5	0%	0%	High/High
7. SP115	Karawara, North of Manning Road, South of Collier Park Golf Course. The catchment is predominantly residential, of which 75% is <=R20 and 25% of catchment is active parks & recreation. The catchment discharges to Lake Gillon is part of WC Collier Pines MD compensating basins, discharging to the Canning River.	72.4	28.2	0%	2%	High/High
8. SP26	Located north of Canning Highway, South Perth. Drainage to Swan River via a compensating, artificial lake located within Sir James Mitchell Park, near Hurlingham Rd. Residential catchment containing commercial areas, Canning Hwy, Mill Point Rd and active parks & recreation.	49.0	31.3	4%	3%	High/ Medium
9. SP 25	Located north of Canning Highway, South Perth. Drainage to Swan River via a compensating, two interconnected artificial lakes of Sir James Mitchell Park, near Douglas Ave. Residential catchment containing commercial areas, Canning Hwy, Mill Point Rd, Douglas Ave and active parks & recreation.	48.6	25.1	6%	3%	High/ Medium
10. SP 86	Catchment draining to Neil McDougall Park Lake, Como. Lake acting as an infiltration basin (wet). Residential catchment, with active parks & recreation and a small commercial area.	69.2	30.8	0%	1%	High/ Medium

Table E2 : ICM Implementation Plan

Item No	Task	Timing & Frequency
I1	<u>Infiltration</u> Promote infiltration for new development as the preferred method of stormwater disposal	Ongoing
I2	<u>Water Quality Monitoring</u> Undertake an integrated monitoring program targeting the identified top ten environmental priority catchments to establish baseline water quality data. Sampling to include stormwater inflow, shallow groundwater water quality, water quality of the receiving environment, and consider potential point sources of pollution. Analysis to include pH, Conductivity, Total Suspended Solids (TSS), Total Phosphorus and Filterable Reactive Phosphorus (FRP), Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), NO_3-N, NO_2-N, Ammonia, Heavy Metals (including Pb, Zn, Cu). Catchments : SP 136, SP 110, SP 140, SP106, SP139, SP120, SP115, SP26, SP 25, SP 86	Annual Program (initially) commencing Year 1
I3	<u>Non Structural Controls : Public Education</u> Develop a framework for a targeted series of education campaigns, coordinated with campaigns of other government agencies/ natural resource management groups. Topics to include but not limited to lawn and garden cutting disposal, car washing detergent use and practices, pet waste disposal, bird feeding in POS areas, composting, drains to rivers, and fertilising habits. Establish framework for a rolling program, initially targeting priority catchment areas.	Rolling Program commencing Year 2
I4	<u>Non Structural Controls : Maintenance Activity Review</u> Integrate an annual review of maintenance activity effectiveness in relation to water quality management with existing annual management review processes. Review activities to include fertilising timing and quantity of application, drainage infrastructure maintenance (eg GPT and gully eduction timings/frequency), street sweeping, native plantings/trees, revegetation practices.	Annual Review commencing Year 1
I5	<u>Structural Controls</u> No current action proposed. Review requirement for further structural controls based on outcomes of water quality monitoring program and established criteria.	Annual Review commencing Year 3
I6	<u>Receiving Environment : Landscape Plans</u> Develop specific landscape plans for artificial wetlands including Sir James Mitchell Park, McDougall Park, and Bodkin Park, to maximise the environmental and aesthetic value of these wetlands.	Individual Studies commencing Year 2
I7	<u>Receiving Environment : Existing Environmental Plans</u> Undertake improvements to receiving environments on the basis of priority environmental catchments identified in this study, consistent with recommendations contained in existing environmental management plans.	Ongoing
I8	<u>Piped Drainage : Known Flooding Locations</u> Complete existing program of pipe drainage upgrades at known flooding locations.	As per Existing Schedule
I9	<u>Piped Drainage : Overall System Review</u> Consider survey of piped drainage system and modelling to review system capacity.	Ongoing commencing Year 1
I10	<u>Basin Capacity : Preliminary Review</u> Undertake site investigation of basin capacities and conduct preliminary modelling to determine priority basins for further investigation.	Year 1
I11	<u>Basin Capacity : Detailed Investigations</u> Undertake detailed individual investigations for basin capacities depending on the outcome of Item I10. Includes detailed site survey.	Ongoing commencing Year 2
I12	<u>Basin Capacity : Rationalisation</u> Undertake investigation to determine opportunity for rationalisation of basins within the Study Area with a view to potential redevelopment of some sites. Requires Item I9, I10, and I11 to be completed prior to commencement.	Ongoing commencing Year 3
I13	<u>Strategy Review : Implementation</u> Integrate an annual review of implementation within existing annual management review processes.	Annual Review commencing Year 1
I14	<u>Strategy Review : Overall</u> Conduct an overall strategy review after a period of 5 years, including : • assessment of the success of measures implemented and programs undertaken. • analysis of monitoring data and monitoring programs. • integration of criteria and policy developments at the State Government level. • review new developments in stormwater quality management. • further refinement of the strategy and reassess priority catchments for future works.	Every 5 Years commencing Year 5

CONTENTS

LIST OF TABLES

APPENDICES

LIST OF FIGURES (Volume 2)

1. INTRODUCTION

1.1 Background

The City of South Perth recognise that existing and historical land use, and drainage systems may pose a threat to water quality and ecological values.

As part of the Swan Canning Cleanup Program, a planning process was developed to provide a framework for catchment management. This process, as detailed in the Local Government Natural Resource Management Policy Manual (2002), provides a mechanism to address urban stormwater management within established areas by local government in co-operation with State Government agencies and drainage utilities. The process aims to :

- Generate commitment to and awareness of best practice flood mitigation, land rationalisation, infrastructure asset management, and environmental management of stormwater and drainage.
- Identify priority issues using a risk based approach.
- Develop management strategies to address priority issues and risks.
- Establish a basis for ongoing cooperation and coordination between different sections of local government and different agencies.
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In this context, to achieve a comprehensive approach to urban water management, the City of South Perth has undertaken the development of an integrated catchment management (ICM) plan with the aim of identifying land use and water quality issues within its catchments and to determine strategies for monitoring and, where necessary, improving ecological values.

1.2 Objective

The overall objective of the study is the development of an integrated catchment management (ICM) plan which considers ways in which water quality can be managed utilising best management practice and innovative approaches in flood mitigation, infrastructure management, land rationalisation, and ecological management.

Specific objectives addressed within the ICM Plan are :

- Catchment Mapping
  To identify surface water and groundwater catchment boundaries
  To identify current extent of stormwater drainage system and associated infrastructure
  To identify historical and current land uses

- Water Quality
  To identify possible causes and sources of pollutants
  To provide recommendations for management of existing and potential pollutants
  To identify management strategies for achievement of water quality targets
  To develop a strategic monitoring program for water quality testing

- Environment
  To identify strategies and opportunities for enhancing and protecting environmental values
  To identify and manage instream and riparian vegetation
  To identify management options for control of exotic plants and animals

- Infrastructure
  To assess existing performance of drainage system (where possible)
  To identify current trends and development in urban stormwater management
  To recommend a risk-based program for collection of stormwater drainage data
  To identify strategies for involving industry, the community and government in managing the catchment
  To develop an implementation plan

1.3 About this Report

This study has been undertaken jointly by a study team comprising of JDA Consultant Hydrologists (JDA) and Ecoscape (Australia) Pty Ltd. The study report comprises two volumes :

- Volume 1 : Main Study Report
- Volume 2 : Figures/Plans

Volume 1 details the Study Outcomes, Objectives, Methodology, Analysis, and Strategy Development. Volume 2 provides a series of A3 plans detailing land use, surface and groundwater catchment boundaries, key drainage facilities, potential point and diffuse contamination sources, and resulting priority catchments.

As part of the process of undertaking the study, a standalone environmental management report was prepared by Ecoscape (Australia) Pty Ltd, with the outcomes of the investigation included within the main study report. A complete copy of the Environmental Management report is included as Appendix A of this document.

1.4 Acknowledgements

JDA and Ecoscape thank the following City of South Perth representatives for their guidance and contribution toward the preparation of the Integrated Catchment Management Plan :

- Murali Mahendran (Environmental Program Coordinator)
- Colin Ward (ex - Infrastructure Assets Engineer)

2. STUDY AREA CHARACTERISTICS

2.1 Location and Topography

The Study Area comprises the local government authority boundary of the City of South Perth (Figure 1). The Study Area is bounded by the Swan River to the north and west, the Canning River to the South and Kent St to the east.

The Study Area comprises of an approximate area of 1970 ha, and shares common borders with other local government authorities, the Town of Victoria Park and City of Canning.

The topography generally ranges from 0 to 5 m AHD along the Swan and Canning River foreshore areas, 5 to 15 m AHD over much of the Central Study Area, with some elevated areas to approximately 30 m AHD in the northern region (Figure 2).

2.2 Climate

The Study Area has a mediterranean climate with mild wet winters and hot dry summers.

The Bureau of Meteorology, Perth Regional Office Station has a long term average annual rainfall of approximately 862 mm (1880-2003). The average rainfall for Perth has decreased significantly since 1975, with the average annual rainfall of 788 mm, reflecting a 9% reduction compared to the long term average (Figure 3, Annual Rainfall).

The total rainfall distribution has also altered since 1975, with a reduction of average monthly totals in the winter months, and an increase in monthly rainfall in the drier summer months of January and February (Figure 3, Monthly Rainfall).

The Indian Ocean Climate Initiative (IOCI) recently published a consolidated report on 5 years of strategic research (IOCI, 2002). In terms of rainfall IOCI (2002) finds that southern Western Australia appears to have undertaken a step change since 1975 with less annual rainfall. IOCI (2002) concludes that climate affected sectors in southern Western Australia should actively revise their previous climate baseline and adapt accordingly to both natural and human induced changes in climate and climate variability.

2.3 Geology and Soils

Figure 4 presents the environmental geology of the Study Area as presented by Gozzard (1986), and similar to the surface geology as mapped by Davidson (1995).

A summary of the geology and soils of the study area from Gozzard (1986) is outlined below.

The geology of the study area is comprised of Quaternary deposits, with an east - west transition from the Pleistocene to the more recent Holocene. The transition is represented by Bassendean Sand in the east, Tamala Limestone in the centre (with an outcrop as exposed cliffs along the southern boundary at the Canning River) and a thin band of alluvial material fringing the western and southern boundaries with the Swan and Canning Rivers.

The Bassendean Sand is light grey at the surface and yellow at depth from an eolian origin. Sand in the centre of the study area is predominantly comprised of sands derived from the weathering of the underlying Tamala Limestone. Sands along the western and southern boundaries, and clay along the northern boundary, are all recent formations from an alluvial origin.

A peaty clay deposit and two peaty sand deposits are also located within the study area representing lakes (Figure 4).

2.4 Surface Drainage

A drainage overview map for the Study Area is shown in Figure 5.

The City of South Perth's surface water drainage system comprises of a piped network of both local and Water Corporation Main Drainage, which discharges to a variety of receiving bodies including:

- Canning River
- Swan River
- Lakes
- Compensating Basins
- Infiltration Basins, Swales, Soakwells
- Public Open Space Reserves

Water Corporation drainage is limited to the south eastern region of the Study Area. Two main drains exist – the Manning Main Drain and Collier Pines Main Drain. Both systems discharge to the Canning River.

Surface drainage considerations vary widely throughout the Study Area. Further detailed discussion on surface drainage, including delineation of catchment areas, is presented in Section 3. Field investigations of the existing stormwater drainage system were undertaken by JDA in April 2004 as part of this commission.

2.5 Groundwater

The City of South Perth is located on the Cloverdale groundwater mound (Figure 6). The Cloverdale mound is bounded by the Darling Scarp to the east and the Helena, Swan, and Canning Rivers covering an area of 171 km^2 (Davidson, 1995).

Perth Groundwater Atlas (Water and Rivers Commission, 1997a) provides maximum recorded groundwater contours for the Perth metropolitan area based on the maximum recorded groundwater levels at Water and Rivers Commission (now Department of Environment) bores.

For the Study Area, maximum recorded groundwater levels vary from less than 2 m AHD near the Swan River to 8 m AHD on the eastern boundary near Berwick St (Figure 6). Seasonal groundwater variation on the Swan Coastal Pain is typically in the order of 1.0 to 1.5 m.

Based on the topography (Figure 2), much of the Study Area has considerable depth to groundwater and hence provides an opportunity for infiltration of surface drainage.

2.6 Wetlands

Conservation Category Wetlands (CCW's) and Environmental Protection Policy (EPP) Lakes located within the Study Area (Figure 7) are :

- Goss Avenue Bushland adjacent to George Burrett Park (CCW, Dampland)
- Centenary Avenue, Clontarf (EPP Lake)
- Sandon Park (CCW, Lake)
- Sir James Mitchell Park (CCW, Estuary Peripheral)
- Salter Pt (CCW, Estuary Peripheral)
- Canning River Foreshore from Sandon Park to Clontarf (CCW, Estuary Peripheral)
- Canning River Foreshore from Canning River Bridge to Mt Henry Bridge (CCW, Estuary Waterbody)

All of these wetlands have existing management plans (Appendix A: Section 2.1). The DoE is currently reviewing the EPP Lake boundary at Clontarf.

All of these wetlands are currently part of the local authority drainage network or part of the Water Corporation's Main Drainage System.

Study Area's surface water drainage system discharges into a variety of bodies including Swan and Canning Rivers (Section 2.4). An EPP exists for the Swan and Canning Rivers.

2.7 Vegetation

The City of South Perth's original vegetation was predominantly Banksia/Jarrah woodlands. The majority of this vegetation has been cleared, with remnants of Jarrah (*Eucalyptus marginata)* and *Eucalyptus rudis/Melaleuca preissana* stands remaining (Bunny and Susanto, 2002).

Bush Forever was prepared by the Department of Environment Protection, Ministry for Planning, CALM and the Water and Rivers Commission and was endorsed by Cabinet and supported by the Environmental Protection Authority as the principle mechanism to identify and protect regionally significant bushland in the Perth Metropolitan Region (Ecoscape, 2004a). There are two Bush Forever Sites within the City of South Perth:

- Canning River Foreshore, Salter Point to Wilson, site 333
  The foreshore is part of the Swan-Canning Estuary which is listed as a wetland of national importance in the Directory of Important Wetlands in Australia and is subject to protection under the Commonwealth EPBC Act, 1999 (Government of Western Australia, 2000).

- Mount Henry Bushland, Salter Point, site 227
  This site contains the most inland vegetated knoll and area of Spearwood Dunes on the Swan-Canning Estuary and is of particular value in providing fauna habitat (Government of Western Australia, 2000)

2.8 Fauna

The wetlands and artificial lakes within the City of South Perth provide habitat for a wide range of fauna, of which birds are most prominent. In the more extensive area of natural vegetation of Salter Point and the Waterford Foreshore a total of 74 bird species have been recorded of which 14 are classified as fauna and protected by international treaties (Siemon, 2000).

There are less obvious species that also inhabit or potentially inhabit the wetlands of the Study Area. The Southern Brown Bandicoot and the Mastiff Bat are two native mammals that were recorded in the mid-1980s in Waterford but they may longer be present (Siemon, 2000). The City of South Perth Green Plan (2002) includes the recommendation that a conservation strategy for the Oblong Tortoise be developed and that its status and ecological requirements be documented.

Feral animals identified within the City of South Perth include the fox, cat and rabbit. The importance of controlling these feral animals is recognised in previous environmental management plans prepared for the City. There is strong evidence to suggest that foxes have caused the decline of many small to medium-sized species of Australian native mammals (Thompson, 2000). With their varied diets and ability to thrive in urban environments foxes pose a threat to a range of native animals in the Study Area.

Cats eat small mammals, birds, reptiles and insects. Results published in 1990 suggested that domestic cats in South Australia killed an average of 26 animals each per year, many of them native birds (Environment Australia, 1999). Rabbits compete with other animals for fodder and destabilise the soil by establishing warrens, reducing vegetative cover, and severely limiting bushland's ability to regenerate from seedlings (Short, 1985).

Further details of native and feral fauna and their habitats are contained in Appendix A (Ecoscape Environmental Management Report).

2.9 Land Use

2.9.1 Historical

Historical records indicate that the Study Area was not developed to any extent prior to the early 1800s.

Development was planned for South Perth in the late 1820s. However due to relative inaccessibility, and productive agricultural land only along the foreshore fringe subject to flooding, the area was relatively slow to develop (WRC, 1997b). In 1840 a Causeway was constructed over Heirisson Island increasing accessibility to the area, and the suburb of South Perth began (WRC, 1997b).

By the 1930s South Perth connected to Perth by the means of Jetties at Mends Street and Coode Street, Canning Bridge and a tram service. Perth Zoological Gardens and Royal Perth Golf Course were established in the early 1900s and the majority of land north of South Terrace had been developed at this time. A dairy farm and Chinese Market Gardens remained along the northern foreshore until the 1950s when the South Perth Council purchased the foreshore area (WRC, 1997b). The 1960s saw the construction of Kwinana Freeway, encouraging a population boom for the City and the development of multi storey high rise development (WRC, 1997b).

Historical records indicate that the foreshore of South Perth was subject to flooding and severe erosion. In an effort to reduce river flooding, erosion, increase boat-landing facilities and to reduce algal blooms between Richardson and Mends Streets, infilling commenced along the South Perth foreshore. In the 1850s Millars Pool located at the tip of Point Belches were filled, as were areas around Melville Parade and Coode Street Jetty (WRC, 1997b).

A domestic rubbish tip operating from 1959 to 1969 located along the foreshore area adjacent to Swanview Terrace, reclaimed 32 ha to a depth of 2 m (WRC, 1997b). The land was later landscaped in the 1980s into Sir James Mitchell Park's artificial lakes and recreation area.

Land filling also occurred along the Canning River foreshore, from Salter Point through to Clontarf Bay. The original wetland at Clontarf was more extensive than present today, extending from the Canning River foreshore to Manning Road and incorporating the area of Waterford Estate. Landfill consisting of sand and builders rubble (ATA, 2004) was deposited on the wetlands at Clontarf and the Canning River foreshore to raise the ground levels, to protect the built environment and to provide ovals (City of South Perth, 1993). Landfilling also occurred along Salter Point, firstly in 1975 with the dredging of the area south of Sandon Park creating a turning circle for Curtin Rowing Club and the sand was pumped ashore. Landfilling also occurred in 1977 at Salter Point Parade (WRC, 1997b).

2.9.2 Existing

Existing land use within the Study Area is shown in Figure 8. The City of South Perth's dominant land use is residential, covering over 46% of the total area. Most urban areas are well established, though there are some newer development areas at Karawara, Waterford, and Mt Henry. The densely populated areas are located at Point Belches, along the South Perth foreshore west of Sir James Mitchell Park and bordering Canning Highway (Figure 8). The City has two main district centres located at Mends Street, South Perth and off Manning Road, Karawara. There is no industrial land use zoning.

There are some pockets of commercial land, and considerable areas of public open space associated with foreshore reserves. The Study Area also contains a number of Private Institutions (Penhros, Clontarf, Wesley, Aquinas College).

The freeway, and primary and secondary road networks are shown in Figure 8, with the only primary road being Canning Highway. Secondary Roads include South Terrace, Labouchere Road, Mill Pt Road, Kent St and Manning Rd.

Further discussion on land use in the context of surface drainage is presented in Section 3.

3. SURFACE WATER CATCHMENT PLANS

3.1 Methodology

3.1.1 Catchment Boundaries

Surface water catchment boundaries for the Study Area were determined based on the following data :

- Existing drainage network detail via City of South Perth
- Water Corporation Main Drainage detail
- Freeway and South Perth drainage outfall condition survey (Brown & Root, 2000)
- Topographic data
- Drainage detail provided by adjacent local authorities (City of Canning and Town of Victoria Park)
- Field verification of selected catchments by JDA

It should be noted that the City of South Perth existing drainage network data is currently incomplete and does not provide full coverage over the Study Area. To this extent catchment boundaries presented in this report should be considered indicative only, subject to further refinement as more detailed survey is undertaken.

A total of 147 catchments were identified.

Verification of catchment boundaries was undertaken by City of South Perth.

3.1.2 Receiving Environment Classification

Surface water receiving environments were classified into 8 types, with each catchment assigned a classification as follows:

- River – Swan Direct
  catchment drains directly to the Swan River
- River – Canning Direct
  catchment drains directly to the Canning River
- River – Swan via Compensating Basin
  catchment drains to a compensating basin and then to the Swan River
- River – Canning via Compensating Basin
  catchment drains to a compensating basin and then to the Canning River
- Infiltration Basin/Swale/Soakwell Dry
  catchment drains to a dry infiltration basin or swale (eg sump).
- Infiltration Basin/Swale/Soakwell Wet
  catchment drains to a wet infiltration basin (eg lake).
- Infiltration Parks/Reserves
  catchment discharges into a park or reserve via a designated outlet without a defined basin.
- Infiltration Diffuse
  catchment does not have a direct discharge point and infiltrates in a diffuse manner
  (eg foreshore reserve without a formal drainage system)

Note that catchments classified with the above drainage receiving environments may also contain soakwells to infiltrate stormwater at a local scale or within some road reserves. The above classifications relate to the predominant receiving environment of the regional drainage network.

3.1.3 Drainage Facilities

The location of key drainage facilities were identified based on the following sources :

- Infiltration basin locations and compensating basin locations via City of South Perth
- Gross Pollutant Traps via City of South Perth, Main Roads WA, and Brown & Root (2000)
- River Outfalls via City of South Perth and Brown & Root (2000)

3.2 Catchment Mapping

Based on the methodology and data collated from Section 3.1, a consolidated surface water catchment map for the Study Area was derived (Figure 9), with more detailed mapping presented in Figure 10 to 13.

Each catchment was assigned a unique identifier for reference purposes. Individual catchment areas are contained in Appendix B.

3.3 Statistical Overview

Table 1 provides a summary of key surface water drainage statistics derived from the catchment mapping contained in Figures 9 to 13. Findings are summarised as follows :

- The City's drainage system is largely fragmented, comprising of a large number of catchments (147), and a large number of drainage facilities, including a total of 80 infiltration or compensation basins, and 54 outlets to the Swan and Canning Rivers.

- Catchments which cross local authority boundaries with the Town of Victoria Park or City of Canning comprise less than 4% of the total Study Area. In addition, Water Corporation main drainage systems drain an external area of approximately 8% of the size of the Study Area into the City of South Perth.

  This interaction of the drainage system across local authority boundaries is considered low, particularly in comparison to WESROC (Western Suburbs Regional Organisation of Councils), where 45% of the total area lies in catchments which cross local authority boundaries (JDA, 2002c).

  To this extent the surface drainage system within the City of South Perth can be considered largely self contained and surface water quality within the Study Area predominately, a result of land use and existing management practices within the City of South Perth and not significantly impacted by external influence.

- Approximately 39% of outlets (21 of 54) discharging to the Swan or Canning Rivers have Gross Pollutant Traps installed. Not all of these GPTs however are current technology, with many of the GPTs for the Freeway being letterbox type and less efficient than current technology. Two GPT's are installed on outlets to lakes.

- Infiltration of stormwater is the predominant method of stormwater disposal for the Study Area.

  Approximately 65% of the Study Area infiltrates stormwater. 41% is infiltrated within designated basins/swales and or soakwells and 3% infiltrated into parks and reserves without a designated basin area. The remaining 21% of area infiltrated corresponds to areas which have diffuse infiltration and do not have a direct discharge point and/or formal drainage system.

- In terms of river discharges, 19% of the Study Area discharges to the Swan River and 16% discharge to the Canning River. The majority of area discharging to the Canning River is via Water Corporation Main Drainage.

- Of the 35% proportion of the Study Area with discharges to the Swan and Canning Rivers, 40% (14% of total Study Area) discharges in to the rivers via compensating basins, which provide some opportunity for treatment prior to discharge, while 60% (21% of total Study Area) of discharges are direct.

Table 1: Surface Water Catchments Statistical Overview

Local Authority Area (ha)	1970
Total No. of Catchments	147
Flow Across Local Authority Boundaries (No. of catchments and Area ha)	
Flow Out to Town of Victoria Park Local Authority Drainage System	3 (32 ha)
Flow Out to City of Canning Local Authority Drainage System	0 (0 ha)
Flow Out to Water Corporation Main Drainage System	2 (11 ha)
Flow In from Town of Victoria Park Local Authority Drainage System	5 (8 ha)
Flow In from City of Canning Local Authority Drainage System	1 (25 ha)
Flow In from Water Corporation Main Drainage System	2 (139 ha)
Number of Drainage Facilities	
Infiltration Basins – Wet	2
Infiltration Basins – Dry	62
Compensating Basins – Wet	13
Compensating Basins – Dry	3
Swan River Outlets	45
Canning River Outlets	9
Gross Pollutant Traps	23
Area Discharging to Receiving Environment Classification (ha and % of total City of South Perth Area)	
River – Swan Direct	271 (14%)
River – Canning Direct	131 (7%)
River – Swan via Compensating Basin	101 (5%)
River – Canning via Compensating Basin	186 (9%)
Infiltration Basin/Swale/Soakwell Dry	720 (37%)
Infiltration Basin/Swale/Soakwell Wet	80 (4%)
Infiltration Parks/Reserves	54 (3%)
Infiltration Diffuse	426 (21%)

3.4 Land Use Analysis

Land use within each catchment of the Study Area was accumulated into 6 main categories to enable analysis of catchment land use in the context of the receiving environment classification (Section 3.1.2) :

- Residential : R20 zoning or less dense
- Residential : greater density than R20 zoning
- Commercial
- Parks and Recreation : Passive (eg Natural Bush)
- Parks and Recreation : Active (eg Sports Fields, Golf Courses)

For analysis purposes in this study, areas zoned Mixed Use Commercial, Private Institution, Public Assembly, Public Purposes, Technology Park were allocated in to the above general land use categories via aerial photograph interpretation on a case by case basis. A detailed breakdown of land use within each catchment is presented in Appendix B.

Table 2 presents a summary of areas discharging to various receiving environment classifications in relation to the six broad land use categories defined above. Table 3 presents this same information tabulated as percentages of the total Study Area. The key findings from Tables 2 & 3 are summarised as follows:

- Based on four broad categories (Table 3) residential areas comprise approximately of 50.1% of City of South Perth, parks & reserves 23.9%, road & reserve 22.3%, and commercial 3.7%. The majority of the parks and recreation areas are active. Passive recreation areas (eg natural bush) comprise 4.9% of the total Study Area.

- Approximately half of all road and road reserve areas are infiltrated, and half are discharged to the Swan and Canning Rivers. Of road reserve areas discharging to the Swan River, the majority is discharged uncompensated.

- Almost three quarters of all commercial land is infiltrated.

- The majority of residential land discharging to the Swan River is higher density (>R20) and uncompensated (Table 2). Conversely, the majority of residential land discharging to the Canning River is lower density (<=R20) with the majority of flow being compensated prior to discharge.

  Uncompensated flows are more likely to have capacity to cause erosion, while lower density residential in likely to results in higher nutrient application (further discussed in Section 4).

- The vast majority of parks and recreation areas are infiltrated

These results are further interpreted in subsequent sections of this report in the context of developing priority environmental catchments (Section 4) and developing strategy and implementation plans (Section 9 & 10).

Table 2: Area Discharging to Receiving Environment Classification by Land Use (As % of Land Use Area)

	Parks & Recreation Active	Parks & Recreation Passive	Residential <=R20	Residential >R20	Commercial	Road & Reserve
Total Area (ha)	373	98	667	321	71	439
Swan River Discharge						
River Direct (%)	1.5	0.7	3.4	41.7	13.6	22.5
River via Comp Basin (%)	4.1	0.0	6.0	5.8	4.4	5.4
Total (%)	**5.6**	**0.7**	**9.4**	**47.5**	**18.0**	**27.9**
Canning River Discharge						
River Direct (%)	0.4	0.2	10.1	2.4	2.8	11.7
River via Comp Basin (%)	9.4	8.7	12.7	2.9	5.7	10.1
Total (%)	**9.8**	**8.9**	**22.8**	**5.3**	**8.5**	**21.8**
Infiltration						
Infiltration Basin/Swale/Soakwell Dry (%)	16.1	9.0	48.1	39.7	51.5	37.8
Infiltration Basin/Swale/Soakwell Wet (%)	3.8	0.0	5.0	4.0	0.6	4.4
Infiltration Parks/Reserves (%)	0.4	0.3	5.1	0.9	0.0	3.6
Infiltration Diffuse (%)	64.3	81.1	9.6	2.6	21.4	4.5
Total (%)	**84.6**	**90.4**	**67.8**	**47.2**	**73.5**	**50.3**
Total of Land Use (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Table 3: Area Discharging to Receiving Environment Classification by Land Use (As % of Total Study Area)

	Parks & Recreation Active	Parks & Recreation Passive	Residential <=R20	Residential >R20	Commercial	Road & Reserve
Total Area (ha)	373	98	667	321	71	439
Swan River Discharge						
River Direct (%)	0.3	0.0	1.2	6.8	0.5	5.0
River via Comp Basin (%)	0.8	0.0	2.0	0.9	0.2	1.2
Total (%)	**1.1**	**0.0**	**3.2**	**7.7**	**0.7**	**6.2**
Canning River Discharge						
River Direct (%)	0.1	0.0	3.4	0.4	0.1	2.6
River via Comp Basin (%)	1.8	0.4	4.3	0.5	0.2	2.3
Total (%)	**1.9**	**0.4**	**7.7**	**0.9**	**0.3**	**4.9**
Infiltration						
Infiltration Basin/Swale/Soakwell Dry (%)	3.0	0.5	16.3	6.5	1.9	8.4
Infiltration Basin/Swale/Soakwell Wet (%)	0.7	0.0	1.7	0.7	0	1.0
Infiltration Parks/Reserves (%)	0.1	0.0	1.7	0.1	0	0.8
Infiltration Diffuse (%)	12.2	4.0	3.2	0.4	0.8	1.0
Total (%)	**16.0**	**4.5**	**22.9**	**7.7**	**2.7**	**11.2**
Total of City of South Perth Area (%)	**19.0**	**4.9**	**33.8**	**16.3**	**3.7**	**22.3**

4. ENVIRONMENTAL PRIORITY CATCHMENTS

4.1 Methodology

The following approach details the framework adopted for defining environmental priority catchments within the Study Area on the basis of existing and historical land use impacts, and the environmental and social values of the receiving environment.

In the absence of detailed water quality data for individual catchments within the Study Area, environmental priority catchments were determined using the process of map overlay techniques (Hollick, 1993) based on the following key indicators to stormwater quality for each catchment identified in Section 3.

- Nutrients
  Estimated nutrient application rates (Total Phosphorus and Total Nitrogen) for each catchment based on current land use

- Metals/Other Pollutants
  Percentage of major roads (primary, secondary, and freeways) with each catchment
  Percentage of current commercial land with each catchment

These diffuse sources of pollution were then analysed in relation to the environmental and social value of their receiving environments to determine environmental priority catchments. The risks associated with potential point sources of pollution and historical land use considerations were then considered in the context of the identified priority catchments.

These priorities do not include consideration of current City of South Perth programs to improve stormwater quality in these sub catchments (eg street sweeping, gross pollutant traps). Existing programs are discussed in relation to environmental priority catchments in Section 9.

4.2 Potential Diffuse Sources of Pollution

4.2.1 Nutrients

NiDSS (Nutrient Input Decision Support System) is a tool developed by JDA Consultant Hydrologists to assist in land use management planning, and allow quantitative estimation of nutrient input rates and the potential reduction in nutrient input (including costings) for various combinations of water sensitive urban design (WSUD) water quality management measures.

NiDSS focuses on the adoption of an integrated catchment approach to water quality management, including evaluating measures to minimise nutrient inputs at source, and it provides a logical framework for the evaluation of the effectiveness of various best management practices for nutrient input management.

It calculates the total expected nutrient input rate for a particular area based on aggregating individual nutrient inputs from different land uses (residential lots, POS, road reserves, conservation areas) prior to implementation of stormwater management measures. The impact of individual at-source and in-transit controls on nutrient input can then be determined by either turning on/off individual controls or varying the effectiveness of these measures. The model results present information on :

- estimates of Total Phosphorus (TP) and Total Nitrogen (TN) application to an area
- estimates of reductions due to source control measures (education, street sweeping)
- estimates of reductions due to in-transit controls (Gross Pollutant Traps, WPCP's)
- estimates of the cost of removal (in PV terms) for a selected WSUD program.

Sample model input and output from NiDSS are shown in Appendix C.

NiDSS was applied to the Study Area to model existing land use within each catchment and identify potential areas of high nutrient input. Land use categories as previously described in Section 3.4 were adopted. Nutrient application rates were adopted from the Southern River Urban Water Management Strategy (JDA, 2002a), which based application rates on nutrient input surveys conducted by JDA in medium density residential areas, and on previous work of Gerritse et al. (1991, 1992).

Results are shown in Appendix C, with estimated total phosphorus input summarised in Figure 14. The results show high nutrient application areas are typically residential areas of lower density. Comparing Figure 14 to Figure 9 (Surface Water Catchment Plan : Overview) most areas with estimated high nutrient input are located in infiltration areas. Areas of estimated high nutrient input discharging to the Swan and Canning Rivers include the suburbs of Salter Pt and Waterford, and South Perth near the Ellam St / Mill Pt Rd intersection.

In interpreting the results of this analysis it should be noted that calculations have been conducted and results collated to a catchment level only, with a view to providing sufficient detail for calculation of environmental priorities at a catchment level. Assessment at a more detailed level within each catchment has not been performed as part of this study.

4.2.2 Metals and Other Pollutants

Indicators used in this study to provide a qualitative assessment of other pollutants (including heavy metals) as discussed in Section 4.1 are the proportion of major roads and commercial land within each catchment.

The use of these variables as indicators are based on Pierce and Davies (1999) and JDA (2002c). Pierce and Davies (1999) and JDA (2002b) found that compared to other diffuse sources of pollutants, road sediment is potentially a significant source of heavy metals (Cu, Pb, Zn) to receiving wetlands in Perth. JDA (2002c) adopted a similar approach to that described above to determining catchments likely to have increased levels of metals and other pollutants, and this has been subsequently supported by water quality data collected from these catchments over two years of monitoring (JDA 2003a, 2003b).

Mapping of major roads and commercial areas as a percentage of individual catchment areas are shown in Figures 15 and 16.

4.3 Environmental/Social Value of Receiving Environment

Classifications and rankings given to protecting and/or enhancing the receiving environment based on social and environmental attributes are shown in Table 4.

Table 4 : Receiving Environment Ranking Based on Social/Environmental Attributes

Ranking	Social Attributes
Low	• No Public Access
Medium	• Limited Public Access and/or Non-focal Point in Public Area
High	• High Degree of Public Access and/or Focal Point of Public Area • Previously identified for incorporation into a public area as a focal point
Ranking	**Environmental Attributes**
Low	• No Native Plants • Highly Modified Site • Extent and Distribution not considered • No natural receiving waterbodies
Medium	• Limited range of native plants • Mixture of weeds and native plants • Moderately Modified Site • Vegetation common in Study Area • Large natural receiving waterbodies (i.e. individual drain has limited influence on water quality of water body)
High	• Predominately Native Plants • Low – Moderate Modification of Site • Vegetation uncommon in Study Area • Small natural receiving waterbodies (i.e. individual drain has significant influence on water quality of water body)

These individual rankings for social and environmental attributes were then combined to a single representative ranking as shown in Table 5. Given the large number of catchments and hence receiving environments in the Study Area, it was not practical to inspect every individual outlet to determine its social and environmental attributes for this investigation. Social and environmental rankings for each catchment were generally determined on the basis of examining the focal points for each of the catchments on aerial photographs and the type of outlet (e.g. infiltration swale, direct to river, wet or dry compensation basin etc). Summarising the method applied to rankings :

- All dry compensation basins were deemed to have low social and environmental ranking (unless recommended for incorporation into parks in the Green Plan(2002)) as they were assumed to have little or no native vegetation and restricted public access.
- Dry compensation basins recommended for incorporation into parks in the Green Plan (2002) were rated of high social and low environmental value on the basis that their incorporation into relatively small parks will make them a focal point and the default environmental value reflects that details of the type and extent of revegetation has not been specified and these sites tend to be isolated from bushland.
- Infiltration swales in parkland or ovals were deemed to be of medium social ranking and low environmental value.
- Parks within catchments that did not have drainage leading into them where not considered in rating the catchment, except where the entire catchment consisted of parkland (e.g. golf courses) in which case the catchment was deemed to be a high social ranking and the environmental ranking was assessed onsite.
- All outlets into the Swan and Canning Rivers were deemed to have medium social and environmental ranking unless the outlet coincided with significant riparian vegetation or other factors were indicated by the City of South Perth. It was assumed that there is public access but that these outlets are not a focal point for activities and there is generally little riparian vegetation. It should be noted that catchments draining directly into the Swan and Canning Rivers were not always adjacent to the river (Figure 9).
- Catchments with direct infiltration next to areas of high environmental priority or the Swan Canning River were deemed as a moderate ranking, as a minimum. This was based on the Water and Rivers Commission recommendation that wetlands of significant conservation value have a buffer of 200 m or greater to allow for the filtration and attenuation of nutrients (WRC, 2000e).
- Any natural bushland was of high social and environmental value; and
- All wet compensation basins were assessed onsite by Ecoscape (as they tended to be vegetated but the level of access and amount of native vegetation needed to be confirmed).

On this basis, all catchments were assigned a ranking as shown in Table 5. Results are shown in Figure 17. The sites that are of the greatest overall significance are generally located in the southern portion of the Study Area. A total of 24 catchments (16% of total) are considered either High-High or High-Medium ranking.

Further detailed description of the calculation of environmental and social ranking of receiving environments is contained in Appendix A (Ecoscape Environmental Management Report).

Table 5: Overall Receiving Environment Ranking

Combinations of Social & Environmental Ranking	Overall Combined Receiving Environment Ranking	Number of Catchments
High-High	1	13
High-Medium	2	11
High-Low	3	16
Medium-Medium	4	41
Medium-Low	5	5
Low-Low	6	61

4.4 Priority Environmental Catchments

Indicators for nutrient and other pollutant input were analysed in relation to the determined environmental/social value for each receiving environment as identified in Section 4.3 to determine the priority environmental catchments.

The top 20 priority catchments are shown in Figure 18, with the top 10 summarised in Table 6. Priority catchments are typically located in the southern region of the Study Area and mainly discharge to the Canning River. Only 2 catchments in the Northern Region are in the top 10 priority list, both of these discharging to basins in Sir James Mitchell Park.

It should be noted that catchment SP 120, rated 6 in the priority list is zoned R20, and hence nutrient input shown in Table 6 reflects potential future input for this catchment rather than its existing land use as Murlali Lodge.

Some of the priority areas identified correspond with areas previously identified by the City of South Perth to improve stormwater discharge quality and areas with existing environmental management plans. Some of the areas identified have already had stormwater quality improvement measures installed.

Further discussion of priority environmental catchments is presented in Sections 9 and 10. Detailed priority catchment calculations and complete priority listings are contained in Appendix D.

4.5 Potential Point Sources of Pollution

Four types of potential point sources of pollution for the Study Area are shown in Figure 19 in relation to the priority catchment identified in Section 4.4 :

- Abandoned Landfill Sites
  (located at Sir James Mitchell Park, Earnest Johnston Oval, Morris Mundy Reserve, Graydon Reserve, Trinity College Playing Fields, The area between Clontarf Bay and Manning Road, Waterford)
- Abandoned Liquid Waste Disposal Site
  (at Village Green Manning Road, Karawara - used for night soil disposal)
- Various Fuel Storage Sites
- Water Corporation Wastewater Pumping Stations

Sites were sourced from the Department of Mines Inventory of Known and Inferred Point Sources of Groundwater Contamination (Hirschberg, 1991), WRC Groundwater Atlas (1997a), Water Corporation Wastewater Pumping Station Plans, and ATA Environmental's Environmental Assessment of East Clontarf (2001).

All Water Corporation pump station locations have been included as potential sources of groundwater contamination. Sewerage overflow has previously occurred on one occasion from the Kilkenny Circle Wastewater Pumping Station, resulting in untreated sewerage entering the surface water drainage system and ultimately discharging to the Canning River. This station is assessed to have a sewerage overflow risk of 1 in 200 years (Ecosystem Management Services, 2000).

Potential point sources of pollution located in priority catchment areas identified in Section 4.4 are considered the priority sites for management consideration. This is discussed in further detail in Section 9. A summary tabulation of potential point sources of pollution for individual catchments is contained in Appendix D.

Table 6: Top Ten Priority Environmental Catchments

Priority. Catchment	Location / Description	Area (ha)	Nutrient Input TP kg/ha/yr	Major Roads (% of area)	Commercial (% of area)	Receiving Environment Social-Env Ranking
1. SP 136	Located south of Manning Rd, Waterford. The predominant land use is Residential (>=R20), also containing Bodkin Park and Manning Rd. Drainage via two Bodkin Park WC Compensating Basins, part of Collier Pines MD discharging to the Canning River.	41.0	34.2	6%	0%	High/High
2. SP 110	The catchment is located North of Manning Rd, Manning. Residential Area (<=R20) including Goss Avenue Bushland, and part Manning Rd drainage. Drainage to WC Manning MD compensating basin discharging to the Canning River.	28.0	32.1	9%	0%	High/High
3. SP 140	Clontarf, east of Clontarf College including catchment extending into City of Canning Predominantly a residential area (<=R20) including Clontarf EPP Lake and part Manning Rd drainage. Drainage compensated to Clontarf EPP Lake discharging to Canning River.	21.3	41.1	7%	0%	High/High
4. SP106	Located within the suburb of Manning and part of Como, including James Miller Oval. Catchment predominantly residential (mainly <=R20), includes Manning Primary School, Highway, Commercial and part Manning Rd drainage. Drainage into Open Bushland and Manning Primary School Oval.	47.3	25.3	4%	7%	High/High
5. SP139	Located South of Manning Rd, Waterford. Catchment drains to infiltration basin located within the park on Doneraile Ct. 78% of the catchment is residential (>=R20), remaining area is active park & recreation.	7.4	37.9	0%	0%	High/High
6. SP120	South of Manning Rd, Como. The catchment consists of Murlali Lodge (zoned R20) and Hogg Ave bushland. Drainage is via diffuse infiltration with depression located at bushland, Hogg Ave.	3.5	38.5	0%	0%	High/High
7. SP115	Karawara, North of Manning Road, South of Collier Park Golf Course. The catchment is predominantly residential, of which 75% is <=R20 and 25% of catchment is active parks & recreation. The catchment discharges to Lake Gillon is part of WC Collier Pines MD compensating basins, discharging to the Canning River.	72.4	28.2	0%	2%	High/High
8. SP26	Located north of Canning Highway, South Perth. Drainage to Swan River via a compensating, artificial lake located within Sir James Mitchell Park, near Hurlingham Rd. Residential catchment containing commercial areas, Canning Hwy, Mill Point Rd and active parks & recreation.	49.0	31.3	4%	3%	High/ Medium
9. SP 25	Located north of Canning Highway, South Perth. Drainage to Swan River via a compensating, two interconnected artificial lakes of Sir James Mitchell Park, near Douglas Ave. Residential catchment containing commercial areas, Canning Hwy, Mill Point Rd, Douglas Ave and active parks & recreation.	48.6	25.1	6%	3%	High/ Medium
10. SP 86	Catchment draining to Neil McDougall Park Lake, Como. Lake acting as an infiltration basin (wet). Residential catchment, with active parks & recreation and a small commercial area.	69.2	30.8	0%	1%	High/ Medium

5. INFRASTRUCTURE PRIORITY CATCHMENTS

5.1 Methodology

The following approach details the framework adopted for defining infrastructure priority catchments within the Study Area on the basis of identifying areas of known flooding and by modelling of the drainage infrastructure.

This methodology has not been fully applied in this study due to infrastructure data constraints, however the approach described below sets a framework for the City of South Perth to apply to determine priority areas as information becomes available.

Similarly to environmental priority catchments, map overlay techniques (Hollick, 1993) are recommended to determine infrastructure priority catchments based on the following key indicators :

- Piped Drainage Capacity
  Based on known areas of flooding (via City of South Perth)
  Based on modelling of piped drainage system
- Infiltration and Compensating Basin Capacity
  Based on known areas of flooding (via City of South Perth)
  Based on modelling of storage volume requirements against existing basin capacity and City of South Perth design requirements

Modelling of basin capacity is particularly recommended, as basins are sized for rarer storm events, therefore anecdotal information on flooding may not exist even if undersized.

5.2 Assessment of Pipe Capacities

Assessment of individual piped drainage systems within each catchment has not been undertaken as part of this commission.

Catchments with known areas of flooding are shown in Figure 20 and summarised in Table 7 in relation to existing programs to investigate and undertake works in these areas. Some of these works have already been commenced or completed. Sites are generally located in the cental region of the Study Area.

Survey data of the piped drainage system is incomplete and would need to be undertaken to enable detailed modelling to occur and all piped systems checked for compliance with City of South Perth drainage criteria.

5.3 Assessment of Basin Capacities

For each basin, information regarding basin area was available but not basin volumes or key survey and infrastructure detail. Without this data, an assessment of basin capacities cannot not be undertaken.

For infiltration basins, based on land use and catchment areas determined in Section 3.2, indicative storage volumes to contain the 10 and 100 year average recurrence interval (ARI) 24 hour duration storm events were determined for each basin. Calculations are detailed in Appendix E. These volumes provide a guide for comparison to existing basin capacities and assess which basins may require further detailed assessment and/or infiltration modelling.

There is no anecdotal information regarding basins overtopping or basins known to be under capacity (Colin Ward, pers comm.) from which a preliminary list of priority basins (without any further information) could be determined.

No further assessment of basin capacities was therefore possible in this study.

5.4 Priority Infrastructure Catchments

Based on the current lack of infrastructure detail available for piped drainage systems and existing basin size details within the Study Area, priority catchments on the basis of infrastructure considerations cannot be determined within the scope of this study.

On a similar basis, consideration of rationalising infiltration sumps within the Study Area with a view to potential redevelopment of some sites cannot be undertaken without detailed survey data.

Sections 9 and 10 contain recommendations for information gathering and additional survey requirements to enable priority infrastructure catchments to be determined on the basis described in this Chapter. Prior to this process being implemented, sites detailed in Table 7 and Figure 20 should be considered the priority infrastructure areas.

Table 7 : Locations of Reported Flooding

ID	Location	Description	Cause	Action	Timing
1	Barker Avenue	Verge in front of low point relatively low allowing stormwater to overtop and run into property	Insufficient pipe and inlet capacities	Currently under investigation by City and David Porter Consulting Engineer - design expected soon	2004/05
2	Bessell Avenue	-	Pipe through easement in properties suspected to be of insufficient capacity	Design subject to results of investigation by David Porter Consulting Engineer - Design options currently being considered include soakwells in verge at low point	2003/04 or 2004/05
3	Craige Crescent	Gully grate outside property prone to blockage	No pits in Craige crescent from Mount Henry Rd to park	Drainage line thought to run north-east to connect with SL9L and not discharge into park area as shown - need to verify on site	-
4	Godwin Avenue	Properties on southern side subject to inundation during heavy storms	Discharge points are bubble up pits thought to have been partially blocked	Problem investigated by City and David Porter Consulting Engineer - new swale / sump area to be created to take overflow from storms in garden area west of cul de sac head	2003/04
5	Sixth Avenue	Recent upgrade completed by installing new pipe in southern verge and upgrading pipe in Banksia Terrace	-	-	-
6	Talbot Avenue	Properties on western side of road were at risk of flooding due to insufficient pipe size	Pipe crossing road replaced in 02/03 financial year however localised flooding of road carriageway still occurring due to insufficient inlet capacity	More inlets required in northern area of catchment	-
7	Todd Avenue	-	Main pipe suspected of having insufficient capacity	Currently being investigated by the City and David Porter Consulting Engineer	2004/05
8	Welwyn Avenue	Localised flooding occurring - road carriageway gets inundated and action from passing traffic washes mulch from property garden bed	-	Subject of investigation by City and David Porter Consulting Engineer - Proposed works of creating a large soak area in middle of Welwyn Ave	2003/04 or 2004/05

6. WATER QUALITY STANDARDS & CRITERIA

Currently applicable standards and criteria for water quality are not clearly defined at State Government level in Western Australia. The Department of Environment (formerly Water and Rivers Commission) are currently in the process of revising their “Manual for Managing Urban Stormwater Quality in Western Australia” (WRC, 1998), and it is expected that the outcomes of this process will provide a clearer definition of water quality standards and criteria to apply in urban stormwater management.

Several chapters of the revised manual have been completed and recently released as part of the first part of a staged release by DoE (DoE, 2004).

This chapter presents a review of recent development in water sensitive urban design and existing documentation, and provides some recommendations toward establishing interim standards and criteria to apply to the Study Area. The Chapter also provides a description of various water quality management options, their applicability and suitability, and relative capital and maintenance costs.

6.1 National Context

The National Water Quality Management Strategy (NWQMS) was introduced by the Commonwealth, State and Territory Governments in 1992 as a response to growing community concern about the condition of the nation’s water bodies and the need to manage them in an environmentally sustainable way. The Strategy has three main elements : policies, process, and guidelines.

The NWQMS guidelines consist of a series of 21 documents prepared by the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand. Of these documents, three related to urban stormwater quality management are :

- Guideline 4 : Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a)
- Guideline 7 : Guidelines for Water Quality Monitoring and Reporting (ANZECC, 2000b)
- Guideline 10 : Guidelines for Urban Stormwater Management (ANZECC, 2000c)

Responsibilities for implementing the NWQMS falls across a number of West Australian state government agencies including the Department of Environment, Environmental Protection Authority (EPA), the Department of Environmental Protection (DEP), and the Health Department of Western Australia.

6.1.1 Australian & New Zealand Guidelines for Fresh and Marine Water Quality

The main objective of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a) is to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values (uses) for natural and semi-natural water resources in Australia and New Zealand.

This document supersedes the Western Australian Water Quality Guidelines for Fresh and Marine Waters (EPA Bulletin 711, 1993). As ANZECC (2000a) contains more site specific information than the previous 1992 version of the same document, the DEP have indicated no separate Western Australian state document will be required.

While ANZECC (2000a) indicates that the guidelines are not intended to be directly applied to stormwater quality, they are applicable where stormwater systems are regarded as having conservation value. Default trigger values (concentrations below which there is a low risk of adverse biological effects) applicable for protection of aquatic ecosystems in south-west Australia are presented in Table 8. These trigger values were derived from ecosystem data for unmodified or slightly-modified ecosystems, and are not based on any objective biological criteria. It is recommended they should only be applied where site-specific values do not exist or until site-specific values can be derived.

Table 8 : ANZECC (2000a) Recommended Default Water Quality Trigger Values

Ecosystem Type	TP (mg/L)	FRP (mg/L)	TN (mg/L)	NOx (mg/L)	NH4+ (mg/L)	pH (mg/L)
Upland River	0.02	0.01	0.45	0.2	0.06	6.5 – 8.0
Lowland River	0.065	0.04	1.2	0.15	0.08	6.5 – 8.0
Freshwater Lakes & Reservoirs	0.01	0.005	0.35	0.01	0.01	6.5 – 8.0
Wetlands	0.06	0.03	1.5	0.1	0.04	7.0 – 8.5
Estuaries	0.03	0.005	0.75	0.045	0.04	7.5 – 8.5

ANZECC (2000a) also provides water quality guideline trigger values for toxicants (including metals, pesticides, hydrocarbons, and industrial chemicals) to provide alternative levels of protection. Values are reproduced in Appendix F together with a decision tree to be applied in assessing toxicant levels.

The current NWQMS approach recommends moving away from relying solely on chemical guideline values for managing water quality to the use of integrated approaches comprising chemical specific guidelines coupled with water quality monitoring, direct toxicity assessment, and biological monitoring.

This approach will help ensure that the water management focus keeps in view the goal of protecting the environment and does not merely shift to meeting numbers.

6.1.2 Australian Guidelines for Urban Stormwater Management

The Australian Guidelines for Urban Stormwater Management (ANZECC, 2000c), aims to provide a nationally consistent approach for managing urban stormwater in an ecologically sustainable manner, and provides details of current best practice in stormwater management and planning in Australia. The document highlights the need for a more holistic approach to stormwater management which addresses issues of stormwater quality and aquatic ecosystem health, and recognises the environmental impacts of urbanisation, the linkages between land and water management and the importance of community values and involvement.

The document references the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a) to provide water quality objectives, but acknowledges that objectives for urban stormwater management are complicated by :

- water quality being affected by other pollution sources, such as point sources, agricultural runoff and sewer overflows
- difficulties in establishing relationships between ambient water quality concentrations and wet weather stormwater discharges.

6.1.3 Australian Guidelines for Water Quality Monitoring and Reporting

The Australian Guidelines for Water Quality Monitoring and Reporting sets out an overall framework for the establishment of monitoring programs, and presents methods and routines for the setting of monitoring objectives, study design, field sampling, laboratory analyses, data analysis and the reporting and dissemination of information.

Similarly to the Australian Guidelines for Urban Stormwater Management (ANZECC, 2000c), the document references the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a) to provide water quality objectives.

6.1.4 State Water Quality Strategy Framework for Implementation

The State Water Quality Management Strategy (SWQMS) for Western Australia was launched by the State Government in May 2001 and adopted the same principles set out in the National Strategy and proposed supporting strategies for implementation based on the national framework.

The implementation framework for the SWQMS was drafted with the primary objective to ensure that an administrative structure for water quality management is established in Western Australia that is consistent with the NWQMS. The framework for implementation is the first document of a series, which will ultimately form the Western Australian SWQMS.

6.2 Local Context

6.2.1 Stormwater Management Manual for Western Australia

The Water and Rivers Commission's A Manual for Managing Urban Stormwater Quality in Western Australia was released in 1998 to define and describe in practical terms Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems. The Manual also aimed to provide guidelines for the incorporation of water sensitive design principles into urban planning and design, which would enable the achievement of improved water quality draining to the Swan and Canning Estuary.

The document was released not as a statutory requirement, but to provide a guideline for best planning and management practices, and was intended for use not only by WRC, but also by other State and Local Government Authorities and sectors of the urban development industry. The Manual did not provide details of design objectives and performance criteria for stormwater quality, and provides only a qualitative comparison of pollutant removal efficiencies and associated costs. The Manual also relies on the use of "in-transit" and "end of pipe" stormwater treatment rather than adopting a whole of catchment approach which includes source control measures.

The Department of Environment recently commenced a major review of the Manual in consultation with a working team comprising industry and government representatives. Several chapters of the revised manual have been completed and recently released as part of the first part of a staged release by DoE (DoE, 2004). The manual is anticipated to be fully complete by early 2005. The manual will contain chapters on retrofitting existing systems and education and awareness, which are of particular importance in developing management responses for existing developed areas such as within the City of South Perth.

DoE's current position on Urban Stormwater Management in WA is outlined in the WRC Interim Position Statement Principles and Objectives (February 2003). Principal objectives for managing urban water quality and quantity in WA are stated as:

- Water Quality
  To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.
- Water Quantity
  To maintain the total water cycle balance within development areas relative to the pre-development conditions.

The following stormwater management hierarchy are then presented to achieve these objectives:

- Retain and restore natural drainage systems
  Retain and restore existing valuable elements of the natural drainage system, including waterway, wetland, groundwater features and processes.
- Implement non-structural source controls
  Minimise pollutant inputs principally via planning, organisational and behavioural techniques
- Minimise runoff
  Infiltrate or reuse rainfall as high in the catchment as possible. Install structural controls at or near the source to minimise pollutant inputs and the volume of stormwater

- Use of 'in-system' management measures
  Includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps

This approach marks a distinct shift of emphasis from previous attempts to trap or retard pollutants in their journey from land application to discharge, to a more fundamental "Prevention is better than Cure" philosophy. The Southern River/Forrestdale/Brookdale/Wungong Structure Plan Urban Water Management Strategy (UWMS, JDA 2002a) was the first strategy to adopt this approach, based on application of catchment management measures (using source control initiatives) rather than relying purely on engineering approaches.

6.2.2 Swan Canning Cleanup Program Action Plan

The Swan Canning Clean-Up Program (SCCP) Action Plan report (Swan River Trust, 1999) was released by the State Government in May 1999 following a five-year project to develop a program for the effective clean up of the Swan Canning river system. The Action Plan recommends key strategies to achieve the program's goals of :

- Public Health and Amenity.
  Algal blooms are to be kept at a level where there is no threat to public health and amenity and they are not a nuisance to the community. Toxic algal blooms are to be kept to a minimum.
- Ecological Function.
  Water quality in the Swan Canning system is suitable for maintaining a healthy ecosystem. People can swim or catch fish at any time.
- Catchments and Targets.
  Contaminants in stream runoff leaving the catchments are to be within set targets. Rural catchments are to be managed at a productive and profitable level while remaining attractive and affordable places to live.
- New Urban and Industrial Areas.
  Areas are to be designed so that discharges have reduced contaminant levels and meet set targets before entering rivers, while they still remain attractive, affordable places to live and productive and profitable places to work.
- Older Urban and Industrial Areas.
  These areas are to be modified over time to reduce contaminant levels so that drainage discharges can meet set targets before entering the rivers.

Water Sensitive Design (WSD) and associated BMP's are presented as the best practical method for managing nutrient inputs to meet long term water quality objectives.

The Action Plan provides general maximum acceptable concentrations for short and long term catchment water quality targets as shown in Table 9. The Action Plan also provides estimates of nutrient loading and water quality targets for individual catchments of the Upper Swan, Middle Estuary and Canning River areas, however specific estimates for the Lower Estuary and Middle Estuary area where the City of South Perth discharges occur are not provided.

Table 9 : Swan Canning Cleanup Program Water Quality Targets

Water Quality Parameter	5 Year Target	20 Year Target
Total Phosphorus (TP)	0.2 mg/L	0.1 mg/L
Total Nitrogen (TN)	2.0 mg/L	1.0 mg/L

6.3 Establishing Targets

The determination of water quality targets for an established area such as the City of South Perth is not straightforward, as no well established guidelines currently exist at State Government level.

Targets provided in Table 8 via ANZECC (2000a) are for application to un-modified or slightly modified ecosystems and do not readily apply to stormwater management. Similarly, no specific standards or criteria are established in WRC's Manual for Managing Urban Stormwater in Western Australia (1998) or its incomplete replacement (DoE, 2004).

The most appropriate targets are considered to be provided in the Swan Canning Cleanup Program Action Plan which recommends targets for Total Phosphorus and Total Nitrogen as shown in Table 9.

The approach recommended for the establishment of criteria for water quality management for is based on first determining existing storm water quality within the Study Area and identifying priority catchments through the development and implementation of a monitoring program, then to use this data together with the SCCP and ANZECC data to establish suitable water quality targets.

The establishment of targets without first determining existing storm water quality is not recommended as this may lead to a perceived failure to meet targets that may not be achievable, and may also lead to the implementation of inappropriate pollution control measures at cost to local community.

A four stage process is recommended for the establishment of water quality targets :

- Phase 1 : Development
  Establishment of a suitable monitoring program
- Phase 2 : Monitoring
  Implement monitoring program to establish baseline water quality data
- Phase 3 : Target Setting
  Based on an assessment of monitoring program data and water quality objectives, determine criteria in terms of establishing achievable improvements.
- Phase 4 : Compliance
  Monitor compliance with established targets to allow an assessment of performance and determination of the need for any remedial actions.

Details of the recommended monitoring program (Phase 1) is contained in Section 9 of this report.

7. WATER QUALITY MANAGEMENT

The following chapter details options for the application of non-structural and structural water quality controls and provides general descriptions of these options. Specific application of these options to the Study Areas is discussed in Chapter 9 (ICM Strategy) and Chapter 10 (Implementation Plan).

7.1 Non- Structural Control Options

Structural controls are usually tested in laboratory situations by manufacturers and some technical information is available on the likely performance under various conditions. This information is used to predict performance in terms of nutrient and pollutant retention ability, and together with associated capital and maintenance cost estimates, can be used to assess the likely unit cost rate of removal.

It is more difficult to predict the effectiveness of non-structural controls in water quality management. This is because non-structural measures cannot be readily tested by the conventional input/output methods, and for this reason, until recently there has traditionally been a reluctance to include non-structural controls in stormwater management programs. Control of pollutants at-source using non-structural measures, by minimisation or prevention of input, is now widespread. Types of non-structural controls include :

- Education Campaigns
  which may include but are not limited to workshops for developers & residents, forming of community action groups, newspaper articles, distribution of leaflets, posters & newsletters, production and distribution of stickers & fridge magnets, drain stencilling or plaques, erection of informative signs in public areas, catchment model or exhibits at local events, shopping centres & schools, development of catchment walks, and performances written by community members. Topics include but not limited to lawn and garden cutting disposal, car washing detergent use and practices, pet waste disposal, bird feeding in POS areas, composting, drains to wetlands and rivers, and fertilising habits. Examples of local education campaign materials are presented in Appendix G.
- Refinement of Local Authority Management and Maintenance Activities
  including but not limited to education of council staff, regular review of council work practices (eg fertilising timing and quantities, disposal of grass clippings, planting of deciduous verge trees), refinement of street sweeping programmes and practices, minimising potential for sewer overflows, landscaping, and enforcement through infringement and pollution control regulation.
- Planting of Native Gardens at Development Stage
  POS areas, encouraging native plantings in residential lots. “Free” landscaping provided in some new house and land packages promoting use of local species.
- Street Sweeping
  undertaking co-ordinated street cleaning programs to remove sediment build up
- Land Use Planning
  inclusion of water quality considerations in planning decisions – land zonings, structure plan layouts, POS design and location.

All the above controls are considered applicable to the Study Area.

7.2 Structural Control Options

Details of various structural control measures are provided in Tables 15 and 16, summarising their suitability for various pollutants, constraints and relative capital and operating costs. The selection of appropriate structural controls for individual applications will involve consideration of:

- Types of pollutants to be removed
- Site constraints
- Lifecycle cost versus removal efficiency
- Public acceptance
- Equity issues (polluter pays principle)
- Ease of implementation

Table 10 : Pollutant Removal Efficiencies For Various Structural Controls

Treatment Measure	Pollutant Removal Efficiency **neg** : Negligible [0-10% removal] **M** :Moderate [50-75% removal] **L** : Low [10-50% removal] **H** : High [75-100% removal]									Potential for pollutant re-mobilisation
	Litter and gross pollutants (>500 µm)	Coarse sediment (>200 µm)	Fine sediment & suspended solids (<200 µm)	Total phosphorus	Dissolved phosphorus	Total nitrogen	Dissolved nitrogen	Oil and grease	Oxygen demanding substances (BOD)	
Litter baskets/ pits/ bags	H	L	neg	neg	neg	Neg	neg	neg	L	L
Litter / trash racks	M	L	neg	neg	neg	Neg	neg	neg	L	M
Sediment Traps	L	H	M	L	neg	L	neg	L	L	M
Gross Pollutant Traps	H	H	M	L	neg	L	neg	L	L	M
Oil and grit traps	M	M	L	L	neg	L	neg	H	L	H
Sand filters	L	M	M	M	neg	M	neg	M	M	L
Filter strips	neg	H	M	L	neg	L	neg	L	L	L
Bioretention systems	L	L	H	H	L	H	L	M	L	L
Soil Amendment	neg	M	M	H	M	M	L	M	M	M
Grass swales	L	H	M	L	neg	L	neg	L	L	L
Infiltration trenches	L	H	M	M	neg	M	neg	L	M	L
Pool and riffles	L	H	M	L	L	L	L	L	L	H
Infiltration basins	L	H	H	M	neg	L	neg	L	M	L
Detention basins	L	H	M	M	neg	L	neg	neg	L	M
Amended Soil Pond Treatment Systems	L	H	H	M	M	L	L	L	L	L
Constructed wetlands / Water Pollution Control Ponds (WPCP's)	L	H	M	M	L	L	L	M	L	M

Reproduced via JDA (2002a). Efficiencies quoted for pollutant removal should be considered indicative only.

Table 11 : Potential Constraints For Various Structural Controls

Treatment Measure	Potential Constraint ✘ : Constraint may preclude use • : Constraint may be overcome with appropriate design ✓ : Generally not a constraint								Indicative Relative Cost H : High M : Medium L : Low	
	Steep site/catchment slope	High water table	Limited land availability	Polluted groundwater	Covered treatment measure is required	High sediment input	Treatment measure requires pre-treatment	Hydraulic head loss limitation	Ongoing operation / maintenance costs	Capital cost
Litter baskets/ pits/ bags	✓	✓	✓	✓	✓	•	✓	•	H	L
Litter / trash racks	✓	✓	✓	✓	•	•	✓	✘	H	L
Sediment Traps	✓	✓	•	✓	✓	•	•	•	M	M
Gross Pollutant Traps	✓	✓	•	✓	•	•	•	✘	H	M
Oil and grit traps	✓	✓	✓	✓	✓	✓	✓	✘	H	M
Sand filters	✓	✓	✓	✓	✓	•	✓	✘	M	M
Filter strips	✘	✘	✘	✓	✘	✓	✓	✓	L	L
Grass swales	✘	✘	✘	✓	✘	✓	✓	✓	L	L
Bioretention systems	✘	✘	✘	✓	✘	✘	✓	✓	M	M
Soil Amendment	•	•	•	✘	✘	•	✓	•	L	M
Infiltration trenches	✘	✘	•	✓	✓	✘	✓	•	M	M
Pool and riffles	✓	•	✘	✘	✘	•	✓	•	M	L
Infiltration basins	✘	✘	✘	✓	•	✘	✓	•	M	M
Detention basins	•	•	✘	•	✘	✘	✓	•	L	M
Amended Soil Pond Treatment Systems	✘	•	✘	✘	✘	•	✓	•	L	M
Constructed wetlands / Water Pollution Control Ponds	✘	•	✘	✘	✘	•	✓	•	M	H

Reproduced via JDA (2002a).

7.3 Relative Cost of Pollutant Removal

JDA (2002a) estimated in the order of only 5% of nutrient application is exported with stormwater runoff. Therefore even efficient structural controls are found to typically trap only small amounts of nutrient application to a catchment. Non structural at-source controls are therefore considered the only method by which significant reduction in nutrient application to a catchment can be achieved.

NiDSS (Section 4.2.1) was used to generically model the impact of implementing various WSUD measures within the Study Area. Order of cost for reducing phosphorus inputs were found to be free for native plantings (where plantings would be otherwise undertaken using exotic species), <$5/kg/yr for education programs, $150/kg/yr for street sweeping, $800/kg/yr for current technology GPTs, and $4000/kg/yr for Water Pollution Control Ponds.

Based on NiDSS modelling, Figure 21 provides a summary of the indicative impact for various degrees of success of education campaigns on reducing nutrient application rates within the Study Area.

With respect to other pollutants besides nutrients there is very little current data available on costs of treatment.

8. RECEIVING ENVIRONMENT MANAGEMENT

The following chapter details general options for application of techniques for management and improvement of receiving environments. Specific application of these options to the Study Area is discussed in Chapter 9 (ICM Strategy) and Chapter 10 (Implementation Plan).

Further detailed explanations of receiving environment management is contained as Appendix A.

8.1 Feral Fauna Control Options

Options for feral fauna control are summarised in Table 12. The most effective pest control programs are considered to be those which integrate several techniques (such as exclusion fencing, baiting and trapping) to control several species (e.g. foxes and rabbits) and targeting larger areas.

The importance of controlling feral animals is recognised in previous City of South Perth environmental management plans. The Mount Henry Peninsula Foreshore Management Plan (Ecoscape, 2004b) recommended that a comprehensive feral animal control program be undertaken, and the Salter Pt and Waterford Foreshore Management Plan (Siemon, 2000) includes the recommendation that vermin control programs be planned in conjunction with managers of adjacent lands.

Table 12: Feral Fauna Control Options

Species	Control Options		
	Habitat Modification/ Prevention of Introduction	Baiting/Trapping	Fencing
Foxes *Vulpes vulpes*	High level of difficulty in removing fox dens. Reduce the efficiency of foraging by reducing open space by having continuous canopy, and thick understorey.	Pindone baiting suitable to use in urban areas.	High construction and maintenance costs.
Cats *Felis catus*	Stringent guidelines for cat ownership in houses adjoining bushland. Promote public awareness of the benefits of keeping cats indoors, and sterilisation.	Poison bates for cats are not commercially available yet as cats prefer live prey. Trapping suitable for semi-feral cats, wire 'treadle-type' box traps.	Netted fences required to be an electrified wire mounted 15 cm from the top and 10 cm outward from a fence; or have a netted ceiling or a curved overhang.
Rabbits *Oryctolagus cuniculus*	Warren network fumigation and destruction. Revegetate using seedling tree guards.	Pindone baiting suitable to use in urban areas.	Provide a better long term, cost effective solution than baiting, in urban areas. Effectiveness is in firstly eliminating rabbits from the site.

8.2 Weed Management

Weed management is based upon identifying and controlling existing weeds and the prevention of their reintroduction. Weeds impact upon wetland ecology by competing, restricting regeneration and recruitment of the native plants, reducing the feeding, breeding and shelter of native fauna and increase the fire risk with greater fuel loading.

Control options need to minimise detrimental impacts on native biota, and are best undertaken in conjunction with bushland restoration programs. Lists of weed species and recommended control methods are detailed in existing bushland management plans, and summarised in Appendix A : Table 7.1 and Table 7.4.

Weed control options are summarised as follows :

- Controlling Ecosystem Degradation Processes that increase ecosystem vulnerability to weeds is often the most effective long-term weed control. That is, by introducing water quality management options, as discussed in Section 7, reduce ecosystem susceptibility to weeds.
- Physical Barriers such as kerbing between riparian vegetation and lawn areas, reducing the level of grass invasion into areas of native vegetation. Kerbings are installed around several wetland areas in Sir James Mitchell Park. Establishment of dense stands of native plants and the use of mulch also reduce the rate of weed invasion into wetlands.
- Manual Control (Physical Removal) is often the most expensive form of weed removal but it is generally the most appropriate method in circumstances where there are small infestations in largely natural bush areas. It is particularly valuable for small infestations, where chemical control is inappropriate and the resources are available. When undertaking manual weed control, the Bradley method (which works from the areas with least weeds to the area with most weeds) should be used, and revegetation or assisted natural regeneration undertaken in conjunction with weed removal. Hand-pulling of weeds can be as time-efficient as spraying where low numbers exist in a localised, well-vegetated area of bush and in these situations should be given priority over herbicide spraying.
- Herbicide application is often the most cost-effective method for weed control. A wide range of herbicides are available for different weed species (Appendix A : Section 7.3).

Further specific detail of weed control options are provided in Appendix A.

8.3 Revegetation / Habitat Creation

Revegetation improves water quality, both directly and indirectly through a number of mechanisms including the uptake and filtering of both nutrients and pollutants, releasing oxygen from the root zone conducive to decomposition of organic material, nitrogen transformation, and discouraging the release of phosphorus (Swan River Trust, 2003).

Vegetation is also critical to habitat creation and the level to which waterbirds utilise wetlands on the Swan Coastal Plain (Storey *et al*., 1993).

In determining which plants are suitable for establishment in and around stormwater outlets consideration has to be given to the native plants occurring in water-gaining sites within the vegetation complexes of the area. Plants need to be established in and around compensation basins and artificial lakes in a series of zones that reflects their ability to withstand varying levels of inundation. Most wetland plants need to be established in spring, to avoid being flooded immediately after planting whilst maximizing soil moisture. Use of tube stock is generally the preferred option in the Study Area.

Further details of revegetation options are contained in Appendix A.

9. ICM STRATEGY

The following chapter details key elements of the proposed strategy for the integrated catchment management plan on the basis of the analysis and data presented in previous sections of this report.

Specific details regarding implementation are presented in Section 10.

9.1 Overview

Recent developments in urban stormwater quality management have seen a shift of emphasis from attempts to trap or retard pollutants in their journey from land application to estuary discharge, to a more fundamental "Prevention is better than Cure" philosophy. Recent developments have also been toward total water cycle management, and considering urban stormwater and its quality within the wider context of the whole hydrological cycle.

The Department of Environments revised Urban Stormwater Management Manual for Western Australia provides a greater emphasis on strengthening the use of non structural source controls and catchment management measures to reduce pollutant input, while still incorporating previously accepted water sensitive urban design (WSUD) measures and best management practice treatment trains.

The strategy recommended for the City of South Perth follows this approach and considers non structural water quality control techniques to be vital to achieving sustainable stormwater quality improvements. The proposed strategy is cognisant of the financial cost of stormwater quality management for its community and has been developed accordingly.

To this end the strategy recommends the use of education campaigns, native plantings, review of maintenance activities, and street sweeping as preferred comparatively low cost methods of reducing nutrients and pollutants and protecting receiving environments. Where possible, integration with existing programs (of state government agencies, catchment groups etc) is recommended.

In terms of the need for additional structural controls, these may be required in certain cases as part of applying a treatment train approach. The need for additional structural controls will require assessment on a case by case basis. Given the number of discharge locations, and the significant cost of installation and maintenance of new controls, it is recommended a water quality monitoring program be undertaken to establish baseline water quality data and more accurately determine the need for (and appropriateness of) structural controls.

The strategy has identified environmental priority catchments and it is recommended these priorities be used as a basis for targeting areas for ongoing works on urban water quality within the Study Area.

In terms of the receiving environment for stormwater discharges the strategy recognises that environmental management plans already exist for some of the wetlands in the Study Area, and the specific details regarding recommendations contained within these management plans are not duplicated in this strategy. In this regard, this strategy is intended to provide an overarching document to assist the City in the allocation of its resources to identified priority areas. The development of specific landscape plans for artificial wetlands in areas of high public access are recommended to maximise the environmental and aesthetic values of these assets.

With regard to infrastructure management, the fragmented nature of the drainage system and large number of infiltration and compensating basins provides some opportunity for consideration of infrastructure rationalisation. Further survey detail is required to enable existing level of service checks to be undertaken and the rationalisation opportunities to be investigated.

A number of priority catchments drain to Water Corporation Main Drainage. Negotiation with Water Corporation regarding any works for these catchments will be required on a case by case basis.

With regard to any new development, infiltration of stormwater on site should be encouraged.

9.2 Environment

9.2.1 Water Quality Monitoring

It is recommended an integrated monitoring program targeting priority catchments be undertaken by the City of South Perth to establish baseline water quality data. This data will be used to :

- establish appropriate water quality criteria and review performance relative to SCCP and ANZECC (2000a)
- determine recommendations for further action and/or appropriate WSUD BMP's for application
- determine the success or otherwise of implemented WSUD techniques

A typical monitoring program would consist of monthly water quality monitoring over a 5 to 6 month winter period (including first flush in April/May). It is recommended that sampling includes stormwater inflow, shallow groundwater water quality, and the water quality of the receiving environment. Consideration should also be given to monitoring potential point sources of pollution within the monitored catchment if appropriate. This approach enables the water quality of stormwater to be viewed in the context of total water cycle management.

Samples would require laboratory analysis, typically for the following parameters :

- pH, Conductivity, Total Suspended Solids (TSS)
- Total Phosphorus and Filterable Reactive Phosphorus (FRP)
- Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), NO_3-N, NO_2-N, Ammonia
- Heavy Metals (including Pb, Zn, Cu)

Targeting of the top ten environmental priority catchments for the initial water quality monitoring program is recommended.

9.2.2 Non Structural Water Quality Controls

It is recommended a framework for a coordinated series of education campaigns be developed by the City. Where possible this should co-ordinate with campaigns being run by other organisations. Topics should include but not limited to lawn and garden cutting disposal, car washing detergent use and practices, pet waste disposal, bird feeding in POS areas, composting, drains to rivers, and fertilising habits. This program should initially target priority catchment areas.

It is also recommended a framework for annual review of maintenance activities in relation to water quality management be established. Activities to be reviewed should include :

- timings and quantities of fertiliser application
- drainage infrastructure maintenance (eg GPT and gully eduction timings/frequency)
- review of street sweeping practices
- use of native plantings/trees, revegetation practices.

Water quality data collected from the integrated monitoring program should be considered in this process.

9.2.3 Structural Water Quality Controls

It is recommended the need for further structural controls be assessed by the City of South Perth based on outcomes of water quality monitoring programs and established criteria.

9.2.4 Receiving Environment

It is recommended specific landscape plans for artificial wetlands in areas of high public access should be developed, including Sir James Mitchell Park, McDougall Park, and Bodkin Park, to maximise the environmental and aesthetic value of these wetlands.

Opportunities for improvements to receiving environments should be prioritised on the basis of priority environmental catchments identified in this study.

9.3 Infrastructure

9.3.1 Pipe Drainage

It is recommended the existing program of pipe drainage upgrades (previously detailed in Table 7) based on known flooding locations be undertaken to address known flooding problems.

While this addresses the City's immediate flooding concerns, the extent to which the remainder of the piped drainage system meets required design standards is unknown. It is recommended consideration be given to survey of the piped drainage system and modelling to review capacity of the piped drainage system.

9.3.2 Basin Capacity

There is no anecdotal information regarding basins overtopping or basins known to be under capacity.

For each basin, information regarding basin area is available but not basin volumes or key survey and infrastructure detail. It is recommended this survey data be collected and basin modelling be undertaken as a two stage process to determine 10 and 100 year ARI storage requirements :

- preliminary modelling of basins (as per Section 5.3) to identify basins for further analysis
- detailed analysis of key basins

9.3.3 Basin Rationalisation

Following from completion of basin capacity checks it is recommended an investigation be undertaken to determine opportunities for rationalisation of basins within the Study Area with a view to potential redevelopment of some sites.

If detailed survey of piped drainage has not been undertaken (Section 9.3.1), survey of piped drainage within catchments considered for amalgamation will be required.

9.4 Strategy Review

Annual review of implementation is recommended. With regard to the ICM Strategy document itself, it is recommended the Strategy be reviewed after a period of 5 years. This review process would include :

- assessment of the success of measures implemented and programs undertaken.
- analysis of monitoring data collected over this period to provide the baseline data to define specific water quality criteria.
- integration of criteria and policy developments at the State Government level.
- review of new developments in stormwater quality management.
- further refinement of the strategy and reassess priority catchments for future works.

10. IMPLEMENTATION PLAN

An Implementation Plan for the strategy detailed in Chapter 9 is shown in Table 13. This plan should be considered indicative only and subject to ongoing review by the City of South Perth based on budget considerations, and an annual review of its implementation.

Table 13 : ICM Implementation Plan

Item No	Task	Timing & Frequency
I1	<u>Infiltration</u> Promote infiltration for new development as the preferred method of stormwater disposal	Ongoing
I2	<u>Water Quality Monitoring</u> Undertake an integrated monitoring program targeting the identified top ten environmental priority catchments to establish baseline water quality data. Sampling to include stormwater inflow, shallow groundwater water quality, water quality of the receiving environment, and consider potential point sources of pollution. Analysis to include pH, Conductivity, Total Suspended Solids (TSS), Total Phosphorus and Filterable Reactive Phosphorus (FRP), Total Nitrogen (TN), Total Kjeldahl Nitrogen (TKN), NO_3-N, NO_2-N, Ammonia, Heavy Metals (including Pb, Zn, Cu). Catchments : SP 136, SP 110, SP 140, SP106, SP139, SP120, SP115, SP26, SP 25, SP 86	Annual Program (initially) commencing Year 1
I3	<u>Non Structural Controls : Public Education</u> Develop a framework for a targeted series of education campaigns, coordinated with campaigns of other government agencies/ natural resource management groups. Topics to include but not limited to lawn and garden cutting disposal, car washing detergent use and practices, pet waste disposal, bird feeding in POS areas, composting, drains to rivers, and fertilising habits. Establish framework for a rolling program, initially targeting priority catchment areas.	Rolling Program commencing Year 2
I4	<u>Non Structural Controls : Maintenance Activity Review</u> Integrate an annual review of maintenance activity effectiveness in relation to water quality management with existing annual management review processes. Review activities to include fertilising timing and quantity of application, drainage infrastructure maintenance (eg GPT and gully eduction timings/frequency), street sweeping, native plantings/trees, revegetation practices.	Annual Review commencing Year 1
I5	<u>Structural Controls</u> No current action proposed. Review requirement for further structural controls based on outcomes of water quality monitoring program and established criteria.	Annual Review commencing Year 3
I6	<u>Receiving Environment : Landscape Plans</u> Develop specific landscape plans for artificial wetlands including Sir James Mitchell Park, McDougall Park, and Bodkin Park, to maximise the environmental and aesthetic value of these wetlands.	Individual Studies commencing Year 2
I7	<u>Receiving Environment : Existing Environmental Plans</u> Undertake improvements to receiving environments on the basis of priority environmental catchments identified in this study, consistent with recommendations contained in existing environmental management plans.	Ongoing
I8	<u>Piped Drainage : Known Flooding Locations</u> Complete existing program of pipe drainage upgrades at known flooding locations.	As per Existing Schedule
I9	<u>Piped Drainage : Overall System Review</u> Consider survey of piped drainage system and modelling to review system capacity.	Ongoing commencing Year 1

Item No	Task	Timing & Frequency
I10	<u>Basin Capacity : Preliminary Review</u> Undertake site investigation of basin capacities and conduct preliminary modelling to determine priority basins for further investigation.	Year 1
I11	<u>Basin Capacity : Detailed Investigations</u> Undertake detailed individual investigations for basin capacities depending on the outcome of Item I10. Includes detailed site survey.	Ongoing commencing Year 2
I12	<u>Basin Capacity : Rationalisation</u> Undertake investigation to determine opportunity for rationalisation of basins within the Study Area with a view to potential redevelopment of some sites. Requires Item I9, I10, and I11 to be completed prior to commencement.	Ongoing commencing Year 3
I13	<u>Strategy Review : Implementation</u> Integrate an annual review of implementation within existing annual management review processes.	Annual Review commencing Year 1
I14	<u>Strategy Review : Overall</u> Conduct an overall strategy review after a period of 5 years, including : • assessment of the success of measures implemented and programs undertaken. • analysis of monitoring data and monitoring programs. • integration of criteria and policy developments at the State Government level. • review new developments in stormwater quality management. • further refinement of the strategy and reassess priority catchments for future works.	Every 5 Years commencing Year 5

11. CONCLUSIONS/RECOMMENDATIONS

General

- The City of South Perth comprises an approximate area of 1970 ha, and is bounded by the Swan River to the north and west, the Canning River to the South and Kent St to the east. The Study Area shares common borders with other local government authorities, the Town of Victoria Park and City of Canning.
- The topography ranges from 0 to 5 m AHD along the Swan and Canning River foreshore areas, 5 to 15 m AHD over much of its central area, with some elevated areas to approximately 30 m AHD in the north.
- The Study Area has a Mediterranean climate with mild wet winters and hot dry summers, and has a long term average annual rainfall of approximately 862 mm. Average rainfall has decreased significantly since 1975.
- The City of South Perth's dominant land use is residential, covering over 46% of the total area. Most urban areas are well established, though there are some newer development areas at Karawara, Waterford, and Mt Henry. The densely populated areas are located at Point Belches, along the South Perth foreshore west of Sir James Mitchell Park and bordering Canning Highway.

Surface & Groundwater Hydrology

- The surface water drainage system comprises of a piped network of both local and Water Corporation Main Drainage, which discharges to a variety of receiving environments including the Canning and Swan Rivers, Lakes, Compensating Basins, Infiltration Basins, Swales, Soakwells, and some Public Open Space Reserves. Water Corporation Main Drainage is limited to the south eastern region of the Study Area discharging to the Canning River.
- The City of South Perth is located on the Cloverdale groundwater mound, which is bounded by the Darling Scarp to the east and the Helena, Swan, and Canning Rivers covering an area of 171 km^2 .
- Maximum recorded groundwater levels vary from less than 2 m AHD near the Swan River to 8 m AHD on the eastern boundary near Berwick St. Seasonal groundwater variation on the Swan Coastal Pain is typically in the order of 1.0 to 1.5 m.
- Based on the topography, much of the Study Area has considerable depth to groundwater and hence provides an opportunity for infiltration of surface drainage.
- Conservation Category Wetlands (CCW's) and Environmental Protection Policy (EPP) Lakes located within the Study Area are Goss Avenue Bushland, Centenary Avenue Clontarf, Sandon Park, Sir James Mitchell Park, Salter Pt, Canning River Foreshore from Sandon Park to Clontarf, and Canning River Foreshore from Canning River Bridge to Mt Henry Bridge. The DoE is currently reviewing the EPP Lake boundary at Clontarf.
- All of these wetlands have existing management plans, and all are currently part of the local authority drainage network or part of the Water Corporation's Main Drainage System.

Vegetation & Fauna

- The original vegetation of the Study Area was predominantly Banksia/Jarrah woodlands. The majority of this vegetation has been cleared, with remnants of Jarrah (*Eucalyptus marginata*) and *Eucalyptus rudis*/*Melaleuca preissana* stands remaining.
- Two bush forever sites exist in the Study Area; Canning River Foreshore, Salter Point to Wilson, and Mount Henry Bushland, Salter Point
- Wetlands and artificial lakes in the Study Area provide habitat for a wide range of fauna, of which birds are most prominent. Less obvious species that also inhabit or potentially inhabit the wetlands include the Southern Brown Bandicoot, the Mastiff Bat, and the Oblong Tortoise.
- Feral animals include the fox, cat, and rabbit.

Surface Water Catchment Plans

- Surface water catchment plans for the Study Area were developed detailing the interaction of flows across local authority boundaries, the location of key drainage facilities (infiltration and compensating basins, GPT's), Water Corporation Main Drainage, and outlets to the Swan and Canning Rivers. Surface water receiving environments were classified into various types and summary statistics prepared based on discharge type and catchment land use.
- The City's drainage system is largely fragmented, comprising of a large number of catchments (147), and a large number of drainage facilities, including a total of 80 infiltration or compensation basins, and 54 outlets to the Swan and Canning Rivers.
- Infiltration of stormwater is the predominant method of stormwater disposal for the Study Area with approximately 65% of the Study Area infiltrating stormwater.
- Of the remaining 35% of the Study Area which discharges to the Swan and Canning Rivers, 40% discharges to the rivers via compensating basins, while 60% of discharges are direct. Less than half of the existing outlets to the Swan or Canning Rivers have Gross Pollutant Traps installed.
- Catchments which cross local authority boundaries with the Town of Victoria Park or City of Canning were found to comprise a small overall proportion of the Study Area. To this extent the surface drainage system can be considered largely self contained and surface water quality within the Study Area predominately a result of land use and existing management practices within the City of South Perth.

Environmental Priority Catchments

- Environmental priority catchments within the Study Area were determined on the basis of existing and historical land use impacts, and the environmental and social values of the receiving environment.
- In the absence of detailed water quality data for individual catchments, environmental priority catchments were determined using map overlay techniques based on key indicators to stormwater quality : nutrient input estimation via land use, and major roads and commercial land use density (for metals/other pollutants).
- Areas identified as likely to have the highest nutrient input, were typically residential areas of lower density, and located in catchments which are currently infiltrating stormwater. Areas of estimated high nutrient input discharging to the Swan and Canning Rivers include the suburbs of Salter Pt and Waterford, and South Perth near the Ellam St / Mill Pt Rd intersection.
- Social and environmental rankings for each catchment were determined on the basis of examining aerial photography, consideration of the type of receiving environment, and some field assessment of selected sites. In general, sites identified with the highest overall significance are generally located in the southern region of the Study Area. A total of 24 catchments (16% of total) are considered either High-High or High-Medium ranking for social-environmental criteria.
- The top 20 priority catchments were identified, with a focus on the top ten for management considerations. Priority catchments are typically located in the southern region of the Study Area and mainly discharge to the Canning River. Only 2 catchments in the Northern Region are in the top 10 priority list, both of these discharging to basins in Sir James Mitchell Park.
- Four types of potential point sources of pollution for the Study Area were identified - abandoned landfill sites, abandoned liquid waste disposal sites, fuel storage sites and Water Corporation wastewater pumping stations. Potential point sources of pollution located in priority catchments are considered the priority sites for management consideration and risk assessment.

Infrastructure Priority Catchments

- Based on the current lack of infrastructure detail available for piped drainage systems and existing basin size details within the Study Area, priority catchments on the basis of infrastructure considerations could not be determined in this study.
- On a similar basis, consideration of rationalising infiltration sumps within this Study Area with a view to potential redevelopment of some sites cannot be undertaken without detailed survey data.
- Survey data of the piped drainage system is incomplete and would need to be undertaken to enable detailed modelling to occur and all piped systems checked for compliance with City of South Perth drainage criteria. Prior to this, known areas of flooding should be considered priority areas for investigation.

- There is no anecdotal information regarding basins overtopping or basins known to be under capacity. Modelling of basin capacity is recommended, as basins are sized for rarer storm events, therefore anecdotal information of flooding may not exist even if undersized.

Water Quality Standards & Criteria

- Currently applicable standards and criteria for water quality are not clearly defined at State Government level in Western Australia. The Department of Environment are currently in the process of revising their "A Manual for Managing Urban Stormwater Quality in Western Australia" (WRC,1998), and it is expected that the outcomes of this process will provide a clearer definition of water quality standards and criteria to apply in urban stormwater management. The manual will contain chapters on retrofitting existing systems and education and awareness, which are of particular importance in developing management responses for existing developed areas such as within the City of South Perth.
- The most appropriate targets are considered to be provided in the Swan Canning Cleanup Program Action Plan which provide general overall targets for Total Phosphorus and Total Nitrogen.
- The recommended approach for the establishment of more detailed water quality criteria is based on first determining existing storm water quality within the Study Area through development and implementation of a monitoring program, then the use of this data to establish suitable targets.
- The establishment of targets without first determining existing storm water quality is not recommended as this may lead to a perceived failure to meet targets that may not be achievable, and may also lead to the implementation of inappropriate pollution control measures at cost to local community.

The Strategy

- The strategy recognises that environmental management plans already exist for some of the wetlands in the Study Area, and specific details regarding recommendations within these management plans are not duplicated in the strategy. In this regard, the strategy is intended to provide an overarching document to the management plans, and assist the City in the allocation of its resources to identified priorities.
- Recent developments in urban stormwater quality management have seen a shift of emphasis from attempts to trap or retard pollutants to a more fundamental "Prevention is better than Cure" philosophy. Recent developments have also been toward total water cycle management, and considering urban stormwater and its quality within the wider context of the whole hydrological cycle.
- The strategy recommends the City of South Perth follows this approach and consider non structural water quality control techniques to be vital to achieving sustainable stormwater quality improvements. The proposed strategy is cognisant of the financial cost of stormwater quality management for its community and has been developed accordingly.
- The strategy recommends the use of education campaigns, native plantings, review of maintenance activities, and street sweeping as preferred comparatively low cost methods of reducing nutrients and pollutants and protecting receiving environments. Where possible, integration with existing programs (of state government agencies, catchment groups etc) is recommended.
- The need for additional structural controls will require assessment on a case by case basis. Given the number of discharge locations, and the significant cost of installation and maintenance of new controls, it is recommended a water quality monitoring program be undertaken to establish baseline water quality data and more accurately determine the need for (and appropriateness of) structural controls.
- The strategy has identified environmental priority catchments and it is recommended these priorities be used as a basis for targeting areas for ongoing works on urban water quality within the Study Area.
- It is recommended specific landscape plans for artificial wetlands in areas of high public access should be developed, including Sir James Mitchell Park, McDougall Park, and Bodkin Park, to maximise the environmental and aesthetic value of these wetlands.
- With regard to infrastructure management, the fragmented nature of the drainage system and large number of infiltration and compensating basins provides opportunity for consideration of infrastructure rationalisation. Further detailed survey is required to enable existing level of service checks to be undertaken and rationalisation opportunities to be investigated.
- With regard to any new developments, infiltration of stormwater on site should be encouraged.

Implementation and Review

- An Implementation Plan for the strategy has been developed. The plan should be considered indicative only and subject to ongoing review by the City of South Perth based on budget considerations, and an annual review of its implementation.
- It is recommended the Strategy be reviewed after a period of 5 years. This review process would include an assessment of the success of measures implemented, analysis of monitoring data and water quality criteria, integration of criteria and policy developments at the State Government level, review of new technologies, refinement of the strategy, and reassessment of priority catchments for future works.

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APPENDIX A

Ecoscape (Australia) Pty Ltd:
Environmental Management Report

Limitations Statement

This report has been exclusively drafted for the needs of City of South Perth. No express or implied warranties are made by Ecoscape (Australia) Pty Ltd regarding the research findings and data contained in this report. All of the information details included in this report are based upon the existent land area conditions, research provided and obtained, and so forth at the time Ecoscape (Australia) Pty Ltd conducted its analysis into the area. Ecoscape (Australia) Pty Ltd will not be responsible for the application of its recommended strategies by City of South Perth

Please note that the strategies devised in this report may not be directly applicable towards another (TYPE OF Council's needs or any other specific land area requiring management strategies. We would also warn against the environmental dangers of adapting this report's strategies to another land area which has not been researched and analysed by Ecoscape (Australia) Pty Ltd. Instead, please contact Ecoscape (Australia) Pty Ltd to provide a tailored report for your area's needs. Otherwise, Ecoscape (Australia) Pty Ltd accepts no liability whatsoever for a third party's use of, or reliance upon, this specific report.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

APPENDICES

1. SUMMARY

In the City of South Perth stormwater is generally disposed of via infiltration basins, lakes/wetlands and the river. In some areas the stormwater is conveyed via open drains which flow into artificially created waterbodies, for example on the South Perth foreshore at Sir James Mitchell Park. These waterbodies and drains have both ecological and aesthetic values and these values have increased significance given that 70-80% of wetlands on the Swan Coastal Plain have been lost or degraded through activities such as draining, filling and clearing (WRC, 2000b).

Given that there are 147 stormwater catchments within the City of South Perth, management strategies are based on stormwater entering the drainage network and the types of outlets. These types are:

- Infiltration Basins without Public Access or Landscaping;
- Landscaped Infiltration Basins with Public Access;
- Outlets discharging directly into Swan/Canning Estuary;
- Outlets discharging into Vegetated Areas (including indirectly in Swan Canning River)

Whilst specific guidance has been provided in this document as to how these sites should be managed specific landscape plans will still need to be developed for the artificial wetlands in areas of high public access such as Sir James Mitchell Park, McDougall Park and Bodkin Park.

Guidance is also provided with regards to weed and feral animal control.

Weeds impact upon wetland ecology in a number of ways, including competing with native species; restricting the regeneration and recruitment of native plants; reducing the resources of native fauna for feeding, breeding and shelter and increasing fire risk as a result of increased fuel loads.

Feral animals impact upon the faunal component of bushland in urban areas and the importance of controlling these feral animals has been recognised in previous environmental management plans prepared for the City. This report discusses options for the control of foxes, cats and rabbits whilst recognising the limitations of control in an urban area.

1. INTRODUCTION

1.1 Background

In the City of South Perth stormwater is generally disposed of via infiltration basins, lakes/wetlands and the river. In some areas the stormwater is conveyed via open drains which flow into artificially created waterbodies, for example on the South Perth foreshore at Sir James Mitchell Park. These waterbodies and drains have both ecological and aesthetic values and these values have increased significance given that 70-80% of wetlands on the Swan Coastal Plain have been lost or degraded through activities such as draining, filling and clearing (WRC, 2000b). However there are a number of issues that need to be managed with regards to these artificial waterbodies and stormwater outlets including water quality and weed control.

This management plan addresses these issues, as a component of an Integrated Catchment Management Plan that is being developed for the City of South Perth in conjunction with JDA Consultant Hydrologists.

1.2 Objectives

The objectives for the environmental management component of the Integrated Catchment Management Plan for the City of South Perth are to:

- Identify strategies and opportunities for enhancing and protecting environmental values within the catchments of South Perth;
- Identify and manage instream and riparian vegetation; and
- Identify management options for control of exotic plants and animals.

2. METHOD

2.1 Identification of Major Environmental Values

The environmental values within the study area are detailed in the management plans that have previously been developed for the City of South Perth, including:

- Clontarf Foreshore Management Plan (City of South Perth, 1993);
- Goss Avenue/Koonawarra Primary School Bushlands Management Plan (City of South Perth, 1997);
- Salter Point and Waterford Foreshore Management Plan – An integral part of the Canning River Wetlands (Siemon, 2000);
- Sir James Mitchell Park Foreshore Management Plan, SRT Report No 32, (Swan River Trust, 2001); and
- Mt Henry Peninsula Foreshore Management Plan (Ecoscape, 2004)

An indication of the environmental value of these areas is that:

- The Clontarf Foreshore supports at least 34 native plant species (COSP, 1993);
- The Goss Avenue/Koonawarra Primary School Bushlands supports two vegetation communities and 114 native plant species (COSP, 1997)
- Salter Point and Waterford supports 7 vegetation communities, 138 native plant species, 74 species of birds (including 14 significant species), 12 species of reptiles and 6 species of amphibians (Siemon , 2000) and 'there is no similar foreshore elsewhere along the Swan and Canning Rivers' (DCE, 1983);
- Sir James Mitchell Park retains a significant stand of remnant vegetation consisting of Melaleuca rhaphiophylla/Eucalyptus rudis' (SRT,2001);
- The Mount Henry Peninsula supports 5 vegetation communities and 185 different native plants including a number of significant species (Ecoscape 2002).

Rather than duplicate all the information included in these previous environmental management plans, this Integrated Catchment Management Plan focuses on identifying which catchments have environmental and social values rather than detailing what these are, except in a strategic sense. In addition to the overview provided above it is worth noting that several sites have been identified as being of regional significance through their listing as Bush Forever Sites, or in Environmental Protection Policies (EPPs) which provide them with some level of protection.

2.1.1 Bush Forever Sites

Bush Forever replaces the System 6 recommendations as a blueprint for conservation of bushland of regional significance in the Perth Metropolitan Region. Bush Forever was prepared by the Department of Environment Protection, Ministry for Planning, CALM and the Water and Rivers Commission and was endorsed by Cabinet and supported by the Environmental Protection Authority as the principle mechanism to identify and protect regionally significant bushland in the Perth Metropolitan Region.

Bush Forever Site 333 – Canning River Foreshore, Salter Point to Wilson

The foreshore is part of the Swan-Canning Estuary which is listed as a wetland of national importance in the Directory of Important Wetlands in Australia and is subject to protection under the Commonwealth EPBC Act, 1999 (Government of Western Australia, 2000).

It is stated in The Directory of Important Wetlands in Australia that the Swan-Canning Estuary (Wetland WA091) covers 3 300 hectares and is a good example of a shallow estuarine system that has substantial tidal exchange with significant areas of tidal flats and marshes, that is in reasonable condition and is situated in a major urban centre. It is a major nursery area for fish, a major migration stop-over area for shorebirds and a vital feeding area for thousands of Cormorants that breed in nearby lakes.

Bush Forever Site 227 – Mount Henry Bushland, Salter Point

The foreshore is part of the Swan-Canning Estuary which is listed as a wetland of national importance in the Directory of Important Wetlands in Australia and is subject to protection under the Commonwealth EPBC Act, 1999 (Government of Western Australia, 2000).

This site contains the most inland vegetated knoll and area of Spearwood Dunes on the Swan-Canning Estuary and is of particular value in providing fauna habitat (Government of Western Australia, 2000)

2.1.2 Environmental Protection Polices (EPP)

Environmental Protection Policy (EPP) for the Swan and Canning Rivers

Stormwater from the study area drains into the Swan and Canning Rivers. The purpose of the Swan and Canning Rivers EPP is to ensure that the values of the Swan and Canning Rivers are restored, maintained and protected by managing the activities that affect them.

Section 17 of Environmental Protection (Swan and Canning Rivers) Approval Order 1998 states that

(a) Drainage systems should be designed, constructed and operated in accordance –
  (i) with best management practices; and
  (ii) in order to prevent and mitigate land degradation within the meaning of the term under the Land and Soil Conservation Act 1945; and

(b) Strategies should be developed and implemented to prevent litter from entering drainage systems

Environmental Protection Policy (EPP) for Swan Coastal Plain Lakes

Part of the Clontarf Foreshore is defined as an EPP Lake, although the boundary is under review by the Department of Environment. The purpose of this policy is to protect the environmental values of lakes on the Swan Coastal Plain and makes it an offence to fill, drain, excavate, pollute or clear any lakes identified in Miscellaneous Plan No. 1815 without the authorisation of the EPA.

2.2 Prioritisation of Areas for Protection and/or Enhancement

The City of South Perth contains 145 stormwater catchments, including 80 compensation basins. Therefore areas of environmental and social significance that can be impacted by stormwater flows need to be identified and recommendations for their protection and enhancement need to be prioritised. The priorities given to protecting and/or enhancing the receiving environment are based on social and environmental attributes shown in Tables 2.1, 2.2 and 2.3 below.

Table 2.1 Priorities Based on Social Attributes

Priority	Social Attributes
Low	• No Public Access
Medium	• Limited Public Access and/or • Non-focal Point in Public Area
High	• High Degree of Public Access and/or • Focal Point of Public Area • Previously identified for incorporation into a public area as a focal point

Table 2.2 Priorities based on Environmental Attributes

Priority	Environmental Attributes
Low	• No Native Plants • Highly Modified Site • Extent and Distribution not considered • No natural receiving waterbodies
Medium	• Limited range of native plants • Mixture of weeds and native plants • Moderately Modified Site • Vegetation common in Study Area • Large natural receiving waterbodies (i.e. individual drain has limited influence on water quality of water body)
High	• Predominately Native Plants • Low – Moderate Modification of Site • Vegetation uncommon in Study Area • Small natural receiving waterbodies (i.e. individual drain has significant influence on water quality of water body)

Table 2.3 Overall Priorities based on Social & Environmental Attributes

Combinations of Social & Environmental Priorities	Overall Priority
High-High	1
High-Medium	2
High-Low	3
Medium-Medium	4
Medium-Low	5
Low-Low	6

Given that there are in excess of 130 stormwater outlets within the study area, it was not practical to inspect every individual outlet to determine its social and environmental attributes, and it was not necessary given the qualitative criteria used for prioritisation. Therefore social and environmental priorities for each catchment were generally determined on the basis of examining the focal points for each of the catchment on aerial photographs and the type of outlet (e.g. infiltration swale, direct to river, wet or dry compensation basin etc) noted. In general the following determinations were made:

- All dry compensations basins were deemed have low social and environmental priorities (unless recommended for incorporation into parks in the Green Plan) as they were assumed to have little or no native vegetation and restricted public access;

- Dry Compensation Basins recommended for incorporation into parks in the Green Plan were rated of high social and low environmental value on the basis of their incorporation into relatively small parks will make them a focal point and the default environmental value reflects that details of the type and extent of revegetation has not been specified and these sites tend to be isolated from bushland;

- Infiltration swales in parkland or ovals were deemed to be of medium social priority and low environmental value;

- Parks within catchments that did not have drainage leading into them where not considered in rating the catchment, except where entire catchment consisted of parkland (e.g. golf courses) in which case the catchment was deemed to be a high social priority and the environmental priority was assessed onsite;

- All outlets into the Swan/Canning Estuary were deemed to have medium social and environmental priorities unless the outlet coincided with significant riparian vegetation or other factors were indicated by the City of South Perth. It was assumed that there is public access but that these outlets are not a focal point for activities and there is generally little riparian vegetation. It should be noted that catchments draining directly into the Swan/Canning Estuary were not always adjacent to the Estuary;

- Catchments with direct infiltration next to areas of high environmental priority or the Swan Canning River were deemed as a moderate priority, as a minimum. This was based on the Water and Rivers Commission recommendation that wetlands of significant conservation value have a buffer of 200 m or greater to allow for the filtration and attenuation of nutrients (WRC, 2000e);

- Any natural bushland was of high social and environmental value; and

- All wet compensation basins were assessed onsite (as they tended to be vegetated but the level of access and amount of native vegetation needed to be confirmed).

On this basis, the 147 catchments in the study area were distributed amongst the categories of prioritisation as is shown in Table 2.4.

Table 2.4 Number of Catchments in each Prioritisation Category

Combinations of Social & Environmental Priorities	Overall Priority	Number of Catchments
High-High	1	13
High-Medium	2	11
High-Low	3	16
Medium-Medium	4	41
Medium-Low	5	5
Low-Low	6	61

The sites that are of the greatest overall significance are generally located in the southern portion of the City of South Perth.

3. NATIVE FAUNA

3.1 Introduction

The wetlands and artificial lakes within the City of South Perth provide habitat for a wide range of fauna, of which birds are most prominent.

Birds that frequent the artificial lakes of Sir James Mitchell Park City include:

- Australian White Ibis (*Threskiornis molucca*)
- Black Swan (*Cygnus atratus*)
- Dusky Moorhen (*Gallinula tenegrosa*)
- Eurasian Coot (*Fulica atra*)
- Little Egret (*Egretta garzetta*)
- Purple Swamphen (*Porphrio porphyrio*)
- White Faced heron (*Egretta novaehollandiae*)
  (Birds Australia, 1997 in SRT, 2001)

In the more extensive area of natural vegetation of Salter Point and the Waterford Foreshore a total of 74 birds have been recorded of which 14 are classified as fauna and protected by international treaties (Siemon, 2000).

The general habitat requirements of birds that should be incorporated into the design and management of artificial wetlands with the City of South Perth are discussed below. The specific requirement of Black Swans is also discussed as The Sir James Mitchell Park Foreshore Management Plan (SRT, 2001) recommended that the potential for modifying or extending the lakes on the foreshore as breeding habitat for Black Swans be investigated (Action 45).

There are less obvious species that also inhabit or potentially inhabit the wetlands of South Perth. The Southern Brown Bandicoot and the Mastiff Bat are two native mammals that were recorded in the mid-1980s in Waterford but they may longer be present (Siemon, 2000).

The City of South Perth Green Plan Final Report (City of South Perth, 2002) includes the recommendation that the City '[d]evelop a conservation strategy for the Oblong Tortoise' that the status & ecological requirements of the Turtle needs to be documented. The requirements of this particular species are also discussed below.

It would be reasonable to expect that in meeting the specific habitat requirements of even a few species would benefit a much larger range of species such as frogs and invertebrates.

3.2 Birds

3.2.1 General habitat requirements

The most common birds on Perth water are the Pied Cormorant (*Phalacrocorax varius*), the Darter (*Aninga melanogaster*), the Australian Pelican (*Pelecanus conspicillatus*) and Caspian Tern (*Sterna caspia*).

Many significant relationships exist between wetland characteristics and waterbird use on the Swan Coastal Plain but these cannot be used to develop routine prescriptions for artificial wetlands due to the amount of deviation from generalisations (Storey *et al*., 1993). However Storey *et al*. (1993) did make the generalisations that more birds used wetlands that were:

- bigger;
- had complex vegetation;
- had high primary productivity;
- deeper than 1 m at the time of primary use; and
- fresh.

Storey *et al*. (1993) also stated that breeding birds probably needed water levels to be at least 50 cm deep and some species prefer wetlands with abundant fish (which generally occur in permanent wetlands).

Storey *et al*. (1993) reported that the more structural complexity there was for vegetation the greater the number of species using the site, and this was particularly important for nesting birds. Storey *et al*. (1993) also noted that the proportion of vegetation did not appear to affect waterbird usage and that previous studies in North America indicated that the highest species on wetlands occurred at intermediate vegetation cover (33-66%). This means that establishing a range of plant types (e.g. sedges and rushes, shrubs and trees) around wetlands is as important as establishing a high density of native plants.

In developing plans for increasing the environmental value of the wetlands of South Perth consideration needs to be given to the achievable outcomes as it will not be practical to me*et al*l the requirements (particularly for breeding) of all the birds that utilise the sites. Waterbirds that nest in trees, such as the Grey Teal or Pacific Black Duck may require a vegetated buffer of 100m and ground nesting birds such as the Australasian Shoveller need a buffer of 40-50 m of low vegetation for successful breeding (WRC, 2000f).

Examples of the use of various habitats by birds on the Swan Coastal Plain are provided in Table 3.1.

Table 3.1 Habitats utilised by Birds

Habitat	Use	Species
Islands	Breeding for species with nests on the ground loafing	Waders and Terns
Mudflats and shallow water	Feeding	Red-necked Stint, Curlew Sandpiper, Sharp-tailed Sandpiper, Egret, pelican, Spoonbill, Avocet, Stilt, Heron, Curlew, Oystercatcher, terns, Grey Teals, Shelducks
Emergent sedges, rushes and grassy banks	Loafing & feeding	Spotless Crake, Buff-Banded Rail, Blue-billed Duck, Marsh Harrier, Ducks, Swans, Moorhens, Coots, Ibis, Herons and Swamphens
Deep open water	Feeding	Ducks such as the Musk Duck and Terns

WRC, 2000b

The Water and Rivers Commission (2000b) recommend the following practices to encourage waterbirds:

- "Stack rocks underwater to provide habitat for small animals and fish that provide food for birds;
- Leave some logs and rocks protruding from the water for waterbirds to roost on;
- Place branches and large logs around the edge of the wetland at varying heights, to provide nesting and roosting sites;
- Provide for a range of water depths. Link shallow area mudflats to an island rather than the shore to provide secure habitat for waders;
- Use natural edges with slopes between 1:4 and 1:15, rather than steep banks. The provision of vegetated banks and some bare areas will provide birds with access in and out of the wetland and will allow them to see predators;
- Eradicate weeds as they can spread rapidly in and around wetlands and have the potential to degrade waterbird habitat and reduce food resources;
- Maintain wetland water quality to prevent the formation of algal blooms which can lead to anoxia and outbreaks of botulism leading to paralysis and death of waterbirds;
- Revegetate the wetland area to restore waterbird habitat by replanting existing vegetation types that are found around the wetland; and
- Maintain mature trees around wetlands to provide habitat for birds and small animals. A number of waterbirds such as Pacific Black Duck, the Australian Shelduck and the Grey Teal utilise tree hollows or forks for nests."

3.2.2 Black Swan (*Cygnus atratus*) Requirements

The City of South Perth has undertaken research into the habitat requirements of Black Swans. The results of this research have not been received for the preparation of this report but the following general comments can be made.

Black Swans live on fresh, brackish and salt water. They gather on large waterbodies, especially when flightless during moulting between September and February. (Blakers, Davies & Reilly, 1984)

Their diet mainly consists of submerged aquatic plants, including algae and they also graze on pastures (Blakers, Davies & Reilly, 1984).

Black Swans also require sufficient vegetation to uproot and form nesting platforms for breeding. (Blakers, Davies & Reilly, 1984) Nesting platforms or mounds are built on reeds or small islands. Construction begins just before, or soon after, the first eggs of the breeding season are laid (beginning around May) and can continue for three to four weeks. The size of the nests will depend upon available material ranging from a ring of plant material to a large mound, but are typically 0.35 m high and 2 m in diameter. The material used in the nests will also be determined by what is available but usually consists of sticks, leaves, rushes or other aquatic plants. (Frith, 1976).

3.3 Reptiles

3.3.1 Long-necked or Oblong Turtles (*Chelodina oblonga*) Requirements

Long-necked or Oblong Turtles (*Chelodina oblonga*) are one of the native reptiles that can be accommodated into the design and management of the stormwater drainage network. These reptiles which have shells up to 40cm in length can be identified by their long necks (which are at least as long as their shells), the four clawed toes on their front feet and their freshwater habitat (Bush *et al*, 1995). They are common in permanent freshwater and seasonal swamps in the Perth region (Bush *et al*, 1995).

The Long-necked Turtle is diurnal and spends most of its time in water but also migrates between water bodies and females may travel considerable distances over land to lay eggs. (Bush *et al*, 1995).

Habitat requirements of Long-necked Turtles identified by Bush *et al*. (1995) and CALM (2004) include:

- Areas to lay eggs (between October and February) which are protected from predators and inundation, and where access to wetlands for the hatchlings is not obstructed by long grass or barriers such as deep drains;
- Partly submerged rocks or logs that can be used for basking and allows a quick escape into the water if needed;
- Adequate food, which may include mosquito larvae, fish, molluscs, crustaceans insects, earthworms, crickets and small mice;
- Ramps or partially submerged logs appropriately positioned to allow turtles to leave the pond if they wish;
- Loose soil or a pile of loose dry grass cuttings or leaf litter turtles to bury themselves in extreme temperatures;
- Non-stagnant water to minimise the risk of eye and shell infections.

The Water and Rivers Commission (2000f) suggests that the Long-necked Turtle 'which lays its eggs in the soil among upland vegetation, requires the retention of a [vegetated] buffer of up to 200 m'.

4. FERAL FAUNA

4.1 The Impact of Feral Animals

The three feral animals in the study area which are discussed in this report include the fox, cat and rabbit.

There is strong evidence to suggest that foxes have caused the decline of many small to medium-sized species of Australian native mammals (Thompson, 2000). With their varied diets and ability to thrive in urban environments foxes pose a threat to a range of native animals in the study area. Foxes diets include invertebrates (e.g. earthworms, centipedes, insects), fish, amphibians, reptiles, birds, small mammals (including rabbits), carrion, fruit and other plant material, and in urban areas have been found scavenging on waste food, stealing pet food, and killing backyard poultry (Thompson, 2000).

Cats eat small mammals, birds, reptiles and insects. Adult male cat consume 5% to 8% of their body weight in prey per day and females raising kittens require 20% (NRME, 2003). Results published in 1990 suggested that domestic cats in South Australia killed an average of 26 animals per year, many of them native birds (Environment Australia, 1999a).

Rabbits compete with other animals for fodder, destabilise the soil by establishing warrens and reducing vegetative cover, and severely limit bushland's ability to regenerate from seedlings as 16 rabbits eat as much as one sheep (Short, 1985).

The importance of controlling these feral animals is recognised in previous environmental management plans prepared for the City. The Mt Henry Peninsula Foreshore Management Plan (Ecoscape, 2004) includes the recommendation that a comprehensive feral animal control program be undertaken (Recommendation G4.6) and The Salter Point and Waterford Foreshore Management Plan (Siemon, 2000) includes the recommendation that vermin control programs be planned in conjunction with managers of all adjacent lands (Recommendation G57).

4.2 General Considerations in Controlling Feral Animals

The alternative options for control of feral animals need careful consideration. The most effective pest control programs are those which integrate several techniques (such as exclusion fencing, baiting and trapping), the control of several species (e.g. foxes and rabbits) and which the larger areas. (WA Ag Dept, 2004)

In allocating resources to feral animal control consideration needs to be given to the re-invasion of a site by feral animals, for example the West Australian Department of Agriculture (2004) noted that whilst organised fox shoots remove a considerable number of foxes the areas are rapidly reinvaded by foxes and there is seldom a reduction in the overall levels (because the area covered is generally small). The problem with controlling foxes over small areas is that foxes occupy distinct areas, called home ranges, from which they exclude other foxes entering (although home ranges can overlap). Fox numbers are therefore relatively stable, except when animals are removed and there is an influx of new individuals. The size of a home range is determined by food and resources but can typically range from 280 to 1600 ha (WA Ag Dept, 2004).

Similar dynamics also exist for feral cats which maintain stable home ranges, the sizes of which depends upon the availability of suitable den sites and food availability, but can range fro 4 to 8 square kilometres (NRME, 2003).

The maintenance costs of options such as exclusion fencing also needs to be considered when alternative management strategies are examined, as breaches resulting from vandalism and tree falls can quickly make them ineffective. However there are also significant limitations to baiting, shooting and biological controls.

Whilst 1080 poison underpins most vertebrate pest control programs for control of exotic vertebrate species in Australia this poison can not be used in urban areas (WA Ag Dept, 2004). Shooting feral animals is also greatly constrained in urban areas due to public safety concerns and therefore it is also not discussed as an option.

Research has been undertaken since 1992 to examine the possibility of reducing the fertility of introduced foxes, rabbits and house mice through the use of target specific naturally spread immunocontraceptive agents for each species. This is to be achieved by modifying viruses that cause target species to mount an immune response against their own reproductive tissue thereby preventing successful reproduction. However it is anticipated that it could be 5-10 years before any product could be considered for general release and the issues of releasing genetically modified organisms into the environment would also need to be addressed. (WA Ag Dept, 2004)

4.3 Control of Foxes (*Vulpes vulpes*)

4.3.1 Habitat Modification

The removal of shelter for foxes is more difficult than for rabbits. A fox may have numerous resting sites within its home range and therefore the destruction of any one shelter is less critical (Thompson, 2000). Foxes rest during the day in dens, often enlarged rabbit burrows, or in sheltered sites such as rock piles, hollow logs, or thickets (Thompson, 2000).

The foraging efficiency of foxes seems to be optimal in open habitats where they are able to range widely and freely. In environments with dense vegetation, steep topography, rocky crevices or extensive wetlands, prey are less likely to be caught by foxes. Thus providing a continuous canopy and a thick understorey of shrubs reduces the risk of fox predation upon native animals. (Environment Australia, 1999b)

4.3.2 Baiting

Pindone may be an option for fox baiting in the study area as the use of 1080 baits is not allowed in urban areas. Other baits that are also not viable options for the study area, but which are discussed in relation to fox control by WA Ag Dept (2004) are Strychnine and Cabergoline.

Strychnine is no longer an option for fox control in WA. Although previously used for this purpose it is no longer registered for this use in the state due to problems associated with it such as it not being target specific, concerns about its humaneness and bait shyness developing amongst target animals. WA Ag Dept (2004).

Cabergoline is not registered for fox control in Australia but there have been a small number of research trials that have been conducted regarding its effectiveness in causing abortions and death of post-natal cubs in foxes. It is expensive, only effective around 25-40% of the time, and may have the problem that vixens, which may need to be treated each year, may develop bait aversion. WA Ag Dept (2004).

The City is currently undertaking a fox control program.

4.3.3 Fencing

The construction and maintenance of fencing that is capable of excluding foxes is expensive and costs in the order of $18 000 to $50 000 per km have been reported (Biodiversity Group Environment Australia, 1999).

4.4 Control of Cats (*Felis catus*)

4.4.1 Categories of Cats

The issue of controlling cats in urban bushland is complicated by the different categories of cats. The Biodiversity Group of Environment Australia (1999) define the following three categories of cats:

- Feral cats are those that live and reproduce in the wild, eg. forests, woodlands, grasslands and wetlands, and survive by hunting or scavenging. None of their needs are satisfied intentionally by people. (Feral cats differ little in appearance from their domestic counterparts except in being generally more robust when in good condition (NRME, 2003)).
- Stray cats are those found in and around cities, towns and rural properties. They may depend on some resources provided by humans, but are not owned.
- Domestic cats are those owned by an individual, a household, a business or corporation. Most of their needs are supplied by their owners.

4.4.2 Containment of Domestic Cats

The Threat Abatement Plan for Predation by Feral Cats by Environment Australia (1999a) states that:

The responsibility for managing domestic cats ultimately rests with their owners. State, territory and local governments are supporting initiatives aimed at encouraging responsible pet ownership, including developing appropriate legislation, education and awareness programs, and management plans to address local problems with domestic and stray cats. Victoria has enacted the Domestic (Feral and Nuisance) Animals Act 1994 which requires cat owners to register their animals and gives councils the power to set fees and take remedial action when landowners experience problems with wandering cats. New South Wales has initiated the development of legislation to promote responsible ownership and improved welfare of companion animals.

The City of South Perth Green Plan Final Report (City of South Perth, 2002) recommends that 'More stringent guidelines be adopted for cat ownership in houses adjoining bushland or wetland areas within the City of South Perth' (Recommendation 49). The Salter Point and Waterford Foreshore Management Plan (Siemon, 2000) recommends that the City 'consider extending the cat local law to make it compulsory to sterilise cats' (Recommendation G66) and 'promote public awareness of the benefits of keeping cats indoors as much as possible, and particularly at night' (Recommendation G67).

4.4.3 Fencing

Fencing is the only feasible method of control when special areas need protection from cats (NRME, 2003) but the fencing required to exclude cats may not be deemed appropriate for some areas of small urban bushland due the visual impact and/or the financial burden. The NRME (2003) suggests that for netted fences to be cat-proof they either need:

- an electrified wire mounted 15 cm from the top and 10 cm outward from a fence; or
- a netted ceiling, or a curved overhang, which prevents the cat from climbing straight up and over the fence.

4.4.4 Trapping

The most practical trapping method for semi-feral urban cats is wire 'treadle-type' box traps. Attractants/lures such as meat, fish, tuna fish oil or visual stimulus (such as a bunch of bird feathers) should be placed within the trap so that they cannot be reached through the wire and be retrieved by clawing. (NRME, 2003)

True feral cats normally avoid box and cage traps, and rubber-jawed leg-hold traps tend to be more effective (NRME, 2003) but these traps are generally deemed unsuitable for urban environments.

4.4.5 Poisoning

Poison baits for cats are being developed but there are none commercially available yet because unlike foxes, cats prefer live prey and do not readily take dried meat baits.

4.5 Control of Rabbits (*Oryctolagus cuniculus*)

4.5.1 Baiting

Both water soluble and water insoluble pindone products are registered for controlling rabbits in Australia but they should be used according to the label and, where appropriate, mechanisms be put in place to reduce the risk to non-target species. The use of Pindone is carefully controlled and the Western Australian Department of Agriculture (2004) recommend that pindone only be used in WA where the use of 1080 is not practicable (such as urban areas). The risk to non-target species needs to be considered in its use because it is toxic to kangaroos, bandicoots, wedge-tailed eagles, possibly some parrots and may affect the reproductive output of domestic animals. WA Ag Dept (2004)

One advantage of pindone is that unlike 1080, there is an effective antidote for pindone (administration of vitamin K) if domestic animals are inadvertently poisoned WA Ag Dept (2004).

Bait stations (small enclosures/coverings for bait) provide one means by which potential risks to non-target species may be reduced although trail baiting is more effective in reducing rabbit numbers. Twigg and Lowe

(2003) note that Pindone in bait stations usually reduces rabbit numbers by about 50 per cent but the result can be highly variable, ranging from little effect to kills of up to 80 per cent; and that results can also take 30-60 days to manifest as the poison does not cause acute death and it takes time for rabbits to become accustomed to taking the bait. Baiting is most effective during summer when natural feed is scarcer.

4.5.2 Warren Fumigation and Destruction

If undertaken correctly, ripping and use of explosives can be an effective means of rabbit control through the destruction of their warrens. However, it is generally a fairly expensive option and warren destruction may not be suitable for all areas (e.g. areas that have been replanted, areas prone to erosion or where rabbits are harbouring in native vegetation rather than in warrens).

Warrens can also be fumigated (gassed) with Phosphine (e.g. Phostoxin®, aluminum phosphide) and carbon monoxide may be an option where warrens and burrows are located. WA Ag Dept (2004). Such activities should only be undertaken by appropriately trained personnel.

The success of both warren destruction and fumigation requires that the entire warren system is treated.

The City is currently undertaking rabbit bating program

4.5.3 Fencing

Rabbit-proof fencing can provide a viable option for excluding rabbits from areas of high conservation value once they have been eliminated from the site. Twigg and Lowe (2003) suggest that fencing can provide a better long-term and cost-effective solution to many rabbit problems in urban areas than baiting, despite the initial cost outlay for rabbit-proofing boundary fences with wire netting being in the order of $1 600 per km.

4.5.4 Tree guards

In the absence of fencing even simple tree guards have been found to be effective in protecting seedlings in revegetation projects around Perth (personal observation).

4.5.5 Biological Control

A number of biological controls have been introduced into Australia to control rabbits. These include:

- Rabbit Calicivirus Disease (RCD);
- The myxoma virus (*myxomatosis*); and
- Rabbit Haemorrhagic Disease Virus (RHD).

Whilst useful in controlling overall rabbit numbers, their impact varies across Australia (for example RHD has little effect in high rainfall areas) and none of these diseases will result in the elimination of rabbits. Therefore it is crucial that biological controls are not relied upon alone for the sustained long-term effectiveness of rabbit control programs in Australia. (WA Ag Dept, 2004)

5. REVEGETATION

5.1 Introduction

The Swan River Trust (2003) notes that vegetation helps improve water quality, both directly and indirectly, by:

- Uptaking nutrients and pollutants;
- Filtering suspended nutrients and pollutants;
- Providing submerged leaves, stalks and roots on which biofilm can grow, and assimilate dissolved nutrients;
- Releasing oxygen from the root zone which is conducive to decomposition of organic material, nitrogen transformation and discourages phosphorous release;
- Providing shade and tannins which reduces algal blooms;
- Stabilising soil which reduces the amount of suspended solids; and
- Reducing wind turbulence which reduces resuspension of particulate matter.

Vegetation is also critical to the level to which waterbirds utilise wetlands on the Swan Coastal Plain (Storey *et al*., 1993).

5.2 Wetland Plants Recommended for Revegetation

In determining which plants are suitable for establishment in and around stormwater outlets consideration has been given to the native plants occurring in water-gaining sites within the vegetation complexes of the area.

Heddle *et al*. (1980) mapped the City of South Perth as consisting mainly of the Bassendean Vegetation Complex (Central & South) with the Vasse Complex occurring along the San and Canning Rivers; and the Karrakatta Complex (Central and South) occurring near the narrows bridge. Plants that occur within the water-gaining sites within these complexes have been identified.

Plants need to be established in and around compensation basins and artificial lakes in a series of zones that reflects their ability to withstand varying levels of inundation.

Powell (1990) noted that woody vegetation around lakes in Perth often follows the sequence (from the lake outwards) of:

- *Melaleuca teretifolia;*
- *Melaleuca rhaphiophylla;*
- *Eucalyptus rudis;*
- *Melaleuca preissiana; and*
- *Banksia littoralis.*

The gentler the slopes on the sides of the artificial water features created, the broader the zones for each group of plants.

It should be noted that some native plants can behave like weeds by dominating disturbed sites into which they are planted. The Water and Rivers Commission (2000c) identified the following native plants as having the potential to behave like weeds in the South West of Western Australia:

- Bracken fern (*Pteridium esculentum*) on seasonally damp areas next to rivers;
- Golden Wreath Wattle (*Acacia saligna*) on floodways and sandy verges of rivers;
- Club Rush (*Bolboschoenus caldwellii*) as a perennial along fresh rivers and as annual on saline saltmarshes (Pen (1983) noted that this species was correlated with fresh water drains);
- Native Bulrush (*Typha domingensis*) although this is usually displaced by the introduced Bulrush *Typha orientalis*; and
- Nardoo (*Marsilea mutica*) which can form large 'rafts' in rivers.

5.3 Plant Establishment

Most wetland plants are established in spring, to avoid the plants being flooded immediately after planting whilst maximizing soil moisture. Direct seeding is an option for *Juncus* species and some sedges including *Carex*, *Isolepis* and *Schoenoplectus* where weed problems are minimal (WRC, 2000e). This is not the situation in the study area and whilst organic matting can be used to the reduce weed competition, the use of tubestock will generally be the preferred option in the study area.

The establishment of most wetland species is relatively simple but there are species with specific requirements such as:

- *Baumea juncea* which should have the top of the pot stock planted approximately 100mm below ground level to encourage vigorous growth (Siemon, 1999); and
- *Bolboschoenus caldwellii* and *Eleocharis acuta* generally need to be protected by some form of fencing during establishment as they have relatively unanchored rhizomes at this time, which are prone to being pulled out by waterbirds that feed upon them (Chambers, Fletcher & McComb, 1995).

Protection provided for establishing sedges and rushes can take the form of a small fenced enclosure, as shown in Plate 5.1.

Plate 5.1 Fence enclosure protecting establishing sedges and rushes at McDougall Park

The densities at which plants are established will depend upon

- Plant material used;
- Growth rates of species; and
- the nature of the root system (DLWC, 1998a).

The Department of Land and Water Conservation, New South Wales (1998a) suggests that densities will vary between 0.2 plants/m2 for some overstorey species to 8 plants/m2 for some emergent plants, and recommended planting densities for sedges and rushes in the order of 2-4 plants/m2 (assuming plant stock is provided in tubes) for a number of common species. In recommending planting densities for local conditions the Water and Rivers Commission (2000e) suggested higher rates of 6 – 9 plants/m2 (with tufted species being planted more densely than rhizomatous species). The difference in recommended planting densities may reflect differences in growth rates in the two states as:

- The DLWC (1998a) suggested that rhizomatous species such as Sea Clubrush *Bolboschoenus caldwellii* are capable of spreading many metres in a few months; and
- the WRC (2000e) suggest that species with spreading rhizomes spread between 0.5-1 m in two years.

A number of sedges and rushes are relatively slow growing and therefore orders for tubestock may need to be placed a year before the required delivery.

6. MANAGEMENT STRATEGIES

6.1 Management Categories

Given that there are 147 stormwater catchments within the City of South Perth, management strategies are based on stormwater entering the drainage network and the types of outlets. These types are:

- Infiltration Basins without Public Access or Landscaping;
- Landscaped Infiltration Basins with Public Access;
- Outlets discharging directly into Swan/Canning Estuary;
- Outlets discharging into Vegetated Areas (including indirectly in Swan Canning River)

In addition to the discussion provided below, the recommendations made in previous environmental management plans for the City of South Perth, that specifically relate to stormwater management, are included in Appendix 2. The recommendations in Appendix 2 should be read and implemented in conjunction with those provided below. Feedback from the City of South Perth with regards to the implementation of these recommendations has not been received at the time of this report, which limits the extent to which they can be discussed in terms of further recommendations.

6.2 Infiltration Basins without Public Access or Landscaping

6.2.1 Examples

There are approximately 65 dry compensation and infiltration basins that fall within this category.

6.2.2 Key Issues

The key issues are:

- Engineering constraints with regards to steep banks;
- The need to remove basin sediment to maintain stormwater capacity
- Odours
- Mosquito breeding

6.2.3 Discussion

Whilst there are opportunities to increase the amount of native vegetation associated with dry compensation basins there are a number of constraints with regards to enhancing the environmental values of these basins.

These basins generally have steep sides to minimise their size and maximise their stormwater capacity. The small reserves that contain these basins usually limit the degree to which slopes can be reduced, and this in turn reduces the opportunity to establish a variety of habitats and broad zones of plants adapted to different hydraulic regimes. Without broad zones the vegetation communities' ability to adjust to long and short term changes in hydrology are lessened. The steep slopes do however provide the advantage that slopes greater than 1V:3H (1V:1H or 1V:2H ideal) do not favour mosquito breeding (DLWC, 1998a).

The Swan River Trust (2003) estimates that 30% of compensating basins would need to be vegetated to have significant improvements in water quality but there will be limitations on the amount of vegetation that can be established within these basins, as sediment needs to be regularly removed in order to maintain the stormwater capacity of these infiltration basins. An additional issue is that sediments can accumulate high levels of nutrients and heavy metals, and the removal of this material can provide logistical problems due to the lack of available disposal sites (SRT, 2003).

Odours can be produced as algae within the compensation basins decompose but the design of traditional compensation basins which minimise hydraulic retention times also minimise this issue as blue-green algae require around 5-10 days to become established (DLWC, 1998a). Short hydraulic retention times will also minimise opportunities for mosquito breeding (DLWC, 1998a).

6.2.4 Recommendations/Conclusion

Given the above considerations there are limited opportunities for developing a significant portion of the traditional compensation basins within the City of South Perth and in general resources are more effectively directed to the other categories of the receiving environment. However native trees and shrubs could be established around the periphery of these basins to provide additional habitat for birds within the area and increase water uptake from the basins.

It should also be noted that a number of dry compensation basins have previously been identified for incorporation into adjacent parkland in the City of South Perth Green Plan Final Report (COSP, 2002) and these are a priority in terms of resources, but are considered under the category which they will eventually included in 'Landscaped Infiltration Basins with Public Access'.

6.3 Landscaped Infiltration Basins with Public Access

6.3.1 Examples

There are 13 wet compensations within the City of South Perth. Sites that are of the greatest significance are

- Bodkin Park;
- McDougall Park;
- Sir James Mitchell Park;
- Lake Gillon; and
- Collier Park Golf Course

The compensation basin in the park at Doneraile Court is also included in this category, although it is categorised as a dry basin.

The dry compensation basins that have been recommended for inclusion into adjacent parklands in the City of South Perth Green Plan Final Report (COSP, 2002) are at the following locations:

- 54 Roebuck Drive (recommendation 34)
- 60 George Street (recommendation 35); and
- 150 Gwenyfred Road (recommendation 36).

Of these three compensations basins, Roebuck Drive will be the easiest to incorporate into the adjacent parkland, followed by George Street then Gwenyfred Road.

6.3.2 Key Issues

The key issues are:

- Public health and safety
- Suitable contours
- Odours
- Aesthetics
- Water velocity

6.3.3 Discussion

Landscape plans need to be developed for each of the parkland areas containing artificial lakes that detail any recontouring of the site and the exact composition, placing and number of plants established around their periphery.

If excavation is proposed in or around any natural or artificial wetlands in the City of South Perth the potential for contacting Acid Sulfate Soils should be investigated. Actual Acid Sulfate Soils (AASS) are generally naturally occurring soils containing sulfides that have reacted with oxygen to produce acids. Potential Acid Sulfate Soils (PASS) contain sulfides that have not reacted with oxygen (usually due to being permanently waterlogged). They produce acids when exposed to air by excavation, filling, creation of artificial water courses, or groundwater abstraction/dewatering.

The impacts of acid sulfate soils can be associated with the increase in acidity and/or the release of heavy metals into the environment. The impacts include:

- Decline in health or death of aquatic organisms including fish;
- Decline in health or death of plants;
- Corrosion of infrastructure;
- Aluminium-rich waters (as a result of low pH) may impair human health, causing stunted growth, poor health and mental impairment.

Most of these sites have existing management plans (Sir James Mitchell Park, Bodkin Park is included in the plan for Salter Point and Waterford) or are having management plans prepared (McDougall Park and Collier Golf Course). In addition landscape plans should be developed for the artificial lakes. These landscape plans should incorporate the following principles.

To maximise the environmental value and water quality of a constructed wetland the extent of peripheral vegetation should be maximised. The width of the vegetated areas around the wetlands will need to consider how the parkland and wetland areas are integrated into an experience for the visiting public. In terms of optimising the environmental value of the wetlands the wider a buffer the better. The Water and Rivers Commission (2000f) recommends a buffer of 20 - 50 m around wetlands to maintain ecological processes and major food webs. This may overly intrude into recreational areas or not be possible within the physical constraints of some, if not all, of the parks within the study area. The width of the present vegetated buffers around some of the lakes in the study area is in the order of 1 m. Such buffers should be a minimum of 5 m to provide some habitat value to most birds.

The WRC (2000e) recommends that approximately half of a wetland should be planted with sedges and rushes, and each species be planted in single species groups to mimic the natural situation and avoid competition loss. Whilst 30% of compensating basins need to be vegetated to have significant effects on water quality (SRT, 2003) Storey *et al*. (1993) reported that the structural complexity of vegetation was correlated with the numbers of species using sites, and this was particularly important for nesting birds. Storey *et al*. (1993) also noted that the proportion of vegetation did not appear to affect waterbird usage and that previous studies in North America indicated that the highest species on wetlands occurred at intermediate vegetation cover (33-66%). This means that establishing a range of plant types (e.g. sedges and rushes, shrubs and trees) around wetlands is as important as establishing a high density of native plants, and that views of lakes do not need to be totally obscured by vegetation for environmental benefits in terms of water quality and fauna to be obtained. Consideration should therefore be given to creating dense stands of riparian vegetation interspersed by open areas which provide vistas across artificial lakes. The heights of plants recommended for revegetation are listed in Appendix 1 to provide guidance when structural complexity and views are considered.

A variety of slopes within a wetland will create a greater variety of habitats for plants and animals. The Water and Rivers Commission (2000b) that artificial wetlands have slopes between 1:4 and 1:15 rather than steep banks. Gentle slopes reduce the possibility of children becoming trapped in waterbodies and a slope of about 1vertical:10 horizontal will provide a gradual changes in depth to encourage development of broad plant zones compared with moderate slopes (about 1 vertical: 5 horizontal) which will encourage relatively narrow zones of plants around the shoreline (DLWC, 1998b).

Gentle slopes are preferred for establishing broad zones of wetland plants and will also minimise any physical dangers with public access to the edge of the wetlands (for public safety a slope of 1V:8H is ideal) (DLWC, 1998a). However access by the public to wetlands should be controlled and managed if pathogenic contaminants are present (DLWC, 1998a). Pathogenic contaminants listed by the Department of Land and Water Conservation (1998a) as potentially being present in constructed wetlands include:

- Heavy metals;
- Pesticides;
- Viruses (e.g. *Adenovirus, Calcivirus, Coronavirus, Coxsackie, Echovirus, Hepatitis A, Poliovirus and Rotvirus*);
- Bacteria (e.g. *Salmonella, Shigella, Vibrio, Aeromonas and some E. coli forms*);
- Protozoa (e.g. *Giardia* and *Cryptosporidium*); and
- Helminths (e.g. Ascaris species – Round worms and *Tania* species – Tapeworms)

The viruses, protozoa and Helminths in the above list tend to be associated with sewage but birds can also be a source of faecal contamination in wetlands (DLWC, 1998a).

The City of South Perth presently monitors water quality in its constructed wetlands and provides warning signs when access into the water poses a risk to public health. Where access needs to be managed wetland plants can also be strategically used to deter access with dense clumps of plants of varying sizes, that are spiky or have rough textures (DLWC, 1998a).

Although specific requirements for the design of wetlands will vary between sites on the basis of environmental and social attributes and management objectives, a general rule of thumb suggested by DLWC (1998b) for the depth of water in artificial lakes is 30% < 0.5 m, 50% at 0.5-1 m, and 20% > 1.5 m but not greater than 2.5 m.

6.3.4 Recommendations/Conclusion

To maximise both the environmental and aesthetic value of the artificial wetlands in the City:

- develop specific landscape plans for the artificial wetlands in Sir James Mitchell park, McDougall Park and Bodkin Park;
- the amount of native vegetation should be increased;
- dense stands of riparian vegetation be established with open areas in between;
- wetlands should have a variety of slopes, varying between 1:4 and 1:15;
- wetlands should have a variety of depths, but preferably deeper than 1 m at the time of primary use by waterbirds;
- a variety of plant types (e.g. sedges and rushes, shrubs and trees) should be established around wetlands;
- Partly submerged rocks or logs be placed for turtles to bask on;
- Ramps or partially submerged logs be appropriately positioned to allow turtles to enter and exit ponds and lakes; and
- Water quality be monitored and managed.

6.4 Outlets discharging directly into Swan/Canning Estuary

6.4.1 Examples

There are approximately 47 outlets emanating from the City of South Perth (including the Kwinana Freeway) discharging into the Swan and Canning Rivers.

6.4.2 Key Issues

The key issues for minimising environmental impacts are:

- Nutrient loads
- Water velocity
- Stagnation

6.4.3 Discussion

Given the design constraints for outlets that discharge directly into the Swan-Canning Estuary (e.g. along the freeway) there are limited opportunities to manage nutrients at these outlet points. Nutrients need to be managed within the catchment.

The issues of water velocity and stagnation are issues that have previously been identified by Brown and Root (2000). The 'Freeway and South Perth Drainage Outfall Condition Survey' undertaken by Brown and Root (2000) included an assessment of each individual outlet in that area and made the following general comments:

- Rock spalls need to be placed at a number of outfall pipes to (reduce water velocity and thus) minimise potential erosion;
- The letterbox outlet structures that do not incorporate low flow pipes typically trap stagnant water that in many cases was associated with algal growth, decaying sea weed and mosquitos; and

- The effectiveness of submerged outfall pipes without groyne encasements was uncertain.

The need to control water speed as it leaves the drainage system is also reflected in the recommendation in the Mt Henry Peninsula Foreshore Management Plan (2002) that the Redmond Avenue drain be modified to place it at ground level. This drain currently discharges water midslope on a steep embankment, several metres above ground level.

Riparian vegetation could be established around these outlets but there does not tend to be large amounts of riparian vegetation in the areas anyway and vegetation should not be established around these outlets that would obstruct the inspection and maintenance of these outlets.

6.4.4 Recommendations/Conclusion

There are a number of recommendations that have been made for specific outlets in the 'Freeway and South Perth Drainage Outfall Condition Survey' (Brown and Root, 2000) and Mt Henry Peninsula Foreshore Management Plan (Ecoscape, 2004). In addition to implementing these recommendations there are limited opportunities for managing storm water discharge from these types of outlets. In general, resources are more effectively directed into non-structural pollutants before they reach these outlets.

6.5 Outlets discharging into Vegetated Areas

(including indirectly in Swan Canning River)

6.5.1 Examples

The areas of foreshore within the City of South Perth that retain riparian vegetation are concentrated along the Canning River on the southern boundary of the municipality. This is principally the Salter Point-Waterford-Clontarf Foreshore. The Goss Avenue Bushland and the bushland on the southern boundary of Manning Primary School also receive stormwater.

6.5.2 Key Issues

The key issues for minimising environmental impacts are:

- Nutrient loads
- Salinity levels
- Weeds

6.5.3 Discussion

The type of riparian vegetation receiving stormwater will determine what management options should be employed at the point of discharge. Pen (1983) recommended that:

- freshwater drains should not be allowed to discharge into salt-marsh communities, rather the drains should be cut through them in order to maintain them. It has been noted that the amount of freshwater been delivered into the Waterford Foreshore by the drainage network is degrading the salt marsh community that is adapted to the more saline conditions of the Swan/Canning Estuary (Siemon, 2000). Siemon (2000) also noted that a proposal to line the eastern side of this drain to limit leakage was rejected by the Swan River Trust in 1994;
- freshwater drains be allowed to empty into *Melaleuca-Juncus* Complexes and Melaleuca (Swamp) Complexes if the drain replaces natural drainage flows; and
- freshwater drains in general should not be emptied into stationary water bodies as this tends to encourage the establishment of the introduced Bulrush, *Typha orientalis*.

As indicated by this last recommendation regarding Bulrush, weeds are a major issue when managing stormwater discharging into bushland and riparian areas, and whilst the three recommendations are reasonable they form only some of the options for managing such situations. Weed control is discussed in Section 7 and other management issued are discussed below.

The major issues for the Goss Avenue Bushland are weeds and establishing native plants and these are discussed in the Weeds and Revegetation Sections. Another area identified as a high priority for managing in terms of social and environmental values is the Collier Pines Main drain that passes through Bodkin Park before discharging into the Waterford Conservation Area, and this is used as an example in discussing a more extensive range of options.

There are presently few modifications to the Collier Pines Main drain to reduce the water or nutrients reaching the Waterford Foreshore. Whilst Bodkin Park itself fits into the category of parkland, addressing water quality issues within the Park is critical to improving the quality of water that flows out of it and into the Waterford Conservation Area. The nutrient stripping and habitat value of the Collier Pines Drain as it passes through Bodkin Park could be increased by replacing exotic species with native species; increasing native plants along drains, increasing native plants in drains; and altering the shape and bathymetry of the drain.

Replacing exotic species with native species reduces nutrient loads both directly in the form of leaf fall and lawn clippings, and providing a nutrient stripping buffer.

The vegetative parts of annual and biannual species die off outside the growing season and can contribute to a sudden nutrient release into waterways. Similarly large exotic tree species such as willows overhanging drains and waterways can decompose too rapidly for macroinvertebrates to process, adding to nutrient loading in the system.

Grasses are also a poor buffer for nutrients running off lawn areas and any grass clippings that are not removed can also block water flows and increase nutrient levels. Annual grasses also die off over summer reducing nutrient stripping capacity over this period. The first rains of the season can be highly nutrient enriched, and the lack of nutrient stripping capability at this time exacerbates the impacts of these first flush events. Native sedges, rushes, shrubs and trees can provide an appropriate nutrient stripping buffer. Native surrogates such as *Jacksonia sericea* and *Neurachne alopecuroides* can be used where a grass-like groundcover is required for access, aesthetics, security or fire concerns.

In addition to reducing nutrient loads, native plants can increase shading of the waterbody which stabilises water temperatures and reduces algal growth by limiting light. At present Bodkin Park has widely spaced trees and these are not concentrated along the drain. Planting large trees and tall shrubs in dense stands adjacent to the drains can help shade the Collier Pines Main Drain. This is particularly important on the northern sides of these drains.

As discussed in Section 5, the Swan River Trust (2003) notes that vegetation helps improve water quality, both directly and indirectly. Effectively vegetation is excluded from directly interacting with the water in the drain due to the side of the drains being 'sealed' with boards. Removing these boards would create a more natural substrate in which to establish submergent and emergent aquatic plants. It would also increase the infiltration of the water into the ground and therefore decrease the volume of water discharged into the Waterford Conservation Area. If there are concerns with increasing infiltration from the drain, the drain could be reconstructed with additional width and depth, with the area of excess capacity filled with soil in which vegetation is established. Aquatic plants such as *Triglochin linearis* (Water Ribbons) and *Bolboschoenus caldwellii* (Marsh Club Rush) could also be established instream as these are highly flexible and will not impede water flows. A recommended redesign for linear drains to improve water quality is shown in Figure 6.1.

Changing a drain to a more meandering and sinuous alignment will create greater hydraulic retention times which also allows more time for nutrients to be absorbed from the water column and promote habitat diversity.

Hydraulic retention time can be increased in artificial lakes by denying a straight flow path between inlets and outlets of lakes with islands, bunds that create large deviations in the shoreline and dense plantings of appropriate sedges and rushes (e.g. *Eleocharis acuta*). An example of how hydraulic retention times can be increased in shown in Figure 6.2.

Increasing the roughness of the base of a drain can also provide benefits in terms of water quality and habitat. Instream areas of small rapids or broken water, known as riffles, also provide habitat for Minnows, Stoneflies, Caddisflies and Blackflies (WRC, 2000d). This increased turbulence also dissipates the energy of the waterflow, and increases oxygenation which is required to reduce ammonia levels in the water column (SRT, 2003).

Erosion from discharges of high water velocity did not appear to be a major issue within this management category of vegetated areas in the study area. As a general rule, where water does not exceed 0.6 m/s then spalls or riprap (gravel bunds) are sufficient to dissipate energy and where water speeds are greater, or a significant drop occurs at the structure, then engineering advice needs to be sought (DLWC, 1998b).

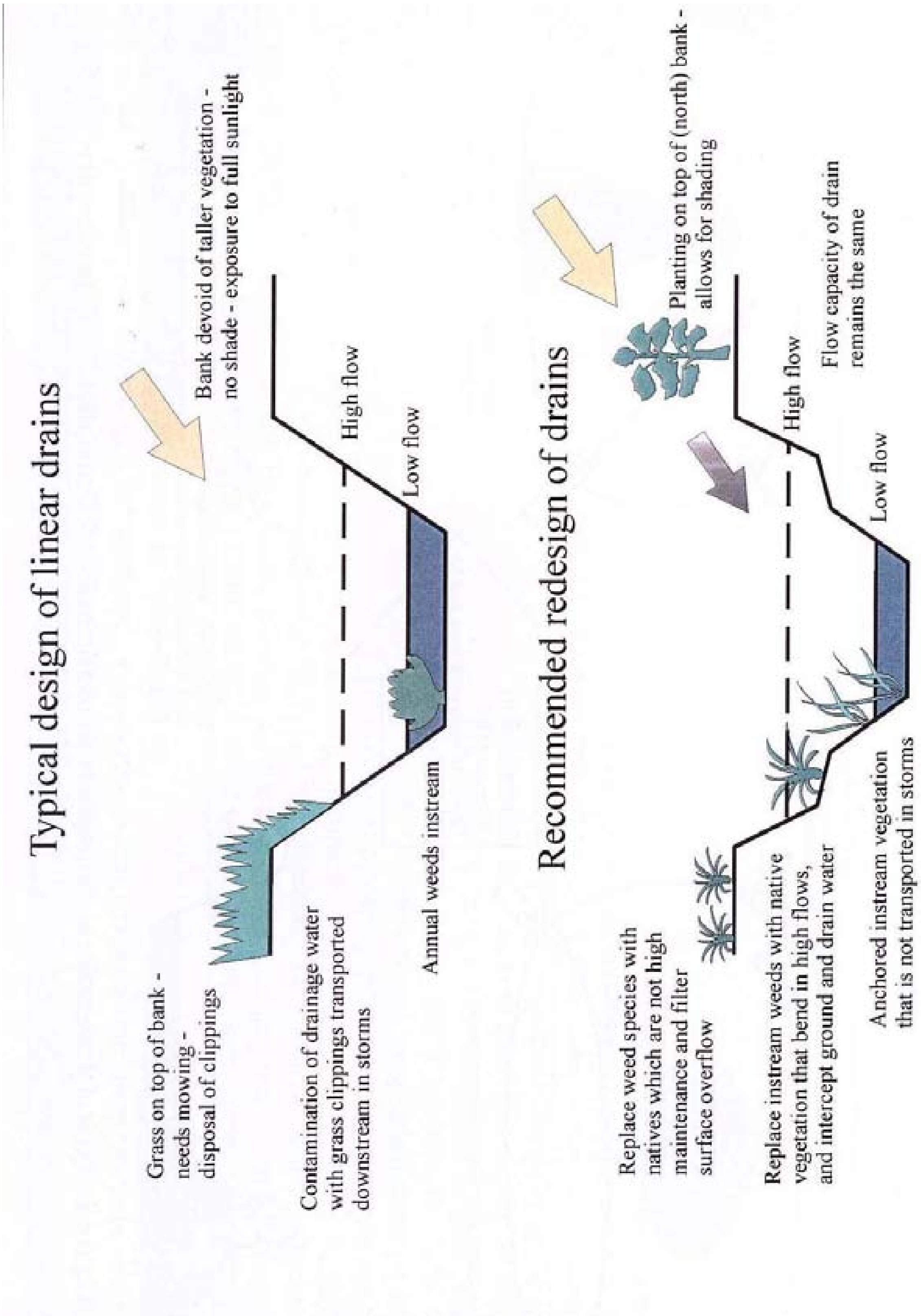

Figure 6.1 Typical Design of linear drains and redesign options to improve water quality (SRT, 2003)

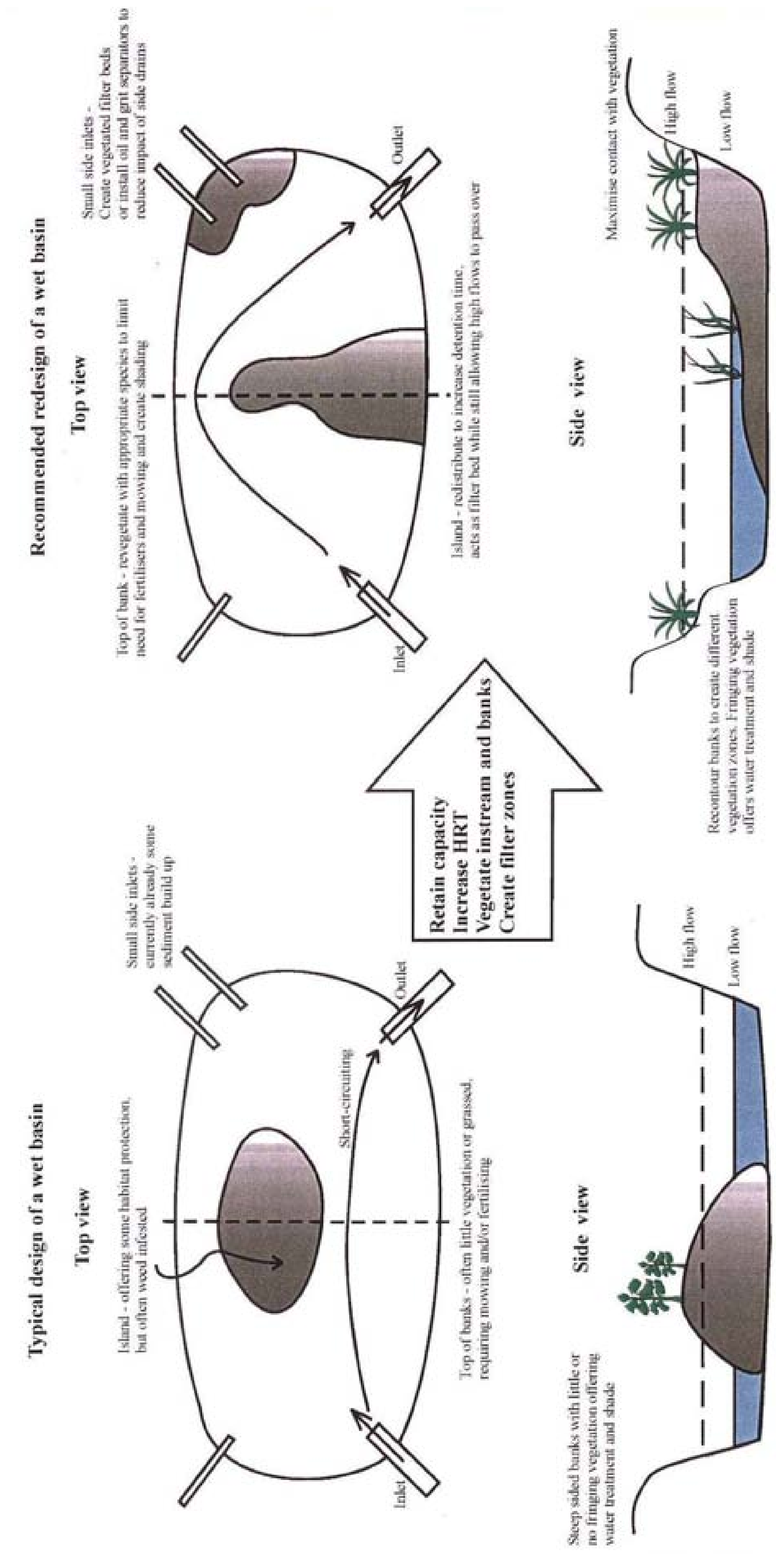

Figure 6.2 Typical Design of a wet compensating basin and redesign options to improve water quality (SRT, 2003)

6.5.4 Recommendations/Conclusion

It is preferable that:

- freshwater drains should not be allowed to discharge into salt-marsh communities, rather the drains should be cut through them in order to maintain them;
- freshwater drains be allowed to empty into *Melaleuca-Juncus* Complexes and Melaleuca (Swamp) Complexes if the drain replaces natural drainage flows; and
- freshwater drains in general not be emptied into stationary water bodies as this tends to encourage the establishment of the introduced Bulrush, Typha orientalis.

The nutrient stripping and habitat value of drains should be increased by replacing exotic species with native species; increasing native plants along drains, increasing native plants in drains; and altering the shape and bathymetry of drains. Landscape plans should be prepared to detail proposals prior to commencement of works.

7. WEED MANAGEMENT

7.1 The Impacts of Weeds

Weeds impact upon wetland ecology in a number of ways, including:

- Competing with native species;
- Restricting the regeneration and recruitment of native plants;
- Reducing the resources of native fauna for feeding, breeding and shelter and
- Increasing fire risk as a result of increased fuel loads.
- (WRC, 2000a)

7.2 Weed Control

7.2.1 Weed Control Objectives

The objectives for weed control are to:

- identify and control existing weeds with the highest priority for control;
- prevent introduction of additional weed species;
- prevent further encroachment of weeds into bushland areas;
- minimise any detrimental effects of the weed control programme on the native biota; and
- integrate the weed control programme with bushland restoration programmes.

7.2.2 Weed Control Prioritisation

Weed control priorities have already been established within the individual management plans for bushland areas with the City of South Perth. To prioritise weed control between reserves, each stormwater catchment has been a priority of environmental and social values. Additionally weed control priorities can include consideration of:

1. Weed species present (species-led control);
2. Site characteristics (site-led control);
3. available resources (resource-led control);
4. Threatened Species / Communities present (Threatened species-led control).

The wetlands of South Perth will require a combination of site-based and species-based control due to different levels of infestation, vegetation communities and weed species. Site-based control is required where relatively small and discrete areas are degraded and where removing weeds may produce bare slopes that are unstable and aesthetically unpleasant. Species-based control is appropriate for highly invasive species.

1. Species-led Control

Species-led control is a proactive strategy to prevent introduction, establishment, survival, reproduction and dispersal of an emerging weed before it becomes a major problem within the study area. Initiatives should be undertaken at a local level to prevent the introduction and spread of weed species through control of degrading processes.

Generally, it is recommended that species-led control be undertaken prior to site-led control. Weed species were placed in this category if they:

- Have small populations;
- Are relatively easy to remove;
- Have a high potential to spread and therefore become a problem in the future; and
- Are located in areas that will not be continually reinfested from the soil weed seed bank or from surrounding areas.

2. Site-led Control

Site-led control focuses on identifying areas that require weed control to maintain their ecological and commercial values. It is good practice to control weeds in upstream areas before downstream areas as weed seeds are continually carried downstream (SRT, 2003).

Generally, it is recommended that site-led control be undertaken after control of weeds recommended for species-led control. Weed species can be placed in this category if they:

- have wide-spread and well-established populations;
- require concentrated and/or long-term efforts to remove; and
- are highly detrimental to ecological functions of bushland if left unchecked.

Site-led control can also be initiated on the basis of opportunities such as fire. Following fire there is an increased opportunity to control weeds because of increased access, weeds are actively growing (increasing the effectiveness of herbicides) and weeds seeds stored in the ground are germinating but not being replaced (at least in the short term).

3. Resource-Led Control

Resource-based weed control is recommended where a particular species is known to be within a defined area, and thereby can provide a focus for community projects. A resources led approach matches volunteer and professional labour to the best possible weed control outcomes. For example, volunteers may be best suited to target small populations of highly visible weeds which are readily removed by simple manual or chemical methods and are ideal for essential follow up and monitoring. Professional contractors should be used where spraying or machinery is required.

4. Threatened Species / Communities led Control

This approach to weed control focuses on the ecological significance of threatened flora species or vegetation types. If a particular site is known to contain either of these, weed control in these areas becomes a priority to protect the ecological integrity of the site, and thereby promote the long-term survival of the species or community.

7.3 Weed Species

There are lists of weeds species, and recommended control methods in the previous bushland management plans within the study area. The weeds previously recorded in management plans as occurring in wetland areas, or those that tend to be associated with wetland areas are shown in Table 7.1.

Table 7.1 also includes the rating for weeds given in the Environmental Weed Strategy for Western Australia (CALM, 1999). The 3 characteristics used for determining the Environmental Weed Strategy for Western Australia (EWSWA) rating are:

- invasiveness – ability to invade bushland in good to excellent condition, and waterways;
- distribution – wide current or potential distribution including consideration of known history of wide distribution elsewhere in the world; and
- environmental impacts – ability to change the structure, composition and function of ecosystems. In particular to form a monoculture in a vegetation community.

The weed priority ratings, are based on these characteristics in the following way:

- High – weeds that have all 3 of the characteristics;
- Moderate – weeds that have 2 of the characteristics;
- Mild – weeds that have 1 of the characteristics; and
- Low – weeds that are not deemed to have any of the characteristics.

Table 7.1 Weeds in wetland areas of Bushland and Parkland in South Perth

Scientific Name	Common Name	EWSWA Priority	Salter Point and Waterford FMP	Sir James Mitchell Park FMP	Mt Henry Peninsula FMP	Clontarf FMP	Goss Avenue / Koonawarra MP
Acacia longifolia	Sydney Golden Wattle	M					■
Arctotheca calendula	Cape Weed	M			■		
Arundo donax	Giant Reed	L	■	■		■	
Carpobrotus edulis	Pigface	M	■	■	■	■	■
Centranthus macrosiphon		L			■		
Chenopodium glaucum	Goose Foot	L	■				
Cortaderia selloana	Pampas Grass	H	■			■	
Cynodon dactylon	Couch	M	■	■	■	■	■
Cyperus tenellus	Tiny Flat-sedge	M					■
Cyperus tenuiflorus	Scaly Sedge	M				■	■
Drosanthemum candens	Redondo Creeper	L	■				
Ehrharta calycina	Veld Grass	H	■		■		
Eucalyptus camaldulensis	Red River Gum	L					■
Foeniculum vulgare	Fennel	U			■		
Homeria flaccida	One-leaf Cape Tulip	H			■		■
Hydrocotyle ranunculoides	Hydrocotyle	M		■			
Juncus bufonius	Toad Rush	M					■
Juncus microcephalus		Mi					■
Lantana camera	Lantana	M			■		
Leptospermum laevigatum	Victorian Tea-tree	H			■		
Paspalum dilatatum	Paspalum	M	■			■	
Paspalum vaginatum	Salt-water Couch	M			■		
Pennisetum clandestinum	Kikuyu	M	■	■	■	■	■
Polypogon monspeliensis	Annual Barbgrass	M	■				
Raphanus raphanistrum	Wild Radish	L			■		
Romulea rosea	Guildford Grass	H	■		■		
Rorippa nasturtium-aquaticum	Watercress	M			■		
Salix babylonica	Willow	L		■		■	
Schinus terebinthifolia	Japanese Pepper	M			■		
Solanum nigrum	Blackberry nightshade	M	■		■		
Stenotaphrum secundatum	Buffalo Grass	M					■
Typha orientalis	Bulrush	H	■	■	■	■	
Vellereophyton dealbatum	White Cudweed	M					■
Vicia sativa	Common Vetch	M			■		
Watsonia sp.	Watsonia	H	■		■		■
Zantedeschia aethiopica	Arum Lily	H			■		

Any weed control undertaken should be overseen by an appropriately experienced person to ensure that weeds are correctly identified and off target damage is minimised. This is critical with species such as the Bulrushes. Both Typha orientalis (Bulrush or Broadleaf Cumbungi), which has been introduced from eastern Australia, and the local native Typha domingensis (Yanget, Bulrush or Narrowleaf Cumbungi) occur in Perth. Intermediates exist between the species and it can be difficult to differentiate between the two (Hussey *et al*., 1997). In general Typha domingensis has narrower leaves and inflorescences and a more upright stand structure (Chambers *et al*, 1995). The characteristics listed in Table 7.2 can aid in identification.

Table 7.2 Comparison of *Typha orientalis* with *Typha domingensis*

Characteristics	***Typha orientalis***	***Typha domingensis***
Height	up to 4.5 m	up to 3 m
Leaf blade width	5 - 14 mm	5 - 8 mm
Separation between male and female flower cluster	0 – 60 mm	5 - 25 mm
Width of female flower cluster	10 – 30 mm	8 - 15 mm
Colour of female flower cluster	cinnamon brown	chestnut brown
Stem width below flower cluster	4 - 7 mm	2.5 – 5 mm

Chambers *et al* (1995)

7.3.1 Weed Control Techniques

Control options for environmental weeds include:

- controlling ecosystem degradation processes;
- physical barriers to encroachment;
- manual control; and
- herbicides.

These options are further discussed below.

Controlling Degrading Factors

The processes that contribute to the spread of weeds include:

- Amenity plants that have been established in garden and parkland situations that spread seed into bushland areas;
- Changed water regimes (e.g. increased freshwater from drains);
- Trampling and off-road vehicles;
- increased fire frequency;
- rubbish dumping, including soil and garden waste; and
- movement of weed seed, including via stormwater

An example of such an interaction is between fire and Bulrush. Broad leaf Bulrush (*Typha orientalis*) competes with both the local Bulrush or Narrow Leaf Cumbungi (*Typha domingensis*) and Freshwater Paperbark (*Melaleuca rhaphiophylla*) for preferred habitat on the fringes of rivers and permanent lakes. *Typha orientalis* usually out competes *Typha domingensis*, but where fire is frequent it also out competes *Melaleuca rhaphiophylla*. Where fire is less frequent *Melaleuca rhaphiophylla* usually outcompetes *Typha orientalis* (Powell, 1990). Pen (1983) also noted that freshwater drains emptying into stationary water bodies encourage the establishment of *Typha orientalis*.

Controlling degradation processes that increase ecosystem vulnerability to weeds is often the most effective way to control weeds in the long term. In terms of this Integrated Catchment Management Plan controlling the amount of and quality of water being discharged from the stormwater system is the crucial element of this strategy.

Options for maintaining water quality presented in previous bushland management plans include street sweeping, the use of Gross Pollutant Traps, and education programs.

Appropriately timing street sweeping and source control can reduce levels of gross pollutants entering drains. However this only effectively removes particles greater than 300µm, which may have a minimal effect at improving stormwater quality since many sediment-bound pollutants and nutrients are bound to finer sediments (Walker and Wong, 1999 in SRT, 2003).

Gross Pollutant Traps (GPTs) are also effective in removing litter, oils, vegetation debris, sand and silt once they have entered the drainage network. These GPTs need to be regularly to avoid the build-up of material that will impede water flow and cause flooding (SRT, 2003) and will have similar limitations as the appropriate timing of street sweeping operations in terms of removing nutrients and fine particles.

Education can play a part in reducing nutrients and pollutants entering the stormwater system from both residential and industrial properties. A survey of randomly selected industries in the Swan-Canning catchment found that 16% of industries used the stormwater system to dispose of wastewater 27% of premises were unaware of the stormwater system within their facilities (SRT, 2000).

Another management technique, often overlooked, is replacing deciduous verge trees with non-deciduous trees. Deciduous trees can deliver bulk nutrients into the drainage system over short periods of time during leaf fall. This is exacerbated by the composition of exotic foliage, which is softer than that of native species and decomposes faster than macroinvertebrates can assimilate the nutrients (SRT, 2003).

The parameters that need to be managed in order to ensure that water quality is satisfactory for maintaining the ecosystem health of receiving environments are shown in Table 7.2.

Table 7.2 Water quality parameters for managing aquatic invertebrates, waterbirds and ecosystem health

Variable	Invertebrates Davies *et al.* (1993)	Waterbirds Storey *et al.* (1993)	Wetland Health WA Govt. (2003)
salinity	√	√	√
pH	√	√	√
colour	√		
dissolved oxygen	√	√	√
nutrients	√		√
chlorophyll a	√	√	√
depth		√	
temperature			√
turbidity/clarity			√
chemical contaminants			√

Whilst the lists of parameters for managing the two faunal groups and general ecosystems in Table 7.2 are similar, the implications of changes in these variables are different for birds and invertebrates and therefore it is important to establish what the wetland is being managed for prior to monitoring commencing (Storey *et al*., 1993).

It is also worth noting that vegetation structure is not a water quality parameter but is a critical factor for managing birds (Storey *et al*., 1993) and an environmental quality indicator (WA Govt, 2003).

Physical Barriers

The problems associated with herbicides in wetland areas means that it is preferable to minimise their use. Physical barriers such as kerbing between riparian vegetation and lawned areas, as are installed around several wetland areas in Sir James Mitchell Park, will reduce the level of grass invasion into areas of native vegetation.

Establish dense stands of native plants and the use of mulch will also help reduce the rate of weed invasion into wetlands.

Manual Control

Manual control refers to the physical removal of the weed by mechanical or human effort. This includes hand weeding, pulling and digging or grubbing out and relates to small infestations of weeds (Dixon and Keighery, 1995). It is often the most expensive form of weed removal but it is generally the most appropriate method in circumstances where there are small infestations in largely natural bush areas. It is particularly valuable for small infestations, where chemical control is inappropriate and resources available.

Manual control needs to be carefully managed in order to avoid gross soil disturbance which can encourage further weed infestation. When undertaking manual weed control, the Bradley method (which works from the areas with least weeds to the area with most weeds) should be used, and revegetation or assisted natural regeneration undertaken in conjunction with weed removal. Hand-pulling of weeds can be as time-efficient as spraying where low numbers exist in a localised, well-vegetated area of bush and in these situations should be given priority over herbicide spraying.

Herbicide Control

The application of herbicides is often the most cost-effective method for weed control and a wide range of herbicides are available for different weed species. It is important that herbicides should always be used strictly in accordance with directions on the label and their application must be undertaken by personnel trained and licensed in the use of herbicide chemicals in public open spaces.

Dixon and Keighery (1995) identified three methods of applying herbicides:

- ❑ Herbicide Wipe, Stem Injection and Cut Stump Application
  - Herbicide Wipe – wipe herbicide onto part of the plant (for example a leaf/leaves) using a weeding wand, wick applicator (rope), waterproof (pesticide resistant) glove or modified hand sprayer;
  - Stem Injection – use a small axle to make cuts at 8 cm intervals at a 45o angle and 4-5 cm long to penetrate the sapwood beneath the bark, or drill at 45 o angle with holes 5 cm apart. If the plant is multi-stemmed, treat all stems at chest height. Use a special injector calibrated to deliver the right amount or use a syringe; and
  - Cut Stump Application – when the plant is actively growing, cut the stump almost to ground level and apply the herbicide immediately using a paint brush.
- ❑ Herbicide Spot Spraying
  - When spot spraying, avoid spraying non-target species unless using selective herbicides such as Fusilade®. Special shields can be purchased or, if necessary, made for spraying close to non-target species.
- ❑ Herbicide Blanket Spraying
  - When blanket spraying, spray over large area using boom spray or similar, when the plant is actively growing (early June to no later than mid-August or when specified).

Stem injection of herbicides or painting herbicides onto freshly cut stumps to eradicate large shrubs and trees will avoid issues associated with herbicide drift. Spray drift is a critical issue when using herbicides in the vicinity of wetlands, as is the choice of herbicides.

The choice of herbicides has not been discussed in detail in the previous bushland management plans in the study area.

In considering which herbicides to use near waterways the Heath Department's 'Circular No.: PSC 88 Use of Herbicides in Water Catchment Areas' was consulted. Whilst the Circular does not dictate which herbicides can be used onsite, as it applies to areas where drinking water is obtained, it can provide some indication as to which herbicides are least detrimental to waterways. The Circular states that 'Other than with the expressed approval of the Executive Director, Public Health, the only herbicides that may be used in water catchment areas are: 2,4-D; amitrole; glyphosate; hexazinone; Picloram; triclopyr (with 2,4 D being the least preferred). This document is presently being revised (Brown and Brooks, 2002).

Glyphosate based products such as Roundup Biactive® and Fusilade® were recommended by the Water and Rivers Commission (2001) for use in the vicinity of wetlands by community groups if used with care and according to instructions.

Glyphosate does not bioaccumulate and has low toxicity to bees, fish and other aquatic organisms (WRC, 2001). Roundup Biactive® is a glyphosate formulation specifically developed for use in the vicinity of wetlands which is 100 times safer for frogs than the original formulation (WRC, 2001). Roundup Biactive® controls many aquatic weeds, as well as an extensive range of grasses, broadleaf weeds and woody weeds. Roundup Biactive® can be used for weed control in aquatic and sensitive environmental areas such as channels, drains, streams and rivers that are in or near all situations including tree crops. (Pest Genie, 2004)

Fusilade® is a herbicide registered for use in bushland that controls most grasses except Winter Grass (*Poa annua*), Silver Grass (*Vulpia bromoides*), Nutsedge (*Cyperus* species) and broadleaf weeds. The Swan River Trust approved the use of Fusilade® after trials to assess its impact on aquatic life (City of South Perth, 1994). Fusilade will not damage sedges and rushes, has low toxicity to bees and rats, is practically non-toxic to ducks and mammals and has low toxicity to fish and aquatic organisms (including aquatic invertebrates) (WRC, 2001).

In addition the WRC (2001) also recommended the following herbicides fro use in the vicinity of wetlands, if applied by professionals:

- Metsulfuron-methyl (Brushoff®, Ally®, Groper® and Escort®) for broadleaf weeds and some grasses;
- Chlorsulforun (Glean®, Siege®, Tackle®) for broadleaf weeds and some grasses; and
- Diquat (Aquacide®/Reglone®) for floating, submerged and emergent aquatic weeds.

Diquat can cause the rapid death of plants that may deoxygenate the water, causing fish deaths, therefore it is not recommended that large areas of weeds are treated at any one time within a wetland (WRC, 2001). Also the effectiveness of Diquat was found to decrease rapidly when applied to species such as Hydrocotyle, as it only killed the portion of the plant contacted and the plants resprouted (WRC, 2001).

Even away from waterways care needs to be taken in applying herbicides. Watt (2002) notes that:

- Wattles (*Acacia species*) are susceptible to sulfometuron methyl (e.g. Oust®); and
- Gum Trees (*Eucalyptus* species) and other Myrtaceous species are susceptible to hexazinone (e.g. Velpar®).

Both glyphosate (Roundup Biactive®) and Amitrole (e.g. TL Plus®) are broad spectrum herbicides that will kill or damage most plants they are applied to, but Amitrole is recommended for weed control amongst eucalypts by Watt (2002). Amitrole is also suitable in, non-crop situations and aquatic areas such as drains and channels, and controls a range of problem weeds not effectively controlled by glyphosate (Pest Genie, 2004).

Species Specific Recommendations Control

The control techniques for weeds for weeds with a high EWSWA rating or have been recorded in three or more reserves are shown in Table 7.3.

Table 7.3 Control Techniques for Selected Weeds

Major Weed	Weed Rating	Timing of Control	Suggested Management and Control
Pampas Grass (*Cortaderia selloana*)	High	All Year	Cut out small plants – do not leave uprooted plants on ground as they can resprout. Remove flower heads – slash clumps and spray regrowth with 1% glyphosate. Treat young plants with 0.5% Fusilade® plus spray oil. May require repeated treatment.
Perennial Veldgrass (*Ehrharta calycina*)	High	Flowering Sep – Oct (2 flushes) & after fires	Cut out – ensure crown removal; spray with Fusilade® 8 mL/L (4L/ha) + wetting agent; Spray regrowth and seedlings 4-6 weeks.
Victorian Tea-tree *(Leptospermum laevigatum)*	High	N/A	Hand pull seedlings; fell mature plants. Resprouting has been recorded in some areas so may need to basal bark spray with triclopyr + picloram.
Guildford Grass *(Romulea rosea)*	High	Just on Flowering (Aug)	Spot spray metsulfuron methyl 0.2g / 15L + Pulse®.
Bulrush (Typha orientalis)	High	Growing season	Repeated cutting and application of Roundup® when actively growing
Arum Lily (*Zantedeschia aethiopica*)	High	Before Seed Set June - Aug	Spot spray metsulfuron methyl or chlorsulfuron 0.4g/15L of water + Pulse®. Higher concentration can be applied a single squirt to leaves.
Kikuyu *(Pennisetum clandestinum)*	Moderate	warmer months	Solarisation over warmer months; spray with 1% glyphosate or Fusilade 10ml / L + wetting agent, 2-3 applications over growing season required.
Giant Reed (*Arundo donax*)	Low	During flowering Summer (Dec – Feb)	Cut down close to ground; paint with glyphosate. Spot spray regrowth 1% glyphosate or Fusilade® 10mL/L + wetting agent.
One-leaf Cape Tulip *(Moraea flaccida)*	High	At or before flowering (Sep-Oct)	Remove small infestations by hand, cut roots with knife or long trowel. Spot spray Glean/Ally in wick application 1g in 1L or Glean 1:10
Watsonia *(Watsonia* sp.)	High	During Flowering (Sep – Nov)	Grub out small populations removing bulbil / seed heads to prevent reinfestation. Spray with glyphosate wick applicator 1:2. Also wipe one side of leaf using sprayer with foam attached at 10 glyph:1 water (October). Spot spray glyph at 1:100. Can also use TCA, Amitrol and 2,2-DPA (caution must be used with the latter as remains in soil for a long time)
Pigface *(Carpobrotus edulis)*	Moderate	N/A	No specific information available. Suggest remove by hand and destroy.
Couch *(Cynodon dactylon)*	Moderate	When actively growing (late spring – autumn)	Fusilage 4L / Ha or similar (e.g. Sertin, Targa) Several applications may be necessary unless spraying immediately after fire. Glyphosate can be used in heavily infested areas

Brown & Brooks (2002), Dixon and Keighery (1995)

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APPENDIX 1: Revegetation List

Genus	Species	Common Name	Bottom of Basin	Lower Slopes	Mid Slopes	Upper Slopes	Height (m)	Growth rate	Salt tolerance	Notes
AQUATICS										
Cotula	coronopifolia	Water Buttons	X				0.25	high	high	Stoniferous, annual to perennial, tolerates still or slow moving water drying to mud
Triglochin	linearis	Water Ribbons	X				0.4	moderate	moderate	Rhizomatous, stationary and moving water
RUSHES/SEDGES										
Baumea	articulata	Jointed Twig Rush	X				2.5			
Baumea	rubiginosa			X			4	slow	moderate	Rhizomatous, swamps and streams
Hypolaena	exsulca			X			0.75	low	low	Rhizomatous, dry or seasonally inundated sites
Schoenoplectus	validus	Lake Club Rush		X			3	moderate	low-mod	Rhizomatous, can be used as replacement for Typha orientalis, prone to desiccation during establishment
Bolboschoenus	caldwellii	Marsh Club Rush	X				1.2	fast	moderate	Rhizomatous,does not obstruct water flows, prone to disturbance by waterbirds, dies back in summer
Eleocharis	acuta	Common Spike Rush	X				0.7	moderate	low-mod	Rhizomatous,dies back during summer, prone to disturbance by waterbirds during establishment, Soft & flexible - does not obstruct water flows
Baumea	juncea	Bare Twig-rush		X	X		1.2		high	Rhizomatous,readily established, prefers waterlogged ground with fairly constant water level, plant slightly below ground level
Baumea	preissii	Broad Twig Rush		X	X		1			Rhizomatous, borders lakes and watercourses
Baumea	vaginalis	Sheath Twig Sedge	X				1.2			Rhizomatous, borders winter-wet depressions and watercourses
Carex	appressa	Tall Sedge	X				2	slow	low	Tufted, sporadically flooded
Typha	domingensis	Bulrush	X	X	X	X	3	moderate	moderate	Rhizomatous, often confused with introduced Typha orientalis, Dies back over summer,
Ficinia	nodosa	Knotted Club Rush		X			1			Rhizomatous, formerly called Isolepis nodosa, suitable for direct seeding, occurs in winter-wet depressions, next to lakes and along streams
Juncus	pallidus	Giant Rush		X			2		moderate	Rhizomatous, primarily grown by seed, particularly suited to areas of constant water level usually remains green all year but has a lot of dead material attached
Lepidosperma	longitudinale	Pithy Sword-sedge		X			2	slow	low-mod	Clumping, readily established
Meeboldina	scariosa			X			1.5			Rhizomatous, Tolerates seasonal inundation, winter-wet depressions and creekbeds
Isolepis	cernua	Nodding Club-rush			X		0.3			Rhizomatous, annual or perrenial
Lepidosperma	squamatum					X	1		NA	Rhizomatous
HERBS & GROUNDCOVERS										
Centella	asiatica	Centella		X	X		0.4			Replacement for Hydrocotyle
Goodenia	filiformis	Threadleaved Goodenia			X		0.25			

Genus	Species	Common Name	Bottom of Basin	Lower Slopes	Mid Slopes	Upper Slopes	Height (m)	Growth rate	Salt tolerance	Notes
Lobelia	alata	Angled Lobelia			X		0.5			
Anigozanthos	manglesii	Mangles Kangaroo Paw				X	1		NA	Rhizomatous
Burchardia	umbellata	Milkmaids				X	0.5		NA	
Conostylis	aculeata	Prickly Conostylis				X	0.25		NA	Rhizomatous
Dianella	revoluta	Flax Lily				X	1		NA	Rhizomatous
Haemodorum	spicatum	Mardja				X	1		NA	
Patersonia	occidentalis	Western Patersonia				X	0.5		NA	
Thysanotus	multiflorus	Many Flowered Fringed Lily				X	0.5		NA	
SHRUBS										
Melaleuca	teretifolia	Banbar	X	X			3			Can survive flooding for several years (but not permanent flooding)
Hypocalymma	angustifolium	White Myrtle		X	X	X	1			
Astartea	fascicularis				X		1.5			
Calothamnus	lateralis				X		1.5			
Euchilopsis	linearis	Swamp Pea			X		1.5			
Hakea	varia	Variable Leaved Hakea			X		3			
Pericalymma	ellipticum	Swamp Tea Tree			X		1			
Kunzea	ericifolia	Spear Wood			X	X	4			Common around Perth, often grows in moist but not waterlogged sites and marks the interface between wetland and dryland vegetation
Labichea	lanceolata	Tall Labichea			X	X	2			Occurs widely in the South-west in rivers and streams, bright yellow flowers, pointed leaves
Oxylobium	lineare	River pea			X	X	1.5			Grows along watercourses but not common on coastal plain (does occur at Bull Creek and previously recorded from Swan River in Melville and Como), does not naturally form thickets
Regelia	ciliata				X	X	2			
Regelia	inops				X	X	2			
Viminaria	juncea	Swishbush			X	X	5			Distribution includes Swan and Canning Rivers and larger lakes on western coastal plain, prefers winter wet sites but tolerates some waterlogging, establishes quickly
Acacia	saligna	Coojong				X	5	fast	NA	Establishes quickly and therefore can be useful for soil stabilisation
Acacia	stenoptera	Narrow Winged Wattle				X	0.5		NA	
Acacia	pulchella	Prickly Moses				X	1.5		NA	
Aotus	procumbens					X	0.25		NA	

Genus	Species	Common Name	Bottom of Basin	Lower Slopes	Mid Slopes	Upper Slopes	Height (m)	Growth rate	Salt tolerance	Notes
Calytrix	flavescens	Summer Starflower				X	1		NA	
Dryandra	nivea	Couch Honeypot				X	0.25		NA	
Gompholobium	tomentosum	Yellow Pea				X	1		NA	
Jacksonia	furcellata	Grey Stinkwood				X	3		NA	
Kennedia	prostrata	Running Postman				X	0.25		NA	
Melaleuca	trichophylla					X	1		NA	
Melaleuca	thymoides					X	2		NA	Winter-wet depressions
Nemcia	reticulata					X	1		NA	
Philotheca	spicatus	Salt and Pepper				X	1.5		NA	
Phyllanthus	calycinus	False Boronia				X	1.5		NA	
Scholtzia	involucrata	Spiked Scholtzia				X	1		NA	
TREES										
Casuarina	obesa	Salt Sheoak	X	X	X		10		high	Occurs in or near saline wetlands especially along the Swan and Canning Rivers, establishes quickly
Eucalyptus	rudis	Flooded Gum	X	X	X	X	25		moderate	Widely distributed in South-west, quickly establishes and grows, medium to large tree
Melaleuca	cuticularis	Saltwater Paperbark	X	X	X	X	7		high	Highly tolerant of salt and waterlogging
Melaleuca	rhaphiophylla	Swamp Paperbark		X			10		moderate	Most used tree by waterbirds in Perth, moderate tolerance of salt, competes with introduced Typha orientalis for habitat
Melaleuca	viminea	Mohan		X	X	X	8		high	Occurs on riverine, swamp and estuarine sites, most abundant at sites less suited to more dominant wetland species on coastal plain
Melaleuca	preissiana	Modong			X		15		moderate	Occurs widely in Perth in winter wet-depressions and further back from rivers and permanent lakes, it is the largest paperbark in the metropolitan area (up to 15m),
Agonis	linearifolia	Swamp Peppermint			X	X	6		low	Inhabits creeks and swamps in Darling Range and eastern coastal plain (but does occur along Bull Creek)
Banksia	ilicifolia	Holly Leaf Banksia				X	10		low	Occurs on sandy soils but has a preference for low-lying sites
Paraserianthes	lophantha	Albizia			X	X	10		low	Occurs predominately along creeks (including Bull Creek) and rivers on coastal plain and requires high levels of moisture, graceful form, short-lived but fast growing and readily sets seed
Banksia	littoralis	Swamp Banksia				X	10		low	Associated with most wetlands on the coastal plain, grows well in parks and gardens that have extra water or high watertable, tolerates fertilizer better than most banksias
Corymbia	calophylla	Marri				X	30		low	Establishes well in modified environments, grows in variety of soils but prefers moderately fertile soils

APPENDIX 2: Recommendations of Previous Plans

Management Plan	Reference	Recommendation	Priority/ Comment (if in source document)	Implemented
Mt Henry Peninsula Foreshore Management Plan (2002)	A 1.1	Move Gentilli Way drain outlet to more appropriate location further south	Medium	
	A 2.8	Investigate and if necessary repair drain immediately to the north of Edgewater Overpass	Low	
	A 3.2	Investigate feasibility of installing a drain to stem stormwater runoff from the freeway.	Low	
	A 3.3	Inspect and if necessary repair drains	Medium	
	A 3.4	Control weeds around drains	Medium	
	A 6.2	Repair and rehabilitate eroded areas around Redmond Avenue drain. Install Biological filters	High	
	G 2.11	Undertake detailed inspections and if necessary repair all drains within the study area	High	
	G 2.12	Undertake weed control measures around all drains within study area	High	
	G 2.13	Renew Redmond Avenue drain and place it at ground level.	High	
	G 2.14	Undertake regular water quality sampling and analysis to ensure that nutrient levels of water entering the wetlands and river is acceptable. Should include peak flows, nutrient levels, pH and dissolved oxygen levels.	Low	
	G 2.15	School and community groups should be encouraged to participate in the 'Rivers of Blue' and 'Yellow Fish Road' programs. Sampling to include all stormwater drain outlets and bores within Aquinas College.	Low	
	G 2.16	Provide educational material to landowners encouraging the proper use of fertilisers and chemicals	Low	
	G 2.17	Use water sensitive design principles and best management practice for proposed future freeway alterations.	High	
Goss Avenue / Koonawarra Primary School Bushlands Management Plan (1997)	5.5.6	Select sedge/rush species for drain planting on the southern bank of the drain from those listed as endemic to banksia sumplands, but also capable of taking up nutrients	Medium	
	5.5.7	Liaise with the Water Corporation to ensure that proposed drain plantings and any propose works are consistent with their objectives	Medium	
Salter Point and Waterford Foreshore Management Plan (2000)	G9	Undertake regular water quality sampling and analysis to ensure that nutrient levels within water entering the wetlands and river is acceptable, including peak flows and seasonal programs		
	G10	Stencil drains so residents are aware that the drains feed directly to the river or wetland systems		
	G11	Provide educational material to landowners encouraging the proper use of fertilizers and chemicals		
	G12	Prepare a feasibility study for the installation of islands and plantings within the Bodkin Lakes, removal of couch between DUPs and water's edge and tree planting		
	G13	Monitor existing plantings in the Bodkin Drain and infill as required		

Management Plan	Reference	Recommendation	Priority/ Comment (if in source document)	Implemented
	G14	Implement streamlining program for the open section of the Elderfield (Manning Road) Main Drain. Plant with species endemic to the area in 1999-2000		
	G15	Develop disaster contingency plan / drainage strategy to manage accidental spillages in accordance with Recommendation 2.4.5 of the Environmental Strategy		
	G16	Liaise with the Water Corporation to ensure sewerage issues are adequately addressed and monitored		
	G17	Provide educational material to residents detailing the chemicals used for mosquito control and the impacts on the environment		
	G18	Provide educational material to residents detailing chemicals that are prohibited for use around wetland environments, and suitable chemicals		
	G19	Provide educational material to mowing contractors, Council staff and landholders detailing that disposal of materials down the stormwater system is illegal, and provide information about the impact of dumping of garden waste and grass trimmings on waterways and the drainage network		
	G20	Investigate the feasibility of installing sediment and gross pollutant traps to improve water quality		
Sir James Mitchell Park Foreshore Management Plan (2001)	Action 39	Trees of endemic species be planted as an entry statement in Coode Street, and to provide shade in car parks and roadside parking areas.		
	Action 40	The Melaleuca rhaphiophylla/Eucalyptus rudis Community and the Melaleuca rhaphiophylla Grove be reinforced and maintained with suitable endemic trees. Any senescent and diseased trees or trees which compromise the safety of the public or health of other trees shall be managed through treatment, or removal and replacement with endemic species.		
	Action 41	A weed management strategy to be developed for the Melaleuca rhaphiophylla groves.		
	Action 45	Conduct an environmental assessment and develop a management plan for the lake system to address the following: water quality; Bird usage around the lakes and the establishment of suitable bird habitat; the potential for modifying or extending the lakes on the foreshore as breeding habitat for Black Swans; Monitoring and management of mosquito and midge breeding		
	Action 46	Council refer to the Sir James Mitchell Park Community Advisory Group to investigate the inclusion of a water feature in parkland development incorporating a lily pond and flowing water linking the existing Melaleuca Grove to the Scented Garden.		
City of South Perth Green Plan (2002)	4	Develop a conservation strategy for the Oblong Tortoise	Status & ecological requirements need to be documented	
	9	Expand native species plantings in Sir James Mitchell Park	Park is of regional significance	

Management Plan	Reference	Recommendation	Priority/ Comment (if in source document)	Implemented
			but has few native species	
	14	Introduce tortoises into water bodies throughout city		
	16	Investigate potential aquatic plants for water bodies throughout city	bird attracting but non-invasive	
	34	Consider removing boundary fencing at the Roebuck Drive drainage sump and the sump be re-battered and landscaped according to water sensitive design principles	Sumps can provide faunal habitat as well as stormwater management	
	35	Consider removing the boundary fencing of the George Street drainage sump and the sump be re-battered and landscaped according to water sensitive design principles	Sumps can provide faunal habitat as well as stormwater management	
	36	The Gwenyfred Road drainage sump be rehabilitated as a native remnant for the purpose of improving the appearance of the area, reducing fire risk and creating a habitat 'island' relatively close to the Kensington bushland	Sumps can provide faunal habitat as well as stormwater management	
	37	The island and lake in Neil McDougall Park be revegetated with local native species.	Minimum 5 five yr timeframe	
	42	Further investigate the opportunities to plant native species in drainage sumps located between Kensington bushland and Hayman Road and Sir James Mitchell Park	Sumps can provide faunal habitat as well as stormwater management	
	46	Encourage the State Government to reserve the conservation category wetland located east of Clontarf College for the purpose of conservation		
	48	More stringent guidelines be adopted for cat ownership in houses adjoining bushland or wetland areas within the City of South Perth, particularly near the Waterford Conservation Area	Will increase potential fauna habitat	
	49	Continue rabbit control program	Focused on the Mt Henry area	
	57	Consideration be given to planting only local native trees in reserves that link to the southern shoreline of the City	Recognises the natural setting, increases fauna habitat & enhances Greenway connectivity	
	61	As a general principle, only local native trees will be planted as street trees along streets adjoining natural bushland or foreshore areas	Expands fauna habitat & increases connectivity	
	66	Consideration be given to enhancing the Melaleuca remnants at Sir James Mitchell Park	Through re-battering and planting to create groves	
	67	The City of South Perth continue it's water quality monitoring program	To further understand sources of excess nutrients	
	68	The City of South Perth continue to monitor blue-green algae blooms in surface water bodies	In conjunction with public education programme	
	69	The City of South Perth consider planting local native submerged aquatic plants in addition to emergent plants that have been planted	To improve water quality and provide a food source for wetland fauna	
	70	The City of South Perth continue to address water quality problems in surface water bodies	Through stormwater treatment and the use of aquatic, wetland and fringing plants	

APPENDIX B

Catchment Areas and Land Use

City of South Perth Catchment Areas and Land Use

For analysis purposes in this study, areas zoned Mixed Use Commercial, Private Institution, Public Assembly, Public Purposes, Technology Park were allocated in to General Land Use$_1$ categories via aerial photograph interpretation on a case by case basis.

Catchment		Road & Road Reserve (ha)				Land Use (ha)									General Land Use$_1$ (%)					
ID	Area (ha)	Freeway	Primary Road	Secondary Road	Minor Arterial	Commercial	Mixed Use Commercial	Parks & Recreation	Private Institution	Public Assembly	Public Purposes	Residential R15/R50	Residential R60/R100	Technology Park	Active	Passive	R10-R20	R25-R100	Commercial	Road & Reserve
SP 1	15.8							15.8							0%	100%	0%	0%	0%	0%
SP 2	2.9	1.6			0.1			1.2							40%	0%	0%	0%	0%	60%
SP 3	1.0				0.1			0.8							87%	0%	0%	0%	0%	13%
SP 4	30.4	30.3	0.0					0.1							0%	0%	0%	0%	0%	100%
SP 5	8.9				2.4		0.2	0.6					5.6		7%	0%	0%	66%	0%	27%
SP 6	0.6				0.3								0.2		0%	0%	0%	40%	0%	60%
SP 7	0.5				0.2								0.3		0%	0%	0%	56%	0%	44%
SP 8	0.4				0.2								0.3		0%	0%	0%	60%	0%	40%
SP 9	0.7				0.3								0.4		0%	0%	0%	60%	0%	40%
SP 10	1.3				0.5								0.8		0%	0%	0%	59%	0%	41%
SP 11	10.6	0.0		0.0	2.7		2.7	0.7					4.6		6%	1%	0%	68%	0%	25%
SP 12	4.4				1.4	0.3	0.4						2.3		0%	0%	0%	61%	7%	32%
SP 13	1.4							1.4							100%	0%	0%	0%	0%	0%
SP 14	2.2	0.8			0.4		1.0								0%	0%	0%	46%	0%	54%
SP 15	8.9				2.2		6.5	0.2							0%	2%	0%	74%	0%	24%
SP 16	6.5				1.8		3.9	0.8							0%	4%	0%	59%	0%	36%
SP 17	2.1			0.8	0.1	0.9							0.4		0%	0%	0%	18%	42%	40%
SP 18	8.2			2.2	1.3	2.6		0.1			0.2		1.8		1%	0%	2%	22%	32%	42%
SP 19	21.0							21.0							100%	0%	0%	0%	0%	0%
SP 20	0.9				0.3	0.1							0.5		0%	0%	0%	61%	9%	30%
SP 21	48.9				0.1			43.4				1.7	3.7		89%	0%	3%	8%	0%	0%
SP 22	2.2				0.4								1.8		0%	0%	0%	82%	0%	18%
SP 23	0.4							0.4							100%	0%	0%	0%	0%	0%
SP 24	25.7			2.2	5.2			0.3	4.4		0.1	10.6	2.8		2%	0%	27%	42%	0%	29%
SP 25	48.6			2.7	6.3	1.6		10.0	4.1	0.1		22.7	1.2		23%	0%	34%	22%	3%	18%
SP 26	49.0		0.1	1.7	11.1	1.6		3.3				26.9	4.5		7%	0%	48%	16%	3%	26%
SP 27	4.5		0.0		1.1	0.4		0.2				2.7			5%	0%	0%	60%	9%	25%
SP 28	42.8			0.0	4.8			38.0							88%	1%	0%	0%	0%	11%
SP 29	0.8				0.3			0.5							62%	0%	0%	0%	0%	38%
SP 30	8.8			0.7	1.4							6.7			0%	0%	0%	76%	0%	24%
SP 31	46.4			4.1	8.9					0.6		31.0	1.8		0%	0%	14%	58%	0%	28%
SP 32	31.3				6.2	1.8		1.2	3.2		1.3	15.8	1.7		10%	0%	40%	24%	6%	20%
SP 33	23.1				6.1	0.1		1.1		0.3	0.6	15.0			7%	0%	47%	19%	0%	26%
SP 34	27.7			1.5	2.8	0.4		4.9	0.8	0.1	2.1	15.2			19%	0%	35%	23%	6%	17%
SP 35	23.0				4.7	0.2						18.2			0%	0%	10%	69%	1%	20%
SP 36	50.1			0.6	11.1	0.8		2.5	1.6	0.3		33.2			8%	0%	59%	8%	2%	23%
SP 37	3.6				0.4	0.4						2.4	0.4		0%	0%	16%	61%	11%	12%
SP 38	7.0		0.5		1.7	0.7						3.8	0.3		0%	0%	38%	21%	10%	31%
SP 39	8.8		1.2		1.5	0.1						5.5	0.6		0%	0%	61%	7%	1%	31%
SP 40	11.4			1.4	1.4	0.2						8.1	0.2		0%	0%	71%	2%	2%	25%
SP 41	10.0				2.8	0.5		0.4		0.2		6.3			4%	0%	61%	3%	5%	28%
SP 42	10.0		0.9	0.4	2.2	1.0						4.7	0.9		0%	0%	42%	15%	10%	34%
SP 43	17.2			0.9	4.0			0.1				12.2			0%	0%	71%	0%	0%	29%
SP 44	6.4		0.8		1.5	0.7						2.9	0.4		0%	0%	39%	13%	11%	36%
SP 45	9.1				2.6			0.7			0.1	5.1	0.7		7%	0%	51%	13%	0%	28%
SP 46	9.7				2.3			3.3				4.1			34%	0%	42%	0%	0%	24%
SP 47	3.8				1.1							2.7			0%	0%	71%	0%	0%	29%
SP 48	11.6			0.8	1.5							7.5		1.8	0%	0%	48%	17%	16%	20%
SP 49	6.8		0.0		2.1	0.1						3.1	1.4		0%	0%	27%	40%	2%	31%
SP 50	2.3				0.4	0.3						1.7			0%	0%	73%	0%	11%	16%
SP 51	22.9				5.7	0.1		0.5			2.7	14.0			8%	0%	66%	0%	0%	25%
SP 52	6.8				1.9							5.0			0%	0%	73%	0%	0%	27%
SP 53	6.8			0.9	1.2	0.1						4.6			0%	0%	68%	0%	1%	31%

Catchment		Road & Road Reserve (ha)				Land Use (ha)									General Land Use[1] (%)					
ID	Area (ha)	Freeway	Primary Road	Secondary Road	Minor Arterial	Commercial	Mixed Use Commercial	Parks & Recreation	Private Institution	Public Assembly	Public Purposes	Residential R15/R50	Residential R60/R100	Technology Park	Active	Passive	R10-R20	R25-R100	Commercial	Road & Reserve
SP 54	5.3			0.5	1.1			0.3				3.3			6%	0%	62%	0%	0%	32%
SP 55	5.8			0.0	0.7			0.1				5.0			1%	0%	36%	51%	0%	12%
SP 56	6.1				1.2	0.1						4.7			0%	0%	78%	0%	2%	20%
SP 57	24.9			0.6	5.5	5.5		2.3				9.7	1.4		9%	0%	0%	45%	22%	24%
SP 58	3.4			0.4	0.8							2.2			0%	0%	0%	66%	0%	34%
SP 59	12.5		0.9		2.6							8.0	1.0		0%	0%	19%	53%	0%	28%
SP 60	19.0		0.6	0.3	3.2	1.0			0.3	0.8		11.8	1.0		0%	0%	17%	57%	5%	22%
SP 61	1.4				0.4	0.1						0.7	0.2		0%	0%	52%	13%	6%	29%
SP 62	16.4		0.9		1.7	0.1						11.8	1.9		0%	0%	57%	26%	0%	16%
SP 63	15.1				3.8	0.3					0.1	10.9			0%	0%	73%	0%	2%	25%
SP 64	18.4				3.9			2.9	4.0		0.4	7.2			16%	0%	39%	22%	2%	21%
SP 65	6.9				1.5							5.4			0%	0%	78%	0%	0%	22%
SP 66	7.5				1.4						2.0	4.1			13%	0%	68%	0%	0%	19%
SP 67	1.6				0.5						0.7	0.3			29%	0%	37%	0%	0%	34%
SP 68	22.9				6.0			1.1				15.8			5%	0%	64%	5%	0%	26%
SP 69	15.8			2.0	0.7	0.1		0.4				2.3		10.3	3%	25%	12%	2%	41%	17%
SP 70	7.8			2.4	1.0							4.3			0%	0%	56%	0%	0%	44%
SP 71	3.0				0.0							3.0			0%	0%	100%	0%	0%	0%
SP 72	9.5				1.9							7.6			0%	0%	80%	0%	0%	20%
SP 73	3.1			1.4	0.6									1.0	0%	0%	0%	0%	34%	66%
SP 74	10.7													10.7	0%	0%	0%	0%	100%	0%
SP 75	23.3			4.4	1.1									17.7	0%	11%	0%	0%	65%	24%
SP 76	8.9			0.0	2.9	0.0						6.0			0%	0%	0%	67%	0%	33%
SP 77	8.3				2.4							5.9			0%	0%	0%	71%	0%	29%
SP 78	8.7				2.3							6.4			0%	0%	0%	74%	0%	26%
SP 79	10.8				3.2							7.6			0%	0%	0%	70%	0%	30%
SP 80	2.4				0.2			2.0				0.2			80%	1%	0%	8%	0%	10%
SP 81	9.7		0.0		2.5					0.1		7.1			0%	0%	1%	74%	0%	26%
SP 82	3.4				1.0			0.0				2.4			1%	0%	0%	69%	0%	29%
SP 83	11.3		2.6		1.5	0.6		0.0				5.0	1.5		0%	0%	8%	50%	5%	37%
SP 84	17.4		0.5		4.1						1.2	10.8	0.9		3%	0%	0%	71%	0%	26%
SP 85	7.9		1.0		1.5	0.4					1.0	3.4	0.6		6%	0%	1%	56%	5%	31%
SP 86	69.2				16.8	0.4		10.9		0.3	0.1	40.8			16%	0%	47%	12%	1%	24%
SP 87	5.9				1.8			0.2				4.0			3%	0%	44%	23%	0%	30%
SP 88	2.8				0.8			0.1				1.9			2%	0%	30%	38%	0%	29%
SP 89	2.5				0.5							2.0			0%	0%	0%	78%	0%	22%
SP 90	5.5				2.2							3.4			0%	0%	0%	61%	0%	39%
SP 91	4.0				0.7	0.3						3.0			0%	0%	45%	30%	8%	17%
SP 92	2.0				0.6							1.4			0%	0%	71%	0%	0%	29%
SP 93	6.9				1.3			0.3			0.1	5.1			5%	0%	76%	0%	0%	19%
SP 94	26.4				2.3				2.0		13.8	8.4			21%	6%	63%	1%	0%	9%
SP 95	7.6				0.0				7.6			0.0			38%	32%	0%	29%	0%	0%
SP 96	4.2				1.9				2.3						6%	20%	0%	29%	0%	45%
SP 97	100.1			1.5	1.0			90.8			4.1	2.7			91%	0%	5%	2%	0%	3%
SP 98	6.1							6.1							100%	0%	0%	0%	0%	0%
SP 99	1.9							1.9							100%	0%	0%	0%	0%	0%
SP 100	2.6							2.6							100%	0%	0%	0%	0%	0%
SP 101	11.7							11.7							0%	100%	0%	0%	0%	0%
SP 102	19.0	19.0						0.0							0%	0%	0%	0%	0%	100%
SP 103	5.3				1.5							3.8			0%	0%	40%	31%	0%	29%
SP 104	21.6	0.2		0.6	5.2	1.3		0.1				14.3			0%	0%	37%	29%	6%	28%
SP 105	4.3				1.4							2.8			0%	0%	29%	38%	0%	33%
SP 106	47.3			1.7	7.9	1.9		3.7	2.3	0.7	8.3	20.9			15%	4%	36%	18%	7%	20%
SP 107	0.9				0.7							0.2			0%	0%	20%	0%	0%	80%
SP 108	7.8				1.9					0.3		5.6			0%	0%	76%	0%	0%	24%
SP 109	2.9				0.5							2.4			0%	0%	81%	0%	0%	19%
SP 110	28.0			2.5	5.4			5.2			0.7	14.2			6%	12%	53%	0%	0%	28%
SP 111	2.5				1.2			0.2				1.1			8%	0%	44%	0%	0%	48%
SP 112	3.5											3.5			0%	0%	100%	0%	0%	0%
SP 113	4.0										4.0				36%	39%	24%	0%	0%	0%
SP 114	8.8							8.8							98%	2%	0%	0%	0%	0%
SP 115	72.4				16.4	1.6		16.3	0.6		0.0	37.5			23%	1%	41%	10%	2%	23%

Catchment		Road & Road Reserve (ha)				Land Use (ha)									General Land Use$_1$ (%)					
ID	Area (ha)	Freeway	Primary Road	Secondary Road	Minor Arterial	Commercial	Mixed Use Commercial	Parks & Recreation	Private Institution	Public Assembly	Public Purposes	Residential R15/R50	Residential R60/R100	Technology Park	Active	Passive	R10-R20	R25-R100	Commercial	Road & Reserve
SP 116	5.7				1.6			0.5				3.6			10%	0%	63%	0%	0%	27%
SP 117	5.1				1.5			0.3	0.0			3.3			3%	2%	65%	0%	0%	30%
SP 118	7.3				2.2			0.2				5.0			0%	3%	68%	0%	0%	29%
SP 119	4.5				1.4			0.3	0.9		0.2	1.7			7%	0%	63%	0%	0%	30%
SP 120	3.5							0.7				2.8			0%	19%	81%	0%	0%	0%
SP 121	3.2								3.2						0%	0%	0%	100%	0%	0%
SP 122	25.9				6.1			0.4		0.1		19.3			0%	2%	75%	0%	0%	24%
SP 123	18.7								18.7						41%	32%	27%	0%	0%	0%
SP 124	57.0				2.2			15.1	32.5			7.2			32%	38%	27%	0%	0%	4%
SP 125	11.8				2.9			0.5				8.4			4%	0%	71%	0%	0%	25%
SP 126	44.3			0.6	12.4	0.7		1.3				29.4			3%	0%	66%	0%	1%	29%
SP 127	11.8				2.5							9.3			0%	0%	78%	0%	0%	22%
SP 128	10.7				2.7	0.1						7.9			0%	0%	74%	0%	1%	25%
SP 129	4.1				1.3							2.8			0%	0%	68%	0%	0%	32%
SP 130	10.6				3.3							7.3			0%	0%	69%	0%	0%	31%
SP 131	8.2				2.7							5.5			0%	0%	67%	0%	0%	33%
SP 132	5.6				1.6							3.9			0%	0%	71%	0%	0%	29%
SP 133	5.5				1.0							4.5			0%	0%	82%	0%	0%	18%
SP 134	14.2								14.2						100%	0%	0%	0%	0%	0%
SP 135	6.0				1.8			0.5				3.6			5%	4%	60%	0%	0%	31%
SP 136	41.0			2.3	9.5			6.4				22.8			15%	1%	56%	0%	0%	29%
SP 137	39.7			0.3	1.5			18.1	9.8			10.0			20%	41%	35%	0%	0%	5%
SP 138	14.1				3.4			0.1				10.6			1%	0%	75%	0%	0%	24%
SP 139	7.4				1.6			0.9				4.9			12%	0%	67%	0%	0%	21%
SP 140	21.3			1.4	1.5			1.3	1.0			15.9			4%	4%	78%	0%	0%	14%
SP 141	2.9				0.1			2.8							53%	42%	0%	0%	0%	5%
SP 142	2.2							2.2							0%	100%	0%	0%	0%	0%
VP 1	22.9		1.2		5.0	0.8		0.2				9.3	6.4		1%	0%	41%	28%	4%	27%
VP 2	3.0			3.0											0%	0%	0%	0%	0%	100%
VP 3	0.8			0.8											0%	0%	0%	0%	0%	100%
VP 4	8.5			2.3	0.3			0.8				5.1			9%	0%	10%	50%	0%	31%
VP 5	7.7			2.4	0.1	2.4		0.5		0.3		2.0			4%	2%	6%	24%	31%	32%

APPENDIX C

Nutrient Input Decision Support System Modelling Results

NiDSS

Nutrient Input Decision Support System

JDA Consultant Hydrologists

Version 1.1 - November 2001

Report Date : 18-Jun-04

South Perth Integrated Catchment Management Plan

Total Nutrient Input - No WSUD (kg/yr)	4,368
Reduction due to Source Control (kg/yr)	73
Percentage Overall Reduction	1.7%
Pecentage Development Reduction	1.7%
Cost of Selected Program ($/kg/yr)	$4.1

(●) Total Nitrogen
( ) Total Phosphorus

Local Authority	City of South Perth
Catchment Name	SP21
Catchment Area	**48.88** ha

Land Use	Lots (<=R20)	3.2%	1.58	ha
	Lots (>R20)	7.8%	3.83	ha
	POS (active)	88.7%	43.35	ha
	POS (passive)	0.0%	0.00	ha
	Road Res	0.2%	0.12	ha

Key Assumptions
Residential Major Source of Nutrient Input
<=R20 adopts R15 data, >R20 adopts R35 data

Sample Only

Nutrient Input Without WSUD

Lots <R20	Garden	64.90	kg/net ha/yr	2.10	kg/gross ha/yr	102	kg/yr	2.3%
	Lawn	92.40		2.98		146		3.3%
	Pet Waste	15.72		0.51		25		0.6%
	Car Wash	0.04		0.00		0		0.0%
	Sub Total	173.05		5.59		273		6.3%
Lots >R20	Garden	17.70	kg/net ha/yr	1.39	kg/gross ha/yr	68	kg/yr	1.6%
	Lawn	23.10		1.81		88		2.0%
	Pet Waste	0.00		0.00		0		0.0%
	Car Wash	0.04		0.00		0		0.0%
	Sub Total	40.84		3.20		156		3.6%
POS	Garden/Lawn	90.00	kg/ha POS/yr	79.83	kg/gross ha/yr	3,902	kg/yr	89.3%
	Pet Waste <R20	0.10		0.09		4		0.1%
	Pet Waste >R20	0.38		0.34		16		0.4%
	Sub Total	90.48		80.25		3,923		89.8%
Road	Road Reserves	132.00	kg/ha RR/yr	0.32	kg/gross ha/yr	16	kg/yr	0.4%
Reserve	Sub Total	132.00		0.32		16		0.4%
		Total		**89.36**	kg/gross ha/yr	**4,368**	kg/yr	**100.0%**

Development Nutrient Removal via Source Control

☐ Native Gardens (Lots - Garden) ☐ Native Gardens (Lots - Lawn) ☐ Native Gardens (POS) ☑ Street Sweeping
☑ Community Education : Fertiliser ☑ Community Education : Pet Waste ☑ Community Education : Car Wash

Education Effectiveness 10%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	20%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	20%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	20%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Fertiliser	100%	0.66	32	0.7%	$0	$79	$2.4
Community Education : Pet Waste	100%	0.09	5	0.1%	$0	$91	$20.0
Community Education : Car Wash	100%	0.00	0	0.0%	$0	$79	$4,047.8
Street Sweeping : Residenital Areas	100%	0.74	36	0.8%	$0	$49	$1.4
Totals		**1.50**	**73**	**1.7%**	**$0**	**$298**	**$4.1**

Development Nutrient Removal via In-Transit Control

☐ Gross Pollutant Trap ☐ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	0%	0.00	0	0.0%	$0	$0	$0.0
Water Pollution Control Ponds	0%	0.00	0	0.0%	$0	$0	$0.0
Total		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input Development without WSUD	89.36	4,368	100.0%			
Removal via Source Control	1.50	73	1.7%	$0	$298	$4.1
Removal via In-Transit Control	0.00	0	0.0%	$0	$0	$0.0
Total Removal	1.50	73	1.7%	$0	$298	$4.1
Net Nutrient Input	**87.86**	**4,295**	**98.3%**			

NiDSS

Nutrient Input Decision Support System

JDA Consultant Hydrologists

Version 1.1 - November 2001

Report Date : 18-Jun-04

South Perth Integrated Catchment Management Plan

Total Nutrient Input - No WSUD (kg/yr)	4,368
Reduction due to Source Control (kg/yr)	73
Percentage Overall Reduction	1.7%
Pecentage Development Reduction	1.7%
Cost of Selected Program ($/kg/yr)	$4.1

(●) Total Nitrogen
( ) Total Phosphorus

Local Authority City of South Perth
Catchment Name SP21
Catchment Area 48.88 ha

Land Use				
	Lots (<=R20)	3.2%	1.58	ha
	Lots (>R20)	7.8%	3.83	ha
	POS (active)	88.7%	43.35	ha
	POS (passive)	0.0%	0.00	ha
	Road Res	0.2%	0.12	ha

Key Assumptions
Residential Major Source of Nutrient Input
<=R20 adopts R15 data, >R20 adopts R35 data

Sample Only

Nutrient Input Without WSUD

Lots <R20	Garden	64.90	kg/net ha/yr	2.10	kg/gross ha/yr	102	kg/yr	2.3%
	Lawn	92.40		2.98		146		3.3%
	Pet Waste	15.72		0.51		25		0.6%
	Car Wash	0.04		0.00		0		0.0%
	Sub Total	173.05		5.59		273		6.3%
Lots >R20	Garden	17.70	kg/net ha/yr	1.39	kg/gross ha/yr	68	kg/yr	1.6%
	Lawn	23.10		1.81		88		2.0%
	Pet Waste	0.00		0.00		0		0.0%
	Car Wash	0.04		0.00		0		0.0%
	Sub Total	40.84		3.20		156		3.6%
POS	Garden/Lawn	90.00	kg/ha POS/yr	79.83	kg/gross ha/yr	3,902	kg/yr	89.3%
	Pet Waste <R20	0.10		0.09		4		0.1%
	Pet Waste >R20	0.38		0.34		16		0.4%
	Sub Total	90.48		80.25		3,923		89.8%
Road Reserve	Road Reserves	132.00	kg/ha RR/yr	0.32	kg/gross ha/yr	16	kg/yr	0.4%
	Sub Total	132.00		0.32		16		0.4%
			Total	**89.36**	kg/gross ha/yr	**4,368**	kg/yr	**100.0%**

Development Nutrient Removal via Source Control

☐ Native Gardens (Lots - Garden) ☐ Native Gardens (Lots - Lawn) ☐ Native Gardens (POS) ☑ Street Sweeping
☑ Community Education : Fertiliser ☑ Community Education : Pet Waste ☑ Community Education : Car Wash

Education Effectiveness 10%

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Native Gardens (Lots - Garden)	20%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	20%	0.00	0	0.0%	$0	$0	$0.0
Native Gardens (POS)	20%	0.00	0	0.0%	$0	$0	$0.0
Community Education : Fertiliser	100%	0.66	32	0.7%	$0	$79	$2.4
Community Education : Pet Waste	100%	0.09	5	0.1%	$0	$91	$20.0
Community Education : Car Wash	100%	0.00	0	0.0%	$0	$79	$4,047.8
Street Sweeping : Residenital Areas	100%	0.74	36	0.8%	$0	$49	$1.4
Totals		**1.50**	**73**	**1.7%**	**$0**	**$298**	**$4.1**

Development Nutrient Removal via In-Transit Control

☐ Gross Pollutant Trap ☐ Water Pollution Control Pond

	% Area of Influence	Removal kg/gross ha/yr	Removal kg/yr	Removal %	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Gross Pollutant Traps	0%	0.00	0	0.0%	$0	$0	$0.0
Water Pollution Control Ponds	0%	0.00	0	0.0%	$0	$0	$0.0
Total		**0.00**	**0**	**0.0%**	**$0**	**$0**	**$0.0**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input Development without WSUD	89.36	4,368	100.0%			
Removal via Source Control	1.50	73	1.7%	$0	$298	$4.1
Removal via In-Transit Control	0.00	0	0.0%	$0	$0	$0.0
Total Removal	1.50	73	1.7%	$0	$298	$4.1
Net Nutrient Input	**87.86**	**4,295**	**98.3%**			

NiDSS Core Data & Cost Calculations

Nutrient Input Decision Support System
Version 1.1 November 2001

Analysis Type (1,2)	2	TN	1		Total Phosphorus
			2		Total Nitrogen

Av Density Assumed =<R20	**15**	lots/ha
Av Density Assumed >R20	**35**	lots/ha
Discount Rate	6%	

Sample Only

Community Education Information

"Who Cares About the Environment ?" (NSW EPA, 2000) Survey
17% stated environment one of two most important issues for govt to address
Of these 27% stated water as most important environmental issue
17% stated education most important issue to protect environment
Impact assumed to reduce fertiliser applications to minimum rates

Fertiliser Application Information/Assumptions

Lots assumed fertilised by property owner
Minor Road Reserves fertilised by property owner (verge assumed 40% road reserve)
Major Road Reserves fertilised by local authority (verge assumed 40% road reserve)
Active POS fertilised by local authority
Passive POS not fertilised
Rural Land Use and Poultry Farms have no reductions due to WSUD applied

Pet Waste

Data Source

Pets per lot and disposal via JDA Survey (2001)
TP & TN application via Gerritse at al (1991)
Cost Estimate via JDA. Distribution cost and frequency is for brochure, bag cost is for POS's

Application Rates

	TN (kg/yr)	TP (kg/yr)	TN or TP specified	Survey Results Pets Per Lot R15	R35
Cats	0.90	0.20	0.90	0.24	0.16
Sml Dogs	2.75	0.70	2.75	0.12	0.16
Med Dogs	5.50	1.40	5.50	0.16	0.08
Lge Dogs	8.25	2.10	8.25	0.19	0.00

Waste Disposal

	R15	R35
Lot	35%	0%
POS	6%	12%
Bins	59%	88%

Cost Data

Distribution	$1.00	per house
Frequency	2	years
Bag Costs	$2.50	per 100 bags

Cost Calculation

	<=R20	>R20	
Area to Apply	2	4	ha
Number of Lots	24	134	
Number of Dogs	11	32	
Disposing in POS	1	4	
POS bags per year	73	422	
Cost of bags per year	$12		
Cost of mailout per year	$79		
Total PV Cost	$1,520		
Removal	4.6	kg/year	
Cost per kg	$20		

Car Wash

Data Source

Frequency based on JDA Survey (2001)
TN/TP based on Polyglaze Autowash data via CRC for Freshwater Ecology (Canberra)
Cost Estimate via JDA. Distribution cost and frequency is for brochure

Application Rates & Washing Frequency

Car wash detergent TN kg/wash	TP kg/wash	TN or TP specified	Washing Frequency (one car every x weeks) R15	R35
0.00009	0.00033	0.00009	2	4.5

Cost Data

Distribution	$1.00	per house
Frequency	2	years

Cost Calculation

	<=R20	>R20
Number of Lots	24	134
Cost of mailout	$79	per year
Total PV Cost	$1,314	
Removal	0.0	kg/year
Cost per kg	$4,048	

Lot Fertiliser

Data Source

Mean Fertiliser Applications via JDA survey (2001)
% garden and lawns estimated via Aerial photography JDA(2001) for various suburbs with similar zonings
Minimum Fertiliser Applications via product recommended application data

Application Rates

	Fertiliser mean application kg TN/sqm/yr	kg TP/sqm/yr	TN or TP specified
Garden	**0.059**	**0.027**	0.05900
Lawn	**0.033**	**0.005**	0.03300

	Fertiliser min application kg TN/sqm/yr	kg TP/sqm/yr	TN or TP specified
Garden	0.010	0.003	0.01000
Lawn	0.009	0.001	0.00900

	Education Campaign Fertiliser Reduction kg TN/sqm/yr	kg TP/sqm/yr	TN or TP specified	% redn
Garden	0.049	0.024	0.04900	83%
Lawn	0.024	0.004	0.02400	73%

Garden and Lawn Areas

	R15	R35
% garden	0.11	0.03
% lawn	0.28	0.07

Cost Data

Distribution	$1.00	per house
Frequency	2	years

Cost Calculation

	<=R20	>R20
Number of Lots	24	134
Cost of mailout	$79	per year
Total PV Cost	$1,314	
Removal	32.3	kg/year
Cost per kg	$2	

POS Fertiliser

Data Source

Application rates based on City of Armadale application to active POS areas in year 1996-2000
are 73.4 kg TN/ha POS/yr and 2.6 kg TP/ha POS/yr . NOT USED as seem low - Manufacturers Rec Rates Adopted

Application Rates

Fertiliser mean application	TN or TP

NiDSS Core Data & Cost Calculations

Nutrient Input Decision Support System
Version 1.1 November 2001

	kg TN/ha POS/yr	kg TP/ha POS/yr	specified
POS	90	10	90.00

Street Sweeping

Data Source

Street Sweeping Revisited - Nutrients and Metals in Particle Size Fractions of Road Sediment
from two major roads in Perth (Davies & Pierce 1999), Water 99 Joint Congress Brisbane
Cost based on Davies & Pierce (1998), $55/km

Estimated Removal Rate
(assumes no WSUD upstream)

	Potential Reduction (kg/gross ha/yr)		TN or TP	reduction due to upstream
	TN	TP	specified	WSUD
Sweeping	0.75	0.35	0.75	1%

Cost Data

Cost	$55.00	$/km
Frequency	6	times per year

Cost Calculation

Cost	$1	$/gross ha/yr
Area to Apply	48.8805105	ha
Total PV Cost	$823	
Removal	36.4	kg/year
Cost per kg	$1	

Note : Street sweeping applied to developed areas only - not existing rural land use areas not to be developed

Costs apply to residential areas only

In-Transit Controls - Stormwater Nutrient Load

Data Source

Nutrients in Perth Urban Surface Drainage Catchments Characterised by Applicable Attributes, Tan (1991)

Data Used to Calculate Nutrients in Stormwater Available for Removal by In-Transit Controls
Removal quantities are for no WSUD and are reduced in calcs based on upstream measures used

Estimated Stormwater Nutrient Load
(assumes no WSUD upstream)

			TN or TP specified
Typical Phosphorus Stormwater Load (Perth Urban Areas)	0.40	kg/gross ha/yr	
Typical Nitrogen Stormwater Load (Perth Urban Areas)	2.53	kg/gross ha/yr	2.53

Gross Pollutant Trap

Data Source

Approximate average retention value via JDA(2001) - GeoTrap Laboratory Test Report
Based on GeoTrap, Humesceptor, Downstream Defender, CDS
Cost of GPT's via CRC report 98/3 (Allison, Chiew and McMahon) April 1998

Estimated Removal Rate

	Percentage Removal		TN or TP
	TN	TP	specified
GPT	35%	50%	35%

Cost Data

Capital Cost	$1,880	per ha
Maintenance	$72	per ha/year

Cost Calculation

Area to Apply	0	ha
Total PV Cost	$0	
Removal	0.0	kg/year
Cost per kg	$0	

Note : GPT's applied to developed areas only - not existing rural land use areas not to be developed

Water Pollution Control Pond

Data Source

TP removal efficiency and cost via Henley Brook Drive WPCP Conceptual Design (JDA,1997)
TN efficiency via Managing Urban Stormwater Treatment Techniques (NSW EPA 1997)

Estimated Removal Rate

	Percentage Removal		TN or TP
	TN	TP	specified
WPCP	35%	50%	35%

Cost Data

Capital Cost	$1,800,000	
Maintenance	$25,000	per year
Removal	34	kg TP/year

Cost Calculation

Cost per kg	$884	per kg
Removal	0.0	kg/year
Capital Cost	$0	
Operating	$0	
Total PV Cost	$0	

Note : WPCP's applied to developed areas only - not existing rural land use areas not to be developed

NiDSS Nutrient Removal Calculator

Nutrient Input Decision Support System
Version 1.1 November 2001

JDA

Analysis Type Total Nitrogen

Sample Only

Catchment Summary of Nutrient Removal due to Source Controls

Without WSUD 89.36 kg/gross ha/yr via developed area
4368 kg/yr

Component	Checkbox Result	% Area to Apply Removal to	Level before Removal	Potential Removal	Adopted Removal (kg/gross ha/yr)
Native Gardens (Lots-Garden)	FALSE	20%	89.36	3.48	0.00
Native Gardens (Lots-Lawn)	FALSE	20%	89.36	4.79	0.00
Native Gardens (POS)	FALSE	20%	89.36	79.83	0.00
Education Campaign - Fertiliser	TRUE	100%	89.36	0.66	0.66
Education Campaign - Pet Waste	TRUE	100%	88.70	0.09	0.09
Education Campaign - Car Wash	TRUE	100%	88.60	0.00	0.00
Street Sweeping	TRUE	100%	88.60	0.74	0.74
Gross Pollutant Traps	FALSE	0%	87.86	0.87	0.00
Water Pollution Control Pond	FALSE	0%	87.86	0.87	0.00

Education Campaign Fertiliser Reduction

	Fertiliser Applied No WSUD kg/gross ha/yr	Removed due to Native Gardens kg/gross ha/yr	Available for further reduction	% applied reduction to min level	education campaign effectiveness	reduction kg/gross ha/yr
Garden	3.48	0.00	3.48	83%	10%	0.29
Lawn	4.79	0.00	4.79	73%	10%	0.35
Road Reserve Minor	0.32	0.00	0.32	73%	10%	0.02
					Total	0.66

Nutrient Removal via In-Transit Controls

Stormwater Load Available for Removal (ie no WSUD) 2.530 kg/gross ha/yr

	reduction due to WSUD upstream	adjusted rate to use
Gross Pollutant Traps	1.68%	2.488
Water Pollution Control Pond	1.68%	2.488

City of South Perth Catchment Landuse and Nutrient Input

Sub Catchment	Area (ha)	Parks & Recreation			Land Use Density			Nutrient Input (kg/gross ha/yr)	
		Active	Passive	**Total**	R10 - R20	R20 - R100	**Total**	Total Nitrogen	Total Phosphorus
SP 1	15.8	0.0%	100.0%	**100.0%**	0.0%	0.0%	**0.0%**	0.00	0.00
SP 2	2.9	40.3%	0.0%	**40.3%**	0.0%	0.0%	**0.0%**	115.06	15.97
SP 3	1.0	87.4%	0.0%	**87.4%**	0.0%	0.0%	**0.0%**	95.27	11.26
SP 4	30.4	0.0%	0.3%	**0.3%**	0.0%	0.0%	**0.0%**	131.66	19.95
SP 5	8.9	6.9%	0.1%	**7.0%**	0.0%	65.7%	**65.7%**	71.84	14.56
SP 6	0.6	0.0%	0.0%	**0.0%**	0.0%	40.1%	**40.1%**	95.42	16.68
SP 7	0.5	0.0%	0.0%	**0.0%**	0.0%	55.5%	**55.5%**	81.37	15.41
SP 8	0.4	0.0%	0.0%	**0.0%**	0.0%	60.0%	**60.0%**	77.26	15.04
SP 9	0.7	0.0%	0.0%	**0.0%**	0.0%	59.5%	**59.5%**	77.73	15.08
SP 10	1.3	0.0%	0.0%	**0.0%**	0.0%	59.0%	**59.0%**	78.18	15.12
SP 11	10.6	5.7%	1.2%	**6.9%**	0.0%	67.8%	**67.8%**	69.10	14.31
SP 12	4.4	0.0%	0.0%	**0.0%**	0.0%	60.9%	**60.9%**	67.62	13.62
SP 13	1.4	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 14	2.2	0.0%	0.0%	**0.0%**	0.0%	45.7%	**45.7%**	90.35	16.22
SP 15	8.9	0.0%	1.8%	**1.8%**	0.0%	73.7%	**73.7%**	62.34	13.54
SP 16	6.5	0.0%	4.5%	**4.5%**	0.0%	59.4%	**59.4%**	71.93	14.19
SP 17	2.1	0.0%	0.0%	**0.0%**	0.0%	18.1%	**18.1%**	60.10	10.11
SP 18	8.2	1.3%	0.0%	**1.3%**	2.3%	22.5%	**24.8%**	70.84	12.53
SP 19	21.0	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 20	0.9	0.0%	0.0%	**0.0%**	0.0%	60.7%	**60.7%**	64.20	13.09
SP 21	48.9	88.7%	0.0%	**88.7%**	3.2%	7.8%	**11.1%**	89.36	11.49
SP 22	2.2	0.0%	0.0%	**0.0%**	0.0%	81.7%	**81.7%**	57.56	13.25
SP 23	0.4	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 24	25.7	1.9%	0.0%	**1.9%**	26.9%	42.2%	**69.1%**	106.30	24.43
SP 25	48.6	22.7%	0.0%	**22.7%**	33.8%	21.9%	**55.7%**	113.95	25.12
SP 26	49.0	6.7%	0.0%	**6.7%**	48.1%	15.9%	**64.1%**	132.23	31.26
SP 27	4.5	5.4%	0.0%	**5.4%**	0.0%	60.4%	**60.4%**	65.65	13.36
SP 28	42.8	87.9%	0.9%	**88.8%**	0.0%	0.0%	**0.0%**	93.91	11.03
SP 29	0.8	61.8%	0.0%	**61.8%**	0.0%	0.0%	**0.0%**	106.05	13.82
SP 30	8.8	0.0%	0.0%	**0.0%**	0.0%	76.5%	**76.5%**	62.26	13.68
SP 31	46.4	0.0%	0.0%	**0.0%**	13.5%	58.4%	**72.0%**	84.31	18.94
SP 32	31.3	10.2%	0.0%	**10.2%**	40.0%	24.0%	**64.0%**	116.64	27.47
SP 33	23.1	6.9%	0.0%	**6.9%**	47.3%	19.3%	**66.7%**	132.59	31.33
SP 34	27.7	18.6%	0.0%	**18.6%**	34.5%	23.3%	**57.8%**	110.58	25.01
SP 35	23.0	0.0%	0.0%	**0.0%**	9.7%	69.1%	**78.8%**	71.82	16.80
SP 36	50.1	8.0%	0.0%	**8.0%**	59.3%	7.6%	**67.0%**	145.81	35.22
SP 37	3.6	0.0%	0.0%	**0.0%**	15.8%	61.4%	**77.2%**	67.64	17.06
SP 38	7.0	0.0%	0.0%	**0.0%**	37.5%	21.3%	**58.8%**	114.65	26.65
SP 39	8.8	0.0%	0.0%	**0.0%**	61.0%	7.4%	**68.4%**	149.26	36.19
SP 40	11.4	0.0%	0.0%	**0.0%**	71.5%	2.1%	**73.6%**	157.33	39.37
SP 41	10.0	3.6%	0.0%	**3.6%**	61.1%	3.2%	**64.3%**	148.33	35.88
SP 42	10.0	0.0%	0.0%	**0.0%**	41.7%	14.5%	**56.2%**	122.86	28.42
SP 43	17.2	0.4%	0.0%	**0.4%**	70.8%	0.0%	**70.8%**	162.82	40.12
SP 44	6.4	0.0%	0.0%	**0.0%**	39.0%	13.4%	**52.4%**	121.03	27.50
SP 45	9.1	7.3%	0.0%	**7.3%**	51.5%	12.8%	**64.3%**	140.36	33.01
SP 46	9.7	34.0%	0.0%	**34.0%**	42.3%	0.0%	**42.3%**	136.22	28.64
SP 47	3.8	0.0%	0.0%	**0.0%**	71.3%	0.0%	**71.3%**	161.28	39.83
SP 48	11.6	0.0%	0.0%	**0.0%**	47.9%	16.7%	**64.6%**	116.00	28.83
SP 49	6.8	0.0%	0.0%	**0.0%**	26.7%	40.2%	**66.8%**	103.77	23.70
SP 50	2.3	0.0%	0.0%	**0.0%**	72.7%	0.0%	**72.7%**	147.39	38.02
SP 51	22.9	8.5%	0.0%	**8.5%**	66.5%	0.0%	**66.5%**	157.10	38.02
SP 52	6.8	0.0%	0.0%	**0.0%**	72.8%	0.0%	**72.8%**	161.90	40.24
SP 53	6.8	0.0%	0.0%	**0.0%**	68.0%	0.0%	**68.0%**	158.14	38.63
SP 54	5.3	6.0%	0.0%	**6.0%**	62.1%	0.0%	**62.1%**	156.65	37.09
SP 55	5.8	1.1%	0.0%	**1.1%**	35.8%	51.2%	**87.0%**	102.70	26.40
SP 56	6.1	0.0%	0.0%	**0.0%**	78.3%	0.0%	**78.3%**	161.28	41.32
SP 57	24.9	9.1%	0.0%	**9.1%**	0.0%	44.5%	**44.5%**	60.51	11.50

Sub Catchment	Area (ha)	Parks & Recreation			Land Use Density			Nutrient Input (kg/gross ha/yr)	
		Active	Passive	**Total**	R10 - R20	R20 - R100	**Total**	Total Nitrogen	Total Phosphorus
SP 58	3.4	0.0%	0.0%	**0.0%**	0.0%	66.3%	**66.3%**	71.54	14.52
SP 59	12.5	0.0%	0.0%	**0.0%**	19.4%	52.6%	**72.1%**	91.98	21.05
SP 60	19.0	0.0%	0.0%	**0.0%**	16.7%	56.5%	**73.2%**	80.70	18.97
SP 61	1.4	0.0%	0.0%	**0.0%**	52.4%	12.5%	**64.9%**	133.79	32.27
SP 62	16.4	0.0%	0.0%	**0.0%**	57.1%	26.3%	**83.4%**	130.98	33.63
SP 63	15.1	0.0%	0.0%	**0.0%**	72.6%	0.0%	**72.6%**	159.20	39.79
SP 64	18.4	15.8%	0.0%	**15.8%**	38.9%	21.8%	**60.7%**	120.51	27.49
SP 65	6.9	0.0%	0.0%	**0.0%**	77.7%	0.0%	**77.7%**	163.88	41.58
SP 66	7.5	12.6%	0.0%	**12.6%**	68.4%	0.0%	**68.4%**	156.62	38.22
SP 67	1.6	29.4%	0.0%	**29.4%**	36.6%	0.0%	**36.6%**	135.69	27.49
SP 68	22.9	5.0%	0.0%	**5.0%**	64.0%	4.7%	**68.7%**	153.85	37.40
SP 69	15.8	2.6%	25.2%	**27.8%**	11.9%	2.4%	**14.3%**	46.89	9.75
SP 70	7.8	0.0%	0.0%	**0.0%**	55.5%	0.0%	**55.5%**	154.78	35.43
SP 71	3.0	0.0%	0.0%	**0.0%**	99.9%	0.0%	**99.9%**	173.00	47.76
SP 72	9.5	0.0%	0.0%	**0.0%**	79.8%	0.0%	**79.8%**	164.75	42.18
SP 73	3.1	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	86.77	13.15
SP 74	10.7	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.00	0.00
SP 75	23.3	0.0%	11.0%	**11.0%**	0.0%	0.0%	**0.0%**	31.44	4.76
SP 76	8.9	0.0%	0.0%	**0.0%**	0.0%	66.6%	**66.6%**	71.26	14.49
SP 77	8.3	0.0%	0.0%	**0.0%**	0.0%	70.9%	**70.9%**	67.35	14.14
SP 78	8.7	0.0%	0.0%	**0.0%**	0.0%	73.9%	**73.9%**	64.60	13.89
SP 79	10.8	0.0%	0.0%	**0.0%**	0.0%	70.2%	**70.2%**	67.97	14.19
SP 80	2.4	80.4%	1.4%	**81.8%**	0.0%	8.2%	**8.2%**	89.23	11.09
SP 81	9.7	0.0%	0.0%	**0.0%**	0.6%	73.9%	**74.5%**	64.90	14.06
SP 82	3.4	1.2%	0.0%	**1.2%**	0.0%	69.4%	**69.4%**	71.25	14.89
SP 83	11.3	0.4%	0.0%	**0.4%**	7.8%	49.6%	**57.4%**	85.27	17.57
SP 84	17.4	3.1%	0.0%	**3.1%**	0.1%	70.7%	**70.8%**	69.39	14.65
SP 85	7.9	6.3%	0.0%	**6.3%**	0.9%	56.2%	**57.1%**	73.70	14.49
SP 86	69.2	15.7%	0.0%	**15.7%**	47.0%	12.5%	**59.5%**	134.30	30.79
SP 87	5.9	2.6%	0.0%	**2.6%**	44.4%	23.5%	**67.8%**	129.92	30.68
SP 88	2.8	2.4%	0.0%	**2.4%**	30.2%	38.4%	**68.7%**	110.85	25.61
SP 89	2.5	0.0%	0.0%	**0.0%**	0.0%	78.3%	**78.3%**	60.57	13.52
SP 90	5.5	0.0%	0.0%	**0.0%**	0.0%	61.0%	**61.0%**	76.42	14.96
SP 91	4.0	0.0%	0.0%	**0.0%**	45.1%	30.0%	**75.1%**	113.24	28.56
SP 92	2.0	0.0%	0.0%	**0.0%**	70.6%	0.0%	**70.6%**	160.99	39.63
SP 93	6.9	4.6%	0.0%	**4.6%**	76.2%	0.0%	**76.2%**	163.42	41.24
SP 94	26.4	20.7%	6.0%	**26.8%**	63.1%	1.5%	**64.6%**	141.69	34.58
SP 95	7.6	38.4%	31.8%	**70.1%**	0.2%	29.5%	**29.7%**	48.45	7.75
SP 96	4.2	5.8%	20.2%	**26.0%**	0.0%	28.8%	**28.8%**	77.93	13.31
SP 97	100.1	90.7%	0.0%	**90.7%**	5.0%	1.8%	**6.8%**	94.57	12.23
SP 98	6.1	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 99	1.9	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 100	2.6	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 101	11.7	0.0%	100.0%	**100.0%**	0.0%	0.0%	**0.0%**	0.00	0.00
SP 102	19.0	0.0%	0.1%	**0.1%**	0.0%	0.0%	**0.0%**	131.87	19.98
SP 103	5.3	0.0%	0.0%	**0.0%**	40.2%	30.9%	**71.1%**	120.36	28.63
SP 104	21.6	0.4%	0.0%	**0.4%**	37.2%	28.9%	**66.2%**	115.23	27.30
SP 105	4.3	0.0%	0.0%	**0.0%**	28.8%	37.8%	**66.6%**	109.35	24.87
SP 106	47.3	14.6%	3.9%	**18.4%**	36.1%	18.0%	**54.1%**	111.33	25.29
SP 107	0.9	0.0%	0.0%	**0.0%**	20.4%	0.0%	**20.4%**	140.38	25.67
SP 108	7.8	0.0%	0.0%	**0.0%**	75.5%	0.0%	**75.5%**	163.01	41.00
SP 109	2.9	0.0%	0.0%	**0.0%**	81.5%	0.0%	**81.5%**	165.44	42.64
SP 110	28.0	6.2%	12.4%	**18.6%**	53.2%	0.0%	**53.2%**	136.29	32.05
SP 111	2.5	8.4%	0.0%	**8.4%**	43.5%	0.0%	**43.5%**	147.51	31.55
SP 112	3.5	0.0%	0.0%	**0.0%**	100.0%	0.0%	**100.0%**	173.05	47.79
SP 113	4.0	36.5%	39.3%	**75.7%**	24.3%	0.0%	**24.3%**	75.48	15.41
SP 114	8.8	98.0%	2.0%	**100.0%**	0.0%	0.0%	**0.0%**	88.24	9.80
SP 115	72.4	22.8%	0.5%	**23.3%**	41.5%	10.4%	**51.8%**	127.95	28.23
SP 116	5.7	9.5%	0.0%	**9.5%**	63.3%	0.0%	**63.3%**	155.69	37.07
SP 117	5.1	2.8%	2.1%	**5.0%**	65.0%	0.0%	**65.0%**	156.43	37.80
SP 118	7.3	0.0%	2.7%	**2.7%**	67.8%	0.0%	**67.8%**	156.28	38.31
SP 119	4.5	6.5%	0.0%	**6.5%**	63.1%	0.0%	**63.1%**	156.87	37.32

Sub Catchment	Area (ha)	Parks & Recreation			Land Use Density			Nutrient Input (kg/gross ha/yr)	
		Active	Passive	**Total**	R10 - R20	R20 - R100	**Total**	Total Nitrogen	Total Phosphorus
SP 120	3.5	0.0%	19.4%	**19.4%**	80.6%	0.0%	**80.6%**	139.41	38.50
SP 121	3.2	0.0%	0.0%	**0.0%**	0.0%	100.0%	**100.0%**	40.84	11.73
SP 122	25.9	0.0%	1.5%	**1.5%**	74.8%	0.0%	**74.8%**	160.68	40.48
SP 123	18.7	41.1%	31.7%	**72.8%**	27.2%	0.0%	**27.2%**	84.76	17.29
SP 124	57.0	31.8%	37.5%	**69.3%**	26.8%	0.0%	**26.8%**	80.85	16.95
SP 125	11.8	4.0%	0.0%	**4.0%**	71.3%	0.0%	**71.3%**	161.50	39.89
SP 126	44.3	3.0%	0.0%	**3.0%**	66.3%	0.0%	**66.3%**	157.80	38.29
SP 127	11.8	0.0%	0.0%	**0.0%**	78.4%	0.0%	**78.4%**	164.20	41.80
SP 128	10.7	0.0%	0.0%	**0.0%**	73.6%	0.0%	**73.6%**	160.65	40.21
SP 129	4.1	0.0%	0.0%	**0.0%**	67.9%	0.0%	**67.9%**	159.89	38.88
SP 130	10.6	0.0%	0.0%	**0.0%**	68.6%	0.0%	**68.6%**	160.17	39.07
SP 131	8.2	0.0%	0.0%	**0.0%**	67.4%	0.0%	**67.4%**	159.65	38.72
SP 132	5.6	0.0%	0.0%	**0.0%**	70.5%	0.0%	**70.5%**	160.95	39.60
SP 133	5.5	0.0%	0.0%	**0.0%**	82.0%	0.0%	**82.0%**	165.66	42.79
SP 134	14.2	100.0%	0.0%	**100.0%**	0.0%	0.0%	**0.0%**	90.00	10.00
SP 135	6.0	4.6%	4.3%	**8.9%**	60.1%	0.0%	**60.1%**	150.71	35.79
SP 136	41.0	15.0%	0.7%	**15.7%**	55.5%	0.0%	**55.5%**	149.11	34.18
SP 137	39.7	19.5%	41.3%	**60.8%**	34.7%	0.0%	**34.7%**	84.47	19.66
SP 138	14.1	0.8%	0.0%	**0.8%**	75.3%	0.0%	**75.3%**	164.63	41.37
SP 139	7.4	11.9%	0.0%	**11.9%**	66.9%	0.0%	**66.9%**	156.26	37.85
SP 140	21.3	4.3%	3.7%	**8.1%**	78.1%	0.0%	**78.1%**	159.41	41.06
SP 141	2.9	53.1%	42.3%	**95.4%**	0.0%	0.0%	**0.0%**	53.87	6.23
SP 142	2.2	0.0%	100.0%	**100.0%**	0.0%	0.0%	**0.0%**	0.00	0.00
VP 1	22.9	1.0%	0.0%	**1.0%**	40.5%	28.1%	**68.6%**	120.28	28.72
VP 2	3.0	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	132.00	20.00
VP 3	0.8	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	132.00	20.00
VP 4	8.5	9.1%	0.0%	**9.1%**	9.9%	49.7%	**59.6%**	89.33	18.32
VP 5	7.7	4.3%	2.5%	**6.8%**	5.8%	24.2%	**30.0%**	66.87	12.69

APPENDIX D

Environmental Priority Catchment Calculations

City of South Perth Determination of Priority Catchments: Priority Rating System

Overall Environmental Priority Weighting System Applied (%)

A. Receiving Environment	50.0%
B. Potential Diffuse Sources of Pollutants	50.0%
Total	***100.0%***

A. Receiving Environment

Overall Priorites based on Social & Environmental Attributes

Receiving Environment	50.0%
Total	***50.0%***

Receiving Environment Social/Environmental Priorities	Assessment Parameter	Rating Normalised to 5 categories
High/High	1	**4.0**
High/Medium	2	**3.2**
High/Low	3	**2.4**
Medium/Medium	4	**1.6**
Medium/Low	5	**0.8**
Low/Low	6	**0.0**

B. Potential Diffuse Sources of Pollutants

Overall Priorities based on Potential Diffuse Sources of Pollutants

Nutrient Input TP (kg/gross ha/yr)	25.0%
Commercial Area (% of Catchment)	12.5%
Major Roads (% of Catchment)	12.5%
Total	***50.0%***

Assessment Parameter	Lower Limit				
Nutrient Input TP (kg/gross ha/yr)	0	1	10	20	30
Commercial Area (% of Catchment)	0%	2%	5%	10%	20%
Major Roads (% of Catchment)	0%	2%	5%	10%	20%
Rating	**0**	**1**	**2**	**3**	**4**

City of South Perth Determination of Environmental Priority Catchments

Total Catchments = 147
No of Catchments receiving flow from outside LA area = 6 (denoted by asterisk)
No of Catchments in other LA areas to which City of South Perth contributes = 5

Catchment ID	Area (ha)	Land Use: Active	Passive	R10-R20	R25-R100	Commercial	Road&Res	Receiving Environment: Discharge Type	Social Attribute	Environmental Attribute	Rating	Potential Diffuse Sources of Pollutants: Nutrients (kg/gross ha/yr) TN	TP	Rating	Commercial Area (ha)	(%)	Rating	Major Roads Area (ha)	(%)	Rating	Total Rating weighted	Rank	Rank unique	Potential Point Sources of Pollutants: Abandoned Landfill	Liquid Disposal	Fuel Storage Existing	Remediated	WW Pump Station	Total
SP 1	15.8	0%	100%	0%	0%	0%	0%	Infiltration Diffuse	Medium	Medium	1.6	0.0	0.0	0	0.0	0%	0	0.0	0%	0	0.80	135	135	0	0	0	0	0	0
SP 2	2.9	40%	0%	0%	0%	0%	60%	River - Swan via Compensating Basin	High	Medium	3.2	115.1	16.0	2	0.0	0%	0	1.6	55%	4	2.60	10	11	0	0	0	0	0	0
SP 3	1.0	87%	0%	0%	0%	0%	13%	Infiltration Basin/Swale/Soakwell - Dry	High	Medium	3.2	95.3	11.3	2	0.0	0%	0	0.0	0%	0	2.10	25	31	0	0	0	0	0	0
SP 4	30.4	0%	0%	0%	0%	0%	100%	River - Swan Direct	Medium	Medium	1.6	131.7	19.9	2	0.0	0%	0	30.3	100%	4	1.80	39	40	0	0	0	0	1	1
SP 5	8.9	7%	0%	0%	66%	0%	27%	River - Swan Direct	Medium	Medium	1.6	71.8	14.6	2	0.0	0%	0	0.0	0%	0	1.30	77	81	0	0	0	0	1	1
SP 6	0.6	0%	0%	0%	40%	0%	60%	River - Swan Direct	Medium	Medium	1.6	95.4	16.7	2	0.0	0%	0	0.0	0%	0	1.30	77	91	0	0	0	0	0	0
SP 7	0.5	0%	0%	0%	56%	0%	44%	River - Swan Direct	Medium	Medium	1.6	81.4	15.4	2	0.0	0%	0	0.0	0%	0	1.30	77	92	0	0	0	0	0	0
SP 8	0.4	0%	0%	0%	60%	0%	40%	River - Swan Direct	Medium	Medium	1.6	77.3	15.0	2	0.0	0%	0	0.0	0%	0	1.30	77	93	0	0	0	0	0	0
SP 9	0.7	0%	0%	0%	60%	0%	40%	River - Swan Direct	Medium	Medium	1.6	77.7	15.1	2	0.0	0%	0	0.0	0%	0	1.30	77	90	0	0	0	0	0	0
SP 10	1.3	0%	0%	0%	59%	0%	41%	River - Swan Direct	Medium	Medium	1.6	78.2	15.1	2	0.0	0%	0	0.0	0%	0	1.30	77	88	0	0	0	0	0	0
SP 11	10.6	6%	1%	0%	68%	0%	25%	River - Swan Direct	Medium	Medium	1.6	69.1	14.3	2	0.0	0%	0	0.0	0%	0	1.30	77	78	0	0	0	0	0	0
SP 12	4.4	0%	0%	0%	61%	7%	32%	River - Swan Direct	Medium	Medium	1.6	67.6	13.6	2	0.3	7%	2	0.0	0%	0	1.55	56	59	0	0	0	0	0	0
SP 13	1.4	100%	0%	0%	0%	0%	0%	Infiltration Diffuse	High	Medium	3.2	90.0	10.0	2	0.0	0%	0	0.0	0%	0	2.10	25	30	0	0	0	0	0	0
SP 14	2.2	0%	0%	0%	46%	0%	54%	River - Swan Direct	Medium	Medium	1.6	90.4	16.2	2	0.0	0%	0	0.8	35%	4	1.80	39	50	0	0	0	0	0	0
SP 15	8.9	0%	2%	0%	74%	0%	24%	River - Swan Direct	Medium	Medium	1.6	62.3	13.5	2	0.0	0%	0	0.0	0%	0	1.30	77	82	0	0	0	0	1	1
SP 16	6.5	0%	4%	0%	59%	0%	36%	River - Swan Direct	Medium	Medium	1.6	71.9	14.2	2	0.0	0%	0	0.0	0%	0	1.30	77	85	0	0	0	0	0	0
SP 17	2.1	0%	0%	0%	18%	42%	40%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	60.1	10.1	2	0.9	42%	4	0.8	37%	4	1.50	62	65	0	0	0	0	0	0
SP 18	8.2	1%	0%	2%	22%	32%	42%	River - Swan Direct	Medium	Medium	1.6	70.8	12.5	2	2.6	32%	4	2.2	27%	4	2.30	17	17	0	0	1	0	0	1
SP 19	21.0	100%	0%	0%	0%	0%	0%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	90.0	10.0	2	0.0	0%	0	0.0	0%	0	1.70	51	52	0	0	0	0	0	0
SP 20	0.9	0%	0%	0%	61%	9%	30%	River - Swan Direct	Medium	Medium	1.6	64.2	13.1	2	0.1	9%	2	0.0	0%	0	1.55	56	61	0	0	0	0	0	0
SP 21	48.9	89%	0%	3%	8%	0%	0%	Infiltration Diffuse	High	Medium	3.2	89.4	11.5	2	0.0	0%	0	0.0	0%	0	2.10	25	27	1	0	0	0	3	4
SP 22	2.2	0%	0%	0%	82%	0%	18%	River - Swan Direct	Medium	Medium	1.6	57.6	13.3	2	0.0	0%	0	0.0	0%	0	1.30	77	87	0	0	0	0	0	0
SP 23	0.4	100%	0%	0%	0%	0%	0%	River - Swan Direct	Medium	Medium	1.6	90.0	10.0	2	0.0	0%	0	0.0	0%	0	1.30	77	94	0	0	0	0	0	0
SP 24	25.7	2%	0%	27%	42%	0%	29%	River - Swan Direct	Medium	Medium	1.6	106.3	24.4	3	0.0	0%	0	2.2	9%	2	1.80	39	41	0	0	0	0	0	0
SP 25	48.6	23%	0%	34%	22%	3%	18%	River - Swan via Compensating Basin	High	Medium	3.2	114.0	25.1	3	1.6	3%	1	2.7	6%	2	2.73	9	9	0	0	0	0	0	0
SP 26	49.0	7%	0%	48%	16%	3%	26%	River - Swan via Compensating Basin	High	Medium	3.2	132.2	31.3	4	1.6	3%	1	1.7	4%	1	2.85	8	8	0	0	0	0	0	0
SP 27	4.5	5%	0%	0%	60%	9%	25%	River - Swan Direct	Medium	Medium	1.6	65.6	13.4	2	0.4	9%	2	0.0	0%	0	1.55	56	58	0	0	1	0	0	1
SP 28	42.8	88%	1%	0%	0%	0%	11%	Infiltration Diffuse	High	Low	2.4	93.9	11.0	2	0.0	0%	0	0.0	0%	0	1.70	51	51	0	0	0	0	0	0
SP 29	0.8	62%	0%	0%	0%	0%	38%	River - Swan Direct	Medium	Medium	1.6	106.0	13.8	2	0.0	0%	0	0.0	0%	0	1.30	77	89	0	0	0	0	0	0
SP 30	8.8	0%	0%	0%	76%	0%	24%	River - Swan Direct	Medium	Medium	1.6	62.3	13.7	2	0.0	0%	0	0.7	8%	2	1.55	56	57	0	0	0	0	0	0
SP 31	46.4	0%	0%	14%	58%	0%	28%	River - Swan Direct	Medium	Medium	1.6	84.3	18.9	2	0.0	0%	0	4.1	9%	2	1.55	56	56	0	0	0	0	0	0
SP 32	31.3	10%	0%	40%	24%	6%	20%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	116.6	27.5	3	1.8	6%	2	0.0	0%	0	1.00	106	106	0	0	1	0	0	1
SP 33	23.1	7%	0%	47%	19%	0%	26%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	132.6	31.3	4	0.1	0%	0	0.0	0%	0	1.00	106	107	0	0	0	0	0	0
SP 34	27.7	19%	0%	35%	23%	6%	17%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	110.6	25.0	3	1.8	6%	2	1.5	5%	2	1.25	95	95	0	0	0	1	0	1
SP 35	23.0	0%	0%	10%	69%	1%	20%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	71.8	16.8	2	0.2	1%	0	0.0	0%	0	0.50	143	143	0	0	0	0	0	0
SP 36	50.1	8%	0%	59%	8%	2%	23%	Infiltration Basin/Swale/Soakwell - Dry	Medium	Low	0.8	145.8	35.2	4	0.8	2%	0	0.6	1%	0	1.40	68	68	1	0	0	1	0	2
SP 37	3.6	0%	0%	16%	61%	11%	12%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	67.6	17.1	2	0.4	11%	3	0.0	0%	0	0.88	131	133	0	0	0	0	0	0
SP 38	7.0	0%	0%	38%	21%	10%	31%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	114.6	26.6	3	0.7	10%	3	0.5	7%	2	1.38	70	74	0	0	1	0	0	1
SP 39	8.8	0%	0%	61%	7%	1%	31%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	149.3	36.2	4	0.1	1%	0	1.2	14%	3	1.38	70	73	0	0	0	0	0	0
SP 40	11.4	0%	0%	71%	2%	2%	25%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	157.3	39.4	4	0.2	2%	0	1.4	13%	3	1.38	70	71	0	0	0	0	0	0
SP 41	10.0	4%	0%	61%	3%	5%	28%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	148.3	35.9	4	0.5	5%	1	0.0	0%	0	1.13	101	103	0	0	0	0	0	0
SP 42	10.0	0%	0%	42%	15%	10%	34%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	122.9	28.4	3	1.0	10%	2	1.2	12%	3	1.38	70	72	0	0	0	0	0	0
SP 43	17.2	0%	0%	71%	0%	0%	29%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	162.8	40.1	4	0.0	0%	0	0.9	5%	2	1.25	95	96	0	0	0	0	0	0
SP 44	6.4	0%	0%	39%	13%	11%	36%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	121.0	27.5	3	0.7	11%	3	0.8	13%	3	1.50	62	63	0	0	1	0	0	1
SP 45	9.1	7%	0%	51%	13%	0%	28%	Infiltration Parks/Reserves	High	Low	2.4	140.4	33.0	4	0.0	0%	0	0.0	0%	0	2.20	19	22	0	0	0	0	0	0
SP 46	9.7	34%	0%	42%	0%	0%	24%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	136.2	28.6	3	0.0	0%	0	0.0	0%	0	1.95	33	33	1	0	0	0	0	1
SP 47	3.8	0%	0%	71%	0%	0%	29%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	161.3	39.8	4	0.0	0%	0	0.0	0%	0	1.00	106	124	0	0	0	0	0	0
SP 48 *	11.6	0%	0%	48%	17%	16%	20%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	116.0	28.8	3	1.8	16%	3	0.8	7%	2	1.38	70	70	0	0	0	0	0	0
SP 49	6.8	0%	0%	27%	40%	2%	31%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	103.8	23.7	3	0.1	2%	0	0.0	1%	0	0.75	137	137	0	0	0	0	0	0
SP 50	2.3	0%	0%	73%	0%	11%	16%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	147.4	38.0	4	0.3	11%	3	0.0	0%	0	1.38	70	76	0	0	0	0	0	0
SP 51	22.9	8%	0%	66%	0%	0%	25%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	157.1	38.0	4	0.1	0%	0	0.0	0%	0	1.00	106	108	0	0	0	0	0	0
SP 52	6.8	0%	0%	73%	0%	0%	27%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	161.9	40.2	4	0.0	0%	0	0.0	0%	0	1.00	106	120	0	0	0	0	0	0
SP 53 *	6.8	0%	0%	68%	0%	1%	31%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	158.1	38.6	4	0.1	1%	0	0.9	13%	3	1.38	70	75	0	0	0	0	0	0
SP 54 *	5.3	6%	0%	62%	0%	0%	32%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	156.7	37.1	4	0.0	0%	0	0.5	10%	3	2.58	12	12	0	0	0	0	0	0
SP 55 *	5.8	1%	0%	36%	51%	0%	12%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	102.7	26.4	3	0.0	0%	0	0.0	0%	0	1.95	33	34	0	0	0	0	0	0
SP 56 *	6.1	0%	0%	78%	0%	2%	20%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	161.3	41.3	4	0.1	2%	1	0.0	0%	0	1.13	101	105	0	0	0	0	0	0
SP 57	24.9	9%	0%	0%	45%	22%	24%	River - Swan Direct	Medium	Medium	1.6	60.5	11.5	2	5.5	22%	4	0.6	2%	1	1.93	35	35	0	0	1	0	0	1
SP 58	3.4	0%	0%	0%	66%	0%	34%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	71.5	14.5	2	0.0	0%	0	0.4	11%	3	0.88	131	134	0	0	0	0	0	0
SP 59	12.5	0%	0%	19%	53%	0%	28%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	92.0	21.0	3	0.0	0%	0	0.9	7%	2	1.00	106	111	0	0	0	0	0	0
SP 60	19.0	0%	0%	17%	57%	5%	22%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	80.7	19.0	2	1.0	5%	2	0.9	5%	1	0.88	131	131	0	0	1	0	0	1
SP 61	1.4	0%	0%	52%	13%	6%	29%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	133.8	32.3	4	0.1	6%	2	0.0	0%	0	1.25	95	99	0	0	0	0	0	0
SP 62	16.4	0%	0%	57%	26%	0%	16%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	131.0	33.6	4	0.1	0%	0	0.9	6%	2	1.25	95	97	0	0	0	0	0	0
SP 63	15.1	0%	0%	73%	0%	2%	25%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	159.2	39.8	4	0.3	2%	0	0.0	0%	0	1.00	106	110	0	0	0	0	0	0
SP 64	18.4	16%	0%	39%	22%	2%	21%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	120.5	27.5	3	0.4	2%	1	0.0	0%	0	0.88	131	132	0	0	0	0	0	0

Catchment ID	Area (ha)	Land Use: Active	Land Use: Passive	Land Use: R10-R20	Land Use: R25-R100	Land Use: Commercial	Land Use: Road&Res	Receiving Environment: Discharge Type	Social Attribute	Environmental Attribute	Rating	Potential Diffuse Sources of Pollutants: Nutrients (kg/gross ha/yr) TN	Nutrients TP	Rating	Commercial Area (ha)	Commercial Area (%)	Rating	Major Roads Area (ha)	Major Roads Area (%)	Rating	Total Rating weighted	Rank	Rank unique	Potential Point Sources of Pollutants: Abandoned Landfill	Abandoned Liquid Disposal	Fuel Storage Existing	Fuel Storage Remediated	WW Pump Station	Total
SP 65	6.9	0%	0%	78%	0%	0%	22%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	163.9	41.6	4	0.0	0%	0	0.0	0%	0	1.00	106	118	0	0	0	0	0	0
SP 66	7.5	13%	0%	68%	0%	0%	19%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	156.6	38.2	4	0.0	0%	0	0.0	0%	0	1.00	106	117	0	0	0	0	0	0
SP 67	1.6	29%	0%	37%	0%	0%	34%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	135.7	27.5	3	0.0	0%	0	0.0	0%	0	0.75	137	140	0	0	0	0	0	0
SP 68	22.9	5%	0%	64%	5%	0%	26%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	153.8	37.4	4	0.0	0%	0	0.0	0%	0	1.00	106	109	0	0	0	0	0	0
SP 69	15.8	3%	25%	12%	2%	41%	17%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	46.9	9.7	1	6.4	41%	4	2.0	13%	3	1.13	101	102	0	0	0	0	0	0
SP 70	7.8	0%	0%	56%	0%	0%	44%	Infiltration Parks/Reserves	Low	Low	0.0	154.8	35.4	4	0.0	0%	0	2.4	31%	4	1.50	62	62	0	0	0	0	0	0
SP 71	3.0	0%	0%	100%	0%	0%	0%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	173.0	47.8	4	0.0	0%	0	0.0	0%	0	1.00	106	126	0	0	0	0	0	0
SP 72	9.5	0%	0%	80%	0%	0%	20%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	164.8	42.2	4	0.0	0%	0	0.0	0%	0	1.00	106	114	0	0	0	0	1	1
SP 73	3.1	0%	0%	0%	0%	34%	66%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	86.8	13.1	2	1.0	34%	4	1.4	47%	4	1.50	62	64	0	0	0	0	0	0
SP 74	10.7	0%	0%	0%	0%	100%	0%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	0.0	0.0	0	10.7	100%	4	0.0	0%	0	0.50	143	144	0	0	0	0	0	0
SP 75	23.3	0%	11%	0%	0%	65%	24%	Infiltration Diffuse	Low	Low	0.0	31.4	4.8	1	15.2	65%	4	4.4	19%	3	1.13	101	101	0	0	0	0	1	1
SP 76	8.9	0%	0%	0%	67%	0%	33%	River - Swan Direct	Medium	Medium	1.6	71.3	14.5	2	0.0	0%	0	0.0	0%	0	1.30	77	80	0	0	0	0	1	1
SP 77	8.3	0%	0%	0%	71%	0%	29%	River - Swan Direct	Medium	Medium	1.6	67.4	14.1	2	0.0	0%	0	0.0	0%	0	1.30	77	84	0	0	0	0	0	0
SP 78	8.7	0%	0%	0%	74%	0%	26%	River - Swan Direct	Medium	Medium	1.6	64.6	13.9	2	0.0	0%	0	0.0	0%	0	1.30	77	83	0	0	0	0	0	0
SP 79	10.8	0%	0%	0%	70%	0%	30%	River - Swan Direct	Medium	Medium	1.6	68.0	14.2	2	0.0	0%	0	0.0	0%	0	1.30	77	77	0	0	0	0	0	0
SP 80	2.4	80%	1%	0%	8%	0%	10%	Infiltration Diffuse	High	Low	2.4	89.2	11.1	2	0.0	0%	0	0.0	0%	0	1.70	51	54	0	0	0	0	0	0
SP 81	9.7	0%	0%	1%	74%	0%	26%	River - Swan Direct	Medium	Medium	1.6	64.9	14.1	2	0.0	0%	0	0.0	0%	0	1.30	77	79	0	0	0	0	0	0
SP 82	3.4	1%	0%	0%	69%	0%	29%	River - Swan Direct	Medium	Medium	1.6	71.3	14.9	2	0.0	0%	0	0.0	0%	0	1.30	77	86	0	0	0	0	0	0
SP 83	11.3	0%	0%	8%	50%	5%	37%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	85.3	17.6	2	0.6	5%	2	2.6	23%	4	1.25	95	98	0	0	0	0	0	0
SP 84	17.4	3%	0%	0%	71%	0%	26%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	69.4	14.7	2	0.0	0%	0	0.5	3%	1	0.63	142	142	0	0	0	0	0	0
SP 85	7.9	6%	0%	1%	56%	5%	31%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	73.7	14.5	2	0.4	5%	2	1.0	13%	3	1.13	101	104	0	0	1	0	0	1
SP 86	69.2	16%	0%	47%	12%	1%	24%	Infiltration Basin/Swale/Soakwell - Wet	High	Medium	3.2	134.3	30.8	4	0.4	1%	0	0.0	0%	0	2.60	10	10	0	0	0	0	0	0
SP 87	5.9	3%	0%	44%	23%	0%	30%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	129.9	30.7	4	0.0	0%	0	0.0	0%	0	1.00	106	121	0	0	0	0	0	0
SP 88	2.8	2%	0%	30%	38%	0%	29%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	110.9	25.6	3	0.0	0%	0	0.0	0%	0	0.75	137	139	0	0	0	0	0	0
SP 89	2.5	0%	0%	0%	78%	0%	22%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	60.6	13.5	2	0.0	0%	0	0.0	0%	0	0.50	143	147	0	0	0	0	0	0
SP 90	5.5	0%	0%	0%	61%	0%	39%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	76.4	15.0	2	0.0	0%	0	0.0	0%	0	0.50	143	145	0	0	0	0	1	1
SP 91	4.0	0%	0%	45%	30%	8%	17%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	113.2	28.6	3	0.3	8%	2	0.0	0%	0	1.00	106	123	0	0	0	0	0	0
SP 92	2.0	0%	0%	71%	0%	0%	29%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	161.0	39.6	4	0.0	0%	0	0.0	0%	0	1.00	106	129	0	0	0	0	0	0
SP 93	6.9	5%	0%	76%	0%	0%	19%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	163.4	41.2	4	0.0	0%	0	0.0	0%	0	1.00	106	119	0	0	0	0	0	0
SP 94	26.4	21%	6%	63%	1%	0%	9%	Infiltration Diffuse	High	Low	2.4	141.7	34.6	4	0.0	0%	0	0.0	0%	0	2.20	19	19	0	0	0	0	1	1
SP 95	7.6	38%	32%	0%	29%	0%	0%	Infiltration Diffuse	High	Low	2.4	48.5	7.8	1	0.0	0%	0	0.0	0%	0	1.45	66	67	0	0	0	0	0	0
SP 96	4.2	6%	20%	0%	29%	0%	45%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	77.9	13.3	2	0.0	0%	0	0.0	0%	0	0.50	143	146	0	0	0	0	1	1
SP 97	100.1	91%	0%	5%	2%	0%	3%	Infiltration Diffuse	High	Medium	3.2	94.6	12.2	2	0.0	0%	0	1.5	1%	0	2.10	25	25	1	0	0	0	0	1
SP 98	6.1	100%	0%	0%	0%	0%	0%	River - Canning via Compensating Basi	High	High	4.0	90.0	10.0	2	0.0	0%	0	0.0	0%	0	2.50	13	14	0	0	0	0	0	0
SP 99	1.9	100%	0%	0%	0%	0%	0%	River - Canning via Compensating Basi	High	Medium	3.2	90.0	10.0	2	0.0	0%	0	0.0	0%	0	2.10	25	29	0	0	0	0	0	0
SP 100	2.6	100%	0%	0%	0%	0%	0%	Infiltration Basin/Swale/Soakwell - Wet	High	High	4.0	90.0	10.0	2	0.0	0%	0	0.0	0%	0	2.50	13	16	0	0	0	0	0	0
SP 101	11.7	0%	100%	0%	0%	0%	0%	Infiltration Diffuse	Medium	Medium	1.6	0.0	0.0	0	0.0	0%	0	0.0	0%	0	0.80	135	136	0	0	0	0	0	0
SP 102	19.0	0%	0%	0%	0%	0%	100%	River - Canning Direct	Medium	Medium	1.6	131.9	20.0	2	0.0	0%	0	19.0	100%	4	1.80	39	42	0	0	0	0	0	0
SP 103	5.3	0%	0%	40%	31%	0%	29%	Infiltration Parks/Reserves	Low	Low	0.0	120.4	28.6	3	0.0	0%	0	0.0	0%	0	0.75	137	138	0	0	0	0	0	0
SP 104	21.6	0%	0%	37%	29%	6%	28%	River - Canning Direct	Medium	Medium	1.6	115.2	27.3	3	1.3	6%	2	0.7	3%	1	1.93	35	37	0	0	0	0	1	1
SP 105	4.3	0%	0%	29%	38%	0%	33%	River - Canning Direct	Medium	Medium	1.6	109.3	24.9	3	0.0	0%	0	0.0	0%	0	1.55	56	60	0	0	0	0	0	0
SP 106	47.3	15%	4%	36%	18%	7%	20%	Infiltration Basin/Swale/Soakwell - Dry	High	High	4.0	111.3	25.3	3	3.4	7%	2	1.7	4%	1	3.13	4	4	0	0	1	0	1	2
SP 107	0.9	0%	0%	20%	0%	0%	80%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	140.4	25.7	3	0.0	0%	0	0.0	0%	0	0.75	137	141	0	0	0	0	0	0
SP 108	7.8	0%	0%	76%	0%	0%	24%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	163.0	41.0	4	0.0	0%	0	0.0	0%	0	1.00	106	116	0	0	0	0	0	0
SP 109	2.9	0%	0%	81%	0%	0%	19%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	165.4	42.6	4	0.0	0%	0	0.0	0%	0	1.00	106	127	0	0	0	0	0	0
SP 110	28.0	6%	12%	53%	0%	0%	28%	River - Canning via Compensating Basi	High	High	4.0	136.3	32.1	4	0.0	0%	0	2.5	9%	2	3.25	1	2	0	0	0	0	1	1
SP 111	2.5	8%	0%	44%	0%	0%	48%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	147.5	31.5	4	0.0	0%	0	0.0	0%	0	1.00	106	128	0	0	0	0	0	0
SP 112	3.5	0%	0%	100%	0%	0%	0%	Infiltration Diffuse	Low	Low	0.0	173.1	47.8	4	0.0	0%	0	0.0	0%	0	1.00	106	125	0	0	0	0	0	0
SP 113	4.0	36%	39%	24%	0%	0%	0%	Infiltration Basin/Swale/Soakwell - Dry	High	High	4.0	75.5	15.4	2	0.0	0%	0	0.0	0%	0	2.50	13	15	0	0	0	0	0	0
SP 114	8.8	98%	2%	0%	0%	0%	0%	Infiltration Diffuse	High	Low	2.4	88.2	9.8	1	0.0	0%	0	0.0	0%	0	1.45	66	66	1	0	0	0	0	1
SP 115	72.4	23%	1%	41%	10%	2%	23%	River - Canning via Compensating Basi	High	High	4.0	128.0	28.2	3	1.6	2%	1	0.0	0%	0	2.88	7	7	0	1	1	0	1	3
SP 116	5.7	10%	0%	63%	0%	0%	27%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	155.7	37.1	4	0.0	0%	0	0.0	0%	0	2.20	19	23	0	0	0	0	0	0
SP 117	5.1	3%	2%	65%	0%	0%	30%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	156.4	37.8	4	0.0	0%	0	0.0	0%	0	1.00	106	122	0	0	0	0	1	1
SP 118	7.3	0%	3%	68%	0%	0%	29%	River - Canning Direct	Medium	Medium	1.6	156.3	38.3	4	0.0	0%	0	0.0	0%	0	1.80	39	46	0	0	0	0	0	0
SP 119	4.5	7%	0%	63%	0%	0%	30%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	156.9	37.3	4	0.0	0%	0	0.0	0%	0	2.20	19	24	0	0	0	0	0	0
SP 120	3.5	0%	19%	81%	0%	0%	0%	Infiltration Diffuse	High	High	4.0	139.4	38.5	4	0.0	0%	0	0.0	0%	0	3.00	5	6	0	0	0	0	0	0
SP 121	3.2	0%	0%	0%	100%	0%	0%	Infiltration Basin/Swale/Soakwell - Dry	Low	Medium	0.8	40.8	11.7	2	0.0	0%	0	0.0	0%	0	0.90	130	130	0	0	0	0	0	0
SP 122	25.9	0%	2%	75%	0%	0%	24%	Infiltration Basin/Swale/Soakwell - Dry	High	Low	2.4	160.7	40.5	4	0.0	0%	0	0.0	0%	0	2.20	19	20	0	0	0	0	1	1
SP 123	18.7	41%	32%	27%	0%	0%	0%	Infiltration Diffuse	High	Medium	3.2	84.8	17.3	2	0.0	0%	0	0.0	0%	0	2.10	25	28	0	0	0	0	0	0
SP 124	57.0	32%	38%	27%	0%	0%	4%	Infiltration Diffuse	High	Medium	3.2	80.8	17.0	2	0.0	0%	0	0.0	0%	0	2.10	25	26	0	0	0	0	2	2
SP 125	11.8	4%	0%	71%	0%	0%	25%	Infiltration Parks/Reserves	High	Low	2.4	161.5	39.9	4	0.0	0%	0	0.0	0%	0	2.20	19	21	0	0	0	0	0	0
SP 126	44.3	3%	0%	66%	0%	1%	29%	River - Canning Direct	Medium	Medium	1.6	157.8	38.3	4	0.7	1%	0	0.6	1%	0	1.80	39	39	0	0	0	1	0	1
SP 127	11.8	0%	0%	78%	0%	0%	22%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	164.2	41.8	4	0.0	0%	0	0.0	0%	0	1.00	106	112	0	0	0	0	0	0
SP 128	10.7	0%	0%	74%	0%	1%	25%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	160.7	40.2	4	0.1	1%	0	0.0	0%	0	1.00	106	113	0	0	0	0	0	0
SP 129	4.1	0%	0%	68%	0%	0%	32%	River - Canning Direct	Medium	Medium	1.6	159.9	38.9	4	0.0	0%	0	0.0	0%	0	1.80	39	49	0	0	0	0	0	0
SP 130	10.6	0%	0%	69%	0%	0%	31%	River - Canning Direct	Medium	Medium	1.6	160.2	39.1	4	0.0	0%	0	0.0	0%	0	1.80	39	44	0	0	0	0	0	0
SP 131	8.2	0%	0%	67%	0%	0%	33%	River - Canning Direct	Medium	Medium	1.6	159.7	38.7	4	0.0	0%	0	0.0	0%	0	1.80	39	45	0	0	0	0	0	0
SP 132	5.6	0%	0%	71%	0%	0%	29%	River - Canning Direct	Medium	Medium	1.6	161.0	39.6	4	0.0	0%	0	0.0	0%	0	1.80	39	47	0	0	0	0	0	0
SP 133	5.5	0%	0%	82%	0%	0%	18%	River - Canning Direct	Medium	Medium	1.6	165.7	42.8	4	0.0	0%	0	0.0	0%	0	1.80	39	48	0	0	0	0	0	0
SP 134	14.2	100%	0%	0%	0%	0%	0%	Infiltration Diffuse	High	Low	2.4	90.0	10.0	2	0.0	0%	0	0.0	0%	0	1.70	51	53	1	0	0	0	0	1
SP 135	6.0	5%	4%	60%	0%	0%	31%	Infiltration Parks/Reserves	Low	Medium	0.8	150.7	35.8	4	0.0	0%	0	0.0	0%	0	1.40	68	69	0	0	0	0	0	0
SP 136	41.0	15%	1%	56%	0%	0%	29%	River - Canning via Compensating Basi	High	High	4.0	149.1	34.2	4	0.0	0%	0	2.3	6%	2	3.25	1	1	0	0	0	0	1	1
SP 137	39.7	20%	41%	35%	0%	0%	5%	Infiltration Diffuse	High	High	4.0	84.5	19.7	2	0.0	0%	0	0.3	1%	0	2.50	13	13	1	0	0	0	1	2

Catchment ID	Area (ha)	Land Use: Active	Passive	R10-R20	R25-R100	Commercial	Road&Res	Receiving Environment: Discharge Type	Social Attribute	Environmental Attribute	Rating	Potential Diffuse Sources of Pollutants: Nutrients (kg/gross ha/yr) TN	TP	Rating	Commercial Area (ha)	(%)	Rating	Major Roads Area (ha)	(%)	Rating	Total Rating weighted	Rank	Rank unique	Potential Point Sources of Pollutants: Abandoned Landfill	Liquid Disposal	Fuel Storage Existing	Remediated	WW Pump Station	Total
SP 138	14.1	1%	0%	75%	0%	0%	24%	Infiltration Parks/Reserves	Medium	Medium	1.6	164.6	41.4	4	0.0	0%	0	0.0	0%	0	1.80	39	43	0	0	0	0	0	0
SP 139	7.4	12%	0%	67%	0%	0%	21%	Infiltration Basin/Swale/Soakwell - Dry	High	High	4.0	156.3	37.9	4	0.0	0%	0	0.0	0%	0	3.00	5	5	0	0	0	0	0	0
SP 140 *	21.3	4%	4%	78%	0%	0%	14%	River - Canning via Compensating Basi	High	High	4.0	159.4	41.1	4	0.0	0%	0	1.4	7%	2	3.25	1	3	1	0	0	0	0	1
SP 141	2.9	53%	42%	0%	0%	0%	5%	River - Canning via Compensating Basi	High	High	4.0	53.9	6.2	1	0.0	0%	0	0.0	0%	0	2.25	18	18	0	0	0	0	0	0
SP 142	2.2	0%	100%	0%	0%	0%	0%	River - Canning via Compensating Basi	High	High	4.0	0.0	0.0	0	0.0	0%	0	0.0	0%	0	2.00	32	32	0	0	0	0	0	0
VP 1	22.9	1%	0%	41%	28%	4%	27%	River - Swan Direct	Medium	Medium	1.6	120.3	28.7	3	0.8	4%	1	1.2	5%	2	1.93	35	36	0	0	0	0	0	0
VP 2	3.0	0%	0%	0%	0%	0%	100%	River - Canning via Compensating Basi	Low	Medium	0.8	132.0	20.0	3	0.0	0%	0	3.0	100%	4	1.65	55	55	0	0	0	0	0	0
VP 3	0.8	0%	0%	0%	0%	0%	100%	Infiltration Basin/Swale/Soakwell - Dry	Low	Low	0.0	132.0	20.0	3	0.0	0%	0	0.8	100%	4	1.25	95	100	0	0	0	0	0	0
VP 4	8.5	9%	0%	10%	50%	0%	31%	Infiltration Basin/Swale/Soakwell - Wet	Low	Low	0.0	89.3	18.3	2	0.0	0%	0	2.3	27%	4	1.00	106	115	0	0	0	0	0	0
VP 5	7.7	4%	2%	6%	24%	31%	32%	River - Canning via Compensating Basi	Low	Medium	0.8	66.9	12.7	2	2.4	31%	4	2.4	31%	4	1.90	38	38	0	0	0	0	0	0

APPENDIX E

Infiltration Basin Storage Requirements for 10 and 100 Year ARI Strom Event (24 hour)

City of South Perth Determination of Basin Volume for 10 year and 100 year, 24hr ARI

The annual rainfall intensity (ARI) sourced from AUS-IFD (2001) calculated in accordance with Chapter 2, IEAust (1987) Australian Rainfall and Runoff

Rational Method Design Coefficients for various land uses, JDA (2002a)

Land Use	Coefficient
POS	0.1
R10-R100	0.1
Commercial	0.9
Road & Reserve	0.8

Catchment No	Basin Type	Within the City of South Perth						Outside City of SP		Total	Volume (m^3)	
		Catchment Area (ha)	Land Use POS	R10-100	Commercial	Road&Res	EIA (ha)	Catchment Area (ha)	EIA (ha)	EIA (ha)	10 Yr 24 hr 3.55 mm/hr	100 Yr 24 hr 5.57 mm/hr
SP 2	Compensation Basin - Wet	2.9	0.4	0.0	0.0	0.6	1.5	0.0	0.0	1.5	1299	2038
SP 25	2 x Compensation Basin - Wet	48.6	0.2	0.6	0.0	0.2	11.0	0.0	0.0	11.0	9345	14662
SP 26	Compensation Basin - Wet	49.0	0.1	0.6	0.0	0.3	13.7	0.0	0.0	13.7	11660	18295
SP 32	Infiltration Basin/Swale/Soakwell - Dry	31.3	0.1	0.6	0.0	0.2	7.3	0.0	0.0	7.3	6233	9779
SP 33	Infiltration Basin/Swale/Soakwell - Dry	23.1	0.1	0.7	0.0	0.3	6.5	0.0	0.0	6.5	5575	8748
SP 34	Infiltration Basin/Swale/Soakwell - Dry	27.7	0.2	0.6	0.0	0.2	5.9	0.0	0.0	5.9	5053	7929
SP 35	Infiltration Basin/Swale/Soakwell - Dry	23.0	0.0	0.8	0.0	0.2	5.6	0.0	0.0	5.6	4747	7448
SP 36	Infiltration Basin/Swale/Soakwell - Dry	50.1	0.1	0.7	0.0	0.2	13.1	0.0	0.0	13.1	11199	17571
SP 36	Infiltration Basin/Swale/Soakwell - Dry	50.1	0.1	0.7	0.0	0.2	13.1	0.0	0.0	13.1	11199	17571
SP 37	Infiltration Basin/Swale/Soakwell - Dry	3.6	0.0	0.8	0.0	0.1	0.6	0.0	0.0	0.6	523	820
SP 38	Infiltration Basin/Swale/Soakwell - Dry	7.0	0.0	0.6	0.0	0.3	2.2	0.0	0.0	2.2	1840	2887
SP 39	Infiltration Basin/Swale/Soakwell - Dry	8.8	0.0	0.7	0.0	0.3	2.8	0.0	0.0	2.8	2369	3716
SP 40	Infiltration Basin/Swale/Soakwell - Dry	11.4	0.0	0.7	0.0	0.2	3.1	0.0	0.0	3.1	2635	4134
SP 41	Infiltration Basin/Swale/Soakwell - Dry	10.0	0.0	0.6	0.0	0.3	2.9	0.0	0.0	2.9	2459	3858
SP 42	Infiltration Basin/Swale/Soakwell - Dry	10.0	0.0	0.6	0.0	0.3	3.3	0.0	0.0	3.3	2788	4374
SP 43	Infiltration Basin/Swale/Soakwell - Dry	17.2	0.0	0.7	0.0	0.3	5.2	0.0	0.0	5.2	4434	6957
SP 44	Infiltration Basin/Swale/Soakwell - Dry	6.4	0.0	0.5	0.0	0.4	2.2	0.0	0.0	2.2	1878	2947
SP 46	Infiltration Basin/Swale/Soakwell - Dry	9.7	0.3	0.4	0.0	0.2	2.6	0.0	0.0	2.6	2192	3440
SP 47	Infiltration Basin/Swale/Soakwell - Dry	3.8	0.0	0.7	0.0	0.3	1.1	0.0	0.0	1.1	961	1508
SP 48	Infiltration Basin/Swale/Soakwell - Dry	11.6	0.0	0.6	0.0	0.2	2.6	1.8	0.4	3.0	2561	4018
SP 49	Infiltration Basin/Swale/Soakwell - Dry	6.8	0.0	0.7	0.0	0.3	2.1	0.0	0.0	2.1	1824	2861
SP 50	Infiltration Basin/Swale/Soakwell - Dry	2.3	0.0	0.7	0.0	0.2	0.5	0.0	0.0	0.5	403	632
SP 51	Infiltration Basin/Swale/Soakwell - Dry	22.9	0.1	0.7	0.0	0.2	6.3	0.0	0.0	6.3	5331	8365
SP 52	Infiltration Basin/Swale/Soakwell - Dry	6.8	0.0	0.7	0.0	0.3	2.0	0.0	0.0	2.0	1690	2651
SP 53	Infiltration Basin/Swale/Soakwell - Dry	6.8	0.0	0.7	0.0	0.3	2.1	0.3	0.1	2.2	1876	2943
SP 54	Infiltration Basin/Swale/Soakwell - Dry	5.3	0.1	0.6	0.0	0.3	1.7	3.3	1.1	2.8	2346	3682
SP 55	Infiltration Basin/Swale/Soakwell - Dry	5.8	0.0	0.9	0.0	0.1	1.1	2.2	0.4	1.5	1239	1943
SP 56	Infiltration Basin/Swale/Soakwell - Dry	6.1	0.0	0.8	0.0	0.2	1.4	1.5	0.4	1.8	1514	2375
SP 58	Infiltration Basin/Swale/Soakwell - Dry	3.4	0.0	0.7	0.0	0.3	1.1	0.0	0.0	1.1	966	1515
SP 59	Infiltration Basin/Swale/Soakwell - Dry	12.5	0.0	0.7	0.0	0.3	3.7	0.0	0.0	3.7	3156	4951
SP 60	Infiltration Basin/Swale/Soakwell - Dry	19.0	0.0	0.7	0.0	0.2	4.7	0.0	0.0	4.7	4009	6290
SP 61	Infiltration Basin/Swale/Soakwell - Dry	1.4	0.0	0.6	0.0	0.3	0.4	0.0	0.0	0.4	343	539
SP 62	Infiltration Basin/Swale/Soakwell - Dry	16.4	0.0	0.8	0.0	0.2	3.5	0.0	0.0	3.5	2980	4676
SP 63	Infiltration Basin/Swale/Soakwell - Dry	15.1	0.0	0.7	0.0	0.3	4.2	0.0	0.0	4.2	3555	5577
SP 64	Infiltration Basin/Swale/Soakwell - Dry	18.4	0.2	0.6	0.0	0.2	4.5	0.0	0.0	4.5	3870	6072
SP 65	Infiltration Basin/Swale/Soakwell - Dry	6.9	0.0	0.8	0.0	0.2	1.8	0.0	0.0	1.8	1511	2370
SP 66	Infiltration Basin/Swale/Soakwell - Dry	7.5	0.1	0.7	0.0	0.2	1.7	0.0	0.0	1.7	1491	2339
SP 67	Infiltration Basin/Swale/Soakwell - Dry	1.6	0.3	0.4	0.0	0.3	0.5	0.0	0.0	0.5	460	721
SP 68	Infiltration Basin/Swale/Soakwell - Dry	22.9	0.0	0.7	0.0	0.3	6.5	0.0	0.0	6.5	5546	8702
SP 69	Infiltration Basin/Swale/Soakwell - Dry	15.8	0.3	0.1	0.0	0.2	2.8	0.0	0.0	2.8	2406	3775
SP 71	Infiltration Basin/Swale/Soakwell - Dry	3.0	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.3	260	408
SP 72	Infiltration Basin/Swale/Soakwell - Dry	9.5	0.0	0.8	0.0	0.2	2.3	0.0	0.0	2.3	1960	3075
SP 73	Infiltration Basin/Swale/Soakwell - Dry	3.1	0.0	0.0	0.0	0.7	1.6	0.0	0.0	1.6	1370	2150
SP 74	Infiltration Basin/Swale/Soakwell - Dry	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
SP 83	Infiltration Basin/Swale/Soakwell - Dry	11.3	0.0	0.6	0.0	0.4	4.0	0.0	0.0	4.0	3401	5336
SP 84	Infiltration Basin/Swale/Soakwell - Dry	17.4	0.0	0.7	0.0	0.3	4.9	0.0	0.0	4.9	4191	6575
SP 85	Infiltration Basin/Swale/Soakwell - Dry	7.9	0.1	0.6	0.0	0.3	2.5	0.0	0.0	2.5	2110	3311
SP 86	Infiltration Basin/Swale/Soakwell - Wet	69.2	0.2	0.6	0.0	0.2	18.6	0.0	0.0	18.6	15855	24876
SP 87	Infiltration Basin/Swale/Soakwell - Dry	5.9	0.0	0.7	0.0	0.3	1.8	0.0	0.0	1.8	1551	2434
SP 88	Infiltration Basin/Swale/Soakwell - Dry	2.8	0.0	0.7	0.0	0.3	0.9	0.0	0.0	0.9	732	1149
SP 89	Infiltration Basin/Swale/Soakwell - Dry	2.5	0.0	0.8	0.0	0.2	0.6	0.0	0.0	0.6	538	843
SP 90	Infiltration Basin/Swale/Soakwell - Dry	5.5	0.0	0.6	0.0	0.4	2.1	0.0	0.0	2.1	1760	2762
SP 91	Infiltration Basin/Swale/Soakwell - Dry	4.0	0.0	0.8	0.0	0.2	0.9	0.0	0.0	0.9	738	1157
SP 92	Infiltration Basin/Swale/Soakwell - Dry	2.0	0.0	0.7	0.0	0.3	0.6	0.0	0.0	0.6	524	821
SP 93	Infiltration Basin/Swale/Soakwell - Dry	6.9	0.0	0.8	0.0	0.2	1.6	0.0	0.0	1.6	1372	2153
SP 98	Compensation Basin - Wet	6.1	1.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6	520	816
SP 99	Compensation Basin - Wet	1.9	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	158	248
SP 100	Infiltration Basin/Swale/Soakwell - Wet	2.6	1.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	225	353
SP 106	Infiltration Basin/Swale/Soakwell - Dry	47.3	0.2	0.5	0.0	0.2	11.1	0.0	0.0	11.1	9436	14806
SP 107	Infiltration Basin/Swale/Soakwell - Dry	0.9	0.0	0.2	0.0	0.8	0.6	0.0	0.0	0.6	499	784
SP 108	Infiltration Basin/Swale/Soakwell - Dry	7.8	0.0	0.8	0.0	0.2	2.1	0.0	0.0	2.1	1803	2829
SP 109	Infiltration Basin/Swale/Soakwell - Dry	2.9	0.0	0.8	0.0	0.2	0.7	0.0	0.0	0.7	570	895
SP 110	Compensation Basin - Dry	28.0	0.2	0.5	0.0	0.3	8.3	0.0	0.0	8.3	7087	11120
SP 111	Infiltration Basin/Swale/Soakwell - Dry	2.5	0.1	0.4	0.0	0.5	1.1	0.0	0.0	1.1	937	1471
SP 113	Infiltration Basin/Swale/Soakwell - Dry	4.0	0.8	0.2	0.0	0.0	0.4	0.0	0.0	0.4	344	540
SP 115	Compensation Basin - Wet	72.4	0.2	0.5	0.0	0.2	18.6	0.0	0.0	18.6	15827	24834
SP 116	Infiltration Basin/Swale/Soakwell - Dry	5.7	0.1	0.6	0.0	0.3	1.7	0.0	0.0	1.7	1415	2221
SP 117	Infiltration Basin/Swale/Soakwell - Dry	5.1	0.0	0.7	0.0	0.3	1.6	0.0	0.0	1.6	1341	2104
SP 122	Infiltration Basin/Swale/Soakwell - Dry	25.9	0.0	0.7	0.0	0.2	6.9	0.0	0.0	6.9	5872	9214
SP 128	Infiltration Basin/Swale/Soakwell - Dry	10.7	0.0	0.7	0.0	0.3	2.9	0.0	0.0	2.9	2513	3943
SP 136	2 x Compensation Basin - Wet	41.0	0.2	0.6	0.0	0.3	12.3	0.0	0.0	12.3	10520	16506
SP 139	Infiltration Basin/Swale/Soakwell - Dry	7.4	0.1	0.7	0.0	0.2	1.8	0.0	0.0	1.8	1567	2459
SP 140	Compensation Basin - Wet	21.3	0.1	0.8	0.0	0.1	4.2	25.2	5.0	9.1	7793	12227
SP 141	Compensation Basin - Wet	2.9	1.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	325	511
SP 142	Compensation Basin - Wet	2.2	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	187	293

APPENDIX F

Water Quality Guidelines
(via ANZECC, 2000a)

Table 3.4.1 Trigger values for toxicants at alternative levels of protection. Values in grey shading are the trigger values applying to typical *slightly–moderately disturbed systems*; see table 3.4.2 and Section 3.4.2.4 for guidance on applying these levels to different ecosystem conditions.

Chemical		Trigger values for freshwater (µgL-1)				Trigger values for marine water (µgL-1)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
METALS & METALLOIDS									
Aluminium	pH >6.5	27	55	80	150	ID	ID	ID	ID
Aluminium	pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Antimony		ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)		1	24	94 C	360 C	ID	ID	ID	ID
Arsenic (AsV)		0.8	13	42	140 C	ID	ID	ID	ID
Beryllium		ID	ID	ID	ID	ID	ID	ID	ID
Bismuth		ID	ID	ID	ID	ID	ID	ID	ID
Boron		90	370 C	680 C	1300 C	ID	ID	ID	ID
Cadmium	H	0.06	0.2	0.4	0.8 C	0.7 B	5.5 B, C	14 B, C	36 B, A
Chromium (Cr III)	H	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (CrVI)		0.01	1.0 C	6 A	40 A	0.14	4.4	20 C	85 C
Cobalt		ID	ID	ID	ID	0.005	1	14	150 C
Copper	H	1.0	1.4	1.8 C	2.5 C	0.3	1.3	3 C	8 A
Gallium		ID	ID	ID	ID	ID	ID	ID	ID
Iron		ID	ID	ID	ID	ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID	ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 C	2.2	4.4	6.6 C	12 C
Manganese		1200	1900C	2500C	3600C	ID	ID	ID	ID
Mercury (inorganic)	B	0.06	0.6	1.9 C	5.4 A	0.1	0.4 C	0.7 C	1.4 C
Mercury (methyl)		ID	ID	ID	ID	ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID	ID	ID	ID	ID
Nickel	H	8	11	13	17 C	7	70 C	200 A	560A
Selenium (Total)	B	5	11	18	34	ID	ID	ID	ID
Selenium (SeIV)	B	ID	ID	ID	ID	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 C	0.8	1.4	1.8	2.6 C
Thallium		ID	ID	ID	ID	ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID	0.0004	0.006 C	0.02 C	0.05 C
Uranium		ID	ID	ID	ID	ID	ID	ID	ID
Vanadium		ID	ID	ID	ID	50	100	160	280
Zinc	H	2.4	8.0 C	15 C	31 C	7	15 C	23 C	43 C
NON-METALLIC INORGANICS									
Ammonia	D	320	900 C	1430 C	2300 A	500	910	1200	1700
Chlorine	E	0.4	3	6 A	13 A	ID	ID	ID	ID
Cyanide	F	4	7	11	18	2	4	7	14
Nitrate	J	17	700	3400 C	17000 A	ID	ID	ID	ID
Hydrogen sulfide	G	0.5	1.0	1.5	2.6	ID	ID	ID	ID
ORGANIC ALCOHOLS									
Ethanol		400	1400	2400 C	4000 C	ID	ID	ID	ID
Ethylene glycol		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl alcohol		ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKANES									
Chloromethanes									
Dichloromethane		ID	ID	ID	ID	ID	ID	ID	ID
Chloroform		ID	ID	ID	ID	ID	ID	ID	ID
Carbon tetrachloride		ID	ID	ID	ID	ID	ID	ID	ID
Chloroethanes									
1,2-dichloroethane		ID	ID	ID	ID	ID	ID	ID	ID
1,1,1-trichloroethane		ID	ID	ID	ID	ID	ID	ID	ID

Chemical		Trigger values for freshwater (μgL^{-1})				Trigger values for marine water (μgL^{-1})		
		Level of protection (% species)				Level of protection (% species)		
		99%	95%	90%	80%	99%	95%	90%	80%
1,1,2-trichloroethane		5400	6500	7300	8400	140	1900	5800 C	18000 C
1,1,2,2-tetrachloroethane		ID	ID	ID	ID	ID	ID	ID	ID
Pentachloroethane		ID	ID	ID	ID	ID	ID	ID	ID
Hexachloroethane	B	290	360	420	500	ID	ID	ID	ID
Chloropropanes									
1,1-dichloropropane		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloropropane		ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropane		ID	ID	ID	ID	ID	ID	ID	ID
CHLORINATED ALKENES									
Chloroethylene		ID	ID	ID	ID	ID	ID	ID	ID
1,1-dichloroethylene		ID	ID	ID	ID	ID	ID	ID	ID
1,1,2-trichloroethylene		ID	ID	ID	ID	ID	ID	ID	ID
1,1,2,2-tetrachloroethylene		ID	ID	ID	ID	ID	ID	ID	ID
3-chloropropene		ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloropropene		ID	ID	ID	ID	ID	ID	ID	ID
ANILINES									
Aniline		8	250 A	1100 A	4800 A	ID	ID	ID	ID
2,4-dichloroaniline		0.6	7	20	60 C	ID	ID	ID	ID
2,5-dichloroaniline		ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichloroaniline		1.3	3	6 C	13 C	85	150	190	260
3,5-dichloroaniline		ID	ID	ID	ID	ID	ID	ID	ID
Benzidine		ID	ID	ID	ID	ID	ID	ID	ID
Dichlorobenzidine		ID	ID	ID	ID	ID	ID	ID	ID
AROMATIC HYDROCARBONS									
Benzene		600	950	1300	2000	500 C	700 C	900 C	1300 C
Toluene		ID	ID	ID	ID	ID	ID	ID	ID
Ethylbenzene		ID	ID	ID	ID	ID	ID	ID	ID
o-xylene		200	350	470	640	ID	ID	ID	ID
m-xylene		ID	ID	ID	ID	ID	ID	ID	ID
p-xylene		140	200	250	340	ID	ID	ID	ID
m+*p*-xylene		ID	ID	ID	ID	ID	ID	ID	ID
Cumene		ID	ID	ID	ID	ID	ID	ID	ID
Polycyclic Aromatic Hydrocarbons									
Naphthalene		2.5	16	37	85	50 C	70 C	90 C	120 C
Anthracene	B	ID	ID	ID	ID	ID	ID	ID	ID
Phenanthrene	B	ID	ID	ID	ID	ID	ID	ID	ID
Fluoranthene	B	ID	ID	ID	ID	ID	ID	ID	ID
Benzo(a)pyrene	B	ID	ID	ID	ID	ID	ID	ID	ID
Nitrobenzenes									
Nitrobenzene		230	550	820	1300	ID	ID	ID	ID
1,2-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,3-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-2-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-methoxy-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-chloro-2,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichloro-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,3-dichloro-5-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,4-dichloro-2-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichloro-2-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID

Chemical		Trigger values for freshwater (µgL⁻¹)				Trigger values for marine water (µgL⁻¹)			
		Level of protection (% species)				Level of protection (% species)			
		99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
1,2,4,5-tetrachloro-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,5-dichloro-2,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,3,5-trichloro-2,4-dinitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1-fluoro-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
Nitrotoluenes									
2-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
3-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
4-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
2,3-dinitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrotoluene		16	65 [C]	130 [C]	250 [C]	ID	ID	ID	ID
2,4,6-trinitrotoluene		100	140	160	210	ID	ID	ID	ID
1,2-dimethyl-3-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dimethyl-4-nitrobenzene		ID	ID	ID	ID	ID	ID	ID	ID
4-chloro-3-nitrotoluene		ID	ID	ID	ID	ID	ID	ID	ID
Chlorobenzenes and Chloronaphthalenes									
Monochlorobenzene		ID	ID	ID	ID	ID	ID	ID	ID
1,2-dichlorobenzene		120	160	200	270	ID	ID	ID	ID
1,3-dichlorobenzene		160	260	350	520 [C]	ID	ID	ID	ID
1,4-dichlorobenzene		40	60	75	100	ID	ID	ID	ID
1,2,3-trichlorobenzene	B	3	10	16	30 [C]	ID	ID	ID	ID
1,2,4-trichlorobenzene	B	85	170[C]	220[C]	300[C]	20	80	140	240
1,3,5-trichlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,4-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,3,5-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1,2,4,5-tetrachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobenzene	B	ID	ID	ID	ID	ID	ID	ID	ID
1-chloronaphthalene		ID	ID	ID	ID	ID	ID	ID	ID
Polychlorinated Biphenyls (PCBs) & Dioxins									
Capacitor 21	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1016	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1221	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1232	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1242	B	0.3	0.6	1.0	1.7	ID	ID	ID	ID
Aroclor 1248	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1254	B	0.01	0.03	0.07	0.2	ID	ID	ID	ID
Aroclor 1260	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1262	B	ID	ID	ID	ID	ID	ID	ID	ID
Aroclor 1268	B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4'-trichlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
4,4'-dichlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
2,2',4,5,5'-pentachloro-1,1'-biphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
2,4,6,2',4',6'-hexachlorobiphenyl	B	ID	ID	ID	ID	ID	ID	ID	ID
Total PCBs	B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,7,8-TCDD	B	ID	ID	ID	ID	ID	ID	ID	ID
PHENOLS and XYLENOLS									
Phenol		85	320	600	1200 [C]	270	400	520	720
2,4-dimethylphenol		ID	ID	ID	ID	ID	ID	ID	ID
Nonylphenol		ID	ID	ID	ID	ID	ID	ID	ID
2-chlorophenol	T	340 [C]	490 [C]	630 [C]	870 [C]	ID	ID	ID	ID
3-chlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
4-chlorophenol	T	160	220	280 [C]	360 [C]	ID	ID	ID	ID
2,3-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,4-dichlorophenol	T	120	160 [C]	200 [C]	270 [C]	ID	ID	ID	ID

Chemical		Trigger values for freshwater (µgL-1)				Trigger values for marine water (µgL-1)			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
2,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,6-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,4-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
3,5-dichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,5-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,3,6-trichlorophenol	T	ID	ID	ID	ID	ID	ID	ID	ID
2,4,5-trichlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,4,6-trichlorophenol	T,B	3	20	40	95	ID	ID	ID	ID
2,3,4,5-tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
2,3,4,6- tetrachlorophenol	T,B	10	20	25	30	ID	ID	ID	ID
2,3,5,6- tetrachlorophenol	T,B	ID	ID	ID	ID	ID	ID	ID	ID
Pentachlorophenol	T,B	3.6	10	17	27 [A]	11	22	33	55 [A]
Nitrophenols									
2-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
3-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
4-nitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
2,4-dinitrophenol		13	45	80	140	ID	ID	ID	ID
2,4,6-trinitrophenol		ID	ID	ID	ID	ID	ID	ID	ID
ORGANIC SULFUR COMPOUNDS									
Carbon disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Isopropyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
n-propyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Propyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Tert-butyl sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Phenyl disulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(dimethylthiocarbamyl)sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Bis(diethylthiocarbamyl)disulfide		ID	ID	ID	ID	ID	ID	ID	ID
2-methoxy-4H-1,3,2-benzodioxaphosphorium-2-sulfide		ID	ID	ID	ID	ID	ID	ID	ID
Xanthates									
Potassium amyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium hexyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Potassium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium ethyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isobutyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium isopropyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
Sodium sec-butyl xanthate		ID	ID	ID	ID	ID	ID	ID	ID
PHTHALATES									
Dimethylphthalate		3000	3700	4300	5100	ID	ID	ID	ID
Diethylphthalate		900	1000	1100	1300	ID	ID	ID	ID
Dibutylphthalate	B	9.9	26	40.2	64.6	ID	ID	ID	ID
Di(2-ethylhexyl)phthalate	B	ID	ID	ID	ID	ID	ID	ID	ID
MISCELLANEOUS INDUSTRIAL CHEMICALS									
Acetonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Acrylonitrile		ID	ID	ID	ID	ID	ID	ID	ID
Poly(acrylonitrile-co-butadiene-co-styrene)		200	530	800 [C]	1200 [C]	200	250	280	340
Dimethylformamide		ID	ID	ID	ID	ID	ID	ID	ID
1,2-diphenylhydrazine		ID	ID	ID	ID	ID	ID	ID	ID
Diphenylnitrosamine		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorobutadiene		ID	ID	ID	ID	ID	ID	ID	ID
Hexachlorocyclopentadiene		ID	ID	ID	ID	ID	ID	ID	ID

Chemical		**Trigger values for freshwater (μgL^{-1})**				**Trigger values for marine water (μgL^{-1})**			
		Level of protection (% species)				**Level of protection (% species)**			
		99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
Isophorone		ID	ID	ID	ID	ID	ID	ID	ID
ORGANOCHLORINE PESTICIDES									
Aldrin	B	ID	ID	ID	ID	ID	ID	ID	ID
Chlordane	B	0.03	0.08	0.14	0.27 [C]	ID	ID	ID	ID
DDE	B	ID	ID	ID	ID	ID	ID	ID	ID
DDT	B	0.006	0.01	0.02	0.04	ID	ID	ID	ID
Dicofol	B	ID	ID	ID	ID	ID	ID	ID	ID
Dieldrin	B	ID	ID	ID	ID	ID	ID	ID	ID
Endosulfan	B	0.03	0.2 [A]	0.6 [A]	1.8 [A]	0.005	0.01	0.02	0.05 [A]
Endosulfan alpha	B	ID	ID	ID	ID	ID	ID	ID	ID
Endosulfan beta	B	ID	ID	ID	ID	ID	ID	ID	ID
Endrin	B	0.01	0.02	0.04 [C]	0.06 [A]	0.004	0.008	0.01	0.02
Heptachlor	B	0.01	0.09	0.25	0.7 [A]	ID	ID	ID	ID
Lindane		0.07	0.2	0.4	1.0 [A]	ID	ID	ID	ID
Methoxychlor	B	ID	ID	ID	ID	ID	ID	ID	ID
Mirex	B	ID	ID	ID	ID	ID	ID	ID	ID
Toxaphene	B	0.1	0.2	0.3	0.5	ID	ID	ID	ID
ORGANOPHOSPHORUS PESTICIDES									
Azinphos methyl		0.01	0.02	0.05	0.11 [A]	ID	ID	ID	ID
Chlorpyrifos	B	0.00004	0.01	0.11 [A]	1.2 [A]	0.0005	0.009	0.04[A]	0.3 [A]
Demeton		ID	ID	ID	ID	ID	ID	ID	ID
Demeton-S-methyl		ID	ID	ID	ID	ID	ID	ID	ID
Diazinon		0.00003	0.01	0.2 [A]	2 [A]	ID	ID	ID	ID
Dimethoate		0.1	0.15	0.2	0.3	ID	ID	ID	ID
Fenitrothion		0.1	0.2	0.3	0.4	ID	ID	ID	ID
Malathion		0.002	0.05	0.2	1.1 [A]	ID	ID	ID	ID
Parathion		0.0007	0.004 [C]	0.01 [C]	0.04 [A]	ID	ID	ID	ID
Profenofos	B	ID	ID	ID	ID	ID	ID	ID	ID
Temephos	B	ID	ID	ID	ID	0.0004	0.05	0.4	3.6 [A]
CARBAMATE & OTHER PESTICIDES									
Carbofuran		0.06	1.2 [A]	4 [A]	15 [A]	ID	ID	ID	ID
Methomyl		0.5	3.5	9.5	23	ID	ID	ID	ID
S-methoprene		ID	ID	ID	ID	ID	ID	ID	ID
PYRETHROIDS									
Deltamethrin		ID	ID	ID	ID	ID	ID	ID	ID
Esfenvalerate		ID	0.001*	ID	ID	ID	ID	ID	ID
HERBICIDES & FUNGICIDES									
Bypyridilium herbicides									
Diquat		0.01	1.4	10	80 [A]	ID	ID	ID	ID
Paraquat		ID	ID	ID	ID	ID	ID	ID	ID
Phenoxyacetic acid herbicides									
MCPA		ID	ID	ID	ID	ID	ID	ID	ID
2,4-D		140	280	450	830	ID	ID	ID	ID
2,4,5-T		3	36	100	290 [A]	ID	ID	ID	ID
Sulfonylurea herbicides									
Bensulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Metsulfuron		ID	ID	ID	ID	ID	ID	ID	ID
Thiocarbamate herbicides									
Molinate		0.1	3.4	14	57	ID	ID	ID	ID
Thiobencarb		1	2.8	4.6	8 [C]	ID	ID	ID	ID
Thiram		0.01	0.2	0.8 [C]	3 [A]	ID	ID	ID	ID
Triazine herbicides									
Amitrole		ID	ID	ID	ID	ID	ID	ID	ID
Atrazine		0.7	13	45 [C]	150 [C]	ID	ID	ID	ID

Chemical	Trigger values for freshwater (µgL-1)				Trigger values for marine water (µgL-1)			
	Level of protection (% species)				Level of protection (% species)			
	99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
Hexazinone	ID	ID	ID	ID	ID	ID	ID	ID
Simazine	0.2	3.2	11	35	ID	ID	ID	ID
Urea herbicides								
Diuron	ID	ID	ID	ID	ID	ID	ID	ID
Tebuthiuron	0.02	2.2	20	160 C	ID	ID	ID	ID
Miscellaneous herbicides								
Acrolein	ID	ID	ID	ID	ID	ID	ID	ID
Bromacil	ID	ID	ID	ID	ID	ID	ID	ID
Glyphosate	370	1200	2000	3600 A	ID	ID	ID	ID
Imazethapyr	ID	ID	ID	ID	ID	ID	ID	ID
Ioxynil	ID	ID	ID	ID	ID	ID	ID	ID
Metolachlor	ID	ID	ID	ID	ID	ID	ID	ID
Sethoxydim	ID	ID	ID	ID	ID	ID	ID	ID
Trifluralin B	2.6	4.4	6	9 A	ID	ID	ID	ID
GENERIC GROUPS OF CHEMICALS								
Surfactants								
Linear alkylbenzene sulfonates (LAS)	65	280	520 C	1000 C	ID	ID	ID	ID
Alcohol ethoxyolated sulfate (AES)	340	650	850 C	1100 C	ID	ID	ID	ID
Alcohol ethoxylated surfactants (AE)	50	140	220	360 C	ID	ID	ID	ID
Oils & Petroleum Hydrocarbons	ID	ID	ID	ID	ID	ID	ID	ID
Oil Spill Dispersants								
BP 1100X	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 7664	ID	ID	ID	ID	ID	ID	ID	ID
Corexit 8667		ID	ID	ID	ID	ID	ID	ID
Corexit 9527	ID	ID	ID	ID	230	1100	2200	4400 A
Corexit 9550	ID	ID	ID	ID	ID	ID	ID	ID

Notes: Where the final water quality guideline to be applied to a site is below current analytical practical quantitation limits, see Section 3.4.3.3 for guidance.

Most trigger values listed here for metals and metalloids are *High reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3 for reference to Volume 2). The exceptions are *Moderate reliability* for freshwater aluminium (pH >6.5), manganese and marine chromium (III).

Most trigger values listed here for non-metallic inorganics and organic chemicals are *Moderate reliability* figures, derived from acute LC_{50} data (see 3.4.2.3 for reference to Volume 2). The exceptions are *High reliability* for freshwater ammonia, 3,4-DCA, endosulfan, chlorpyrifos, esfenvalerate, tebuthiuron, three surfactants and marine for 1,1,2-TCE and chlorpyrifos.

* = *High reliability* figure for esfenvalerate derived from mesocosm NOEC data (no alternative protection levels available).

A = Figure may not protect key test species from acute toxicity (and chronic) — check Section 8.3.7 for spread of data and its significance. 'A' indicates that trigger value > acute toxicity figure; note that trigger value should be <1/3 of acute figure (Section 8.3.4.4).

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (see Sections 8.3.3.4 and 8.3.5.7).

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) — check Section 8.3.7 for spread of data and its significance. Where grey shading and 'C' coincide, refer to text in Section 8.3.7.

D = Ammonia as TOTAL ammonia as [NH_3-N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2.

E = Chlorine as total chlorine, as [Cl]; see Section 8.3.7.2.

F = Cyanide as un-ionised HCN, measured as [CN]; see Section 8.3.7.2.

G = Sulfide as un-ionised H_2S, measured as [S]; see Section 8.3.7.2.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3).

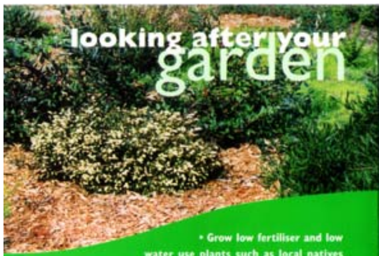
J = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is the issue of concern.

ID = Insufficient data to derive a reliable trigger value. Users advised to check if a low reliability value or an ECL is given in Section 8.3.7.

T = Tainting or flavour impairment of fish flesh may possibly occur at concentrations below the trigger value. See Sections 4.4.5.3/3 and 8.3.7.

APPENDIX G

Education Campaign Material Examples



looking after your garden

- Grow low fertiliser and low water use plants such as local natives
- Minimise the use of deciduous trees as their falling leaves may enter stormwater drains contributing to nutrient problems in waterways
- Group plants with similar water/fertiliser/shade requirements
- Plant deep rooted perennials rather than annuals
- Mulch garden beds. This will reduce watering and therefore the amount of nutrients seeping through soil and into groundwater.
- Take care when using animal manures. They generally have nutrient ratios (N:P:K) of 3:1:1 and thus are relatively high in phosphorus.

Pesticides

Pesticides include fungicides, insecticides and herbicides and should be considered the last option.

Excessive and repeated pesticide application can build up resistance in the pest, making the pesticide less effective. Also, residues may seep into groundwater or be carried in surface run-off.

If you use the right fertiliser, in the right amount, at the right time, with the right amount of water, our wetlands and rivers would like to thank you.

PRINTED ON RECYCLED GLOSS

For more information please contact:

ALGAE BUSTER

PHOSPHORUS ACTION GROUP

Canning Catchment Coordinating Group
Phosphorus Awareness Project Coordinator
40 Edgeware Street
Lynwood WA 6147
Phone/Fax: (08) 9258 3493

Please refer to the Water Corporation's website for their Waterwise Guides.
www.watercorporation.com.au/water-saving

Look out for the 'Fertiliser Guide' in your local nursery or garden centre for more specific information about your soil type.

Natural Heritage Trust

River FRIENDLY Lawns and Gardens

Home lawns and gardens are a major source of nutrients entering wetlands and the Swan and Canning Rivers. Excessive nutrients in wetland and river systems lead to algal blooms.

By following the guidelines outlined in this pamphlet, you will not only be helping to keep our wetlands and rivers healthy but also saving your time and money.

fertilise wise

Excess fertiliser used in YOUR garden will eventually find its way into YOUR wetlands and rivers via the stormwater drainage system or through the soil into groundwater.

Nutrients are essential for plant growth but excess application can cause nutrient enrichment of rivers, estuaries, lakes and wetlands resulting in algal blooms.

- When you fertilise, fertilise wise
- Fertilise only when symptoms of nutrient deficiency occur (eg. yellowing)
- Aim for lawn to have a uniform pale green colour with an even growth rate
- If fertiliser is needed it should be applied in spring when grass grows rapidly. It should be applied in small quantities to avoid wastage, leaching into groundwater and run-off into waterways. Avoid applying fertilisers just before and during winter when applied nutrients will largely be washed into stormwater drains.
- In suburbs near lakes or wetlands, bore water may contain sufficient nutrients so that fertilisers are not needed. Check with the local Council or have bore water analysed.
- Most of the soils on the Swan Coastal Plain contain a surplus of phosphorus and a deficiency in nitrogen.

ESTABLISHING A New Lawn

The establishment stage is vital for both the lawn and the environment because root systems are immature and have minimal water and nutrient collection capacity.

- Minimise areas of lawn at the design stage
- Choose a water efficient and drought tolerant lawn eg. Couch, Saltene, Kikuyu or Buffalo
- Add organic matter and/or loam or clay to sandy soils to improve water and nutrient retention
- Incorporate a complete trace element mix prior to planting to improve the soil
- Frequently apply SMALL amounts of water until deep roots are established
- The MAXIMUM amount of general purpose lawn fertiliser that should be applied to Couch is 20-30g/m^2 and for Kikuyu 10-15g/m^2. Apply in small amounts, every 4-6 weeks in spring. A handful of fertiliser is about 50 grams.
- Fertiliser application should be drastically reduced once the lawn is established. In most areas use a fertiliser with ratios of Nitrogen to Phosphorus to Potassium (N:P:K) around 10:1:5
- Spring is the best time to establish a new lawn.

looking after your lawn

- Apply chemicals and water as set out in this guide
- Lawn growth is affected by fertiliser and water applications, the more you apply the more you need to mow. Consider reducing your lawn area to save money, time and water.

Alternatives could be:

- native gardens that attract wildlife and require little maintenance
- paved areas
- gravel.

Don't let grass clippings, leaves and soil, which are rich in nutrients, enter stormwater drains. They can be composted or put into green waste bins provided by some councils.

water wise

- Water at the coolest time of the day, which is early in the morning before 9am or after 6pm
- Do not water during the heat of the day
- If necessary, use a good soil wetting agent in spring to prevent fertiliser run-off to stormwater drains. Application rates should be in accordance with the manufacturer's instructions.
- Overwatering or watering at night can cause fungal problems
- Reticulate lawns separately from garden areas
- Use good quality sprinklers that deliver a uniform spray of coarse droplets
- Lawns should receive only a 'standard drink' (10mm depth of water on sandy soil) each time they are watered. 'Waterwise Catchcups' can be used to determine how long to water your lawn and can be obtained free from irrigation retailers.

Frequency of water should be as follows to avoid overwatering and wastage.

Month	Frequency
Jan/Feb	Every second day
Mar	Every third day
Apr	Every fifth day
May/June/July	No watering
Aug	Once a fortnight (if needed)
Sept	Once a week (if needed)
Oct	Every fourth day
Nov	Every third day
Dec	Every second day

Note: If water restrictions apply, you must comply with these restrictions.

Every year more than 6 million tonnes of rubbish is dumped into the world's oceans.

Much of this rubbish is plastic waste such as bags, bottles, synthetic ropes and fishing nets, which are discarded by ships at sea, by fishermen, coastal communities, particularly large urban communities and holidaymakers.

While plastic products can benefit the environment and consumers, when not properly disposed, plastic waste can be harmful and even deadly to marine life.

Turtles, whales and sea birds can mistake it for food or get entangled in it, causing painful injuries.

The plastic problem

In every square mile of ocean it is estimated that there are over 46,000 pieces of plastic.

The plastic originates from both land and marine activities and includes plastic bags, abandoned fishing nets and lines and other solid waste such as polystyrene packaging material.

Of all the marine debris washed, dumped or blown into the ocean, more than 70 per cent is plastic.

Photo: Norbert Wu / ANTphoto.com.au

Photo: Frank Park / ANTphoto.com.au

The threat to wildlife

A wide array of marine creatures, including threatened species such as Green Turtles, Loggerhead Turtles, Blue Whales and Humpback Whales, albatrosses and petrels, may be severely injured and even die after ingesting and becoming entangled with plastic waste.

Fishing line, fragments of trawl netting, and synthetic ropes can cut into their skin, leading to infection or the slow and painful amputation of flippers, tails or flukes.

Seabirds caught in marine debris may also be prevented from moving quickly through the water, reducing their ability to catch prey and avoid predators. They can also suffer constricted circulation, asphyxiation and death.

Seabirds are also known to eat polystyrene balls and plastic buoys after confusing them with sea eggs or crustaceans, leading to fatal consequences.

What can you do?

If you accumulate plastic waste – whether on land or water – make sure you dispose of it in appropriate bins and recycling facilities.

Never throw it into the ocean, rivers or waterways where it can harm marine life.

And remember, plastic dumped on land can be blown long distances or carried along waterways where it eventually ends up in the ocean.

Our marine and aquatic environments are magical places, so keep them that way by being more responsible with plastic.

Photo: courtesy of Melbourne Zoo

Photo: Kelvin Aitken / ANTphoto.com.au

Keep the sea plastic free.

For more information please visit www.deh.gov.au/plasticdebris

Natural Heritage Trust

Helping Communities Helping Australia

An Australian Government Initiative

Bin it.

Cover photo: Dr Col Limpus

Keep the sea plastic free.

Bin it.

There are some simple things that we can all do to prevent the spread of weeds.

- ☑ Check:
  - clothing & camping equipment,
  - boat motors,
  - trailers,
  - other recreational equipment before leaving an area.
- ☑ Leave weed seeds and fragments in the weed infested area, burn them in a camp fire, or bag and dispose them responsibly.
- ☑ Stay on marked tracks.
- ☑ Sweep your tent or swag out at each location.
- ☑ Don't sweep your horse float out in the bush.

You can also help combat the introduction and spread of weeds in your State by becoming familiar with your State/Territory weed lists.

"weed prevention is the intention"

For further information contact your local council office, agriculture, conservation, land management, primary industries or natural resources state government department.

WEEDBUSTERS

WEEDBUSTER WEB SITE
www.weedbusterweek.info.au

NATIONAL WEEDS STRATEGY
ENVIRONMENT ACT
NSW Agriculture
CRC Weed management systems
PRIMARY INDUSTRIES AND RESOURCES SA
CSIRO
Natural Heritage Trust
Queensland Government
Tasmania
Agriculture
URBAN SERVICES
Natural Resources and Environment

THIS IS A NATIONAL WEED AWARENESS PRODUCT.

make sure your recreational activities don't spread weeds

make sure your recreational activities don't spread weeds

It is a shame our passion for outdoor recreational activities can contribute to the introduction and spread of weeds which are now considered one of Australia's worst environmental and agricultural problems. But there is hope if we do some simple things to prevent their spread.

The things that we love doing and are healthy for us, like bush walking, camping, fishing or trail-bike riding, can contribute to the weed problem. Weed seeds can be accidentally dispersed by humans by sticking to camping gear, boots, clothing, vehicle radiators, vehicle tyres, boat motors & trailers.

Weed seeds can also pass through the gut of stock or pets, risking further spread.

Human activities can also contribute to the spread or establishment of weeds when vegetation or soil is disturbed.

Weeds are not just a problem for pastoralists or farmers. They also invade natural areas such as National Parks and bushland. Weeds take the place of desirable plants and animal habitats, degrade land for livestock, agriculture, recreation, conservation and forestry. They may cause injury to livestock and affect human health.

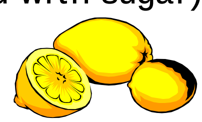
"weed prevention is the intention"

Alternative Cleaners

There are cleaners that you can use in your home which are not harmful to the environment or your family. Here are seven cleaning aids that are appropriate for use in your home. Always test the cleaner on a small area first to make sure that there are no unexpected reactions on the material being cleaned.

Bicarbonate of Soda (bicarb, soda, cooking soda, baking soda)
This can clean just about anything including: plastic surfaces, cups and plates, metals such as brass or copper, baths and basins, toilets, the oven, pots and pans, carpet, teeth, refrigerator smells and nappies. It is also good for indigestion. Note: Do not wet the powder or it won't work. Use a damp cloth to rub the bicarb over the surface.

Borax (sodium borate)
Borax comes from sodium borate which is found in the ground, dug up and then purified. Borax is poisonous so be careful with it. It can be used for removing mould and mildew, enamel surfaces such as basins and tiles, concrete paths, removing stains, fabric softener and eradicating ants (when mixed with sugar).

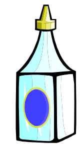


Lemon (lime also)
Lemon contains citric acid that is great for cleaning and bleaching things. It leaves a fresh smell and can be used to clean and brighten plates, cutlery, glasses, chopping boards, furniture, copper and nappies.

Salt (sodium chloride- cooking salt is a coarser abrasive than table salt)
Salt may be used as a disinfectant to bathe cuts and grazes, and clean chopping boards. It is also an abrasive to polish brass and copper and any other surface where you normally use an abrasive cleaner.

Soap

A gel made from grated or left over pieces of soap is great for washing hair, clothes and dishes. Avoid using scented soaps, and try to buy in bulk to avoid excess packaging.



Vinegar (white is best)

All vinegars contain acetic acid, which is the cleaning ingredient. White vinegar is the best to use for cleaning, as it is colourless. Vinegar is good for cleaning glass, chrome, tiles, slate, lino and cork floors, brass and copper, windows, mouldy surfaces, baths, toilets and basins. It is even good with fish and chips!!

Washing Powder (sodium carbonate)

Washing powder is a natural substance called sodium carbonate. It may be used as a water softener. It is also used to clean away grease, so walls and other painted areas, pots and pans and blocked drains are a specialty.

Alternative Cleaner Recipes

Window and Lino Cleaner

Mix equal parts of vinegar and warm water.

Furniture Polish

Mix two parts of vegetable oil to one part lemon juice. Great on all wooden furniture.

Scouring Powder

Mix equal parts of bicarb soda and salt. Great for any surface where you need an abrasive cleaner.

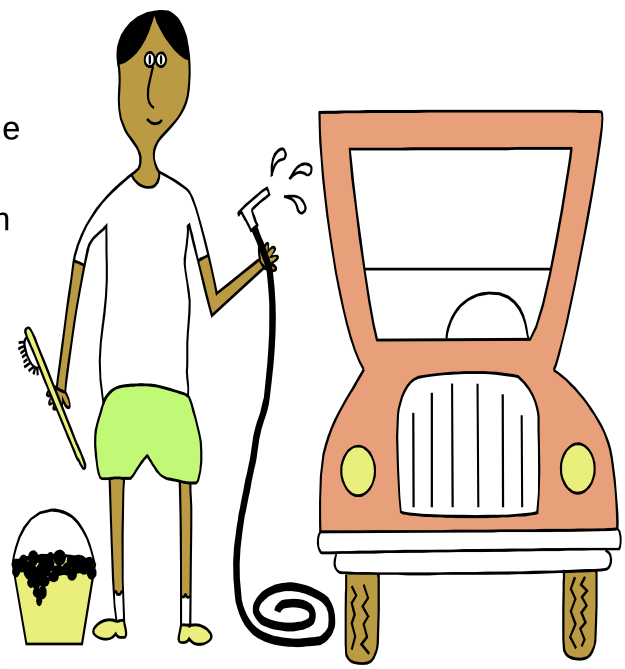
Adapted from the Lismore City Council Phosphorus Education Project, 1998.
Produced as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare, 2003.
For more information please contact Amy on 9458 5664.

Car Washing –
The Environmentally Friendly Way

Cars that are washed on the driveway or other hard surfaces can pollute our rivers and wetlands. The soapy water that runs off from the car can go down our street drains. This waste water contains detergents and dirt which contribute nutrients, such as phosphorus, to our waterways. Nutrients cause algal blooms which can devastate animal and plant species living in the waterways and prevent recreational use of the rivers.

It is easy to wash your car in an environmentally friendly way that will not only reduce algal blooms in our rivers and wetlands but save precious water as well.

Where to Wash Your Car



- Wash your car on the lawn where the water and nutrients from the detergent can be used by the lawn to grow.
- Ensure that the water does not run off the lawn and on to the street where it can go down our street drains and into rivers and wetlands.
- If you don't have a lawn at home, then find an alternative location such as at a friends or neighbours.
- Take your car to a commercial car wash, they treat waste water before disposing of it to sewer and many recycle and reuse the water.
- The 'do it yourself' car wash bays use less water and detergent than automatic car washes.

When You Wash Your Car

- Use a bucket and save our precious water. This also results in water and detergent not running off the lawn and into street drains.
- If using a hose switch if off when not rinsing or use a trigger hose.
- Use detergents sparingly and ensure they are phosphorus free.
- An even better option is to just use water, one of the many fibre technology cleaning cloths and some elbow grease.
- Dispose of waste water onto your garden or lawn.
- Don't wash your car!! (or consider washing your car only once a month).

Produced as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare, 2004. For more information please contact Amy on 9458 5664.

Don't let your dog be the downfall of our rivers

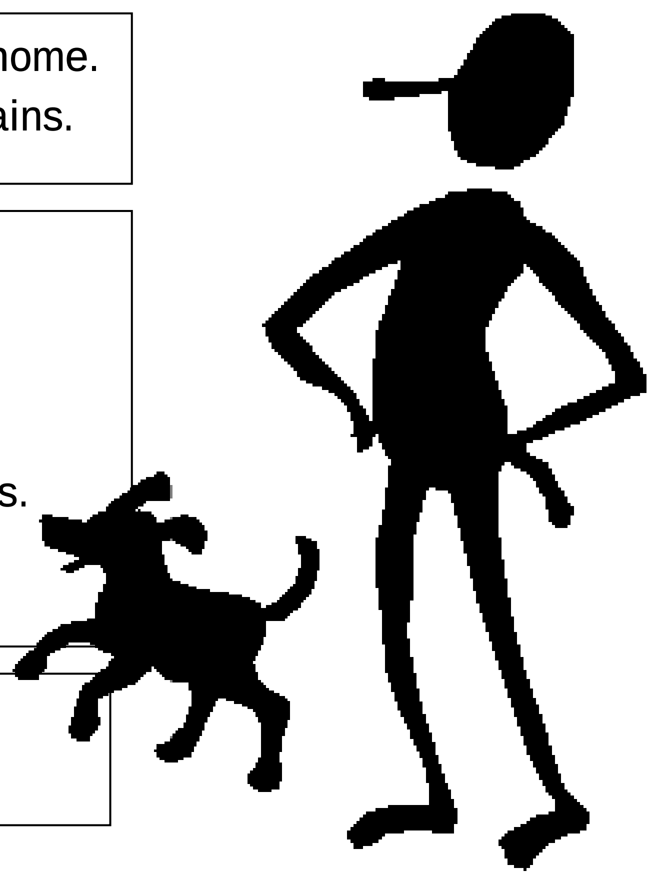
The population of domestic pets in residential areas makes a significant contribution to phosphorus and other nutrient loads in the catchment. For residential areas, estimates of 10 to 20% of phosphorus loads are from pet faeces, with the remainder mainly from garden fertilisers.

There are steps you can take to reduce the phosphorus input that your pet makes to the river and thus the incidence of algal blooms.

Pick up after your dog on walks and at home. Don't let droppings get into street drains.

Worm farms are an excellent way to compost what you collect. Worm composters turn your dog's droppings into nutrient rich, odourless, pH neutral, worm castings. This is the best form of soil conditioner known.

Alternatively, put your pet's droppings in your rubbish bin.



Produced as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare, 1999.

For more information please contact Amy on 9458 5664.

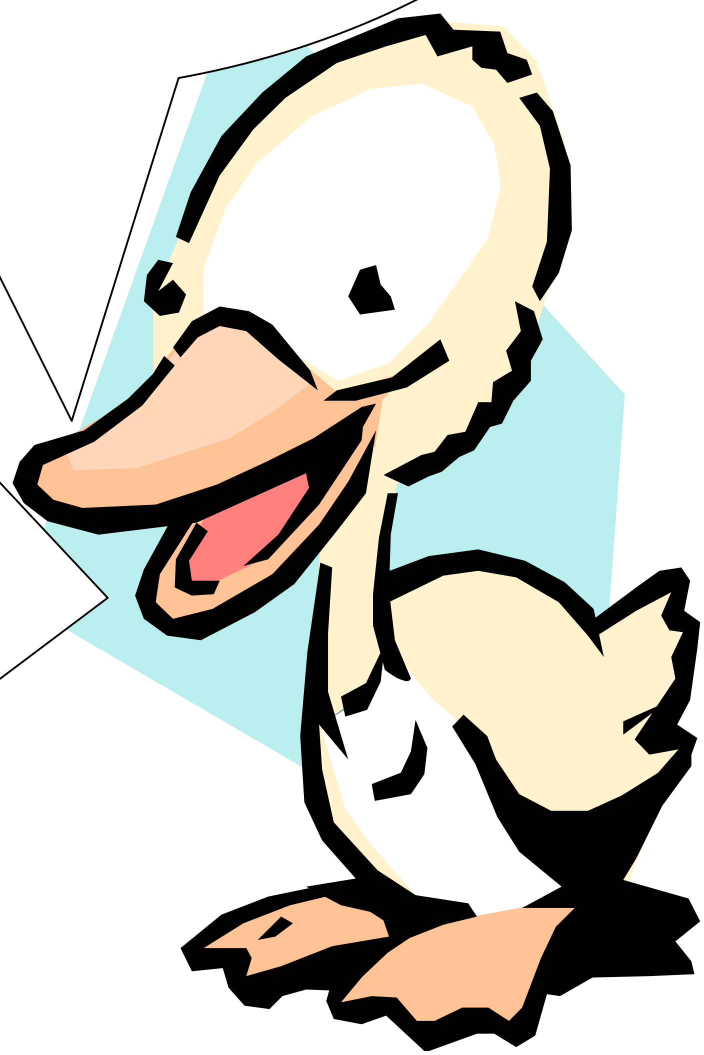
Please Don't Feed Us

The bread that you feed us contains between one and two grams of phosphorus. This is enough to make a volume of lake water the size of a backyard swimming pool nutrient rich. A lake is considered nutrient rich (able to support an algal bloom) when available phosphorus in the water rises above only 0.02 grams per cubic metre.

Algal blooms in lakes also encourage midge to breed.

Remember, nutrient rich water from lakes may end up in a river.

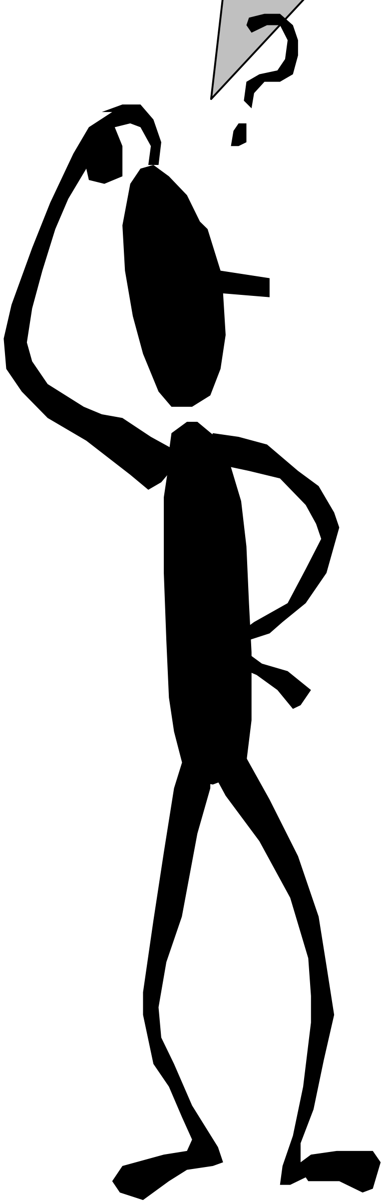
Bread also makes us very sick. We become reliant on bread and thus do not eat our natural food. This can cause malnutrition and disease as only one type of food is being eaten. Bread does not contain the right balance of nutrients to keep us alive. It can also cause us to starve when there is no bread around for us to eat. If you must feed us we really like snails and worms.



Compiled as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare, 2001. For more information please contact Amy on 9458 5664.

Green Lawns = Green Rivers

We are drastically over-fertilising our lawns & gardens



Most fertilisers contain phosphates and other nutrients, which eventually find their way into the rivers via the stormwater drainage system or through the soil into groundwater.

Only low levels of phosphorus can be retained in Perth's porous, sandy soils, as they contain low amounts of metals, clay, silt, and organic matter needed to bind the phosphorus. This allows phosphates to become mobile, and a high percentage is then leached into ground and surface waters. This phosphorus then feeds algal blooms in our rivers.

Even in areas of the catchment where soil is heavy clay and phosphorus retention is greater there are still problems. Surface run-off and soil erosion causes the release of phosphorus into the river.

Garden wastes also contain phosphorus that can enter river systems and feed algal blooms.

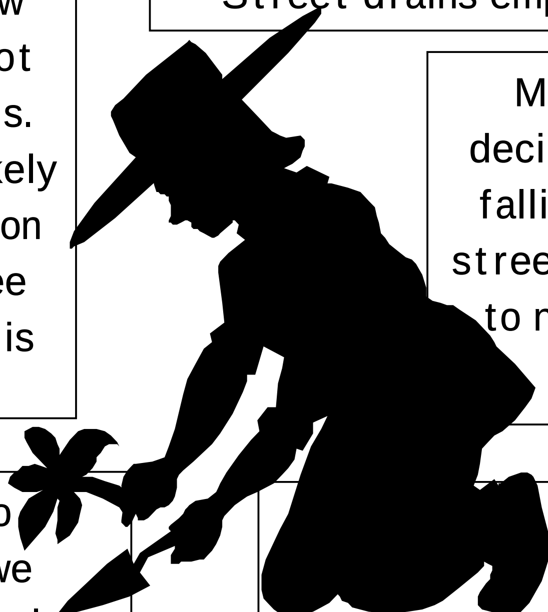
HOWEVER, THERE IS HOPE!

With improved garden practices, phosphorus levels can be reduced dramatically.

Turn page over to find out how...

Fertiliser applications to lawns can be stopped until symptoms of nutrient deficiency occur, such as yellow patches. This may not occur for many years. When it does, it is likely that a light application of a phosphorus free fertiliser is all that is needed.

Sweep paved areas rather than hosing them. Prevent soil, grass clippings, leaves and other garden waste from entering street drains as they contain P. Street drains empty into our rivers.



Minimise the use of deciduous trees as their falling leaves may enter street drains contributing to nutrient problems in waterways.

If we do need to apply fertiliser, we should use it sparingly in spring and autumn when grass grows rapidly. Applying it in winter is silly as heavy rains flush fertilisers from soils to waterways. This also wastes fertiliser!

If fertilising garden plants, use organic fertilisers and apply sparingly. Worm farms, composting and mulching of grass clippings and plant wastes recycle nutrients back to gardens. Adding compost and mulch to gardens also improves nutrient and water holding capacity of soils.

Grow plants that are already adapted to our soils and harsh local conditions. That is, grow local native plants rather than European or other exotic plants with high nutrient requirements. After all, local natives save water and attract birds and other wildlife to our gardens.

ALGAE BUSTER

PHOSPHORUS ACTION GROUP

Become a volunteer in the campaign to reduce phosphorus levels in our rivers. For more information telephone Amy on 9458 5664.

Produced as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare.

Use phosphorus free detergents

Most household detergents contain high levels of phosphorus, which endanger our rivers. In unsewered areas in particular, phosphorus from detergents eventually ends up in groundwater, creeks, wetlands and rivers via stormwater drains. This feeds algal blooms in these waterways.

It's so *easy* to reduce phosphorus use at home and help ease the phosphorus load and threat to our rivers.

Buy products which <u>do not</u> contain P

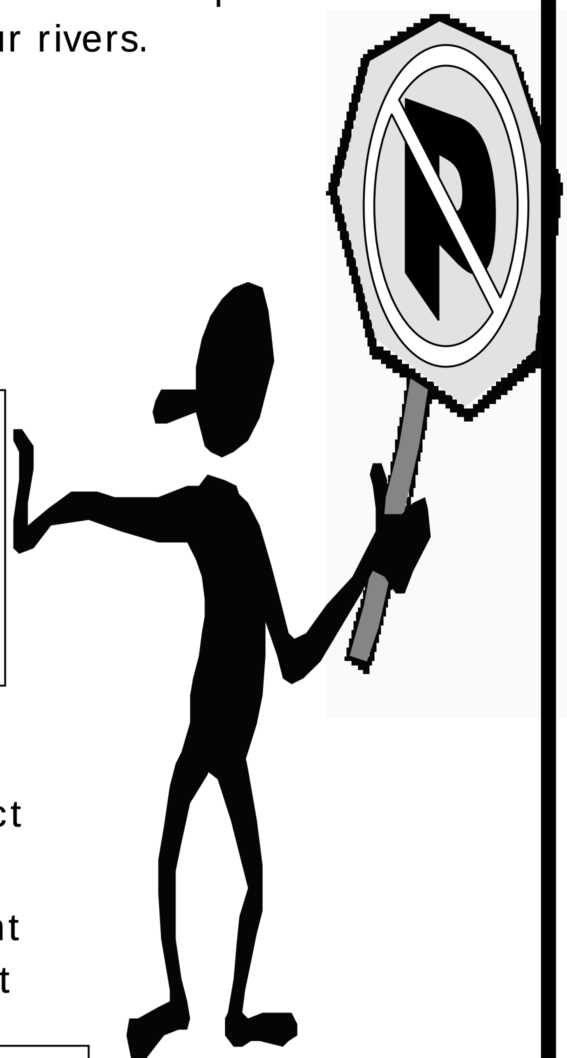
Look for these words:

- zeolite
- alternative builders
- phosphorus or phosphate free

Avoid products containing P

Look for these words:

- STPP (sodium tri-polyphosphates)
- polyphosphates
- phosphate builders



NP	Means there is NO PHOSPHORUS in the product
P	Means there is a small amount of phosphorus in the product

Remember, biodegradable does not mean P free

Produced as part of the Phosphorus Awareness Project by the South East Regional Centre for Urban Landcare.

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