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URBAN WATER MANAGEMENT FOR WESROC, A LOCAL GOVERNMENT GROUP IN WESTERN AUSTRALIA

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ABSTRACT

Many local authorities in Australia have developed a Stormwater Management Plan relevant to their local area. In areas where both groundwater and surface water discharge pollutants to the environment, the term Urban Water Management Plan may be more appropriate. In the western suburbs of Perth Western Australia a group of local authorities commissioned preparation of a Regional Stormwater Strategy to give direction to their individual efforts. Although the local authorities share boundaries, there was a diverse history of water management, ranging from reliance from infiltration almost exclusively in one local authority, to a main drainage system with ocean outfall in an adjacent authority. The Strategy devised therefore had to take into account both surface water and groundwater pollution potential and solutions. This paper describes the Strategy and techniques used to identify priority areas at both a local and regional scale. The need for Best Management Practices (BMP's) to consider land use constraints and existing drainage infrastructure is discussed, particularly where landuse is already largely urban with little opportunity for additional area to be made available for water quality treatment. The applicability of this regional approach to other areas is discussed.

1. INTRODUCTION

The views expressed in this paper are those of the authors and do not necessarily represent those of individual Councils, or the Western Suburbs Regional Organisation of Councils (WESROC).

The Western Suburbs Regional Organisation of Councils (WESROC) comprises of the local governments of the Cities of Nedlands and Subiaco, Towns of Claremont, Cottesloe and Mosman Park, and the Shire of Peppermint Grove. The Town of Cambridge although not a formal member of WESROC is a contributing participant for this study. Together with the Swan River Trust (SRT), Water & Rivers Commission (WRC) and the Department of Environmental Protection (DEP), WESROC identified the need for better management of stormwater quality and to address the associated strategic issues on a broad catchment basis.

The development of a strategy was commissioned by WESROC, to draw together issues concerning the collection and disposal of stormwater with the aim of managing the quality of stormwater discharging into the Swan River, Indian Ocean, local wetlands, and the groundwater system, to provide a framework for a co-ordinated approach to improving stormwater quality.

This paper describes the development of the Strategy.

2. STUDY AREA CHARACTERISTICS

The Study Area comprises of approximately 64.4 sq km and is generally bounded by the Indian Ocean to the west, Kings Park and the Mitchell Freeway to the east, Herdsman Lake to the north and the Swan River to the south (Figure 1). The area effectively forms a natural catchment grouping between the Swan River and the ocean. The size of local authorities varies widely from approximately 1.5 sq km for the Shire of Peppermint Grove to 22 sq km for the Town of Cambridge. The elevation typically varies between 0 m and 30 mAHD, with Town of Cambridge's Bold Park in excess of 80 mAHD.

The area has a Mediterranean climate with mild wet winters and hot dry summers. Long term average rainfall is approximately 860 mm although since 1975 average annual rainfall has been 790 mm, representing an 8% reduction. The soils of the area are predominantly derived from calcareous Safety Bay Sand and sands derived from Tamala Limestone, Davidson (1995). Outcrops of Tamala Limestone are evident in the north and south western parts of the Study Area. Localised deposits of peaty clay and peat occur in low lying areas, usually in association with wetlands

Surface drainage comprises of a network of piped local drainage and Water Corporation Main Drainage (Figure 1), which discharge to :

- Swan River
- Indian Ocean
- Lakes (Monger, Herdsman, Jualbup, Claremont, Mabel Talbot, Perry, QE2 Medical Centre)
- Compensating Basins
- Infiltration Basins, Swales, Soakwells.

Maximum recorded groundwater levels vary from 0 mAHD near the coast and river to 14 mAHD on the north east boundary at Lake Monger. Seasonal groundwater variation is typically 1.0 m, and much of the area has considerable depth to groundwater and hence opportunity for infiltration of surface drainage.

Water & Rivers Commission Conservation Category Wetlands (CCW's) within the Study Area are Perry Lakes and Lake Monger (Town of Cambridge), Mabel Talbot and Pelican Point (City of Subiaco), and Lake Claremont (Town of Claremont). There are no CCW's within the City of Nedlands, Towns of Cottesloe and Mosman Park and the Shire of Peppermint Grove. All CCW's apart from Pelican Point are part of the drainage network, and all lakes except Claremont are part of Water Corporation's Main Drainage network.

The majority of land is urban with some pockets of commercial and industrial land associated particularly with town centres. Large areas of POS occur at Perry Lakes and Bold Park in Town of Cambridge. Most urban areas are well established, with new sub-divisions at Mount Claremont (City of Nedlands), Subi Centro (City of Subiaco) and Minim Cove (Town of Mosman Park).

Overall, little data exists regarding stormwater quality for the Study Area. Data available on focuses on sampling the water quality of receiving environments (Perry Lakes, Lake Monger etc) rather than the quality of stormwater inflow. Clearly, water quality management is best addressed at catchment scale which crosses local authority boundaries.

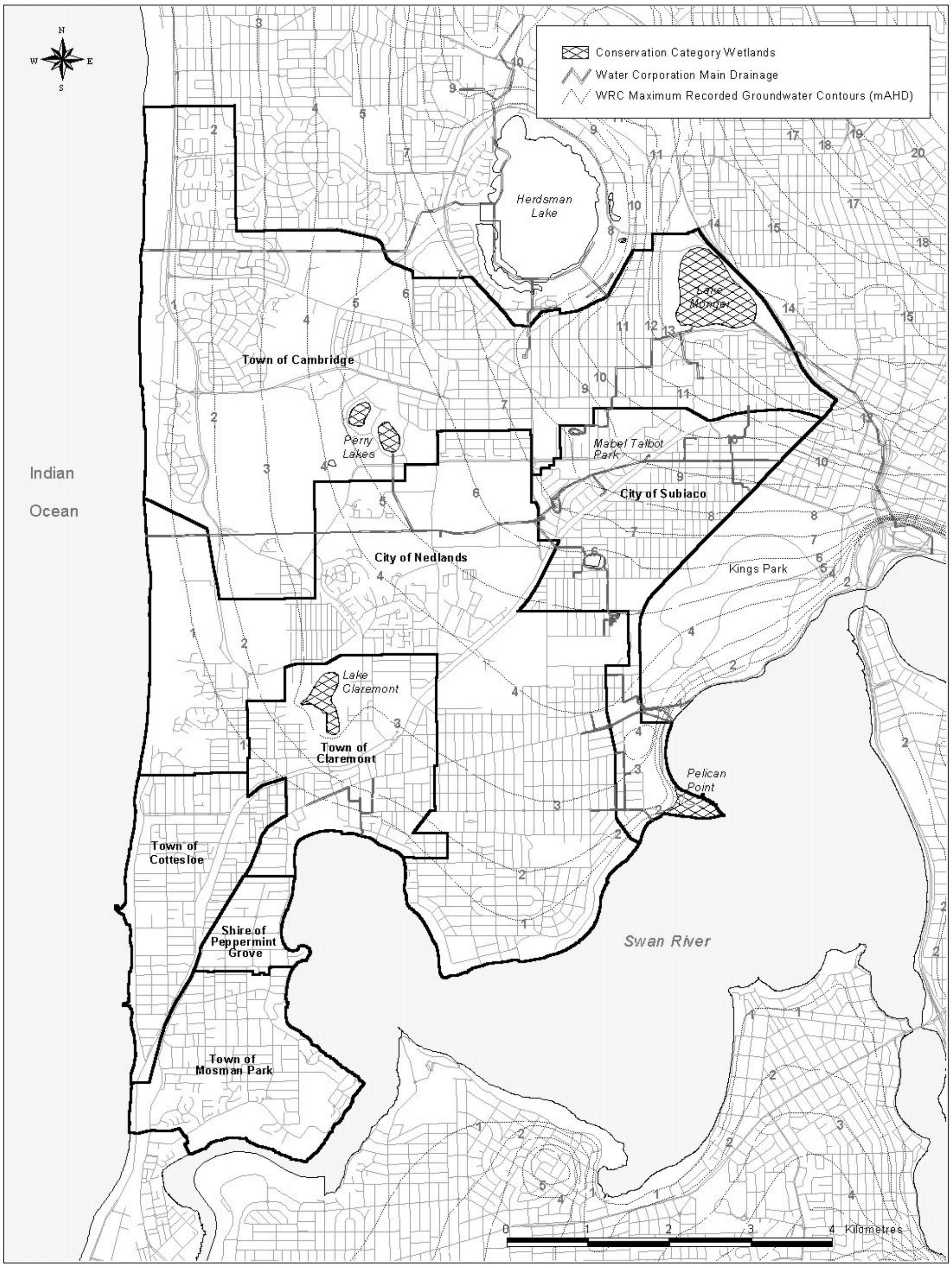

Figure 1 : Study Area

3. WATER QUALITY STANDARDS AND CRITERIA

Currently applicable standards and criteria for stormwater quality are ill-defined at the State Government level in Western Australia. WRC are currently in the process of reviewing its approach to urban stormwater management and it is expected that the outcome of this process will provide a clearer definition of water quality standards and criteria to apply in urban stormwater management. This chapter presents a review of existing documentation, and provides some recommendations toward establishing interim standards and criteria to apply to the Study Area.

3.1 NATIONAL STANDARDS

The National Water Quality Management Strategy (NWQMS) was introduced by the Commonwealth, State and Territory Governments in 1992. 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 with reference to urban stormwater quality management are :

- **Guideline 4 : Australian and New Zealand Guidelines for Fresh and Marine Water Quality**
  The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a) provide a 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. While 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 provided in the guidelines, together with water quality guideline trigger values for toxicants (including metals, pesticides, hydrocarbons, and industrial chemicals) to provide alternative levels of protection.

- **Guideline 7 : Guidelines for Water Quality Monitoring and Reporting (ANZECC, 2000b)**
  These guidelines set an overall framework for the establishment of monitoring programs.

- **Guideline 10 : Guidelines for Urban Stormwater Management (ANZECC, 2000c),**
  These guidelines 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.

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

3.2 WESTERN AUSTRALIAN STANDARDS

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 (Government of WA, 2001) was the first document of a series, which will ultimately form the Western Australian SWQMS.

Key reference documents for stormwater quality in Western Australia include :

- **A Manual for Managing Urban Stormwater Quality in Western Australia (WRC, 1998)**
  This manual, released by WRC in 1998, defines and describes Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems. The Manual does 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. WRC have recently commenced a major review of the Manual, and until the Manual is updated, WRC have encouraged the use of "source control" and "in-transit" control as the primary approach for stormwater quality management.
- **Swan Canning Clean-Up Program Action Plan (SRT, 1999)**
  The Swan Canning Clean-Up Program (SCCP) Action Plan report was released in May 1999 and recommended key strategies in the areas of public health and amenity, ecological function, and setting contaminant targets for both old and new urban and industrial areas. The Action Plan provides general maximum acceptable concentrations for short and long term catchment water quality targets (Nitrogen and Phosphorus), and 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 where WESROC discharges occur are not provided.

3.3 ADOPTED APPROACH

Given the absence of established guidelines at State Government Level, and the general absence of data regarding stormwater quality in the Study Area, the approach recommended for establishment of criteria for water quality management is based on a 4 phase process :

- **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 targets to allow an assessment of performance.

The establishment of targets without first determining existing storm water quality is not recommended as this may lead to a 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.

4. DEVELOPMENT OF REGIONAL DRAINAGE PLANS

Regional drainage plans were developed for each local authority, providing detail of sub catchment boundaries and the drainage flows across local authority boundaries, the location of key drainage facilities (infiltration basins, compensating basins, gross pollutant traps, Water Corporation Main Drainage), and the location of key outlets to the Swan River and Indian Ocean. For calculation purposes, receiving environments for drainage were classified into nine types as follows :

- **Type 1 : Lake**
  Drainage to a lake without an outflow
- **Type 2 : River**
  Drainage directly to Swan River
- **Type 3 : River via Compensating Basin**
  Drainage to the Swan River via a basin
- **Type 4 : Ocean/Dunes**
  Drainage directly to the Indian Ocean
- **Type 5 : Ocean/Dunes via Compensating Basin**
  Drainage to the Indian Ocean via a basin
- **Type 6 : Infiltration Basin/Swale**
  Drainage to a basin or swale
- **Type 7 : Soakwell**
  Drainage by infiltration into soakwells
- **Type 8 : Parks/Reserves**
  Drainage by infiltration in a park or reserve
- **Type 9 : Railway Reserves**
  Drainage by infiltration into railway reserve

Statistics for each local authority was derived using ArcView GIS as summarised in Table 1. Data sourced from individual Authorities was provided in various formats, including MicroStation, AutoCAD, MapInfo and ArcView as well as hard copy maps. Data was imported into ArcView GIS then collated to prepare a drainage overview map for the whole of the Study Area (Figure 2).

With respect to individual local authority areas, results highlighted considerable differences between local authorities drainage systems. The Town of Mosman Park have the highest proportion of area infiltrated at 83%, ranging to the City of Subiaco which infiltrate less than 2% of its area. Conversely, 68% of the total City of Subiaco area is exported to the Indian Ocean via Water Corporation Main Drainage while the Town of Claremont has none. The City of Subiaco has the largest percentage of area which discharges to the Swan River at 31%.

Other key summary statistics resulting from the analysis :

- 45% of the Study Area are in catchments which cross local authority boundaries.
- 52% of the Study Area was found to infiltrate stormwater, 21% to discharge to the Swan River, and 27% to discharge the Indian Ocean, mainly via Water Corporation Main Drainage.
- Dis-aggregating the 21% of the area which discharges to the Swan River, 7% discharges to the River via a compensating basin which provides some opportunity for pre-treatment of discharge, with the remaining 14% discharging directly to the Swan River.
- Almost half of the 14% of total Study Area directly discharging to the Swan River comes from the City of Nedlands. Although Claremont contributes 29% of its total area to the Swan River, in a regional context this equates to only approximately 2% of the total Study Area
- Almost 80% of the area which discharges to the Swan River via compensating basins comes from the Town of Cambridge.
- The City of Subiaco and Town of Cambridge provide the largest area contributions to flow which discharge to the Indian Ocean via compensating basins (16% of total Study Area).
- Infiltration basins and swales were found to be the most common discharge type accounting for 37% of the total Study Area.

- Of the 37% of total area which is infiltrated in basins and swales, the Town of Cambridge and City of Nedlands are the largest contributors providing almost 25% of the total Study Area. While the Town of Cottesloe infiltrates 53% of its area to basins and swales and the Town of Mosman Park 74%, in a regional context this equates to a total of only 8% of the Study Area.

Table 1 : Drainage Overview by Local Authority

Local Authorities	Claremont	Cambridge	Cottesloe	Mosman Park	Subiaco	Nedlands	Peppermint Grove	Total
Local Authority Area (sq km)	4.9	22.0	4.0	4.3	7.1	20.6	1.5	64.4
Total % of Study Area	7.6	34.2	6.2	6.7	11.0	32.0	2.3	100.0
Sub Catchments								
Total [1]	25	40	46	39	10	52	6	218
Sub Catchments receiving flow from another local authority	11	8	2	1	6	15	3	46
Sub Catchments providing flow to another local authority	9	11	3	4	2	19	2	50
Drainage Facilities								
Infiltration Basins [2]	17	24	31	28	0	33	4	137
Compensating Basins [3]	0	4	0	0	5	1	0	10
River Outlets [4]	2	0	0	17	4	12	0	35
Ocean Outlets [5]	0	1	16	0	0	1	0	18
Gross Pollutant Traps	0	0	4	4	1	2	0	11
Discharge as % of Local Authority Area								
Swan River Discharge								
River Direct	29.0	5.9	0.9	16.8	18.8	17.3	43.4	-
River via Comp Basin	0.0	15.1	0.0	0.0	11.8	1.1	0	-
Indian Ocean Discharge								
Ocean/Dunes Direct	0.0	6.5	23.2	0.6	0.0	10.4	0.0	-
Ocean/Dunes via Comp Basin	0.0	24.7	0.0	0.0	67.6	13.5	0.0	-
Groundwater Discharge								
Lake	25.6	0.0	0.0	0.0	0.0	1.8	0.0	-
Infiltration Basin/Swale	35.4	30.8	53.4	74.5	0.1	44.4	54.9	-
Soakwell	6.7	0.0	0.9	2.2	0.0	4.2	0.9	-
Parks/Reserves	0.0	17.0	0.0	3.3	0.0	6.5	0.0	-
Railway Reserve	3.3	0.0	21.6	2.6	1.7	0.8	0.8	-
Discharge as % of Total Study Area								
Swan River Discharge								
River Direct	2.3	2.1	0.1	1.1	2.0	5.5	0.7	13.8
River via Comp Basin	0.0	5.3	0.0	0.0	1.3	0.3	0.0	6.9
Indian Ocean Discharge								
Ocean/Dunes Direct	0.0	2.3	1.4	0.0	0.0	3.3	0.0	7.0
Ocean/Dunes via Comp Basin	0.0	8.7	0.0	0.0	7.5	4.2	0.0	20.4
Groundwater Discharge								
Lake	2.0	0.0	0.0	0.0	0.0	0.6	0.0	2.6
Infiltration Basin/Swale	2.7	10.7	3.3	5.1	0.0	14.0	1.0	36.8
Soakwell	0.5	0.0	0.1	0.2	0.0	1.3	0.0	2.1
Parks/Reserves	0.0	5.9	0.0	0.2	0.0	2.0	0.0	8.2
Railway Reserve	0.3	0.0	1.3	0.2	0.2	0.3	0.0	2.2

Notes :
1. Subcatchment are assigned as part of the local authority into which they discharge. As an exception, the total number of subcatchments in Cambridge includes 3 sub catchments draining to City of Stirling
2. Some sub catchments contain more than 1 infiltration basin
3. In Subiaco, 4 of 5 compensating basins are Water Corporation Main Drainage
4. One river outlet for both Subiaco and Claremont is Water Corporation Main Drainage
5. Cambridge and Nedlands ocean outlets are Water Corporation Main Drainage

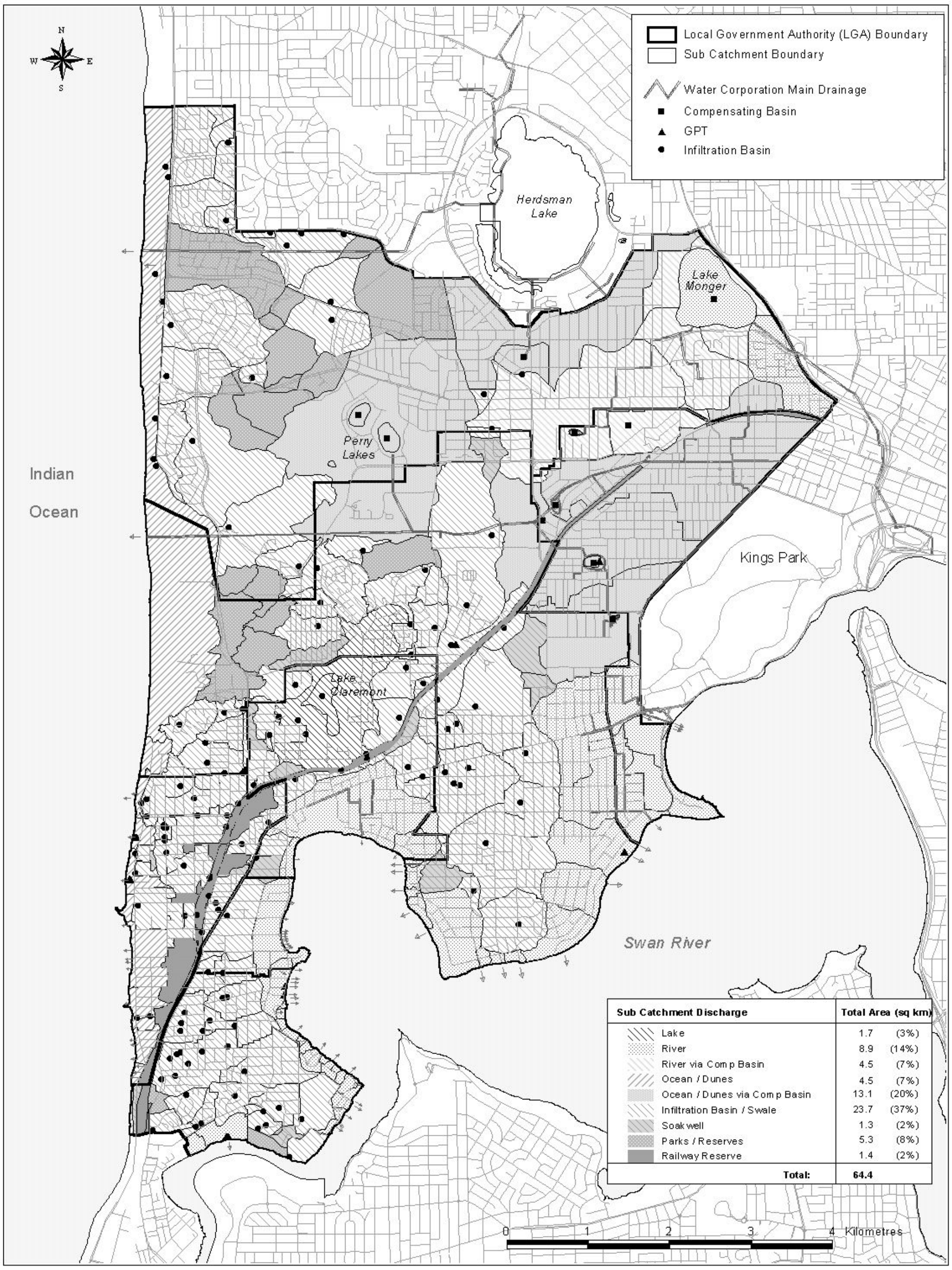

Figure 2: Regional Drainage Plan

Data was also analysed at the regional scale in terms of land use classifications (Table 2). Key findings of this analysis were :

- Accumulating land use into 3 broad categories, residential areas comprise 51% of the total Study Area, industrial/commercial 7%, and parks and recreation 42%.
- Of the 21% of total area which drains to the Swan River, approximately 60% is residential land. The majority of this residential land is R20 zoning or less dense, which is likely to have a higher nutrient input levels than more dense residential development areas.
- Less than 2% of the total Study Area is industrial land which drains to the Swan River.
- Approximately 44% of industrial area is discharged to the Indian Ocean.
- Almost half of all residential development is infiltrated.

In summary, these results highlight the need for management at both regional and local scales, particularly given the large variation in the size of local authorities and diversity of stormwater drainage systems. The results also highlight the importance of the two largest participating authorities (City of Nedlands, Town of Cambridge) toward achieving regional outcomes.

5. DETERMINATION OF PRIORITY SUB CATCHMENTS

The development of Regional Drainage Plans identified 218 subcatchments in the region. To identify priority subcatchments for consideration by individual local authorities and the WESROC region as a whole, map overlay techniques (Hollick, 1993) were used based on the following key indicators of individual sub catchment stormwater quality (nutrients and other pollutants) :

- estimated nutrient input of Total Phosphorus (TP) and Total Nitrogen (TN) based on land use
- the density of major roads (primary, secondary, and freeways)
- the proportion of a total catchment which is commercial and industrial land use
- the number of potential groundwater contamination sites

Table 2 : Drainage Overview by Land Use

Land Use Type	Parks & Recreation Passive	Parks & Recreation Active	Residential <=R20 zoning	Residential >R20 zoning	Commercial & Industrial	**Total**
Land Use Area (sq km)	12.8	14.2	25.8	7.1	4.5	64.4
Total % of Study Area	**19.8**	**22.0**	**40.1**	**11.1**	**7.0**	**100.0**
Discharge as % of Land Use Area						
Swan River Discharge						
River Direct	7.4	17.2	13.5	22.2	9.2	-
River via Comp Basin	0.6	5.7	7.2	14.9	13.9	-
Indian Ocean Discharge						
Ocean/Dunes Direct	30.4	1.2	0.2	5.1	1.5	-
Ocean/Dunes via Comp Basin	16.5	16.1	23.4	13.7	37.0	-
Groundwater Discharge						
Lake	1.4	5.3	1.6	4.4	0.4	-
Infiltration Basin/Swale	22.6	36.2	44.9	36.5	34.1	-
Soakwell	0.4	3.3	2.8	1.2	0.2	-
Parks/Reserves	14.0	14.7	4.8	0.9	2.9	-
Railway Reserve	6.7	0.3	1.6	1.1	0.8	-
Discharge as % of Total Study Area						
Swan River Discharge						
River Direct	1.5	3.7	5.4	2.5	0.7	13.8
River via Comp Basin	0.1	1.3	2.9	1.6	1.0	6.9
Indian Ocean Discharge						
Ocean/Dunes Direct	6.0	0.3	0.1	0.6	0.1	7.1
Ocean/Dunes via Comp Basin	3.3	3.5	9.4	1.5	2.6	20.3
Groundwater Discharge						
Lake	0.2	1.2	0.6	0.5	0.0	2.5
Infiltration Basin/Swale	4.5	8.0	18.0	4.1	2.4	37.0
Soakwell	0.1	0.7	1.1	0.1	0.0	2.0
Parks/Reserves	2.8	3.2	1.9	0.1	0.2	8.2
Railway Reserve	1.3	0.1	0.7	0.1	0.0	2.2

Indicators were weighted in relation to the nine discharge and receiving environment types and results aggregated to determine priority sub catchments, with priority consideration given where drainage is to a Conservation Category Wetland.

Estimates of nutrient input were developed using NiDSS (Nutrient Input Decision Support System, Figure 3), a tool developed by JDA to assist in landuse 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 WESROC

Nutrient Input Decision Support System
Version 1.1 February 2001
JDA Consultant Hydrologists
Report Date: 19-Feb-02

JDA

Total Nutrient Input - No WSUD (kg/yr)	1,545
Reduction due to Source Control (kg/yr)	454
Percentage Overall Reduction	29.4%
Pecentage Development Reduction	29.4%
Cost of Selected Program ($/kg/yr)	$191.9

(•) Total Phosphorus
( ) Total Nitrogen

Local Authority
Catchment Name
Catchment Area 100 ha

Key Assumptions
Residential Major Source of Nutrient Input
<=R20 adopts R15 data, >R20 R35 data
Road reserve assumed at 30% of residential area

Land Use	Lots (<=R20)	**15.0%**
	Lots (>R20)	**15.0%**
	POS (active)	**10.0%**
	POS (passive)	**25.0%**
	Road Res	30.0%

Total 95.0% Industrial/ Commercial 5.0%

Nutrient Input Without WSUD

Lots <R20	Garden	29.70	kg/net ha/yr	4.46	kg/gross ha/yr	446	kg/yr	28.8%
	Lawn	14.00		2.10		210		13.6%
	Pet Waste	3.96		0.59		59		3.8%
	Car Wash	0.13		0.02		2		0.1%
	Sub Total	47.79		7.17		717		46.4%
Lots >R20	Garden	8.10	kg/net ha/yr	1.22	kg/gross ha/yr	122	kg/yr	7.9%
	Lawn	3.50		0.53		53		3.4%
	Pet Waste	0.00		0.00		0		0.0%
	Car Wash	0.13		0.02		2		0.1%
	Sub Total	11.73		1.76		176		11.4%
POS	Garden/Lawn	2.60	kg/ha POS/yr	0.26	kg/gross ha/yr	26	kg/yr	1.7%
	Pet Waste <R20	1.02		0.10		10		0.7%
	Pet Waste >R20	1.61		0.16		16		1.0%
	Sub Total	5.23		0.52		52		3.4%
Road Reserve	Road Reserves	20.00	kg/ha RR/yr	6.00	kg/gross ha/yr	600	kg/yr	38.8%
	Sub Total	20.00		6.00		600		38.8%
		Total		**15.45**	kg/gross ha/yr	**1,545**	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 20%

	% 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%	1.13	113	7.3%	$0	$0	$0.0
Native Gardens (Lots - Lawn)	20%	0.53	53	3.4%	$0	$0	$0.0
Native Gardens (POS)	20%	0.05	5	0.3%	$0	$0	$0.0
Community Education : Fertiliser	100%	2.10	210	13.6%	$0	$375	$1.8
Community Education : Pet Waste	100%	0.17	17	1.1%	$0	$493	$28.7
Community Education : Car Wash	100%	0.01	1	0.1%	$0	$375	$476.8
Street Sweeping : Residenital Areas	100%	0.26	26	1.7%	$0	$12,375	$476.4
Totals		**4.25**	**425**	**27.5%**	**$0**	**$13,618**	**$32.0**

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	100%	0.14	14	0.9%	$178,600	$6,840	$1,211.1
Water Pollution Control Ponds	100%	0.14	14	0.9%	$757,493	$10,521	$3,911.8
Total		**0.29**	**29**	**1.9%**	**$936,093**	**$17,361**	**$2,552.6**

Net Nutrient Input

	kg/gross ha/yr	kg/yr	%	Capital Cost $	Operating Cost $/yr	Cost $/kg/yr
Nutrient Input Development without WSUD	15.45	1,545	100.0%			
Removal via Source Control	4.25	425	27.5%	$0	$13,618	$32.0
Removal via In-Transit Control	0.29	29	1.9%	$936,093	$17,361	$2,552.6
Total Removal	4.54	454	29.4%	$936,093	$30,978	$191.9
Net Nutrient Input	**10.91**	**1,091**	**70.6%**			

Figure 3: Sample NiDSS Modelling Output

NiDSS calculated the total expected nutrient input for particular land zonings based on aggregating individual nutrient inputs from different land uses (lots, POS, road reserves, conservation areas). The results (Figure 4) show high nutrient application areas to be typically the residential areas of low density (R20 or less dense). Key areas included :

- Town of Cottesloe sub catchments adjacent to the railway line and Stirling Highway
- City of Nedlands sub catchments south of Stirling Highway
- City of Subiaco sub catchment draining to Lake Jualbup
- the north eastern residential areas of the Town of Cambridge adjacent to Herdsman Lake

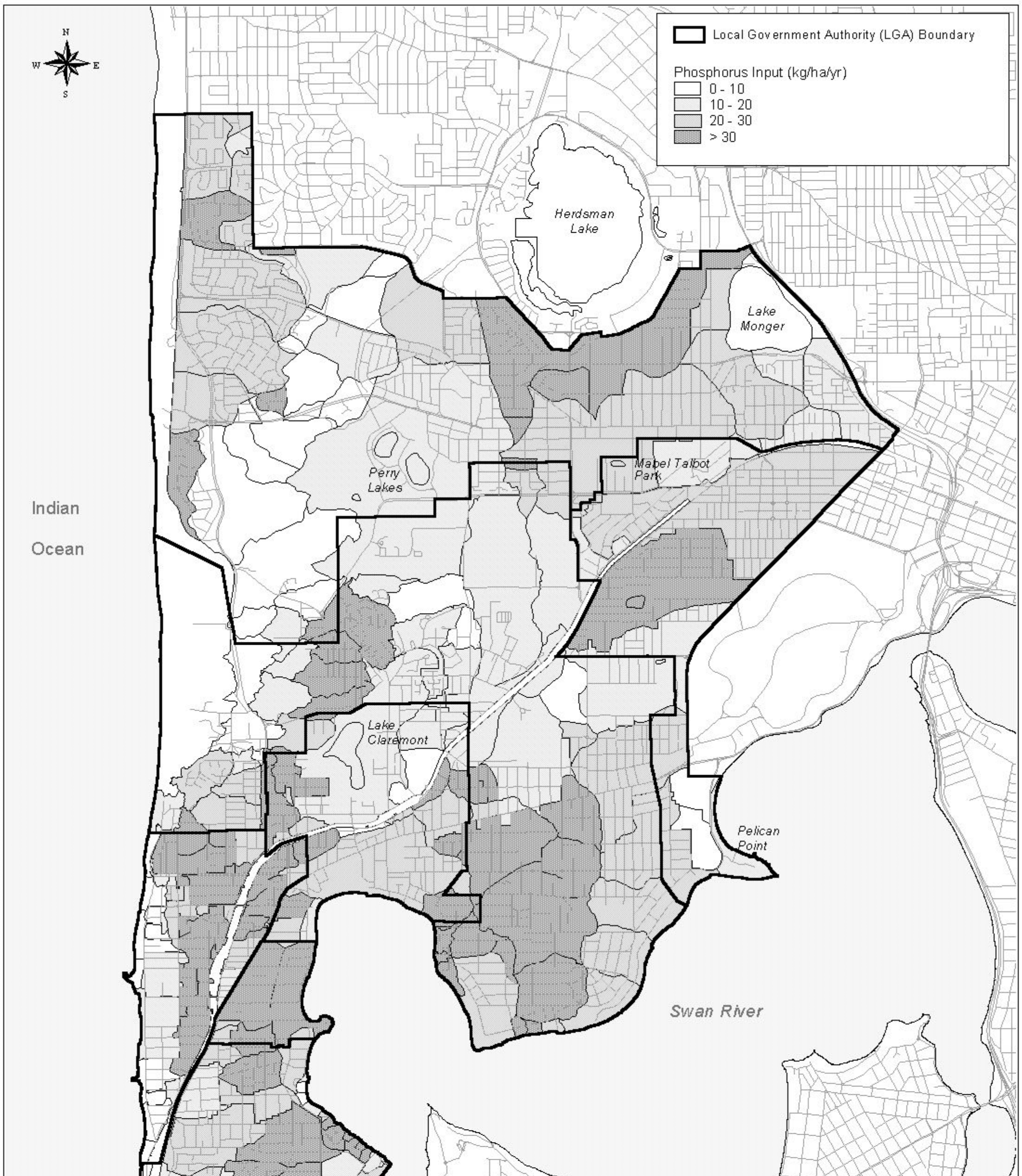

Figure 4 : Estimated Phosphorus Input

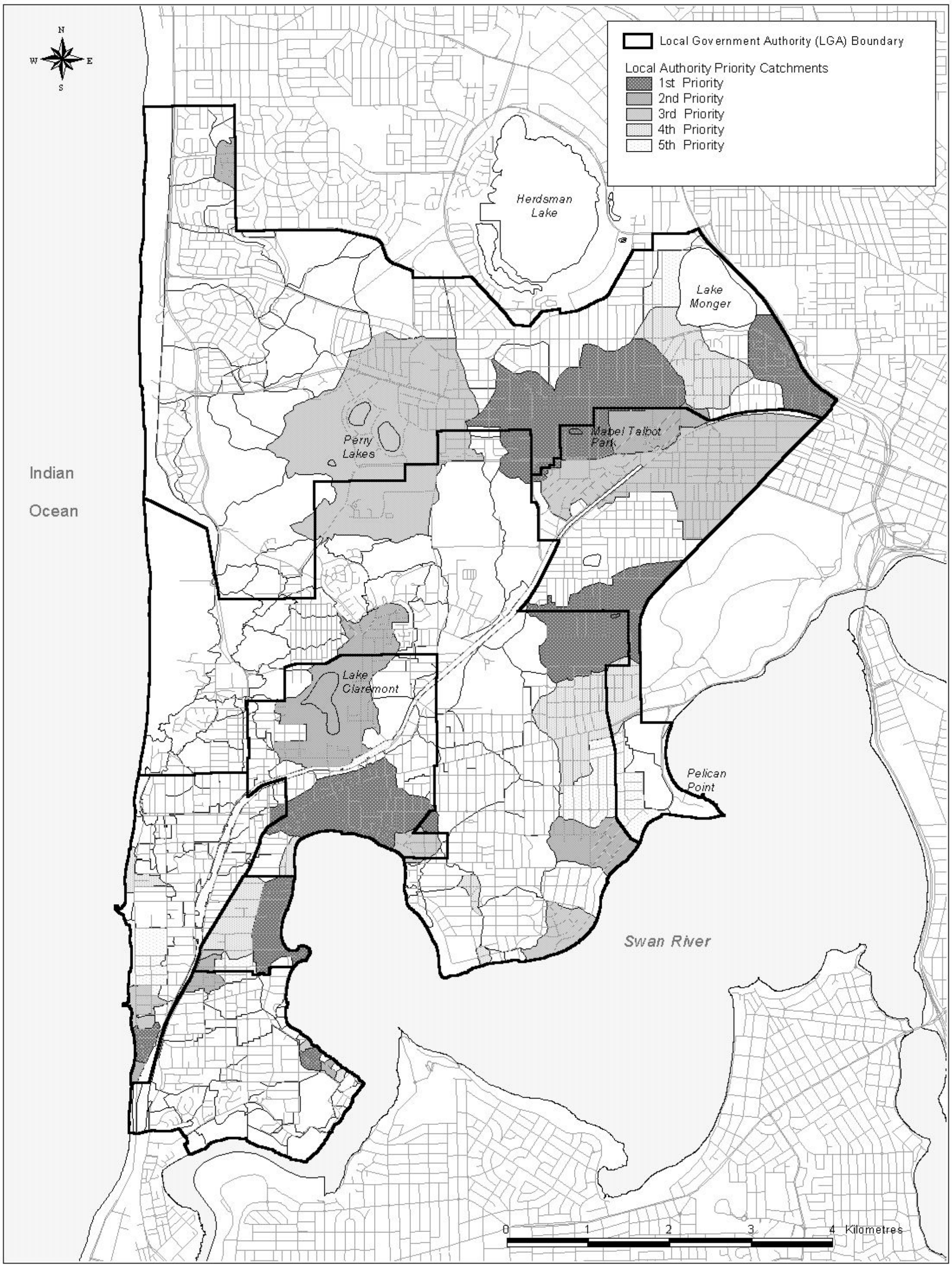

Figure 5 : Local Authority Priority Subcatchments

Priority subcatchments at local authority level are shown in Figure 5. Priority areas correspond with areas previously identified by individual local authorities to improve stormwater discharge quality, providing confidence in techniques applied in this study.

6. CONCLUSIONS

The Regional Strategy for Stormwater Management described in this paper was developed on behalf of the Western Suburbs Regional Organisation of Councils (WESROC) to provide the framework for a coordinated approach to stormwater quality management across the local governments of the Towns of Claremont, Cambridge, Cottesloe and Mosman Park, and the Cities of Nedlands, Subiaco, and the Shire of Peppermint Grove.

The Strategy is as yet incomplete. Local authority and regional drainage plans have been developed and priority subcatchments identified. Analysis findings have highlighted the need for management at both the local and regional scales.

Currently, cost benefit evaluation of stormwater quality management measures is being undertaken using NiDSS. This will lead to the development of implementation plans (including BMP recommendations and monitoring programs) for each individual local authority within the framework of the Regional context. It is considered likely that, given landuse is already largely urban with little opportunity for additional area to be made available for water quality treatment, implementation plans will include the use of non structural source control techniques (eg public education) to achieve improvements in water quality.

The approach to stormwater quality management described in this paper provides a qualitative technique to assess priority stormwater quality catchments on the Swan Coastal Plain.

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