Geographe Bay Coastal Catchment

Land Capability Assessment for Managing the Impact of Land Use Change on Water Resources

Final report by Acacia Springs Environmental, Gravitas Consulting, Parsons Brinckerhoff, Landvision

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February 2005
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Final report

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Cover Illustration: Digital elevation model of the project area

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Summary

This investigation analysed data describing landscapes, water resources and related ecosystems for the Busselton-Dunsborough coastal area. This Natural Heritage Trust funded project draws from its technical synthesis of available data and makes recommendations for improved land and water resources management at whole-of-catchment, precinct and streetscape scales in a manner consistent with the National and State Water Quality Management Strategies (NWQMS and SWQMS).

The project was initiated because of an increasing need for sustainable management of surface water resources in the region, particularly to manage the effects of both the region's rapid expansion and the adverse impacts of past and existing rural and urban land uses.

Water quality management

The nationally adopted framework for water resources and related ecosystems management used to guide this project recommends the protection and enhancement of natural water systems within rural and urban developments. For stormwater management, this means the retention or restoration of existing valuable elements of the stormwater/waterway system, such as natural channels, seasonal and permanent wetlands and riparian vegetation.

The emphasis for new urban or rural developments or for restorative projects in existing areas should be the establishment of management measures at or near the source of stormwater generation. For the coastal sands of Western Australia, this means maximising infiltration and bio-retention throughout the stormwater system, but particularly at the paddock or block scales.

The National Water Quality Management Strategy - Australian Urban Stormwater Management Guidelines (ARMCANZ/ANZECC, 2000), recognise the importance of distributed, at-source control of both stormwater quantity and quality. The NWQMS states that “constructed management techniques installed at the bottom-end of stormwater systems prior to discharge into receiving waters should only be proposed if there are residual impacts that cannot be cost-effectively mitigated by source or near-source controls”. The national guidelines also recommend stormwater reuse and non-structural measures, such as education and promotion of improved infrastructure maintenance, as an essential component of comprehensive stormwater management systems.

The Stormwater Management Manual for Western Australia (Department of Environment, 2004a) also reflects the national approach to stormwater management.

Local priorities

At the local level, priority issues for improved water resources and related ecosystems management have been identified in the Geographe Catchment Management Strategy (Geographe Catchment Council, 2000). These include nutrient enrichment and degradation of many receiving waters throughout the catchment, extensive clearing and the widespread loss of riparian nutrient attenuation processes, and loss of biodiversity. It has been found that less than 17% of the original vegetation remains within the coastal catchments, mostly in severely dissected remnants. Locally, the implementation of best planning and management practice was seen as an important first step in better managing the region’s water resources.

This project provides outcomes for several of the themes identified as priorities in national and state water resources management guidelines, including recommendations for:
• The implementation of 'at source' controls of both stormwater quantity and quality;
• Maintaining or improving surface and groundwater quality within urban or rural development areas relative to predevelopment conditions, and
• Maintaining the total water cycle balance within development areas relative to pre-development conditions.

At the whole-of-catchment scale, the project identified areas and land uses having the potential for higher-than-normal nutrient loss (hotspots). Hotspots were found to be associated with developments situated on land having very low capability for that particular land use. The project also provided a description of available catchment-wide best management practices (BMPs) to use in targeted hot spot areas. These included practices aimed at improved land, vegetation and runoff management.

At the level of urban subdivision, the project used previously identified areas of potential urban development as a basis for demonstrating correct application of water sensitive urban design (WSUD) principles. It presents management measures with the required emphasis on distributed treatment trains and at-source quality and quantity control through infiltration and bio-retention.

In this preferred model, streamlines and constructed channels should mimic natural streams, with their in-built flood conveyance and in-channel storage, to minimise flow velocities for all flow conditions. Under our prevailing Mediterranean climate, the stormwater management system should mimic seasonal wetting and drying cycles of natural systems and this will optimise the attenuation of stormwater pollutants.

During urbanisation of old rural land, urban renewal or restoration of existing urban areas (retro-fit), this would mean the conversion of existing constructed drains into 'natural' meandering streams with flood storage accommodated along the streamline. In this approach, infiltration and detention of the stormwater is maximised at base flow and low intensity rainfall events. During infrequent high rainfall events, the water flow velocities are minimised and flood storage is maximised.

Guiding principles
Objectives of water sensitive urban design are to:
1. Protect and enhance natural water systems within urban developments;
2. Integrate stormwater treatment into the landscape by incorporating multiple use corridors that maximise the visual and recreational amenity of developments;
3. Protect the quality of water draining from urban developments;
4. Reduce run-off and peak flows from urban development by local detention measures and minimising impervious areas, and
5. Add value while minimising development costs through cost effective use of natural systems within the drainage infrastructure.
**Detailed stormwater management recommendations for the study area**

1. Direct drainage or discharge of stormwater shall not be permitted into any wetland with conservation value (receiving environment), including its designated buffer area. (Conservation value are those wetlands rated as conservation status under the Department of Environment and Conservation ‘Geomorphic Wetland Management Categories’ dataset).

2. Stormwater runoff within a development area, including its associated road reserves, generated from up to 1 in 1 year, 1 hour Average Recurrence Interval (ARI) rainfall events shall be retained as close to its source as possible, using techniques such as soakwells, porous paving, vegetated swales or shallow depressions.

3. Runoff from greater than 1 in 1 year, 1 hour Average Recurrence Interval (ARI) rainfall events shall be mitigated through the use of landscaped retention or detention areas that are integrated within public open space / linear multiple use corridors. The runoff overflow from large rainfall events are directed via overland flow pathways into regional drainage systems or into wetlands (subject to the pre-development hydrologic regime of the wetland being unaltered).

For up to date information and guidelines, see the Department of Environment’s *Stormwater Management Manual for Western Australia*. 
1 Background and aims of this investigation

1.1 Background

The Department of Water (formerly Department of Environment) commissioned Acacia Springs Environmental (ASE) to prepare a water resources strategy for the Busselton-Dunsborough area (ASE, 2002a). The “Strategic Framework for Managing Stormwater in the Busselton-Dunsborough Coastal Area” is required to provide a technical synthesis and recommendations for management of the main landscape issues influencing water resources and related ecosystems in the region that is consistent with the National Water Quality Management Strategy (ANZECC 1992, 2000).

The project was initiated because of an increasing need for the sustainable management of surface water resources in the region, particularly to manage the effects of the region's rapid expansion and its impacts on existing and proposed rural and urban land uses.

The tasks for the project were broken into three stages, each producing a working paper:

i) Working paper 1 provided a review of available information on issues of concern for the maintenance and protection of surface water quality and dependant ecosystems at the whole of catchment scale;

ii) Working paper 2 provided a regional technical synthesis of issues, constraints and opportunities for existing rural and urban areas at the whole of catchment scale, and

iii) Working paper 3 provided guidance for development of particular areas identified in the Shire of Busselton Land Release Plans as having potential for future urbanisation, such as the Ambergate precinct.

Following review of each of the three working papers by the project steering committee (PSC), this final framework document was prepared.

A digital database of all spatial data used in this investigation has also been prepared and copies of the CD-ROM can be requested from the Catchment Management Branch, Department of Water (DoW).

A steering committee of the following stakeholders provided guidelines and advice to ASE in the preparation of this document:

- Department of Water (formerly Department of Environment)
- Department for Planning and Infrastructure
- Shire of Busselton
- Geocatch

1.2 Aims of this investigation

This document was to provide water resources-related information for policy makers and land and waterway managers aiming to improve water quality (and other environmental outcomes) at both the whole-of-catchment and local streetscape scales. Three broad areas of investigation were required, which included the following.

1. Synthesis of available water resources management-related data

A robust technical synthesis of available data was required, which included:
− Collation of all relevant spatial data (GIS);
− Building a high resolution (±30cm) digital elevation model (DEM);
− Building a stream and drainage coverage from the DEM and drain map;
− Building a land cover theme from satellite data, land monitor maps, digital air photos and other available digital coverage’s;
− Preparing a capability audit of existing land uses using land cover information and existing land capability maps;
− A statistical summary of all available water quality data for the bottom ends of rivers, the estuary and across the coastal catchment, and
− A cross tabulation of spatial data and water quality data.

- Identification of potential nutrient-loss and land use hotspots across the catchment:
  − Identification of potential hotspots by precinct (environmental management units (EMU), and
  − Description of impacts of land uses on land with low capability for the existing land use.
- Description of available catchment-wide best management practices (BMPs):
  − Description of BMPs to address water resource related issues, and
  − Maps showing potential priority areas for implementation of improved management practices.

ii) **Guidance for land and waterway managers at the whole-of-catchment scale**

At the whole-of-catchment scale, the following aims were addressed:

- Identification of issues;
- Identification of problem areas, and
- Describe interim best management practices for problem areas.

iii) **Guidance for future urban developments**

Within the context of Shire of Busselton Land Release Plans, the following aims were addressed:

- Description of relevant water sensitive urban design (WSUD) guiding principles for Priority 1 development investigation areas (DIAs);
- Identification of constraints for local DIAs;
- Identification of examples of stormwater BMP treatment trains for both the streetscape and precinct scales, and
- Recommendations of design principles for preparing WSUD stormwater management plans for local urban developments.

### 1.3 Structure and content of this document

The above aims were addressed and are reported on below. Table 1 summarises the structure and content of this document.
Table 1  Structure and content of this document.

<table>
<thead>
<tr>
<th>Report Section</th>
<th>Elements</th>
</tr>
</thead>
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| **Chapter 1**  
Background and aims of this investigation  
Guiding principles for water resources management | • Background to this investigation  
• Aims of this investigation  
  – Synthesis of available water resources management-related data  
  – Guidance for rural land managers  
  – Guidance for future urban development  
• Structure and content of this document  
• Water resource management objectives |
| **Chapter 2**  
A brief description of the project area | • Topography  
• Hydrology  
• Land cover  
• Nutrient management units (soils) |
| **Chapter 3**  
Issues for water resources management as identified by Geocatch | • Nutrient enrichment of waterbodies  
• Loss of native vegetation  
• Impact of land use on marine areas  
• Best land use management practices  
• Use of water resources  
• Drain management  
• Wetlands  
• The community’s voice in the catchment  
• Coastal/shore-line change  
• Waste disposal  
• Pests  
• Salinity |
| **Chapter 4**  
Guidance for land and water resource managers at the rural scale | • Identify issues  
• Identify goals and objectives (multi-scale vision)  
• Identify problem areas (nutrient loss and land degradation hotspots)  
• Describe process to evaluate management options  
• Develop and implement an interim plan of actions  
• Undertake monitoring, evaluation and refinement of the plan of actions |
| **Chapter 5**  
Guidance for future urban development | • Identify development investigation areas (DIAs in Shire Land Release Plans)  
• Describe guiding principles at the local urban development scale  
• Description of constraints for DIAs  
• Example BMPs for stormwater treatment trains |
| **Chapter 6**  
Recommendations | • Catchment repair  
• Urban development  
• Implementation  
• Monitoring, evaluation and review |
| **Appendix 1** | • GIS-based technical synthesis of available information at the whole-of-catchment scale |
| **Appendix 2** | • Example of the application of guiding principles at the local development scale using the Ambergate DIA |
1.4 Water resource management objectives

This section uses available water management guidelines for urban areas as the basis of presenting interim guidelines for water management at the whole-of-catchment scale.

National guidelines are available for urban water management but as yet, there are no similar national guidelines for whole-of-catchment water resource management.

The principles embodied in the national guidelines for urban areas have been modified and adapted as appropriate to apply to whole-of-catchment scale water cycle investigations.

1.4.1 Adapted National Water Sensitive Design objectives

The 'National Water Quality Management Strategy - Australian Urban Stormwater Management Guidelines' (ARMCANZ/ANZECC, 2000) has set out a stormwater management preference hierarchy which has application at the whole-of-catchment scale. This, together with the objectives of water sensitive urban design (CSIRO, 1999), have been adapted for whole-of-catchment scale water management and include the following.

- Protect natural systems: protect and enhance natural water systems within rural and urban developments.
- Retain and restore valuable ecosystems: retain or restore existing valuable elements of the natural drainage system, such as natural channels, wetlands and riparian vegetation.
- Source control - non structural measures: techniques such as education, for limiting changes to the quantity and quality of stormwater at the source.
- Source control - structural measures: constructed management techniques installed at or near the source to manage stormwater quantity and quality.
- In-system management measures: constructed management techniques installed within stormwater systems to manage stormwater quantity and quality prior to discharge into receiving waters. These are only proposed if there are residual impacts that cannot be cost-effectively mitigated by source or near-source controls.

1.4.2 Adapted framework for water resources management in Western Australia

Within the context of the national objectives outlined above, the following objectives and principles have been developed to manage the unique relationship found between surface and shallow groundwater on the Swan Coastal Plain (Department of Environment, 2004a).

**Western Australian Stormwater Management Objectives**

*Water Quality*

- To maintain or improve the surface and groundwater quality within the 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.

*Water Conservation*

- To maximise the reuse of stormwater.
Ecosystem Health
To retain natural drainage systems and protect ecosystem health.

Economic Viability
To implement stormwater management systems that are economically viable in the long term.

Public Health
To minimise the public risk, including risk of injury or loss of life, to the community.

Protection of Property
To protect the built environment from flooding and waterlogging.

Social Values
To ensure that community social, aesthetic and cultural values are recognised and maintained when managing stormwater.

Development
To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

Western Australian Stormwater Management Principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management (NRM).
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection and conservation and reuse.

Accordingly, the stormwater management hierarchy applied in WA follows.
1. Retain and restore natural drainage lines - retain and restore existing valuable elements of the natural drainage system.
2. Implement non-structural source controls - planning, organisational and behavioural techniques to minimise the amount of pollution entering the surface water management system.
3. 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.
4. Use 'in-system' management measures - includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.
For further information about the Western Australian stormwater management hierarchy, see the Stormwater Management Manual for Western Australia - Chapter 2: Understanding the Context (Department of Environment, 2004a).
2 Description of the resource

The project area (Figure 1) is around 200 km south of Perth and extends from Rocky Bay to Capel and includes the catchments of the Carbunup, Buayanyup, Vasse, Sabina, Abba and Ludlow Rivers. The catchment of the Capel River is not part of the project area.

The project area includes much of the Shire of Busselton and small areas of the Shire of Augusta-Margaret River. Busselton and Dunsborough are the main urban centres within the project area.

The study area has a Mediterranean-type climate, with hot dry summers and cool wet winters. Dominant wind directions are from the south in summer and spring and from the north-west in the autumn and winter. Much of the coastal plain of the study area is very low-lying, with numerous permanent and seasonal wetlands.

2.1 Landscape

The study area falls within the southern extremity of the Swan Coastal Plain and consists of a series of remnant parallel dunal sequences of marine and fluvial origin. The sandy coastal plain is of relatively low relief and is terminated inland by the Whicher Scarp and the Dunsborough fault. Much of the coastal plain portion of the study area has been cleared for urban and rural development. The uplands to the east and south of the scarp are characterised by fine-textured soils of lateritic origin. These ancient laterites and duricrusts have become deeply incised by erosive processes and have much of their original native vegetation remaining intact as State Forest.

2.1.1 Rainfall

Daily rainfall has been collected continuously since 1907 from the Boyanup Post Office, situated in the Leschenault Estuary Catchment on the Preston River 50 km to the north of the project area and this site. Due to its proximity, it was considered to represent the distribution of rainfall for the project area.

From 1900 to 2000, the long term average annual rainfall was around 1000 mm but this figure was only exceeded two times since 1980. Most of the rain falls in the months May to September. Apart from the annual variability and the seasonal variability, a characteristic of the rainfall distribution for the region is the presence of rare but extreme events in December and January. These rare events (>99% probability of non-exceedence) can produce daily rainfall well in excess of that observed in the normal winter months. These episodic events have been associated with monsoonal and cyclonic influences from the tropics, and they have a significant influence on flooding, soil erosion, nutrient export and the summer salinity patterns in south-west estuaries (SKM, 2002).

There appears to have been a significant reduction in annual rainfall over the last 30 years.

2.1.2 Landforms and soil systems

The Busselton Region is located within a section of the southern Perth Basin, bounded to the west by the Dunsborough fault, to the east by the Darling fault and to the south by the Whicher Scarp. To the west of the Busselton Region is a block of Pre Cambrian crystalline rocks named the Leeuwin-Naturaliste Ridge and to the east is the Darling Plateau, which is
part of the Pre Cambrian Yilgarn Shield. The southern Perth Basin in the Busselton area is a
down faulted block of predominantly elasic sediments comprising mostly sandstones,
siltstones and shales, and minor limestone. Geomorphically, the area is better known as the
Swan Coastal Plain, a low lying plain characterised by coastal dunes and inland swamps and
wetlands punctuated with ridges of harder limestone or sandstone.

The Swan Coastal Plain in the study area extends from the base of the Whicher Range for
about 20 kilometres to the sea between Capel and Dunsborough (see Figure 1). The Capel-
Dunsborough area characterises a sub-unit of the coastal plain known as the Pinjarra Plain.
The geology of this area runs approximately parallel to the coast, forming sub parallel belts of
similar landform. This has been divided into the three main land systems of the Busselton-
Dunsborough area:

- The Quindalup Coast,
- The Ludlow Plain,
- The Abba Plain.

The coastal zone is characterised by a belt of two dunal sand systems known as the Quindalup
and Spearwood Dune Systems, separated by a low lying strip of lagoons and swampy flats. The Quindalup Dune System is characterised by ridges of poorly consolidated dunal sands, which coincide with the Safety Bay Sands (Figure 5b Appendix 1). The sands are moderately calcarceous, yellow-brown in colour and overlie the Tamala Limestone. The dunal systems support peppermint woodland, although much of this has been cleared for agriculture or urban development. Immediately inland of the Quindalup Dune System are elongate estuarine lagoons and swampy flats of the Vasse-Wonnerup and Broadwater wetland systems (WRC, 1997).

Inland of the Spearwood and Quindalup Coastal dunes are swampy plains and wetlands
underlain by silts and clays interspersed with sandy flats and low ridges. The Ludlow Plain is
a gently undulating plain made up of deep brownish-yellow sand to the north and lower-lying
Cokelup Clays to the south. The Bassendean Sand (Playford and Low, 1972) is a quartz sand
that typically forms low quartz sandhills over a wide strip of the Coastal Plain with its
western edge about 5kms inland. Much of the native tuart, flooded gum, jarrah and marri
vegetation that is native to this land type has been cleared.

The Abba Plain is a broad belt of alluvium between the Ludlow Plain to the north and the
Whicher Scarp to the south. This land is characterised by a mosaic of poorly drained
depressions and rises, as well as dunes of bleached sands occurring along the northern edge of
the plain (Kinhill, 1998).

2.1.3 Vegetation assemblages and fauna

The native vegetation of the Geographe Bay catchment can be described as consisting of
severely dissected sand plain remnants and large contiguous upland blocks. The vegetation
complexes in both groups are currently poorly represented in nature reserves (Connell et al,
2002).

The broad seasonally wet areas of Pinjarra Plain soils once supported Jarrah-Marri forest and
Marri woodland, but much of this has now been cleared for agriculture. In sandy areas low
woodlands of Banksia species with or without jarrah predominated, particularly on the broad
sandy areas about Capel and towards Bunbury. On the better quality Spearwood Dune soils,
tall woodland of tuart occurred in a narrow coastal strip between Busselton and Bunbury.
Most of the remaining remnant tuart woodland is contained within National Park. However, the remnant tuart woodland is somewhat degraded as a result of logging and livestock grazing.

Low woodlands and thickets of peppermint and paperbarks, sedgelands and samphire marshes (Succulent Steppe) were found about the Vasse-Wonnerup and Broadwater estuarine wetlands, but much of this has been cleared or severely degraded by weed invasions, grazing and alteration to the natural hydrological regimes caused by drainage and the prevention of saline tidal inflows. In the wetter and fresher sites, thickets of Melaleucas were found and many still remain, particularly near Capel and south of the Broadwater (WRC, 1997).

There is a real need to protect and enhance scattered and isolated vegetation complexes through appropriate use of setbacks, buffers and replanting and regeneration schemes (Hobbs and Saunders, 1990). Superficial groundwater needs to be protected in areas like the Broadwater wetland and the Carbanup bushland where the remaining vegetation is dependant on superficial groundwaters (Aquaterra, 2002).

Figure 1 is a LANDSAT TM image showing land cover for the Busselton-Dunsborough area, where remnant vegetation is represented by the dark red tones and cleared land is represented by the paler tones.

### 2.1.4 Streamlines, runoff and waterways

Between Bunbury and Cape Naturaliste, nine short rivers and major creeks drain the Whicher Range and/or the Swan Coastal Plain and discharge into Geographe Bay. The more substantial systems are the Capel, Ludlow, Abba and Sabina and Vasse which have head waters in the forested Whicher Range. Smaller streams draining the coastal plain include the Carbanup and Buayanyup Rivers.

Many of the creek systems and lower reaches of the rivers have been either entirely or partially modified as part of artificial drainage systems to drain the very low-lying and now cleared Swan Coastal Plain and thus enable its use for dairy farming and other forms of agriculture (WRC, 1997).

There is a real need to protect and enhance riparian corridors throughout the project area both to enhance ecological function and to help attenuate sediments and nutrients (Weaver et al, 1994, USEPA, 1998). Some recommendations are made in later sections of this document.

### 2.1.5 Groundwater

Groundwater is the major water source in the Busselton-Capel Groundwater Area. It is utilised to meet the requirements of town water supplies, agriculture and horticulture as well as mining, industry and domestic uses (WAWA, 1995).

The project area is proclaimed under the Rights in Water and Irrigation Act 1914 as the Busselton-Capel Groundwater Area. Groundwater abstraction within the project area requires a licence from the Department of Water. Licensing is used as a management tool to manage the resource in a sustainable manner. Licenses are issued in accordance with the Busselton-Capel Groundwater Management Plan (WAWA, 1995).
Current levels of abstraction from the underlying aquifers in the area are predominantly at or near the estimated allocation limits. Volumes available for future allocation are site and aquifer specific in the Busselton-Capel Groundwater Area.

Groundwater occurs in three distinct systems in the Busselton area: the unconfined superficial aquifer, and the confined aquifer systems in the underlying older formations, including the Leederville aquifer and the Yarragadee aquifer. Due to the thinness of the superficial aquifer, the amount of groundwater available in this system is limited in some areas. Recharge is generally by direct infiltration of rainfall and in specific coastal areas, by upward leakage from the underlying Leederville aquifer. The unconfined aquifer tends to be too saline for domestic use and is primarily used for stock-watering. Water in the confined aquifers is less saline and is used extensively for domestic, town water supply, horticultural and other agricultural purposes (Kinhill, 1998).

There is an ongoing need to protect the quality of groundwater supplies for the project area for future abstraction and for environmental water requirements (Aquaterra, 2002).

2.1.6 Wetlands
The Department has an evaluation process to determine wetland management categories. The Department’s objectives for the management of wetlands on the Swan Coastal Plain are for the preservation of Conservation Category Wetlands, the management and restoration of Resource Enhancement Wetlands and the application of ecologically sustainable development for Multiple Use Wetlands (WRC, 2001). Conservation Category Wetlands are considered to be the most valuable wetlands, as they have high natural values and support high levels of ecological attributes and functions.

Wetlands in part of the study area have been classified and evaluated (see V & C Semeniuk Research Group, 1998). The wetland management categories, wetland types and boundary information are provided in the Department of Environment and Conservation’s (DEC) ‘Geomorphic Wetlands, Swan Coastal Plain’ dataset. The wetland management categories are shown in Figure 3b, Appendix 1. The ‘Geomorphic Wetlands, Swan Coastal Plain’ dataset is available from the Department of Environment and Conservation’s Wetland Management Section. Wetland mapping data can also be obtained from the Western Australian Land Information System website (www.walis.wa.gov.au).

Wetlands are valued by society for many varied and complex reasons. It is helpful to describe the values of a given wetland so that they may be more readily understood. Claridge (1991) developed a comprehensive nomenclature that has been used to describe wetland values (Table 2).

The VALUE of a wetland benefit (function, use or attribute) may be defined as a measure or expression of the worth placed by society on that particular function, use or attribute;

CHARACTERISTICS are those properties of a wetland which describe the area in the simplest and most objective possible terms, e.g. wetland size, species present, soils and water quality. Characteristics, singly or in combination, give rise to benefits (existing or future) which may be functions, uses or attributes of a wetland;

A FUNCTION is some aspect of a wetland that, potentially or actually, supports or protects a human activity or human property without being used directly;

A USE is some direct utilization of one or more of the characteristics of a wetland, and
An ATTRIBUTE of a wetland is some characteristic or combination of characteristics which is valued by a group within society, but which does not necessarily provide a function or support a use.

### Table 2 Characteristics, functions, uses and attributes of wetlands (after Claridge, 1991).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Functions</th>
<th>Uses</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Groundwater recharge</td>
<td>Extraction of naturally occurring plant products</td>
<td>Richness or diversity of flora or fauna</td>
</tr>
<tr>
<td>Shape</td>
<td>Flood control</td>
<td>Extraction of naturally occurring animal products</td>
<td>Landscape/aesthetic qualities</td>
</tr>
<tr>
<td>Species present</td>
<td>Shoreline erosion/stabilization control</td>
<td>Extraction of mineral products</td>
<td>Valued as a cultural, symbolic or spiritual place by a defined group within the community</td>
</tr>
<tr>
<td>Abundance of species vegetation structure</td>
<td>Sediment retention</td>
<td>Water supply/storage</td>
<td>Presence or rare, endangered or uncommon flora, fauna, communities, ecosystems, natural landscapes, processes or wetland types</td>
</tr>
<tr>
<td>Extent of vegetation</td>
<td>Nutrient/pollutant absorption</td>
<td>Production of plant products</td>
<td>Site of historically significant research or other historically significant event</td>
</tr>
<tr>
<td>Pattern of vegetation distribution, soils</td>
<td>Export of nutrient</td>
<td>Production of animal products</td>
<td>Wilderness Type locality of a taxon</td>
</tr>
<tr>
<td>Geology</td>
<td>Storm protection/windbreak</td>
<td>Recreation/tourism</td>
<td>Constitutes a significant gene pool</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>Microclimate stabilization</td>
<td>Water transport</td>
<td>Contains evidence of products of past processes important in the evolution of flora, fauna, landscapes, wetland systems or climate</td>
</tr>
<tr>
<td>Processes occurring (Physical and biological)</td>
<td>Flow regulation/maintenance</td>
<td>Research site</td>
<td>Contains evidence demonstrating, or contributing the maintenance of, existing processes or natural systems at the local, regional or national level</td>
</tr>
<tr>
<td>Nature and location of water entry</td>
<td>Nursery/breeding area</td>
<td>Monitoring site</td>
<td>Source of information which has lead to better understanding of evolutionary processes, existing natural systems or processes or the history of human occupation</td>
</tr>
<tr>
<td>Nature and location of water exit</td>
<td>Habitat for fish</td>
<td>Education site</td>
<td>Presence of a distinctive way of life, custom, process, Land use, function or design in danger of being lost</td>
</tr>
<tr>
<td>Climate</td>
<td>Habitat for wildlife</td>
<td>Waste disposal/water treatment</td>
<td>Demonstrates the principal characteristics of one or more of the range of types of wetlands, or landscapes</td>
</tr>
<tr>
<td>Location in respect of human settlement and activities</td>
<td>Contribution to the maintenance of existing processes or natural systems</td>
<td></td>
<td>Demonstrates the principal characteristics of the range of human activities in the wetland</td>
</tr>
<tr>
<td>Location in respect of other elements in the environment</td>
<td>Wildlife corridor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water flow/tumover rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope fertility nutrient cycles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass production/export</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of habitat, habitat interspersion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage pattern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of open water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent evident of human usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historic or prehistoric evidence of human usage pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporation/precipitation balance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tidal range/regime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of the catchment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of other wetlands in the region</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.2 Land use

Urban development is an important feature of the Geographe Bay coastline, radiating out from the rapidly growing town of Busselton. Agriculture, particularly cattle grazing and dairy farming, dominates the Abba Plain (Table 3). On more fertile soils, market gardens grow vegetables such as potatoes, cauliflowers, pumpkins and beans. Viticultural land use is expected to increase on suitable soil types but at this stage, vineyards are not widely established. Forestry is increasing in importance but the requirement for good quality land means it is in competition with agriculture. In general, land selected for intensive forestry
should have relatively deep, well-drained soils and adequate moisture-holding capacity. Mining of remnant sand-dunes occurs on the northern perimeter of the Abba Plain and on the southern perimeter e.g. Yoganup mine. Mining leases are held over a large proportion of the region.

Busselton is a popular holiday destination and recreational activities include swimming, boating, snorkelling and scuba-diving. Although not encouraged or approved, the Vasse Diversion Drain is also used for fishing, canoeing and swimming. With increasing residential and tourist populations, it is probable that these uses will increase (Kinhill, 1998).

Table 3 Areas of various land uses for the project area.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (Ha)</th>
<th>Area % Upland EMUs</th>
<th>Area % Coastal Plain EMUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual horticulture</td>
<td>3489</td>
<td>0.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Perennial horticulture</td>
<td>4145</td>
<td>2.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Residential urban</td>
<td>1966</td>
<td>0.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Residential rural</td>
<td>3131</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Grazing pasture</td>
<td>46528</td>
<td>16.0</td>
<td>49.1</td>
</tr>
<tr>
<td>Forestry</td>
<td>465</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Perennial vegetation</td>
<td>46155</td>
<td>68.7</td>
<td>15.5</td>
</tr>
<tr>
<td>Estuary</td>
<td>977</td>
<td>0.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Cropping</td>
<td>663</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Dairy (intense animal)</td>
<td>15935</td>
<td>6.3</td>
<td>16.3</td>
</tr>
<tr>
<td>Mining</td>
<td>225</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Roads easements</td>
<td>2966</td>
<td>1.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Other intensive uses</td>
<td>1418</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>128064</strong></td>
<td><strong>49469</strong></td>
<td><strong>78595</strong></td>
</tr>
</tbody>
</table>

2.2.1 Population and trends in population growth

The Shire of Busselton is one of the fastest growing areas of the state with an annual population increase of around 5-6% from 1986 - 1999 (BSC, 1999, WAPC, 2000). A population of 35,000 has been projected for 2010. Much of the population increase has centred on the urban areas of Busselton and Dunsborough although there have been modest increases in population in more rural areas of the region. Planning will need to take account of requirements for urban expansion and rural intensification in the context of fragile receiving environments (Guise, 1994).

2.2.2 Urban areas and urban expansion

The urban areas of Busselton and Dunsborough have evolved in a linear form parallel to the coastline of Geographe Bay. Urban form has also been shaped to some degree by the presence of extensive linear wetlands of the Vasse-Wonnerup system, the Broadwater, Toby Inlet and other waterways. The inefficiencies of the linear form have been recognised (BSC, 1999) since a more compact form would provide more effective access to the commercial centres of Busselton and Dunsborough.

Future development areas are located within a relatively narrow corridor running parallel and in close proximity to the coastline. Urban development in close proximity to the valuable linear wetlands formed behind the primary dunes, places considerable pressure on the
environmental health of these wetland systems. Changes in the pattern and quality of
stormwater runoff entering these receiving ecosystems, or changes to hydrological cycles
through filling or draining wet areas has the potential to adversely impact their conservation
significance (Lane et al., 1997, Coastwise, 2001).

2.2.3 Rural areas and intensification

Much of the coastal plain has been extensively cleared for agricultural pursuits and there are
currently only low rates of population growth projected for the rural areas of the project area
(SOB, 1992). For some areas, divertible surface and groundwater resources have been
extensively allocated to various consumptive uses and there is limited potential for local
supplies to supplement increasing demands. In other coastal areas, there are supplies of
groundwater available for rural enterprises. There has been ongoing demand for an increase
in the intensification of rural activities in the catchment.

Irrigated horticulture and intensive animal-based industries are on the increase to service the
rapidly increasing urban populations. Increasing levels of pasture productivity and
intensification of rural enterprises have the potential for greater nutrient loads being applied to
the sandy coastal plain soils.

There is a need to further identify and manage the sources of sediments and nutrients being
generated from rural activities (Bott, 1993, Weaver et al., 1994) throughout the catchment
(McAlpine et al, 1989, Lane et al, 1997, GCC, 2000). The GIS investigation described later
in this document uses land capability and land use data to predict sediment and nutrient-loss
hot spots throughout the catchment. Generic recommendations to manage land degradation
hazards are also provided.
3 Issues related to human-induced disturbance

This section briefly describes some of the issues arising from changes to ecosystem services that follow traditional rural and urban land development practices. The desired environmental quality of receiving waterbodies is the ultimate arbiter of the nature of land use and land management requirements. There is however great uncertainties, lags and variability associated with predicting the response of land use change (and restoration) on receiving water bodies.

This means that receiving waterbodies may appear to be accommodating increased inputs of sediments and nutrients for many years after particular rural or urban development occurred. Slow gradual changes in pollutant inputs or an episodic event such as a cyclone, flood or severe bushfire may change the behaviour of a waterbody and lead to the commencement of algal blooms. Neither of these waterbody responses can be easily linked to the particular developments that initially triggered the adverse impacts that were displaced in space and time (Allanson et al, 1993, Deeley, 2002).

3.1 Defining issues of concern

This section summarises the major issues of concern (Table 4) to the community raised in previous consultations (GCC, 2000).

Some receiving waterbodies in the area have been experiencing occasional phytoplankton blooms (cyanobacteria) and have been classified as being eutrophic based on nitrogen concentrations, mesotrophic based on phosphorus and eutrophic based on chlorophyll a (McApline et al, 1989, Hosja and Deeley, 1993, DA Lord, 1995).

Of all of the estuaries in the south-west of WA, the Vasse-Wonerup Estuary has the greatest influx of nutrients per square kilometre of catchment (McAlpine et al., 1989).

The degraded condition of the waterbodies in terms of nutrient enrichment was caused by historical inputs from surrounding agricultural and other land uses and by nutrient regeneration mechanisms within the enriched waterbody sediments. Historical nutrient inputs to the waterbodies have included market gardens, intensive animal industries, broad-scale rural uses, urban stormwater runoff, rubbish and other waste disposals.

The fact that these waters have been historically enriched with nutrient inputs from contaminated regional groundwater and nutrient regeneration from the sediments has implications when assessing the performance of water resource management strategies that focus on current nutrient inputs from surface runoff from agricultural and urban areas.

Additionally, drainage in the catchment has been highly modified, which has affected nutrient cycling and flushing capacities of waterways. For example, barriers have been installed on the Vasse and Wonnerup estuaries and some natural drainage systems have been re-routed to artificial drains.

Because the receiving waterbodies were already severely degraded by nutrient enrichment, the first goal of this framework should more appropriately be seen as a series of measures to ensure that the situation in the waterbodies does not deteriorate further. A second and longer term goal should be the restoration and widespread improvement in the degraded condition of receiving waterbodies. This means that assessing the performance of this framework itself
means identifying whether there has been further degradation, maintenance or even an improvement in the water quality of the receiving waterbodies.
Table 4  Issues of concern for water resources management (After Geocatch, 2000).

<table>
<thead>
<tr>
<th>Issue</th>
<th>Management direction</th>
</tr>
</thead>
</table>
| 1  Eutrophication of waterbodies                                     | - reduce nutrients in waterbodies to levels that maintain or restore ecological and community values  
|                                                                      | - identify sources of nutrients  
|                                                                      | - reduce nutrients available for transport to waterbodies  
|                                                                      | - slow water movement and promote assimilation  
|                                                                      | - reuse enriched runoff waters  |
| 2 Loss of native vegetation                                          | - to maintain sufficient levels of remnant vegetation to maintain and enhance biodiversity  
|                                                                      | - to assist in the identification of important vegetation elements  
|                                                                      | - to implement recommendations of the remnant vegetation study  
|                                                                      | - develop strategies to assist land managers to revegetate degraded parts of the catchment  
|                                                                      | - to maintain and encourage revegetation of degraded and over-cleared lands  |
| 3 Impact of land use on marine areas                                 | - to ensure that cooperative arrangements are in place which recognise the inter-relationship between land use and ecological health of marine areas  
|                                                                      | - to support DEC in the development of the proposed marine park  
|                                                                      | - to undertake State of the Environment reporting and provide indicators of marine health to regulatory agencies to assist in policy development on land use and development  |
| 4 Best land use management practices                                 | - to achieve widespread utilisation of best land use management practices throughout the catchment  
|                                                                      | - to assist in the dissemination of information to land holders  
|                                                                      | - to encourage farm planning as a process for developing an integrated approach to land use and environmental management  |
| 5 Use of water resources                                              | - to recognise social, economic and environmental needs in water allocation and to apply Integrated Catchment Management (ICM) through best management practices  
|                                                                      | - to support local area management committees in managing, allocating and trading water  
|                                                                      | - to assist in establishing linkages between local area groundwater management committees and ICM groups  |
| 6 Drain management                                                    | - to have enhanced surface water balance which improves riverine values through implementation of best management practices  
|                                                                      | - to encourage farmers, Water Corporation and DoW to liaise in relation to drainage management and on-farm strategies  
|                                                                      | - to encourage land holders to develop check structures in consultation with Water Corporation  |
| 7 Wetlands                                                           | - to have a healthy, productive, functioning range of wetland systems which represent the existing values, functions and attributes for wetlands in the catchment  
|                                                                      | - to encourage the implementation of water sensitive urban design guidelines in all residential development proposals  
|                                                                      | - to assist DoE in maintaining up to date information on the physical and biological characteristics of wetlands in the catchment  |
| 8 The community’s voice in the catchment                             | - to have community understanding and involvement in ICM for Geographe Bay and its catchment  
|                                                                      | - to encourage and support community groups involved in the management of natural areas  
|                                                                      | - to develop a communication strategy for Geocatch  |
| 9 Coastal/ shoreline change                                          | - to minimise the threats to environmental values and community assets as a result of possible changes to coastal and shoreline areas  
|                                                                      | - to continue to assist LGA’s in the development of a coastal management plan  |
| 10 Waste disposal                                                    | - to have waste disposal systems in place which comply with the goals of ICM and maintain community values across the catchment  
|                                                                      | - to provide feedback and to work with the Department of Agriculture and Food, Western Australia (DAFWA) and other agencies on issues related to farm effluent management  |
| 11 Pests                                                             | - to have long term strategies in place that reduce the adverse impacts of introduced plants and animals on the natural environment  
|                                                                      | - to support DEC’s eradication programs  
|                                                                      | - to develop a weed management plan for the project area  |
| 12 Salinity                                                          | - to form cooperative arrangements with land managers to slow and then reverse salinisation within the catchment  
|                                                                      | - to encourage landholders to develop farm plans to assist in reducing regional groundwater tables and increase planting of deep-rooted vegetation  
|                                                                      | - to support agencies developing a Regional Salinity Action Plan in the catchment  |
3.2 Clearing of native vegetation

Much of the coastal plain of the project area has been extensively cleared for agricultural and urban development, with less than 17% of the original vegetation remaining in severely dissected sand plain remnants (Connell et al, 2002) (Table 2). This has resulted in threats to biodiversity in the region because of the increasing fragmentation of remnant native communities.

Our knowledge of threats to biodiversity of the Busselton region is limited but increasing, with requirements for the ongoing survival of many species not being scientifically described, and the conservation status of many species being unknown. There is some information available for ecosystems, ecological communities and their conservation status but not in enough detail throughout the catchment to make a comprehensive assessment of trends in biodiversity. Indicators currently being used to assess biodiversity point to the fact that most remaining vegetation complexes are currently poorly represented in nature reserves (Connell et al, 2002). Knowledge of the genetic diversity of species is almost non-existent.

Connell et al, (2002) have recommended that monitoring and management of ecosystems and species is essential if the region's natural heritage is to be maintained. Conservation of biodiversity can be achieved by expanding the conservation reserve system, improving conservation outside the reserve system, ameliorating threatening processes, conserving threatened ecosystems and species, and promoting ecologically sustainable development. Many of these activities are already under way, but their continuing success will require a commitment from all local residents and improved methods of monitoring and management.

Most of the activities of our society, such as providing food, shelter, water, energy, transport, recreation and goods and services, affect biodiversity. The rapidly expanding population of the Busselton-Dunsborough region will continue to place great pressure on biodiversity in the region.

The most significant pressure is the ongoing modification of habitat. This can be by the clearing and grazing of native vegetation, filling and draining of wetlands, damming rivers, recreation, contamination and introducing feral animals, weeds and diseases. To avoid detrimental impacts on biodiversity, activities such as agriculture, aquaculture, forestry, fishing, tourism, mining and urban and industrial development need to be carefully managed. Some recommendations as to how and where to improve vegetation assemblages are provided in later sections of this document.

3.3 Agricultural development

In their natural state, dissolved and particulate solids in streams are regulated substantially by the vegetation (USEPA, 1998, Pen, 1999). Removal or damage to vegetative cover disrupts the linkages between streams and their catchments and leads to unregulated movement of water and dissolved and particulate solids to receiving waterways.

In an undeveloped area, a natural stream normally adjusts so that its cross section and slope are in approximate equilibrium. Increased stormwater runoff volumes and peak discharge rates may lead to drastic changes in natural stream channels through flooding and erosion (WRC, 1998). Accelerated channel erosion may create downstream damage through mobilisation and deposition of eroded sediment. Lakes, reservoirs and estuaries may fill,
storm sewers and culverts may become clogged, causing flooding, and areas adjacent to streams may become covered with mud and debris. Increased stream volumes and velocities associated with stormwater from urbanised areas may also lead to more frequent floods. Areas that previously flooded once every five years may flood every year, or several times each year (WRC, 1998).

Changes in stream velocity/frequency relationships after development may have implications for the survival of stream faunal communities and thus the processing and recycling of organic carbon and nutrients into riparian areas and ultimately impact estuaries and nearshore areas (Pen, 1999).

3.4 Urban and industrial development

Intensification of rural activities and urban developments generally leads to increases in nutrient export from catchments (Bott, 1993, Sharpley, et al., 1993, Weaver, et al, 1994, Sharma et al., 1994, Sharpley, 1995) and subsequently nutrient enrichment in receiving waterbodies. Symptoms of nutrient enrichment include changes in nutrient cycling, changes in primary productivity, simplification of food webs, reductions in species diversity, increased dominance of opportunists, changes in oxygen status of deeper waters in receiving ecosystems and increased amplitudes of species populations (Deeley, 2002).

Waterbodies most sensitive to nutrient enrichment appear to be characterised by poor flushing and circulation, where oxygen depleted waters cannot be effectively oxygenated. Affected areas are creeks and rivers, lakes, estuaries, and shallow coastal bays and estuaries with constricted entrances that have low relative freshwater inputs and attenuated tidal ranges. The impacts of eutrophication include a shift from pelagic nutrient regeneration mechanisms to benthic nutrient regeneration mechanisms.

Four stages have been identified in the process of nutrient enrichment.

- Stage 1 - an initial growth response with an increase in primary and secondary producers.
- Stage 2 - changes in species composition where primary producers shift toward ephemeral opportunists and faunal assemblages shift from dominance of slow-growing, larger, longer-lived species with low production:biomass ratios, toward dominance of smaller, fast-growing, short-lived species with high production to biomass ratios.
- Stage 3 - negative feedback interactions between components of the community with a loss of species and dominance by a few opportunistic species.
- Stage 4 - periods of hypoxia and anoxia which may increase in intensity, frequency and duration over a greater area, episodes of mass deaths and ultimately loss of most of the benthos leaving bacterial mats and a few tolerant species.

Symptoms of severe nutrient enrichment may also include increased occurrence of potentially harmful cyanophyte or dinoflagellate blooms, fish kills and an increase in the risk of shellfish poisoning through the presence of certain dinoflagellate species (Hosja and Deeley, 1993).

3.5 Changes in the catchment water balance

Clearing native vegetation and establishing rural and urban landuse has a significant impact on water balance and on the nature of catchment hydrographic responses. Development leads to an increase in impervious areas through construction of paved surfaces and because of soil compaction in many rural areas (Engel et al, 1993, Heidke and Auer, 1993). Rainfall does
not infiltrate into the ground as readily as it did prior to development and this generally leads to an increase in the volume and velocity of stormwater runoff. Additionally, extensive networks of artificial drainage are often constructed to remove stormwater from the land surface into receiving waterbodies as quickly as possible.

Unfortunately, this conveyance mentality has often led to drainage networks that maximise local convenience and protection from flooding, without fully considering other important factors such as off-site damage from accelerated flow, water pollution, or even the loss of the water resource itself. Other problems associated with traditional stormwater conveyance through natural and constructed channels include increased downstream flooding, channel erosion and deposition of sediment, all of which may damage private property, wildlife habitat and natural vegetation.

Increasing volumes of stormwater runoff from developed urban and rural areas have been identified as a constraint to providing adequate flood protection for the low-lying areas from Busselton to Dunsborough (SKM, 2002).

The fragile nature of water dependant ecosystems means that water allocation strategies in the face of increasing demand for potable and irrigation supplies will have to be ever more responsive to climatic conditions (WRC, 1999, 2001), especially if predicted decreases in annual rainfall eventuate.

### 3.6 Status of receiving environments

#### 3.6.1 Wetlands and waterways

The following text has been taken from a comprehensive review by Luke Pen (WRC, 1997).

Most of the important wetlands in this region are located in the lower coastal plain catchments of the Sabina, Abba, Ludlow and Capel Rivers. The wetlands range from small to large seasonal and permanent swamps and floodplains. There are also a number of small permanent lakes. The large elongate estuarine wetland systems of the Vasse-Wonnerup and Broadwater run along the coast for about 50 km either side of Busselton-Wonnerup and Broadwater run along the coast for about 50 km either side of Busselton.

The condition of most of the wetlands is poor, ranging from C to D, as much of the coastal plain has been cleared and/or drained for farming. Some B grade wetlands remain in small blocks of remnant bush, but few of these are reserved on public land. As a result, none of the wetland groups on the coastal plain are A grade.

Ludlow Wetlands. Small area of small lakes, swamps and floodplain, just to the east of the Busselton Highway, on private land. Wetland condition ranges from B to D, with the small lakes being C grade. The group includes McCarley's Swamp which is listed as a wetland of National Significance. This fresh wooded permanent swamp, covering an area of 25 ha, is important waterbird habitat, supporting as many as a thousand or more individual birds and 31 species, nine of which breed in the wetland. McCarley's Swamp is known to support the largest breeding colonies of the great egret and straw necked ibis in the south-west and is regionally significant for three other species. Waterbird habitat is threatened by the die-off of paperbarks, the cause of which is not clear. Some nearby wetlands within the group support the rare aquatic herb *Aponogeton hexatepalus* (CALM data).

Ironstone flats. A floristic survey of the southern Swan Coastal Plain discovered seasonally waterlogged flats on ironstone country in two areas at the base of the Whicher Range,
between the Capel and Carbunup Rivers. These wetlands were found to support rare plant communities with some rare flora, and are considered to be threatened.

Ludlow-Abba Wetlands. Small lakes and swamps and medium floodplain between Ludlow and Abba Rivers; some in State Forest, but most on private land. The Swan Coastal Floristic Survey found rare wetland plant species in freshwater paperbark swamps on claypans in the Ludlow tuart forest. The rare aquatic herb *Aponogeton hexatepalus* and sedge *Schoenus natans* are also known from the area (CALM data).

Vasse-Wonnerup Wetland System. A very large wetland of estuarine marshland and tidal floodplain, mainly on private land, about the Vasse-Wonnerup estuarine lagoon. It is as wide as 1.5 km and runs for about 25 km behind narrow coastal dunes. Today most of the wetland is cleared and the natural hydrology has been greatly altered by tidal barrages and drainage; but some saline samphire marshes and stands of remnant estuarine forest trees remain in places, including on small Conservation and Land Management (CALM) reserves on the Vasse Estuary and near its connection with the Wonnerup.

Despite the wetland's very poor condition, which ranges from DI to Dc, it remains highly significant waterbird habitat, both on a regional and international scale. Between 20 and 30 thousand birds may make use of the wetland annually, the numbers being swelled by migratory wading species which use the system as a major 'stopover'. Out of the thousand or so wetlands in the south-west which are surveyed for waterfowl every so often, this system often tops the counts or is in the top 15 wetlands. In all, 78 species have been observed on the wetland and 12 species are known to breed there, including the largest breeding population of black swan. Despite the importance of the Vasse-Wonnerup, it is threatened by eutrophication, development pressure and changes wrought by the exclusion of seawater, such as weed invasions.

Broadwater floodplain. Very large area of tidal floodplain and lagoon on the modified Vasse and Buayunup Rivers. The lagoon, known as the Broadwater, is mostly contained with a CALM reserve, but the rest of the wetland is mainly cleared pasture. Even the lagoon itself is mainly surrounded in pasture, with only a fringe of wetland vegetation on the north and northwestern sides and a broad paperbark forest on the southern and eastern sides. The condition of the wetland is poor, mainly ranging from DI to Dc with some C grade parts. Nevertheless, the wetland, with its remnant shrub and paperbark thickets, is important waterbird habitat, supporting 41 species, 8 breeding species and as many as 6000 individuals. The rare aquatic herb *Villarsia submersa*, is known from the area (CALM data).

River Action Plans have been developed by Geocatch and community group/Land Conservation District Committee (LCDC) partners for the following rivers: Sabina, Abba, Ludlow, Vasse, Carbunup and Yallingup.

### 3.6.2 Geographe Bay

Seagrass meadows are a known indicator of nutrient enrichment in marine environments. Approximately 70% of the Geographe Bay is a covered by seagrass. Studies of nutrients entering Geographe Bay have shown that the total discharge of nutrients in the Bay is derived from surface flows from rivers and drains, groundwater discharges, and discharges from unsewered areas adjacent to the coast. Studies have been carried out within the Bay to determine the nature and extent of algal blooms and the status of the seagrass meadows in Geographe Bay (Walker, 1994).
In the 1990s, local concern over the health of seagrasses in Geographe Bay prompted the then Water Authority of Western Australia (WAWA) to fund a series of studies investigating the impacts of nutrient discharge on the benthic communities of Geographe Bay (Lord & Associates, 1995). A component of the Study was the investigation of the seagrasses, algae and water quality of Geographe Bay by McMahon (1994), Walker et al. (1994, 1995a, b, c, d, e) and McMahon & Walker (1998).

The study concluded that the seagrasses in Geographe Bay were mostly in a healthy condition, without exceptional epiphyte loads, excepting the inshore sites at Buayanup Drain and the Vasse Diversion Drain.

Most of the nutrient input to the Bay occurs in winter, when rainfalls flush nutrients into the Bay. The McMahon and Walker study of 1998 assessed the impact of the agricultural drains that flow from July to September on nutrient concentrations in the water column, sediment and the seagrass *Posidonia sinuosa* in near-shore Geographe Bay.

These studies identified that during winter, nearshore nutrient concentrations adjacent to the drains increased 10-fold compared to the reference site (Dunsborough). However, the levels were not detectable more than 100m offshore. The high biomass of the meadows makes the seagrasses an important nutrient pool, as they absorb nitrogen and phosphorus both from the water column and from the sediments.

In 2001 – 2003, Sinclair Knight Merz completed another nearshore marine monitoring program. This study focused on water quality samples and periphyton data. These results were compared to similar work by D A Lord and Associates (1995) and cross referenced against terrestrial catchment data such as rainfall, stream flow and agricultural production statistics for the past decade. All data were compared with relevant ANZECC/ARMCANZ (2000) trigger values for the protection of marine ecosystems. Periphyton is the complex assemblage of algae and other organisms that settle on surfaces in the sea, and if in excessive amounts, can smother seagrass leaves and epifauna causing their death.

Sinclair Knight Merz (2003) found there was deterioration in several water quality parameters at eastern sites across the project area, particularly when compared with the data of D A Lord and Associates (1995). In 1995, D A Lord and Associates (1995) concluded that Geographe Bay was “a healthy environment that has not been degraded by nutrient enrichment, however there was a need to control the quality of surface runoff and discharges from drainage systems into the Bay.”

Using the latest dataset for Southern Geographe Bay, Sinclair Knight Merz (2003) described the marine environment as being “slightly disturbed”. This deterioration coincided with a period of increase in the value of agricultural production within the Shire of Busselton and a large increase in population in the Shire of Busselton, primarily along the coastal strip.

### 3.7 Acid Sulphate soils

Acid sulphate soils are potentially a problem in the project area. The following has been copied from a planning bulletin providing guidance about acid sulphate soils (WAPC, 2003).

Acid sulfate soil is the common name given to naturally occurring soil and sediment containing iron sulfides. In Australia, the acid sulfate soils of most concern are those that formed in the Holocene geological period (the last 10,000 years) after the last major sea level rise. During the sea level rise, new coastal landscapes were created as a result of rapid
sedimentation, and acid sulfate soils were created when bacteria in these organically rich waterlogged sediments converted the sulfate from the seawater, and iron from the sediments, into iron sulfides.

These naturally occurring iron sulfides are generally found in a layer of waterlogged soil or sediment, and are benign in their natural state. When disturbed and exposed to air however, they oxidise and produce sulphuric acid, iron precipitates and concentrations of dissolved heavy metals such as aluminium, iron and arsenic.

The principal environmental, social and economic impacts of acid sulfate soils have been documented as follows:

- Adverse changes to soils and water quality;
- Deterioration of ecosystems and the ecosystem services associated with soils, groundwater, wetlands, watercourses and estuarine environments;
- Local and regional loss of biodiversity in areas affected by acid sulfate soils leachate;
- Loss of groundwater and surface water resources used for irrigation and other purposes;
- Reduction in opportunities for agriculture and aquaculture;
- Human health concerns particularly from arsenic contamination of groundwater in areas affected by acid sulfate soils;
- Corrosion of engineering works and infrastructure such as bridges, culverts, floodgates, weirs, drainage pipes and sewerage lines;
- Conflict between activities that depend on healthy surface and groundwater regimes (e.g. commercial fishing, recreation and tourism) and activities that may have resulted in disturbance to acid sulfate soils (e.g. agriculture and urban development);
- Loss of visual amenity from plant deaths, weed growth and invasion by acid tolerant aquatic plants and algae, and
- Costs to the community in terms of financial outlays and the community’s and government's time and effort in minimising impacts and rehabilitating disturbed areas.

Areas in the project boundary where there is a risk of acid sulphate problems include coastal areas (including the Swan Coastal Plain) where the following pre-disposing factors exist:

- Areas known to contain peat or a build up of organic material;
- Areas near bores in which peat or other organic deposits have been recorded as part of the stratigraphy;
- Permanently inundated wetlands;
- Seasonally or occasionally saturated or inundated floodplains and sumplands;
- Shallow estuarine areas receiving alluvium;
- Mangrove areas;
- Tidal swamps, wetlands and shallow estuarine areas receiving alluvium;
- Artificial lakes excavated in peaty material;
- Sites known or believed to contain carbonaceous or pyritic material, such as:
  - sites containing fill;
  - existing or former municipal waste disposal sites;
  - industrial sites;
– food industry waste disposal areas, and
– animal-based waste disposal areas;

• Areas where the highest known water table level is within three (3) metres of the surface, and
• Areas where the pH of the soil or water is less than 5.

Any change of zoning that will lead to any intensification of land use on at-risk land shall be accompanied by a Preliminary Site Assessment, which is to be prepared in accordance with the Department of Environment and Conservation guidelines.

Where the presence of acid sulfate soils has been confirmed by a Preliminary Site Assessment, the change of zoning shall also be accompanied by a Detailed Site Assessment, which is to be prepared in accordance with the Department of Environment and Conservation guidelines.

The following guideline documents apply to acid sulphate soils:


• Acid Sulphate Soils Guideline Series: Treatment and Management of Disturbed Acid Sulphate Soils and Acidic Ground and Surface Waters: Draft (Department of Environmental Protection and Water and Rivers Commission, 2003b).
4 Guidance for land and water resource managers at the whole-of-catchment scale

This chapter firstly identifies strategies available for restoring degraded areas of the project area and secondly recommends interim best management practices. Appendix 1 provides a GIS-based technical synthesis of the main issues at the whole-of-catchment scale, which helped inform the following section.

4.1 Strategies for degraded rural areas in the Busselton-Dunsborough coastal area

A detailed description of current activities within the Busselton – Dunsborough Region can be found in the Geocatch Business Plan (www.geocatch.asn.au).

4.1.1 Nutrient loss prevention strategies

Nutrient loss is one of the most important issues for the region (Table 4) and can occur through the leaching of soluble nutrients from coastal sandy soils or sandy valleys and depressions in the hills, or from water erosion and particulate transport in the steeper unvegetated slopes.

Nutrient loss can be addressed by the adoption of the following practices:

- Improved fertiliser management programmes incorporating soil and tissue nutrient analysis and application on demand;
- Increased use of deeper rooting plant species;
- Retention of drainage from rural properties;
- Retention or establishment of vegetated buffer zones (nutrient filters) along drainage channels and tributaries and around wetlands;
- Fencing of riparian zones to prevent stock access, and
- The incorporation of agroforestry or tree plantations into farming systems.

4.1.2 Revegetation strategies / vegetation protection

Considering that only 15% of the natural vegetation remains on the coastal plain, revegetation has been identified (Table 4) as a significant land management issue.

This should be carried out adhering to the following principles:

- Use of local species with appropriate preparation and establishment techniques;
- Planting appropriate tree species where they will assist salinity or nutrient loss control, and priority planting in areas identified as land management risk areas, and
- Locate trees to establish ecological corridors between isolated remnant vegetation patches.

Vegetation protection and retention can be achieved by the adoption of the following practices:

- Local involvement in land clearing assessment (based mainly on land degradation risk, but also considering habitat, landscape and conservation values);
- Location of new developments to protect remnant vegetation;
- Fence off remnant vegetation within rural-residential areas;
- Protection of individual trees where animals are grazed;
- Minimise clearing to building envelopes in rural-residential areas, and
- Incentives for retention of significant remnant vegetation areas (White, 2002).

4.1.3 Waterlogging prevention strategies
The risk of waterlogging is greatest in the 4 and 5 nutrient management units (Figure 7 in Appendix 1). Waterlogging can be addressed with the following practices:
- Establishment of trees that are adaptable to particular environmental conditions and, if possible, also suitable for commercial harvesting;
- Manipulation of farming practices so that pastures and crops use more water;
- Removal of excess water by surface drainage but only in areas where lower portions of the catchment will not be adversely affected;
- Management of pasture cover in late spring, and
- Management of stock numbers to prevent complete loss of pasture cover on areas susceptible to salinity.

4.1.4 Water erosion prevention strategies
Water erosion is likely to occur on the steeper slopes associated with Whicher Scarp and within streams and drains. This contributes to stream turbidity, channel sedimentation and nutrient loading. More information on erosion control is available from DAFWA. Water erosion can be addressed by the adoption of the following practices:
- Retention of native vegetation, particularly along drainage lines;
- Use of earthworks on farms to detain runoff or direct it to stabilised (vegetated) waterways;
- Encourage farming practices which increase soil infiltration/soil water storage (gypsum, stubble retention, increased organic matter) and evapotranspiration (suitable tree species to maximise soil water use onsite), and thereby reduce runoff, and
- Stock management, revegetation and stabilisation of waterways.

4.1.5 Salinity prevention strategies
The risk from salinity is highest in the 5 nutrient management units (Figure 5a in Appendix 1). Salinity can be addressed by the following practices:
- Establishing trees that are high water users, adaptable to particular environmental conditions and, if possible, are suitable for commercial harvesting;
- Plant pasture and crop species with a high water demand;
- Remove excess water by surface drainage but only when downstream areas are not affected, and
- Manage pastures to maintain cover in late spring.
4.1.6 Wind Erosion Prevention Strategies

The risk from wind erosion is highest for unvegetated slopes of the uplands and some fine textured soils of the coastal plain. Wind erosion can be addressed by the adoption of the following practices:

- The establishment of tree shelter belts in strategic locations;
- Stock management that avoids overstocking during dry periods and total depletion of pasture cover on areas at risk from wind erosion and salinity, and
- Maintain soil structure via stubble retention and gypsum if required.

4.2 A framework for water management in the Busselton-Dunsborough coastal area

The Geographe Catchment Council (Geocatch) is the peak non-government ICM Group for the Geographe Catchment. Within the State NRM framework, Geocatch is a subregion of the South West NRM Region. Geocatch is an incorporated community group and is sponsored by the Department of Water to coordinate catchment management in the Geographe Catchment.

The Geographe Catchment Management Strategy (2000) was developed following extensive consultation. The Strategy identifies management principles, issues, objectives and strategies for action. The partners to the Strategy, including the Shire of Busselton, implement the Strategy through annual Business Plans.

In September 2002, the State’s first Water Resource Management Committee (WRMC) was formed under the Rights in Water and Irrigation Act (1914) in the Whicher Region that covers the respective Shires of Augusta-Margaret River, Busselton, Capel and Nannup. The Whicher Committee is intended to be the vehicle for community involvement in the management of water resources in the region. Membership is drawn from people residing in these shires and is heavily community based. One of the Committee’s roles is to provide the South West Region with a direct link to the views of the local community. In addition, they will also provide advice and assistance in considering various matters, including allocation and use of water resources within the defined boundary of the Whicher Region.

It is expected that the functions of the Whicher WRMC will develop in accordance with their growth in expertise. In the initial phase, the functions of the WRMC will be recommending and advising in the areas of:

I) The management, allocation and planning for all water resources;
II) Setting water allocation objectives and principles;
III) Coordinating community consultation planning for water resource management;
IV) Creation of local by-laws, if required;
V) Dispute resolution, if required, and
VI) A central means of input for both the Region and the community into each others respective positions.

The following strategy has been recommended for implementing effective ICM (Mitchell, 1991, Walters, 1993).
There are a number of definitions of ICM and most have holistic elements, as they articulate the need to integrate and balance the social, economic and environmental aspects of catchment management (Mitchell, 1991). The important thing to remember is that ICM is a process, not a commodity. It has to be built or evolved over time in its social, economic and environmental context. Professor Bruce Mitchell, a Canadian academic, provided us with what has proved to be an enduring prescription of the building blocks of ICM when he was reviewing progress in WA in 1990, they are outlined as follows.

- A systems approach in which attention is directed toward both natural and human systems, their component parts, and the interrelationships among those parts. To be consistent with this approach, the management unit should be one that highlights linkages. This will often, but not automatically, lead to the catchment or river basin being the appropriate planning and management unit.
- An integrated approach in which attention is directed to key issues and variables, rather than all issues and variables, and to the linkages among the key issues and variables. In this regard, integrated management is more focused and selective than comprehensive or total management.
- A stakeholder approach in which it is recognised that citizens and non-government groups should be able to participate in decisions about what ought to be, what can be, and what will be for an area.
- A partnership approach in which it is recognised that state agencies, local governments, non-government organisations and individuals each have a role. This requires:
  - a search for common objectives;
  - decisions at the outset about the relative roles and powers of state agencies, local governments and citizens; and
  - identification of mechanisms that will be used to make decisions when there are conflicts.
  - (Refer to the above comments on the Whicher Water Resource Management Committee and its combined stakeholder partnership approach.)
- A balanced approach which weighs concerns about enhancing economic development, protecting the integrity of natural systems, and satisfying social norms and values is required. In this manner, the integrated approach becomes implemented at the local scale.

A number of steps have been identified in establishing an appropriate process to oversee the development of integrated catchment management plans. This document should be seen as one component in a greater ICM plan for the region. The following sections in this chapter list the various steps for an ICM plan as applicable for water resources management planning and describe the current status of each of these steps. From this analysis, the requirements and objectives of this document are given a more appropriate context.

The final section of this chapter describes the scope of this framework document and how it might fit within the umbrella of a full ICM plan at some later date.

4.2.1 Steps in the process

A number of steps have been identified for effective ICM. They include the following.

- Identify issues

  Issues-of-concern to the community must be identified early in the process. The issues-of-concern need to be evaluated and those considered key issues for water resources
management need to be described using best available information. Socio-economic and environmental linkages and dependencies for key issues also need to be described where possible.

- **Identify goals and objectives**
  Identify the environmental values of receiving waterways and shallow groundwater systems. Identify threats to values posed by current, past and possible future land uses. Develop interim targets for surface and shallow groundwater and receiving water quality.

- **Identify problem areas**
  Areas at risk of land degradation and nutrient and sediment-loss need to be identified on a catchment-wide basis. GIS-modelling can be used to identify such hot-spots for catchment management and water resources protection (Negahban *et al.*, 1995, Deeley *et al.*, 1999). This information can then be used to develop priority areas and issues for restorative or conservation measures.

- **Establish process to evaluate management options**
  An open, inclusive process of enquiry will accommodate the complexity and breadth of required scenario evaluation. Tools to be used for scenario evaluation include:
  - Indicators of key processes for water resources and their management;
  - A quantitative evaluation of existing legislative tools;
  - A quantitative evaluation of existing planning and land management tools;
  - A quantitative evaluation of existing agricultural practices and possible BMPs;
  - A quantitative evaluation of existing urban stormwater practices;
  - An evaluation of institutional and community management capacity;
  - An integrated technical synthesis of key issues and linkages (social, economic and environmental), and
  - Evaluate socio-economic and environmental consequences of alternative policy and implementation scenarios.

- **Develop and implement an interim plan of actions**
  There are a number of components of an interim plan of actions. It is called an interim plan because it would have been based on best available information that was available at the time of developing the plan. In most instances, plans have been developed on imperfect data with much uncertainty and doubt. The plan of actions must be improved in time as better information comes to hand.

Components in the interim plan-of-actions as part of a larger process should include:
  - Development of a community capacity building program so that there is a clear path of induction for community members participating in the management planning process;
  - Negotiations and resolutions over key roles and responsibilities between stakeholders must have a major input from current landowners;
  - Implementation of interim plan of actions;
  - Identification and procurement of seed funding for demonstration sites, incentive schemes etc, and
  - Identification and development of required policy and regulatory amendments.
• Undertake monitoring, evaluation and refinement of the plan of actions

The interim plan must be improved over time. This requires an ongoing commitment to monitoring a range of indicators across a range of disciplines and spatial and temporal scales. Social, economic and environmental indicators should be monitored.

Environmental monitoring of land use impacts is a difficult task because of climatic variability and the unconnected links of environmental cause and impacts, especially from diffuse-source pollutants like sediments and nutrients (Deeley, 2002). What this means is that a downstream wetland may only show the impacts of an upstream rubbish tip several decades after the impact commenced because of lags in groundwater flows.

Similarly, restoration at the hypothetical tip-site may take many years to take effect in the downstream wetland. For example, it may take trees that were planted at the tip-site years to draw water levels down, it may take many years for the polluted groundwater to move from the tip to the wetland and finally it may take many years for the wetland to recover after inputs from the groundwater ceased because of effective recycling of nutrients in waterbodies.

A systems analysis of the performance of the management plan (in this case, the framework document) must be part of ongoing performance evaluation. This would need to include a quantitative analysis of progress toward achieving targets and objectives. A review of these monitoring and evaluation data would form the basis of refining the ongoing plan-of-actions.

4.2.2 Supporting integrated catchment management

The previous section identified some of the steps involved in a full ICM study for the region. The current project and this document specifically address some of the issues previously described.

• Identify issues

Some issues-of-concern to the community have been identified early in the process. The issues-of-concern have been evaluated and those considered key issues for water resources management have been identified (GCC, 2000). This document aims to describe the nature of and linkages between key environmental issues for the region using the previously collected information. It also describes a GIS-based analysis of available spatial and water quality information.

For ICM to be truly effective, socio-economic and environmental linkages and dependencies for key issues also need to be described where possible. These will not be addressed as part of the current investigation.

• Identify goals and objectives

This document aims to identify goals and objectives applicable at the whole-of-catchment scale that are consistent with the environmental values of receiving waterbodies and shallow groundwater systems that have been previously documented elsewhere (WRC, 1999, 2001, GCC, 2000, Coastwise, 2001).

This document also identifies threats to values posed by current, past and possible future land uses. The DoW is currently undertaking an analysis of local water quality data and working with Geocatch to develop water quality targets for local waterways. This
• Identify problem areas
  Areas at risk of land degradation and nutrient and sediment-loss need to be identified on a catchment-wide basis. This document describes a GIS-based analysis, which was used to identify potential nutrient-loss hotspots throughout the catchment. It also describes the results of this investigation and identifies priority areas and issues for restorative or conservation measures.

• Establish a process to evaluate management options
  The following would be required:
  – An integrated technical synthesis of key issues and linkages (social, economic and environmental) toward achieving water resources management. This document specifically identifies linkages and interactions between some key environmental issues pertaining to water resources management. This paper does not investigate the social or economic implications of various recommendations or alternative policy or BMP implementation scenarios.
  – A quantitative evaluation of existing legislative tools in terms of their success in changing community behaviour to achieve water resources management. This document does not evaluate existing legislative instruments.
  – A quantitative evaluation of existing agricultural practices and possible BMPs in terms of their success in achieving water resources management outcomes. This document, while identifying hot spots and recommending potential improved management practices, will not quantitatively evaluate the nature of improvements in water quality or biodiversity or farm viability arising from alternative BMP implementation strategies at the catchment scale. This will be required in the near future.
  – An evaluation of the management capacity of various government institutions and the land owning community in terms of their ability to change management practices for water resource related issues is required. This document does not evaluate the management capacity of local water resource managers (urban and rural land owners).
  – Some environmental indicators of key processes for water resources and their management have been identified. This would need to include an assessment of the variability in indicators, lags, normal and extreme readings, and specificity at measuring causes and effect. Socio-economic indicators relating to water resources management have not been identified.

• Develop and implement an interim plan of actions
  This document, at the catchment scale:
  – Provides a technical synthesis of available bio-physical information pertaining to water resources management;
  – Provides water resource management objectives applicable at the whole-of-catchment scale and for receiving environments;
  – Identifies hot spots for sediment and nutrient loss, and
  – Provides recommendations for improved management practices.
This document does not provide an interim plan of actions which tracks changes in community behaviour toward improved water resources management but rather identifies some of the elements that should be included in an interim plan of actions.

- Undertake monitoring, evaluation and refinement of the plan of actions
  This document provides some recommendations on environmental monitoring.

### 4.3 Interim plan of action for the Busselton-Dunsborough coastal area

The following sections identify some plans of action that will be needed as part of future water resource protection for the Busselton-Dunsborough coastal area.

#### 4.3.1 Water balance study

An agreed water balance is required for the region. The water balance study would need to focus on the hydrological cycle within the Busselton-Dunsborough coastal area. It will ensure that there is a common understanding of the hydrological processes occurring within the Busselton-Dunsborough catchment, and how both natural and anthropogenic changes within the catchment can affect this water balance. Changes may include urbanisation and development projects or conversely BMP adoption such as agroforestry or native revegetation programs. Climate change can also cause changes.

The completion of such a study, with results openly discussed in an open forum, will allow catchment stakeholders to appreciate how on ground actions (whether they are developmental, remedial or the "do nothing" approach) will affect the local water balance, and how these considerations can be taken into account for catchment-wide planning and management.

#### 4.3.2 Regional vegetation assessment

More detailed regional vegetation assessment will need to be undertaken. The regional vegetation assessment will need to include a combination of field assessments and aerial photograph and satellite image interpretation in order to provide up to date information regarding the distribution and status of the remnant vegetation throughout the Busselton-Dunsborough area. From this information, fencing and other vegetation management activities can be prioritized to protect remnants with the highest conservation status and greatest perceived threats.

The Department of Environment and Conservation are currently completing a project called the Swan Bioplan. This project assesses the vegetation along the swan Coastal Plain from Moora to Dunsborough. The assessments include field and aerial mapping condition ratings and vegetation unit classification. The information collected within this project will provide a good vegetation regional assessment for the Busselton to Dunsborough Region.

#### 4.3.3 GIS database with regular maintenance and updating

A GIS system is a collection of hardware and software which enables the collection, storage, query and manipulation of spatial data which can be attributed with information stored in a database. Spatial data can be used to represent the distribution of many environmental phenomena in the real world, such as soil types, geology, streamlines, etc. A preliminary GIS database has been prepared for the Busselton-Dunsborough catchment. This will need to be
extended and updated to include appropriate search, query and analysis functions. This updated GIS database will serve a number of important functions, including:

- To collect and store relevant spatial data for the Busselton-Dunsborough catchment so that this information can be readily accessed by the Shire, LCDCs, working groups and land-holders;
- To store spatial data generated as part of evaluation and target setting such as, drains mapping, "hot spot" identification and the regional vegetation assessment;
- To combine layers of information so that priority works areas can be identified;
- To store information on works schedules, including the proposed start and completion dates as devised by the working groups as part of the various targets, and
- To store information regarding completed on-ground works and therefore facilitating performance reviews at regular intervals.

To further determine the capability of land uses within the project area, refer to the Department of Environment and Conservation ‘Geomorphic Wetlands, Swan Coastal Plain’ dataset. Information about the management objectives and recommended buffer widths between land uses and wetlands is available in the Water and Rivers Commission Position Statement: Wetlands (WRC, 2001).

A system similar to the one being proposed for the Busselton-Dunsborough catchment has already been successfully implemented for the Lake Eppalock Catchment by the Centre for Land Protection Research which is a corporate arm of the Victorian Department of Natural Resources and Environment (CRCFE, 1997).

4.3.4 Formulation of Farm Management Plans

Farm Management Plans (FMP) are a strategic approach developed by the farmer to balance economic, social and environmental factors that need to be taken into consideration when managing a farm business (Swan River Trust, 1999). They need to be tailored to individual farms and will be influenced by the nature and profitability of the farming operation and the farmer's own personal values. Effective FMPs need to contain a number of operational elements such as:

- Stocking rates;
- Planting of perennial and forage trees for summer pasture;
- Streamline fencing and restoration;
- Erosion control (catchment and foreshore);
- Fertiliser use;
- Management of natural and constructed wetlands, and
- Earthworks (e.g. grassed waterways to manage surface water).

To ensure their success, FMPs should be integrated with farm budgeting and financial management, and will assist individual landowners in obtaining funding for remedial works as outlined in their FMP.

4.3.5 Integrated whole farm BMP demonstration sites

Whole farm demonstration sites are required to demonstrate best practice for a range of land uses and management methods. These whole farm demonstration sites should be implemented as an educational tool to show other local landowners how whole farm BMP
implementation is achieved. As a minimum, two demonstration sites will be required to represent the two geomorphologic extremes, the coastal plain and the uplands east of the scarp.

The implementation of these two separate demonstration sites should focus on the planning and selection process involved with farm scale BMPs just as heavily as the display of the final site. In this way, local landowners will be able to gain an insight into how this sort of whole-scale farm management and planning can be carried out and how it can be implemented through a Farm Plan. Most importantly it will demonstrate the benefits of BMP adoption and therefore will encourage other landowners to implement such works and measures.
5 Guidance for future urban development

This chapter identifies development investigation areas (DIAs) as described in Shire Land Release Plans (BSC, 1999, 2002), describes guiding planning principles at the local urban development scale, describes constraints for DIAs and provides example BMPs for stormwater treatment trains.

An example interpretation of the urban area guidelines is provided for the Ambergate DIA (Appendix 2). This example is by no means intended to prevent other innovations being applied for the Ambergate area, but more to illustrate how the guidelines may be interpreted.

5.1 Water Sensitive Land Use Management

Examples of land use management controls to maintain water quality and water balance are:

- Restrictions on fertiliser application rates, with strict controls on the application of pesticides and field operations;
- Restrictions on the storage of fuels and chemicals, with strict guidelines for rehabilitation.
- Restrictions on the use of fuel and chemicals;
- Special rural developments to require appropriate planning justification, including provisions in the town planning scheme text;
- Urban development to be connected to deep sewerage, where practical, or otherwise to an approved wastewater disposal system that meets water quality protection objectives for the subject area;
- Some land uses may be permitted, if the use is incidental to the overall land use in the area and consistent with planning strategies;
- Extra restrictions apply to sitting of effluent disposal systems in areas with poor land capability and a shallow depth to groundwater;
- Restrictions on density of accommodation;
- Restrictions on road design and construction and the types of goods that may be carried;
- Restrictions to stocking levels in Special Rural zones, and
- Some storage of chemicals may be permitted if the type, volume and storage mechanisms satisfy water quality protection objectives.

For example, the following provisions apply at Jandakot (located in Perth's southwest corridor), where a balance is being sought between groundwater supply, wetland protection and urban development (Parsons Brinckerhoff, 2004).

- Development of urban and special rural areas include measures to protect wetlands and vegetation within these areas.
- Possible future urban development to be subject to further groundwater and/or environmental assessments. Specifically, urban development is to be fully serviced and engineering and environmental investigations should be undertaken to determine the nutrient and water management requirements for urban development. These investigations should include water management plans to:
  i. minimise fertiliser sources;
  ii. control stormwater by maximising local recharge;
  iii. manage maximum groundwater levels through sub-soil drainage and other mechanisms (eg. plantation scale tree planting), and
iv. redirect surplus stormwater from major events to areas where retention and infiltration processes promote later reuse.

- Special Rural zones to be consolidated and be subject to land use and management controls (eg. clearing controls).
- Establishment of the Jandakot Botanic Park to protect groundwater, significant wetlands and vegetation and for recreation purposes.
- Activities within rural areas to be compatible with the protection and enhancement of landscape features and conservation values associated with rural areas.

Apart from existing approved subdivisions with lots less than 2 hectares in size and innovative subdivision proposals such as cluster form development which demonstrates an average 2 hectare lot size, all future subdivisions will have a minimum lot size of 2 hectares. This density control mechanism is important to minimise the risk of pollution to the water source from increased chemical use and nutrient application.

5.2 Water Sensitive Urban (Residential) Design

In the late 1980’s to early 1990’s the concept of water sensitive urban design was introduced largely in response to then concerns over the Thomsons Lake urban development at Jandakot and other anticipated urban development in environmentally sensitive areas.

In Perth, the above concerns were addressed in Water Sensitive Urban Design (WSUD) guidelines that were prepared for the former Department of Planning and Urban Development, the former Water Authority of Western Australia and the Environmental Protection Authority and were released as a public document in June 1994 for information and reference. These guidelines provided a framework for incorporating the stormwater related issues for water quantity, water quality and water conservation with broader environmental and social objectives at a range of planning levels.

The aim was to ensure that residential development was designed so that its impacts upon water resources were managed in ways that maintain or meet specified water resource management values or objectives. In terms of stormwater management, the emphasis of water sensitive design is on retention, treatment, use and environmental and cultural benefit from the stormwater system rather than purely conveyance and disposal. A number of best management practices were described in the guidelines together with complementary Best Planning Practices (BPPs).

The Stormwater Management Manual for Western Australia (Department of Environment, 2004a) contains a chapter on WSUD.

5.2.1 The multiple use corridor concept

To improve the effectiveness of BMPs, a “treatment train” concept is recommended in the Stormwater Management Manual for Western Australia (Department of Environment, 2004a), where the water flow is subjected to a series of practices which ideally are located as close to the source of the water as possible. This treatment train better enables the objectives of water sensitive design to be achieved.

Features of multiple use corridors are:

- Opportunity to use vegetated areas for peak stormwater flow attenuation;
- Variable width to allow continuity of urban form and pedestrian safety;
- Development fronting on to open space;
- Incorporation of existing and constructed waterway and wetland features;
- Co-location of compatible and land hungry uses - Schools, active and passive recreation, etc;
- Opportunity to include trunk service routes;
- Opportunity to establish habitat for flora and fauna;
- At its simplest - a series of linked parks, and
- Alternatively, a continuous corridor of variable width.

### 5.2.2 Stormwater Quantity Criteria

The following surface water flow and flood level criteria should be set for the development areas.

1. Direct drainage or discharge of stormwater shall not be permitted into any wetland with conservation value (receiving environment), including its designated buffer area. (Conservation value are those wetlands rated as conservation status under the DEC’s ‘Geomorphic Wetland Management Categories’ dataset.)

2. Stormwater runoff within a development area, including its associated road reserves, generated from up to 1 in 1 year, 1 hour Average Recurrence Interval (ARI) rainfall events shall be retained as close to its source as possible, using techniques such as soakwells, porous paving, vegetated swales or shallow depressions.

3. Runoff from greater than 1 in 1 year, 1 hour Average Recurrence Interval (ARI) events shall be mitigated through the use of landscaped retention or detention areas that are integrated within public open space / linear multiple use corridors. The runoff overflow from large rainfall events are directed via overland flow pathways into regional drainage systems or into wetlands (subject to the pre-development hydrologic regime of the wetland being unaltered).

Flow rates to be attenuated through a series of management practices (see Figure 2). These include the following:

- Lot Level – Soakwells/Infiltration & Rainwater Tanks;
- Streetscape – Detention and Infiltration (wider road reserves may be required), and
- Multiple Use Corridors – Detention (Pool & Riffle) and Infiltration.

At the lot level, flow rates will be attenuated by the common use of soakwells installed at the building stage to infiltrate roof runoff. It is not recommended, nor should the Shire accept the direct connection of lots to the road drainage network.

It is recommended that the use of rainwater tanks be promoted for both potential infrastructure-related and environmental benefits (some local authorities encourage the use of rainwater tanks at the lot level through policy which can include offering grants upon their installation).

At the streetscape level, dual carriageways will shed runoff to a central median to assist infiltration, provide detention storage and reduce times of concentration. The central median will incorporate a bio-retention system to treat water quality and further enhance infiltration.
Investigations should be undertaken into the feasibility of reusing infiltrated surface water for irrigation of landscaped areas.

Multiple use corridors will assist infiltration, detain stormwater and reduce times of concentration. Where multiple use corridors are proposed over degraded areas, they can be reshaped and landscaped to incorporate linear constructed ephemeral wetlands. As part of this, reshaping longitudinal slopes can be modified to include a pool and riffle profile to slow velocities, assisting infiltration and detaining stormwater.

5.2.2.1 Flood conveyance – waterways

For some sites, fill and/or subsoil drainage may be required to raise development levels above both groundwater levels and 100 year flood levels (Figure 3). During a more detailed phase of design when detailed hydraulic modelling is undertaken, outlet hydrographs may be required to define storage volumes. This will determine fill or floor levels for development. It may also help in designing the type of storage. Constructed wetland’s is only one option for achieving storage volumes and other methods should be investigated as a matter of priority. These may include temporary storage in various elements of the multiple use corridors, such as playing fields, etc.

For developments the location of multiple use corridors need to be selected to maintain the natural flow path and thus be used as a flood management path for significant storm events. Post development flows need to be attenuated to match pre-existing conditions so that the downstream hydraulic regime does not change. Proposed multiple use corridors will include water management function, as well as other uses such as recreation.

Significant areas of Busselton are flood-prone from a number of watercourses and wetlands. The Vasse River Diversion was constructed to divert floodwaters around the central business district and residential areas to its outlet into Geographe Bay. In August 1997, intense rainfall occurred in the upper catchment of the Vasse River Diversion, causing major flows and the levee banks being overtopped in the lower reaches around Busselton. A preliminary review of this flooding by the Department of Water indicated that Busselton has only 20 year ARI flood protection and not, as was previously thought, 100 year ARI flood protection.

In 1998, a detailed flood management study was conducted, which included an evaluation of flood mitigation measures that would provide Busselton with 100 year ARI flood protection. The flood management study confirmed Busselton has only 20 year ARI flood protection and consequently the level of flood protection is considered inadequate. The increase in the 100 year ARI flow in the Vasse Diversion Drain can be attributed to a more efficient rural drainage system and some increased land clearing of the upper catchment. The preferred option for increasing the level of flood protection for Busselton is a combination of retaining floodwaters in the upper catchment and minor upgrading of the Vasse River Diversion. Any drainage design proposing discharge into the Vasse River Diversion Drain will need to be cognisant of flood levels in the drain. Sufficient storage of local flood events may be necessary until flood levels subside in the diversion drain.
5.3 Surface water quality management

5.3.1 Identifying water sensitive urban design opportunities

The adoption of WSUD principles in the planning of the layout of the proposed development and the treatment of stormwater runoff is a recommended strategy for progressing the proposed development to protect the environmental values of both the surface water system and the groundwater system.

The strategy for the management of stormwater runoff will be directed at reducing the impact of the development on the receiving waters in terms of stormwater quantity and quality and will involve the use of non-structural controls, infiltration of roof runoff into the Ludlow sand formation, streetscape bioretention systems for paved areas other than roofs and linear ephemeral wetland systems on multiple use corridors.

5.3.2 Stormwater Best Management Practices

5.3.2.1 Structural measures

Best practice stormwater management measures should ideally be incorporated into the design of the residential developments around the following treatment objectives:

- Capturing stormwater for reuse;
- Managing peak flows, and
- Managing stormwater pollutant loads.

The treatment (removal) of suspended solids and pollutants (eg. nutrients and hydrocarbons) are the primary objectives of the stormwater treatment measures. Possible stormwater treatment measures that are capable of achieving the above best practice stormwater management objectives are summarised below. Means to promote harvesting stormwater for reuse have an indirect beneficial water quality outcome in terms of the reduction in the volume of stormwater requiring treatment for removal of suspended solids and pollutants. Similarly, the reduction in peak flows will also result in reduced hydraulic loading of the stormwater treatment measures, making it more efficient in the removal of stormwater pollutants. A well designed system has the capability of reducing peak discharges entering receiving waters for frequent flood events and thus has an added flood mitigation benefit in terms of reduction in the frequency of physical disturbances to aquatic habitats in natural waterways.

Storage tank. Storage tanks are sealed tanks (to prevent mosquito breeding) capable of collecting stormwater directly from a roof or other above ground surfaces. It is designed to allow reuse of the collected water as a substitute for reticulated water for use as landscape water and in some cases toilet flushing / washing machines.

Infiltration of stormwater. Infiltration of stormwater is common practice in Western Australian land development projects and is considered an appropriate source control measure that can significantly reduce the magnitude and volume of stormwater runoff generated from the site. For much of the project area, the sandy soils are likely to have low phosphorus retention capacity and nutrients generated from the proposed development will contribute to the nutrient load conveyed by the groundwater. Where appropriate (ie. in high nutrient loading risk areas), stormwater could be infiltrated through a top layer of sandy loam soil (soil amendment), for treatment and retention of nutrients, before reaching the groundwater.
**Infiltration of rainwater.** Rainwater generated from the roof area can be put into the groundwater without the need for pre-treatment on the basis that roof areas generate significantly lower nutrient loads. The infiltration of roof runoff can be through the use of soakwells installed at the building stage.

The conceptual water quality management treatment train is demonstrated in Figure 4.

**Vegetated swale.** Vegetated swales are grassed or vegetated channel capable of conveying stormwater runoff and used as an alternative to kerbs and gutters. Additional road reserve widths may be required in some locations. The types of vegetated swales can range from well landscaped systems that form a part of the overall presentation of individual dwellings to one which consists of native vegetation planting and which is more accommodating of the climatic conditions of the area. The latter has also been shown to require less maintenance cost.

Vegetated swales can perform a pre-treatment function in terms of removal of sediments and nutrients prior to the stormwater being conveyed towards other treatment measures.

Typical analysis of the performance of grassed swales that encompass approximately 2% of the development catchment area indicates approximate total suspended solids, total phosphorus and total nitrogen removal of 75%, 45% and 17%, respectively (Wong, pers comm 2004, unpublished research results).

**Grass buffer.** A grassed or vegetated filter or buffer strip capable of treating shallow overland flow before it enters the drainage network. Most suited for road reserves and used in combination with vegetated swales.

**Street bioretention system.** Street bioretention systems combine the stormwater treatment functions of a vegetated swale and stormwater filtration system. Stormwater is filtered through a prescribed media (eg. sandy loam) before either being collected by an underlying perforated pipe for subsequent discharge to a stormwater system or allowed to infiltrate into the groundwater system.

Bioretention systems can also be incorporated within road reserves, either along the median strip of dual carriageway roads or on one or both verges of single carriageway roads.

Typical depth of filter media is 600 mm, although there have been recent projects in the eastern states of Australia where a wider and shallow system (approx. 400 mm) has been adopted. Typical analysis of the performance of bioretention systems that encompass approximately 3.5% of the development catchment area indicates approximate total suspended solids, total phosphorus and total nitrogen removal of 90%, 65% and 60%, respectively (Wong, pers comm 2004, unpublished research results).

**Street tree bioretention system.** This has recently been adopted in a number of urban designs for treatment of road runoff by a combination of landscape watering and filtration through soil (sandy loam) placed in street tree planter boxes. This system of street scaping will significantly reduce the need for tree watering.

**Constructed wetlands at neighbourhood scale.** These wetlands involve the use of a macrophyte zone, or a permanent or ephemeral shallow water body with extensive emergent vegetation as part of a landscape park feature within the development.
Consultation with officers of the DoW has highlighted a degree of concern about the sustainability of constructed wetland systems for stormwater treatment in the climatic conditions of south-west Western Australia. These concerns are based on poor past experiences with constructed wetlands in the Perth region attributed, we believe, to poor design and management practices. We recommend the use of ephemeral wetland systems that are designed to accommodate a drying period during the summer months.

Mosquitoes are common inhabitants of natural wetlands, so their occurrence in constructed wetland systems should be expected. The control and management of mosquitoes requires consideration. The traditional concept of 'eradication' of mosquitoes by treating habitats with organic insecticides has been replaced by the more realistic objective of 'control', wherein mosquito population numbers are reduced to a tolerable or non-threatening level through a habitat and mosquito management approach.

To minimise mosquito-breeding problems, adequate surface drainage must be maintained, especially in ephemeral wetlands, swales, and along multiple use corridors, to prevent isolated pools forming for more than four days.

Mosquito control is best achieved by a composite methodology, known as integrated control. This involves various complementary techniques that are designed to reduce the mosquito habitat or make it unsuitable, as well as encourage biological regulation of the mosquitoes, and thus limit or even eliminate the use of toxic pesticides. Features to be considered at the design stage and operational considerations used to mitigate against mosquito production are discussed in the following sections.

These include:

- Manipulating water levels;
- Providing areas of sufficient depth to discourage mosquito breeding;
- Constructing bank gradients to discourage development of mosquito habitats;
- Preventing the development of stagnant pools of water;
- Providing chemical control, and
- Instituting mosquito monitoring.

Constructed wetland systems have been successfully incorporated into the urban design to form part of the landscape feature of the urban development.

5.3.2.2 Non-structural measures

In addition to structural measures, consideration should be given to non-structural measures. Dealing with pollution at the source is the most effective means of protecting stormwater quality. The following practices can be utilised by Local Government to help manage stormwater pollution resulting from municipal operations and household and business activities in urban areas:

**Street Sweeping.** A widely used practice to reduce accumulations of litter, dirt and vegetation from streets and footpaths;

**Drain Maintenance.** Inspection, cleaning and repair of open and piped drains, pits, gross pollutant traps and outfall structures to ensure excessive build up does not occur;
**Domestic Waste and Recycling Collection.** Spillage during kerbside waste and recycling collections can contribute to stormwater system pollution;

**Education Programs.** Education is a key non-structural control tool for dealing with activities carried out within residential households and business premises, which have potential to contaminate stormwater runoff. Simple changes in attitude and behaviour can vastly reduce pollution of stormwater from domestic and business activities. Examples include the planting of waterwise native gardens at lot level (requiring less water and less input of nutrients), use of mulches and soil conditioning of topsoils.

**Enforcement.** Enforcement should be seen as a complement to management and education strategies. The primary purpose of enforcement should be to prevent future problems by making polluters accountable. This acts to improve the polluter’s practices and deter others from carrying out polluting activities.

More information on non-structural measures is available in the Stormwater Management Manual for Western Australia (Department of Environment, 2004a).

### 5.4 Implications for urban development

Parts of Section 5.4 has been adapted from the *Albion Water Management Plan* (Parsons Brinckerhoff, 2003).

#### 5.4.1 Fill and subsoil drainage

*5.4.1.1 General*

Due to the presence of near-surface water, expressed either as high groundwater tables or localised inundation of surficial sands overlying sandy clay and clay, both clean sand fill and subsoil (subsurface) drainage might be required over much of the project area.

Where near surface water levels are present, clean sand fill might be imported and laid on-site to increase the distance to the phreatic line (free water surface). Subsoil drainage where approved by the DoW, would locally control maximum groundwater levels and eliminate seasonal fluctuations when placed in conjunction with fill.

Sites designated as areas suitable for future urban development should have detailed site investigations to identify hydrological and geotechnical conditions, design parameters and likely development constraints. The depth of imported fill and the drainage layout and spacing at a new development site is to be based upon the site’s specific situation and physical variables, in particular:

- Resultant topography and natural drainage direction after site preparation;
- Groundwater and surface water levels (including perched water tables). Monitoring should be undertaken at the proposed sites over at least three wet seasons / years);
- Soil properties of underlying natural soil, and
- Proximity to ecologically sensitive areas.

The control of maximum groundwater levels must also address impacts on down gradient receiving waterbodies from altered water levels and the input of water with high nutrient loads, as well as the impacts on remnant vegetation from altered groundwater levels.
Modelling of the proposed site drainage system and fill depths should provide the basis for recommendations for the control of maximum groundwater levels. The Department of Water will then assess proposed maximum controlled groundwater levels / fill heights.

Local building regulations, Australian Standards (e.g. AS2870 Residential Slabs and Footings Code) and Local Government engineering requirements set the minimum distance between the underside of footings or concrete slabs and the water table (or phreatic zone).

The following sub-sections 5.4.1.2 to 5.4.1.6 provide a hypothetical example of drainage calculations and actual thickness of fill and drain spacing will be derived by modelling using site specific parameters and hydrologic conditions.

5.4.1.2 Subsurface drainage

Subsurface drainage is accomplished by placing an artificial channel/subsoil drain below the perched groundwater table so that the hydraulic head of the channel is less than that of the soil to be drained. The hydraulic head differential creates a hydraulic gradient in the direction of the subsoil drain, depressing the phreatic line (free water surface) in the vicinity of the subsoil drain. The constant removal of water flowing into the drain maintains the hydraulic head differential, thus maintaining the depressed phreatic line (see Figure 3).

The hydraulic gradient and the hydraulic conductivity ($K$) of the soil to be drained govern the rate at which water moves toward the drain. Control of water is accomplished by controlling the hydraulic gradient. Therefore, flow is regulated by adjusting the effective depth of the drain ($H$) and the spacing between drains ($L$).

5.4.1.3 Subsurface drain modelling

Most formulae for determining subsurface drain spacing/depth assume that the drainage requirements are continuous as a result of a steady supply of water (rainfall), where upon a state of equilibrium exists for recharge and discharge, or steady-state condition.

True steady-state conditions are less frequent than non-steady, transient flow conditions, the latter usually resulting from rainfall activity that creates a temporary increase in groundwater content and a rise in level ($H/Z$), for example, in areas where short and intense rainfalls are expected.

In transient flow design, the objective is to systematically balance available groundwater storage and drain outflow with periodic recharge events ($t$).

One commonly used approach to transient state subsurface drainage design was developed by the U.S. Bureau of Reclamation (USBR), and generally conforms to the equation below.

$$KHt/SL^2 = C.(Z/H),$$

where $C$ is a dimensionless scale factor.

Definitions of the variables involved in the USBR procedure are as follows:

- $H$ – groundwater table height immediately after a build-up caused by a recharge (rainfall) event;
- $Z$ – the level to which the groundwater table falls during a drain out period;
- $K$ – represents the hydraulic conductivity in the flow zone between drains;
- $S$ – the specific yield or effective porosity (volume fraction of pores drained at a falling water table). The specific yield value for any soil can be used to estimate the build-up of
the groundwater table from each increment of recharge by dividing the depth of rainfall by the specific yield;

- T – this variable represents the drain-out time between rainfall events, and
- L – the drain spacing between parallel subsurface drains.

5.4.1.4 Drain spacing / depth scenarios

Based on the proposed zoning for the study area, the average lot could have an area of 500 m² with typical overall lot depths of approximately 35 m (this can obviously vary with typical depths anticipated between 32 to 35m). Consequently, subsoil drain spacing could be placed in the road reserves, which would generate a grid network with an average spacing (L) of 70 m or additionally include subsoil drains at the rear of abutting lots as well, which would result in an average spacing (L) of 35 m.

Utilising the modelling procedure discussed above and utilising the following assumed parameters and design conditions, four hypothetical alternative drain spacing and depth alternatives have been developed and are represented in Table 5.

- Hydraulic Permeability (K) – 10 m/day.
- Specific Yield (S) – 0.25.
- Recharge Build-up (H-Z) – based on draining the 1 in 1 year ARI 24 hour duration storm in 5 days. The rational behind employing this criterion is that this storm represents 99% of the storms on average per year and the 24 hour duration generates the most rainfall volume (48 mm) when using days as increments of time, this results in recharge build-up of approximately 0.2 m.
- Drain-Out Time (t) – Perth average frontal rain bearing patterns are spaced by approximately 5 days.
- Freeboard (F) – normally the height of additional fill to accommodate dampness due to capillary action – 0.3m.

The overall fill height (Y) is the combination of the effective drain depth (H) and the assigned freeboard. Consideration can be given to lowering this value when no subsoil drainage is proposed at the rear of lots and consequently periodic dampness could be tolerated where the phreatic line peaks at the surface. Caution should be exercised when reducing the freeboard in scenarios where the phreatic line peaks beneath the building envelope.

Table 5 Hypothetical drain spacing and depth alternatives

<table>
<thead>
<tr>
<th>Approximate Drain Spacing (L/m)</th>
<th>Lots Connected to Street Stormwater System</th>
<th>Effective Drain Depth (H/m)</th>
<th>Overall Fill Height1 (Y/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>No</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>70</td>
<td>Yes</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>35</td>
<td>No</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>35</td>
<td>Yes</td>
<td>0.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

1. The overall fill height is from the invert level of the subsoil drains.
5.4.1.5 Subdivision layout incorporating WSUD streetscape

An example of a typical subdivision layout incorporating WSUD elements is illustrated in Figure 4. The pattern is predominantly rectangular, in line with the fundamental principles of the Liveable Neighbourhoods Code.

The layout consists of dual carriageway roads on a regular spacing incorporating a central median to capture surface runoff. The median includes a bioretention system to treat stormwater runoff at its source as part of conveyance prior to outfall into multiple use corridors.

Single lane roads fall towards the dual carriageway and drain into the bioretention system. The spacing between single lane roads is 70 to 80 metres thus permitting two 35 to 40 metre deep lots.

Spacing between dual carriageways is in the order of 200 metres. Single lane roads are crested half way along their length thus only requiring gullies at intersections, which would then convey runoff to the central bioretention system in the median. Spread rates would need to be calculated at the detailed design stage.

House roofs drain through infiltration via soakwells (constructed at the building stage) into the sand fill. Groundwater levels could be controlled by subsoil drainage.

5.4.1.6 Benefit cost analysis

Table 6 presents various hypothetical fill depths required based on the spacing of subsoil drainage. The table also considers whether lots are directly connected to the street stormwater system or not. The DoW has indicated it will not support the direct piped connection of stormwater from lots to the street stormwater system. Therefore, sufficient fill should be placed to ensure the preferred strategy could be adopted.

Table 6 presents a benefit cost analysis for various fill and subsoil drainage scenarios. The results demonstrate significant development cost savings for reduced subsoil drainage spacings and subsoil levels.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Subsoil Drainage Spacing (m)</th>
<th>Subsoil Drainage Level</th>
<th>Overall Fill Height (m)</th>
<th>Imported Fill Depth (m)</th>
<th>Cost per Lot (Fill &amp; Subsoil) (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>Natural Surface</td>
<td>1.8</td>
<td>1.8</td>
<td>$15,000</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>Natural Surface</td>
<td>1.1</td>
<td>1.1</td>
<td>$10,100</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>0.5m below (3) Natural Surface</td>
<td>1.1</td>
<td>0.6</td>
<td>$6,300</td>
</tr>
</tbody>
</table>

1. Subsoil drainage spacing of 70 m represents subsoil drainage with road reserves only, whilst 35 m represents road reserves and at rear of lots.
2. Cost estimates are based on imported fill rates of $15.00 per cubic metre and subsoil drainage rates of $60.00 per metre.
3. The assumption that subsoil drainage can be located 0.5 m below the natural surface requires investigation of maximum groundwater level and DoE approvals.
6 Recommendations

This investigation drew together information from a wide variety of sources to form the basis of formulating recommendations for implementing best practice for water resources and related ecosystem management at the whole-of-catchment scale, targeting potential nutrient-loss and land use hotspots and areas of potential urbanisation. Accordingly, there are a significant number of recommendations spanning many themes. These have been grouped into the following:

- Rural areas;
- Urban development;
- Monitoring evaluation and refinement, and
- Institutional arrangements and implementation.

6.1 Rural areas

This section provides recommendations for whole-of-catchment implementation of improved land and water resource management in rural areas.

6.1.1 Integrated catchment management

Point sources should be managed as a priority through development and adoption of codes of practice, industry self-regulation, incentive schemes for performers and non-performers.

The best mix of best management practices (BMPs) and best planning practices (BPPs) should be identified.

Peer innovators in the community should be identified and solutions they have developed to manage particular land degradation issues should be evaluated and extended to the broader catchment community.

The existing partnership between the Department of Water, Shire of Busselton and Geocatch should be maintained to assist integrated catchment management.

6.1.2 Implement best practice as a first step

As a first step in a more integrated and holistic process, best practice should be identified and extended. Recommendations for best practice to manage nutrient loss, revegetation, waterlogging, water erosion, salinity and wind erosion have been provided (ie. for information about rural land use best management practices, see the Codes of Practices and guidelines on the Guidelines page at: [http://drinkingwater.water.wa.gov.au](http://drinkingwater.water.wa.gov.au) and [www.agric.wa.gov.au](http://www.agric.wa.gov.au)).

6.1.2.1 Nutrient loss prevention strategies:

- Improve fertiliser management programs, incorporating soil and tissue nutrient analysis and application of nutrients to better match plant demand;
- Increased use of deeper rooting plant species;
- Retention of drainage from rural properties;
- Retention or establishment of vegetated buffer zones (nutrient filters) along drainage channels and tributaries;
- Fencing of riparian zones to prevent stock access, and
- The incorporation of agroforestry or tree plantations into farming systems.

6.1.2.2 Revegetation and agroforestry strategies
Vegetation protection and retention can be achieved by the adoption of the following practices:
- Local species should be used in revegetation strategies, with appropriate preparation and establishment techniques;
- Appropriate tree species should be planted where they will assist salinity or nutrient loss control, and priority planting in areas identified as land management risk areas;
- Trees should be located to establish ecological corridors between isolated remnant vegetation patches;
- Local involvement in land clearing assessment (based mainly on land degradation risk, but also considering habitat, landscape and conservation values);
- Remnant vegetation within rural-residential areas should be fenced and managed properly;
- Individual trees should be protected where animals are grazed;
- Clearing during development should be limited to building envelopes in rural-residential areas, and
- Incentives should be established for retention of significant remnant vegetation areas (White, 2002).

6.1.2.3 Waterlogging prevention strategies
The following should be considered in areas subjected to seasonal waterlogging:
- Trees that are adaptable to particular environmental conditions and, if possible, suitable for commercial harvesting should be established;
- Farming practices should be modified so that pastures and crops use more water;
- Excess water can be managed by temporary storage on-site or by surface drainage. This should only be considered in the absence of nutrient attenuation of drainage waters for areas where lower portions of the catchment will not be adversely affected, and
- Pasture cover in late spring should be better managed to maximise water use.

6.1.2.4 Water erosion prevention strategies
The water erosion prevention strategies include:
- Retention of native vegetation, particularly along drainage lines;
- Use of earthworks on farms to detain runoff or direct it to stabilised (vegetated) waterways, and
- Encourage farming practices which increase soil infiltration/soil water storage (gypsum, stubble retention, increased organic matter) and evapotranspiration (suitable tree species to maximise soil water use onsite), and thereby reduce runoff.

6.1.2.5 Salinity prevention strategies
Salinity prevention strategies include:
- Trees that are high water users, adaptable to particular environmental conditions and, if possible, are suitable for commercial harvesting should be established;
- Stock numbers should be managed to prevent complete loss of pasture cover on areas susceptible to salinity;
- Pasture and crop species with a high water demand should be planted;
- Excess water should be controlled by on-site storage where possible or by surface drainage where downstream areas are not affected by salt, nutrients or sediment in drainage waters, and
- Pastures should be managed to maintain cover in late spring.

6.1.2.6 Wind erosion prevention strategies

Wind erosion prevention strategies include:
- Tree shelter belts should be established in strategic locations;
- Stock should be managed to avoid overstocking during dry periods and total depletion of pasture cover on areas at risk from wind erosion and salinity, and
- Soil structure should be maintained via stubble retention and gypsum if required.

6.2 Urban development

6.2.1 Principles

For stormwater management, the emphasis of water sensitive design is on retention, treatment, use and environmental and cultural benefit from the stormwater system, rather than purely conveyance and disposal. WSUD aims to:
- Prevent flood damage to the built and natural environment, inundation of dwellings and stormwater damage to properties;
- Contain nuisance flows and ensure that the stormwater system operates safely during and after storm events;
- Provide an urban water management system for both stormwater quantity and quality;
- Provide for urban water management through multiple use systems where feasible and where efficient use of urban land and structuring principles are met;
- Ensure that stormwater does not degrade the quality of surface water and groundwater resources;
- Maximise opportunities for local on-site storage and reuse where feasible and appropriate;
- Avoid adverse alteration to water balance and groundwater levels, and
- Provide an urban water management system that can be economically maintained and to ensure that arrangements are in place for on-going maintenance.

6.2.2 Plans

During planning for future urban areas, the following should be considered:
- Integrate land planning at the regional catchment level and the lot level and incorporate integrated catchment principles into town planning schemes;
- Ensure that urban bushland (including riparian vegetation) is considered in the development process;
- Ensure that rehabilitation measures are included as conditions of subdivision/development or change of land use in areas of land degradation;
- Ensure the use of strategic revegetation and best management practices;
- Ensure that structure plans, statutory region schemes and town planning schemes consider the effects of nutrient flows and drainage of the whole catchment to receiving waterbodies;
- Identify environmentally significant areas which should have compatible surrounding land uses reflected in town planning schemes;
- Improve town amenity - support townscape improvements;
- Implement strategies to reduce water usage and re-use wastewater for areas with limited potable water, and
- Encourage the consolidation of services into single integrated corridors.

6.3 Products

The following surface water flow and flood level criteria should be set for the development areas.

- Direct piped drainage or discharge of stormwater shall not be permitted into any wetland with conservation value (receiving environment), including its designated buffer area. (Conservation value are those wetlands rated as conservation status under the DEC’s ‘Geomorphic Wetland, Management Categories’ dataset.)
- Stormwater runoff within a development area, including its associated road reserves, generated from up to 1 in 1 year, 1 hour Average Recurrence Interval (ARI) rainfall events shall be retained as close to its source as possible, using techniques such as soakwells, porous paving, vegetated swales or shallow depressions.
- Runoff from greater than 1 in 1 year Average Recurrence Interval (ARI) events shall be mitigated through the use of landscaped retention or detention areas that are integrated within public open space / linear multiple use corridors. The runoff overflow from large rainfall events are directed via overland flow pathways into regional drainage systems or into wetlands (subject to the pre-development hydrologic regime of the wetland being unaltered).

Flow rates should be attenuated through a series of management practices that include:

- Lot Level – Soakwells/Infiltration & Rainwater Tanks;
- Streetscape – Detention and Infiltration;
- Multiple Use Corridors, and
- Detention (Pool and Riffle) and Infiltration.

At the lot level, flow rates should be attenuated by the common use of soakwells installed at the building stage to infiltrate roof runoff. It is not recommended, nor should the Shire accept the direct piped connection of lots to the road drainage network.

It is recommended that the use of rainwater tanks be promoted for both potential infrastructure-related and environmental benefits (some local authorities encourage the use of rainwater tanks at the lot level through policy which can include offering grants upon their installation).

The following BMPs should be used consistently within in the catchment.
• **Storage tanks** are sealed tanks capable of collecting stormwater directly from a roof or other above ground surfaces. It is designed to allow reuse of the collected water as a substitute for reticulated water for use as landscape water and in some cases toilet flushing.

• **Infiltration of roof runoff** generated from roof areas into the groundwater can be adopted without the need for pre-treatment, on the basis that roof areas generate significantly lower nutrient loads.

• **Infiltration of stormwater** is common practice in Western Australian land development projects and is considered an appropriate source control measure that can significantly reduce the magnitude and volume of stormwater runoff generated from the site.

• **Grass buffers** are grassed or vegetated filters or buffer strips capable of treating shallow overland flow before it enters the drainage network.

• **Vegetated swales** are grassed or vegetated channels capable of conveying stormwater runoff and used as an alternative to kerbs and gutters. Vegetated swales can perform a pre-treatment function in terms of removal of sediment as the stormwater is conveyed towards other treatment measures which are more effective in the removal of nutrients.

• **Street bioretention system** combines the stormwater treatment functions of a vegetated swale and stormwater filtration system. Bioretention systems can also be incorporated within road reserves, either along the median strip of dual carriageway roads or on one or both verges of single carriageway roads.

• **Street tree bioretention systems** have recently been adopted in a number of urban designs for treatment of road runoff by a combination of landscape watering and filtration through soil (sandy loam) placed in street tree planter boxes.

• **Constructed wetlands at neighbourhood scale** should only be proposed if there are residual impacts that cannot be cost-effectively mitigated by source or near-source controls. Constructed wetlands involve the use of a macrophyte zone, combined with a permanent or ephemeral shallow water body with extensive emergent vegetation as part of a landscape park feature within the development.

• **Non-structural measures** deal with pollution at source and are the most effective means of protecting stormwater quality. The following practices can be utilised by Local Government, state government agencies, landowners, businesses and drainage service providers to help manage stormwater pollution resulting from municipal operations and household and business activities in urban areas:
  
  − **Street Sweeping** – A widely used practice to reduce accumulations of litter, dirt and vegetation from streets and footpaths;
  
  − **Drain Maintenance** – Inspection, cleaning and repair of open and piped drains, pits, gross pollutant traps and outfall structures to ensure excessive build up does not occur;
  
  − **Domestic Waste and Recycling Collection** – Spillage during kerbside waste and recycling collections can contribute to stormwater system pollution;
  
  − **Education Programs** – Education is a key non-structural control tool for dealing with activities carried out within residential households and business premises that have potential to contaminate stormwater runoff. Simple changes in attitude and behaviour can vastly reduce pollution of stormwater from domestic and business activities. Examples include the planting of waterwise native gardens at lot level (requiring less water and less input of nutrients), use of mulches and soil conditioning of topsoils, and
Enforcement - Enforcement should be seen as a complement to management and education strategies. The primary purpose of enforcement should be to prevent future problems by making polluters accountable. This acts to improve the polluter’s practices and deter others from carrying out polluting activities.

6.4 Monitoring, evaluation and refinement

6.4.1 Reliability of monitoring programs

It has been found elsewhere that disturbed systems such as nutrient-enriched waterbodies experience much greater variability in the amplitude of nutrient concentrations and populations of opportunistic species such as nuisance midges or potentially harmful phytoplankton, or fish kills than do undisturbed systems (Lane et al., 1997). Trend detection in highly variable, disturbed systems is more difficult and requires a different sampling and analysis scheme than for undisturbed systems (Donohue et al., 1994, Donohue and van Looij, 2003).

For example, an undisturbed wetland normally has relatively low and constant levels of nutrients and phytoplankton blooms are absent. Sampling for water quality at monthly intervals may be adequate to document the existing condition of the waterbody or to detect the early onset of a change in conditions. Against a very low baseline, a slow progressive increase in nutrient levels or chlorophyll $a$ in the waterbody is easy to observe and trend detection is relatively simple.

Conversely, a severely nutrient enriched waterbody has higher baseline levels and usually experiences large variability in nutrient and chlorophyll $a$ conditions, as both fresh inputs and nutrient regeneration from enriched sediments fuel the cycle of phytoplankton blooms and crashes. Trend detection in the face of this large background variability requires a sampling program that is more responsive to the bloom and crash cycles (weekly or daily during blooms). This may need more sophisticated data collection, transformation and analysis techniques that incorporate seasonal and other outside (exogenous) effects such as temperature, light or concentrations of plant nutrients other than nitrogen or phosphorus.

A second important consideration is that there is generally only a very slow recovery (decades) of waterbodies that have become nutrient-enriched over lengthy time frames in the absence of some form of external intervention to remove existing nutrient accumulations. This is especially true where regional groundwaters and sediments have also become highly enriched with nutrients, like many areas of the Geographe Catchment.

6.4.2 Document review

The implementation of this document should be reviewed at regular intervals. This target is very important in terms of identifying the performance of behaviour change efforts by the natural resource management agencies.

To assess the performance of this document, indicators and targets should be developed for the catchment and for receiving waterbodies, they are:

- Surface water quality should be assessed at regular intervals. The current sampling programs by DoW and Water Corporation should be reviewed with appropriate water quality targets put in place within the Catchment and further monitoring points added where necessary;
• **Groundwater quality** at strategic locations should be assessed at regular intervals. Shallow groundwater quality targets should be established as soon as possible. It is not possible to generate reliable data on the impacts of land use change in disturbed systems from bottom-end monitoring of water quality in drains and receiving wetlands. This is because of potential time lags of up to 20 years between land use change and changes in downstream water quality in this locality. Monitoring recharge and superficial groundwater quality for a variety of affected land use areas will provide more timely information on the impacts of urbanisation, and

• **Receiving waterbodies** should be monitored for water quality. Targets for water quality variables such as; dissolved oxygen, nutrient concentrations, chlorophyll $a$, total suspended solids, zooplankton grazing activity etc, should be developed as soon as possible. Targets should be reported at regular intervals.
7 References and related reading


BSC, (1999) Busselton urban growth strategy. Report by the planning and development services department, Busselton Shire Council May 1999


Department of Environmental Protection (December 2001) Potentially Contaminating Activities, Industries and Landuses.

Department of Environmental Protection (April 2001) Reporting of Known or Suspected Contaminated Sites - Draft.


Figure 1. Busselton Dunsborough Water Resource Management Strategy Project Location
Figure 2 Water quantity and quality treatment train.

LOW WATER/NUTRIENT/ CHEMICAL USE GARDENS

RAINWATER TANKS

SOAKWELLS/ INFILTRATION/ POROUS PAVEMENT

Note: This shows a pipe for less pervious soils. Sands may not need the pipe.

RAINWATER TANKS

BIORETENTION

WATERWAY

MULTIPLE USE CORRIDOR

RECEIVING WATER BODY (Vasse River Diversion)

LOT LEVEL

WATER MANAGEMENT 
TREATMENT TRAIN

WATER

QUALITY

SOAKWELLS/INFILTRATION

RAINFALL

INfiltration

REDUCED FERTILIZERS/PESTICIDES

AMENDED SOILS

PROPAGATION (e.g. MULC/ES, NATIVE 
GARDENS, SOIL AMENDMENT, XERISCAPING)

STREETScape

DETENTION STORAGE 
(MEDIAN STRIP OR VERGE)

BIORETENTION

AMENDED SOILS

MULTIPLE USE 
CORRIDOR

INfiltration/DETENTION 
(POOL & RIFFLE)

LINEAR EPHEMERAL WATERWAYS/ WETLANDS
Figure 3: Fill height versus drain spacing.