Cardno
Shaping the Future

District Water Management Strategy

Shire of Exmouth

Job Number: V11049

Cardno (WA) Pty Ltd
ABN 77 009 119 000
11 Harvest Terrace
West Perth WA 6005
PO Box 447, West Perth
Western Australia 6872 Australia
Telephone: 08 9273 3888
Facsimile: 08 9486 8664
International: +61 89273 3888
perth@cardno.com.au
www.cardno.com.au

Document Control

Version	**Date**	**Author**		**Reviewer**	
1	2/12/2011	Justine Jones	JMMJ	Brett Loney	BL
2	16/03/2012	Justine Jones	JMMJ	Carrie Kruchell	CLK
3	10/07/2012	Justine Jones	JMMJ	Carrie Kruchell	CLK
Filename	V11049--SLC110020.50--BL Clk_Issued To Client				

Author: Justine Jones
Position Title: Practice Leader - Water

Reviewer: Carrie Kruchell
Position Title: Section Leader: Water, Waste and CLASS

Printed on 100% Australian Recycled Paper

Executive Summary

The Shire of Exmouth (SoE) is currently proposing the expansion of the existing Townsite to accommodate the future population projection of Exmouth. As part of this process a District Structure Plan (DSP) (TBB, 2011) has been prepared to identify the potential opportunities and constraints for future development. Exmouth is located on the North West Cape within the Gascoyne Region of Western Australia, 1260km north west of Perth.

The District Water Management Strategy (DWMS) is a key supportive document for the DSP. The development of the DWMS has been undertaken with the intention of providing a structure within which subsequent development can occur consistent with a 'total water cycle management' approach described in this document. It is also intended to provide overall guidance to the general stormwater management principles for the area and to guide future Local Water Management Strategies (LWMS) and Urban Water Management Plans (UWMP) that will support subdivision approval.

This DWMS has been developed to:

- Provide a broad level stormwater management framework to support future development.
- Incorporate appropriate best management practices into the drainage systems that address the environmental and stormwater management issues identified.
- Minimise development construction costs, which will result in reduced land costs for future home owners.
- Minimise ongoing operation and maintenance costs for the land owners and Shire of Exmouth.
- Develop a water conservation strategy for the area that will accommodate existing groundwater allocation constraints for the area.

A regional environmental context for the LWMS has been detailed within **Section** 2 and is summarised below:

- Exmouth experiences very hot summers and mild winters, receiving an average of 267mm of rainfall principally between January and July, with heaviest falls related to tropical cyclones;
- The Exmouth Townsite is largely unconstrained by its slightly sloping westerly topography, however the dunal ridge to the east may result in flooding;
- No detailed mapping of soil type has occurred, however there is the potential for Karst formations and perched groundwater;
- Current information illustrates that ASS is contained to the eastern boundary of the site.
- The site is dominated by a Hummock grassland with the possibility of 19 DEC priority listed species;
- 14 terrestrial species have been identified that may inhabit the area, including Oroglobites and Stygofauna;
- Cape Range Subterranean Waterway is the closest wetland to the site, located 5kms south and is not considered to be a constraint upon the Exmouth Townsite DSP;
- Cameron's Cave is the only environmentally sensitive area within the site, being declared as critically endangered by the DEC, requiring a 500m buffer;
- DoW do not have any long term data for groundwater quality and quantity under the Townsite
- Four floodplains have been located throughout the site by a SKM study;
- Nine sites are located within the Townsite that may have potential for contamination;
- No areas of Aboriginal significance have been recorded; however three sites have been recorded adjacent to the study area; and
- Eight sites have been identified within the site as important to European heritage.

The DWMS outlines the proposed water supply and conservation strategy, stormwater management strategy, groundwater management strategy and a monitoring strategy. These strategies have been determined based on the physical constraints of the site, as well as to achieve the requirements of government authorities.

Monitoring of both groundwater levels and quality is required prior to commencement of any LWMS for the development within the townsite as existing site specific information is not currently available. A number of management measures have been proposed should groundwater levels be close to ground level with **Section 5.4**. Monitoring of groundwater quality should be implemented to ensure that the nutrient concentrations within the underlying aquifers are not significantly increased due to development. This monitoring is particularly important given the sensitive subterranean ecosystems noted within the townsite.

The principle behind the stormwater management strategy is to detain the first 15mm of rainfall onsite within lot gardens or swales and Public Open Space area. All remaining stormwater should be directed towards the existing creek lines for quick removal offsite. Broad scale calculations have been provided which show the anticipated volume of stormwater detention required for each catchment. These volumes are meant for catchment scale planning only. It is not proposed that flood storage areas are designed to detain this stormwater. Full details are provided within **Section 5.3**.

The DWMS covers an extended area across which both Water Corporation systems are available and connection to serviced utilities is not currently available. The availability of freshwater is limited across the townsite and is therefore carefully controlled and managed by the Department of Water. Currently the Exmouth North and Town sub areas are over allocated, with no further allocations for access made available. Exmouth Central and South have groundwater available, with new applications to be made available with further developments. New applications for groundwater access will have to involve total water cycle management principles to achieve a more efficient use of water application and detail the rate at which groundwater is planned to be extracted. At a lot scale, households will be required to implement water saving strategies including rainwater tanks (where appropriate), water efficient appliances and water efficient gardens.

The Exmouth DWMS provides a framework that future landowners can follow to assist in establishing stormwater management methods that have been based on site specific investigations, are consistent with relevant State and Local Government policies and have been endorsed by the Shire of Exmouth. The responsibility for working within the framework established within the DWMS rests with the individual landowners, although it is anticipated that future LWMPs/UWMPs will be developed in consultation with the Shire of Exmouth, Department of Water and in consideration of other relevant policies and documents as well as this DWMS.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ASS	Acid Sulfate Soils
ATUs	Aerobic Treatment Units
BMP	Best Management Practices
BOM	Bureau of Meteorology
DEC	Department of Environment and Conservation
DIA	Department of Indigenous Affairs
DoH	Department of Health
DoW	Department of Water
DSEWPaC	Department of Sustainability, Environment, Water, Populations, and Community
DSP	District Structure Plan
DWMS	District Water Management Strategy
EFMS	Exmouth Floodplain Management Study
EPBC Act	Environmental Protection and Biodiversity Conservation Act
LIA	Light Industrial Area
LSP	Local Structure Plan
LWMS	Local Water Management Strategy
MGL	Maximum Groundwater Level
MU	Multiple Use
NTU	Nephelometric Turbidity Unit
POS	Public Open Space
PRI	Phosphorus Retention Index
RR	Rural Residential
SOE	Shire of Exmouth

SPP	State Planning Policy
UWMP	Urban Water Management Plan
WA	Western Australia
WAPC	Western Australian Planning Commission
WC	Water Corporation
WSUD	Water Sensitive Urban Design
WWTF	Wastewater Treatment Facility

1 Introduction

1.1 Background

The Shire of Exmouth (SoE) is currently proposing the expansion of the existing townsite to accommodate the future population projection of Exmouth. As part of this process, a District Structure Plan (DSP) (TBB, 2011) has been prepared to identify the potential opportunities and constraints for future development. Exmouth is located on the North West Cape within the Gascoyne Region of Western Australia (WA), 1260km north west of Perth.

The Exmouth Townsite ('Townsite') has historically been utilised for residential and commercial purposes, with some rural residential development located on the fringes. The growth of the SoE has increased the demand of developable land, however, a number of constraints limit the extent of future development. Due to the semi-arid climate, rainfall mainly occurs in the wet season (January to July) and can involve tropical cyclones, including high wind speeds and heavy rainfall. As a result the key issues identified for the Townsite expansion are flooding and stormwater conveyance.

This District Water Management Strategy (DWMS) has been produced in conjunction with the 2011 Exmouth Townsite Structure Plan (TBB 2011) as a statutory document to guide proposed development across the 300+Ha Townsite. The provision of a DWMS is a requirement of the Department of Water (DoW) document *Better Urban Water Management* (WAPC 2008). This DWMS will provide an outline to the key environmental opportunities and constraints and the future work to be considered at more detailed stages of the planning process. The establishment of overall objectives, constraints and opportunities for whole water cycle management will be outlined. **Table 1** below provides a checklist of the Better Urban Water Management requirements for a DWMS.

Table 1 Better Urban Water Management DWMS Checklist

	Status	Comments/proposal
Introduction		
Principles and objectives	✓	See Section 1.2
Previous Studies and recommendations	✓	See Section 1.3
Design and Management Objectives		
Design objectives for potable water use, stormwater quality and quantity (including flood management), groundwater quality and quantity, wastewater and water re-use	✓	See Section 4
Pre-development Environment		
Site characteristics – opportunities, constraints, areas requiring specialised investigation and management – discussed and mapped	✓	See Section 2, mapping provided where available
Hydrologic information – previous work, recent investigations, groundwater levels, flow and availability, groundwater and surface water quality identified and mapped, environmental water requirements identified including waterways/wetland buffers	✓	See Section 2, mapping provided where available
Analysis of Development Impacts and Options		
Assessment of proposed land use scenario by DoW (SQUARE)	N/A	Proposed land uses were provided by the Shire of Exmouth.
Response to assessment	N/A	
Strategies and recommendations for planning precincts to guide and control land use and development where necessary	N/A	Shire of Exmouth to undertake this work in response to developer enquiry.
Fit-for-purpose Water Source Planning		
Site water balance	✓	See Section 5
Allocation of water for all types of uses, including discussion of options	✓	See Section 5
Infrastructure (potable, non-potable, wastewater) – existing and required	✓	See Section 5
Water Management Strategy		
Drinking water conservation and efficiency of water use	✓	See Section 5.1
Surface water management strategy – flood management (flow paths, flow rates and levels at control points), conceptual stormwater management system, best planning practices, appropriate best management practices	✓	See Section 5.3
Groundwater management strategy – groundwater contours, levels and quality, allocation availability	✓	See Section 5.4
Wastewater management strategy	✓	See Section 5.2
Implementation Framework		
Considerations and requirements for local planning	✓	See Section 6
Monitoring – pre-development, post development, data analysis, presentation and reporting mechanisms	✓	See Section 6.2.2.1
Technical review	✓	See Section 6.6
Funding and ongoing maintenance responsibilities	✓	See Section 6.7 and Table 7

1.2 Aim and Objectives

1.2.1 Aim

To demonstrate that the land zoned in the District Structure Plan (DSP) 2011 is capable of supporting urban development. This would be undertaken through the development and documentation of strategies for sustainable best practices for water conservation, groundwater protection, wetland dependent ecosystem production, maintenance of existing hydrological regimes, assessment of any further work that may be required at future stages of development and monitoring programmes that may be implemented to ensure that these strategies are achieved.

1.2.2 Objectives

This DWMS has been developed to meet the following major objectives:

- Provide a broad level stormwater management framework to support future urban development and allow for the determination of shared stormwater management costs across multiple landholdings;
- To provide clarity for agencies involved in water management;
- Incorporate appropriate Best Management Practices (BMP) into the drainage systems that address the environmental and stormwater management issues identified;
- Minimise ongoing operation and maintenance costs for the land owners and SoE; and
- To maintain and improve surface and groundwater quality and total water cycle balance within development areas relative to pre-development conditions.

1.3 Methodology

The State Water Strategy (Government of WA, 2003a) promotes a total water cycle management plan, endorsing the application of Water Sensitive Urban Design (WSUD) principles. These initiatives are intended to provide improvements for the management and efficient use of existing water supplies and stormwater.

Total water cycle management therefore addresses not only physical and environmental aspects of water resource use and planning, but also integrates other social and economic concerns. Management design objectives should therefore seek to deliver better outcomes in terms of:

- Consideration of all water sources, including wastewater, stormwater and groundwater;
- Sustainable use of all water sources;
- Allocating and using water equitably including potable water consumption;
- Integrating water use with natural water processes, including maintaining environmental flows and water equality;
- Stormwater quality management;
- Shallow groundwater management; and
- Flood mitigation.

A fundamental first step in applying total water cycle management in catchments for rural and urban use is to establish agreed environmental values for receiving waters and associated ecosystems. Guidance regarding environmental values and criteria is provided by a number of National and State policies, guidelines and Townsite specific studies undertaken in and around the Townsite.

The DWMS was prepared having undertaken a Townsite visit and review of previous relevant studies undertaken within the Townsite geographical area. These documents included:

- Exmouth-Learmonth (North-West Cape) Structure Plan 1998 (WAPC 1998)
- Ningaloo Coast Regional Strategy Carnavon to Exmouth 2004 (WAPC 2004)
- Exmouth Structure Plan (TBB 2011)
- Exmouth Flood Management Study (SKM 2007)
- Exmouth Water Reserve Water Source Protection Review (DoW 2011)

In addition, a number of State Government documents were consulted. These policies include:

- State Sustainability Strategy (WAPC, 2003);
    - Environmental and Natural Resources (SPP 2);
    - State Coastal Planning Policy (SPP 2.6);

  - Public Drinking Water Source Policy (SPP 2.7);
  - Water Resources (SPP 2.9);
  - Urban Growth and Settlement (SPP 3);
  - State Industrial Buffer Policy (SPP 4.1);
- State Water Strategy (Government of WA, 2003a);
- State Water Plan (Government of WA, 2007);
- Better Urban Water Management (WAPC, 2008); and
- Stormwater Management Manual for Western Australia, Department of Environment and Conservation (DEC 2007).

The DWMS requires a good understanding of the quality and quantity of the surface water and groundwater across and beneath the proposed development area. A sound understanding of these constraints and opportunities enables appropriate management strategies to be presented.

Groundwater levels across the Townsite are used to determine the most appropriate post development land use (e.g. areas of shallow watertable are more suitable for Public Open Space (POS) than for dwellings or flood storage areas). The quality of groundwater and the surface runoff leaving the Townsite also needs to be determined. Water exiting the Townsite has the potential to deposit pollutants into the waterbody that it drains into; therefore an understanding of the water quality is the first step to managing it to acceptable standards. No groundwater monitoring was undertaken as part of the production of this report.

The quantity of surface runoff is the most visually obvious constraint to management, nevertheless it should be considered equally as important as groundwater quantity, quality and surface water quality. The management of surface runoff rates and volumes are important to protect areas from flooding and potential erosion.

1.3.1 Modelling Assumptions

Due to the high level planning detail associated with the structure plan the following assumptions have been made regarding the land use types:

- Tourism: Considered to be urban in nature and therefore stormwater runoff will be generated rapidly in a storm event. Where more permeable forms of development are incorporated, such as golf courses, this will reduce peak storm runoff due to the permeable nature of the land use, resulting in a reduction in the detention volumes required.
- Proposed Urban, Town Centre, Service Commercial/Service Industry, Mixed Use, Light Industry, Public Purposes, Marine precinct and Boat-Harbour Precinct: Considered to be 100% impermeable. Should the detailed design of these areas incorporate permeable areas into the design this will reduce the volume of attenuation required to be detained.

2 Pre-Development Environment

2.1 Geotechnical Conditions

2.1.1 Climate

Exmouth is located within a hot, semi-arid climatic zone, with very hot summers and mild winters. The average annual rainfall is 267mm, however, rainfall is highly variable and is offset by high evaporation rates. According to the Bureau of Meteorology (BOM), the majority of rainfall occurs during the wet season from January to July, with heaviest falls occurring early in the season (February to March) as a result of tropical cyclones (BOM, 2011).

2.1.2 Topography

The Townsite ranges in elevation from 20mAHD in the west where the Townsite is bounded by Cape Range National Park gently sloping to 0mAHD along the eastern boundary. Dune formation along the eastern boundary of the Townsite can restrict drainage of heavy rainfall, leading to flooding along the foreshore corridor (**Figure 1**).

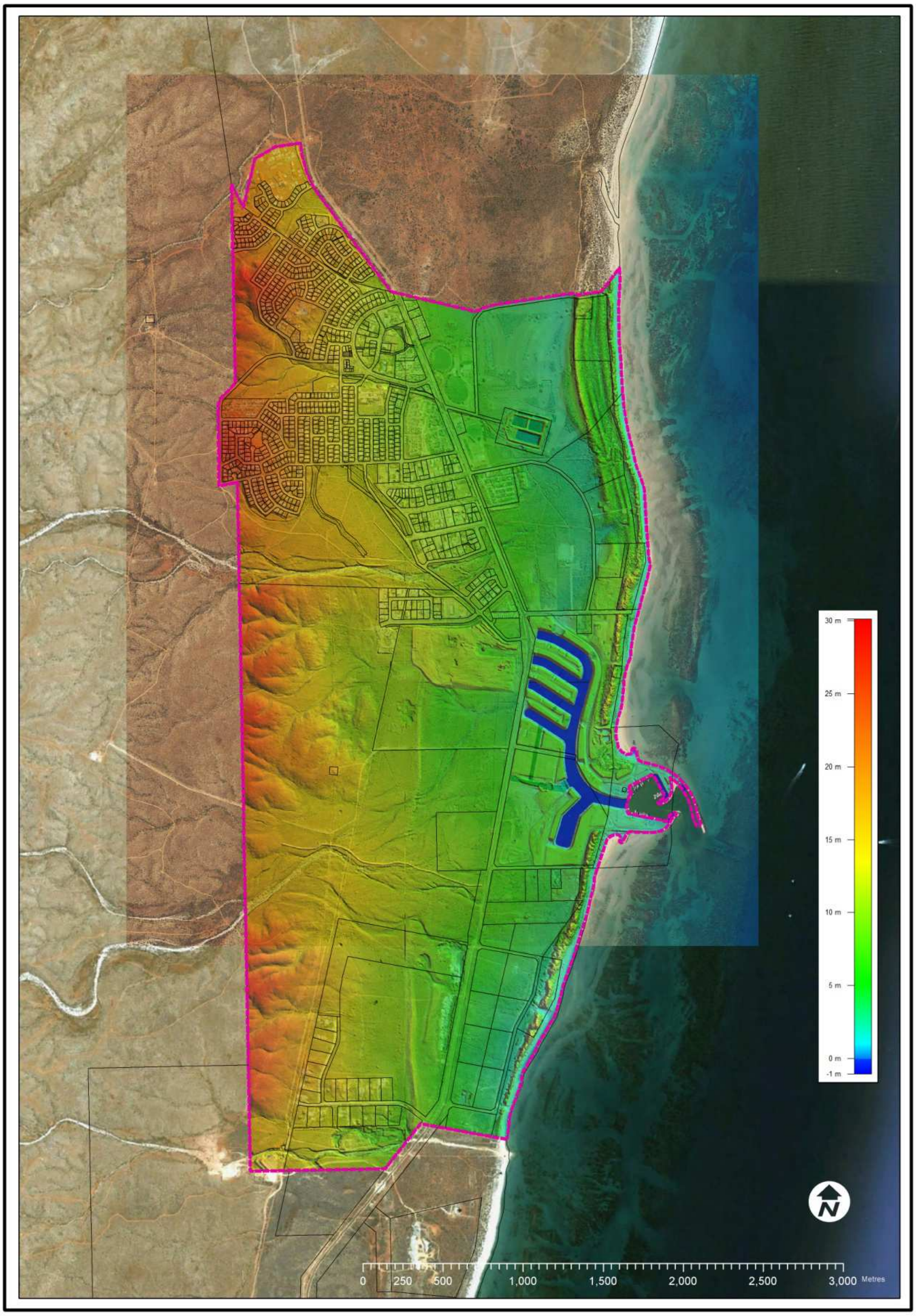

Figure 1 Townsite Topography

2.1.3 Soils

At present, no detailed soil mapping has been undertaken. The peninsular is composed of Cenozoic (Tertiary and Quaternary) marine limestone and sediments with Colluvium soils and some Trealla

Limestone deposits on the western fringe of the Townsite (**Figure 2**). Sedimentary deposits have largely been stripped from across the site, exposing limestone deposits. It is considered that there is a low soil depth, with the potential for Karst formations and perched groundwater. The hydraulic conductivity will need to be determined through geotechnical investigation.

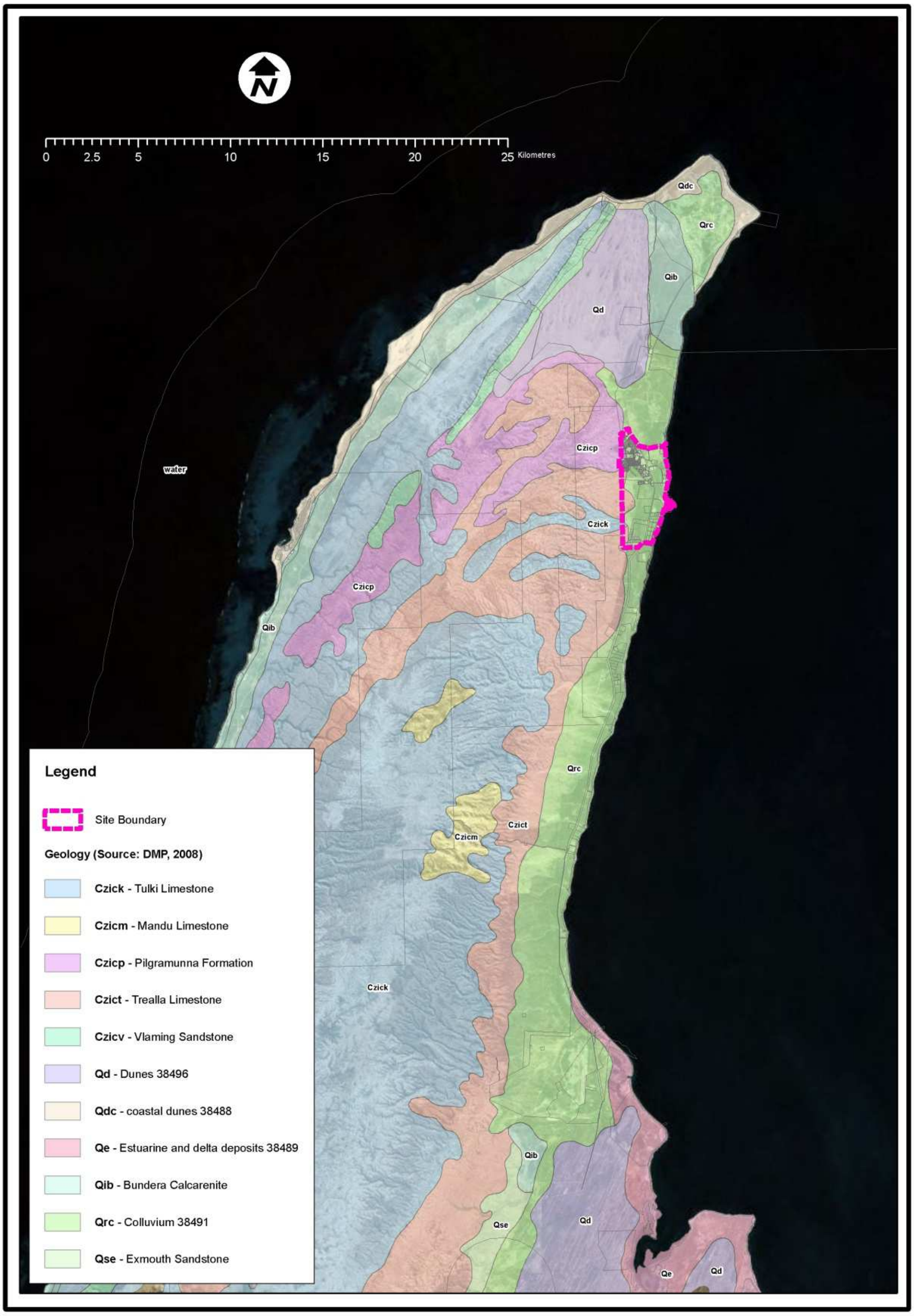

Figure 2 Soils

2.1.4 Acid Sulfate Soils

Regional mapping prepared by the DEC (2011a) indicates that the majority of the Townsite is unconstrained by Acid Sulfate Soils (ASS) (**Figure 3**). The eastern boundary of the Townsite adjoining the estuarine soils of Market Street Creek and LIA Creek have been mapped as "moderate to low risk of ASS occurring up to 3.0 m below ground surface". The coastal soils within the dunal ridge on the eastern perimeter of the Townsite are at risk of "high to moderate ASS disturbance occurring up to 3.0 m below ground surface".

Figure 3 Acid Sulfate Risk Mapping

During the production of a Local Structure Plan (LSP), a preliminary Townsite assessment for ASS may be required.

2.1.5 Drinking Source Protection Zones

The Townsite is known to adjoin the eastern boundary of the Exmouth Water Reserve, which is a sensitive water resource. Regional groundwater flows to the east and therefore away from the reserve, however, as the aquifer is unconfined there is a potential for contamination to occur through poor management. DoW guidance *Rezoning and Subdivision of Land in Public Drinking Water Source Areas* (DoW, 2009a) should be referred to for advice.

2.2 Environmental Assets

2.2.1 Flora

Broad scale mapping of vegetation across the Townsite indicates that the area is dominated by a Hummock Grassland (DSEWPaC, 2007) (**Figure 4**).

Given the proximity of the Townsite to the Cape Range National Park, there may be significant flora present across the areas of remnant vegetation; however, historical land use suggests that past grazing may limit the diversity of flora species.

A search of the DEC 'Declared Rare and Priority Flora' database in 2011 (DEC, 2011b) identified the following flora species may potentially occur throughout the Townsite:

- *Abutilon sp. Quobba* (H Demarz 3858) (Priority 2);
- *Abutilon sp. Cape Range* (A.S. George 1312) (Priority 2);
- *Acacia alexandri* (Priority 3);
- *Acacia ryaniana* (Priority 2);
- *Acacia startii* (Priority 3);
- *Acanthocarpus rupestris* (Priority 2);
- *Brachychiton obtusilobus* (Priority 4);
- *Corchorus congener* (Priority 3);
- *Crinum flaccidum* (Priority 2);
- *Daviesia pleurophylla* (Priority 2);
- *Eremophila forrestii subsp. capensis* (Priority 3);
- *Eremophila occidens* (Priority 2);
- *Eremophila youngii subsp. lepidota* (Priority 4);
- *Grevillea calcicola* (Priority 3);
- *Harnieria kempeana subsp. rhadinophylla* (Priority 2);
- *Livistona alfredii* (Priority 4);
- *Stackhousia umbellata* (Priority 3);
- *Tinospora esiangkara* (Priority 2); and
- *Verticordia serotina* (Priority 2).

A search was conducted using the federal protected matters search tool (DSEWPaC, 2011) on the 18th July 2011. DSEWPaC maintains a list of species regarded to be of national environmental significance, as listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). No flora species listed as rare and as such protected under the EPBC Act were noted to be within the Townsite search area at the time of the search.

Figure 4 Environmentally Sensitive Areas

2.2.2 Fauna

The Exmouth Townsite DSP identifies 14 species of terrestrial fauna that have been declared rare or likely to become extinct which inhabit the area. This includes subterranean fauna such as troglobites and stygofauna.

A number of significant fauna species are listed by the DEC and Department of Sustainability, Environment, Water, Populations and Communities (DSEWPaC) as potentially utilising the site, however, it is considered that potential fauna habitats are limited to remnant native vegetation. Species listed under the DSEWPaC protected species database include:

- *Macronectes giganteus* (Southern Giant-Petrel) listed as Endangered;
- *Dasycercus cristicauda* (Mulgara) listed as Vulnerable;
- *Petrogale lateralis* (Black-flanked Rock-wallaby) listed as Vulnerable;
- *Apus pacificus* (Fork-tailed Swift) listed as Migratory;
- *Ardea alba* (Great Egret, White Egret) listed as Migratory;
- *Ardea ibis* (Cattle Egret) listed as Migratory;
- *Haliaeetus laucogaster* (White-bellied Sea-Eagle) listed as Migratory;
- *Hirundo rustica* (Barn Swallow) listed as Migratory; and
- *Merops ornatus* (Rainbow Bee-eater) listed as Migratory.

While these species are listed within the Townsite search area, no site specific survey has been undertaken to confirm their presence.

2.2.3 Environmentally Sensitive Areas

2.2.3.1 Wetlands

The Exmouth Townsite contains no listed wetlands. The Cape Range Subterranean Waterway (WA006) is the closest recognised wetland, circa. 5km south of the Townsite (**Figure 4**). This wetland is listed as a nationally important wetland (DSEWPaC, 2011). As such a buffer of 5m is required to be maintained for all development.

2.2.3.2 Cameron's Cave

Cameron's Cave is a Karst formation relief located just north of the Preston Street rural residential area, within the southern section of the Townsite (**Figure 4**). This formation is the habitat for both aquatic and terrestrial species found in the Cameron's Cave Troglobitic Community. This community is considered Critically Endangered by the DEC and has been placed on the 'Threatened Ecological Community' list. Management plans are being prepared to ensure the protection of this ecological community. The North West Cape Karst Management Advisory Committee have recommended a 500m land use buffer be installed, which has been included within the Exmouth Townsite DSP.

2.2.4 Hydrology

2.2.4.1 Flooding

The Townsite for the DWMS includes a number of watercourses which flow eastwards from a source in the Cape Ranges towards the Exmouth Gulf. These watercourses were identified within the Exmouth Floodplain Management Study (EFMS) prepared by SKM (2009) and are detailed in **Figure 5** below. The principal watercourses of note within the Townsite are Town Creek, Light Industrial Area (LIA) Creek, Market Street Creek and Preston Street Creek.

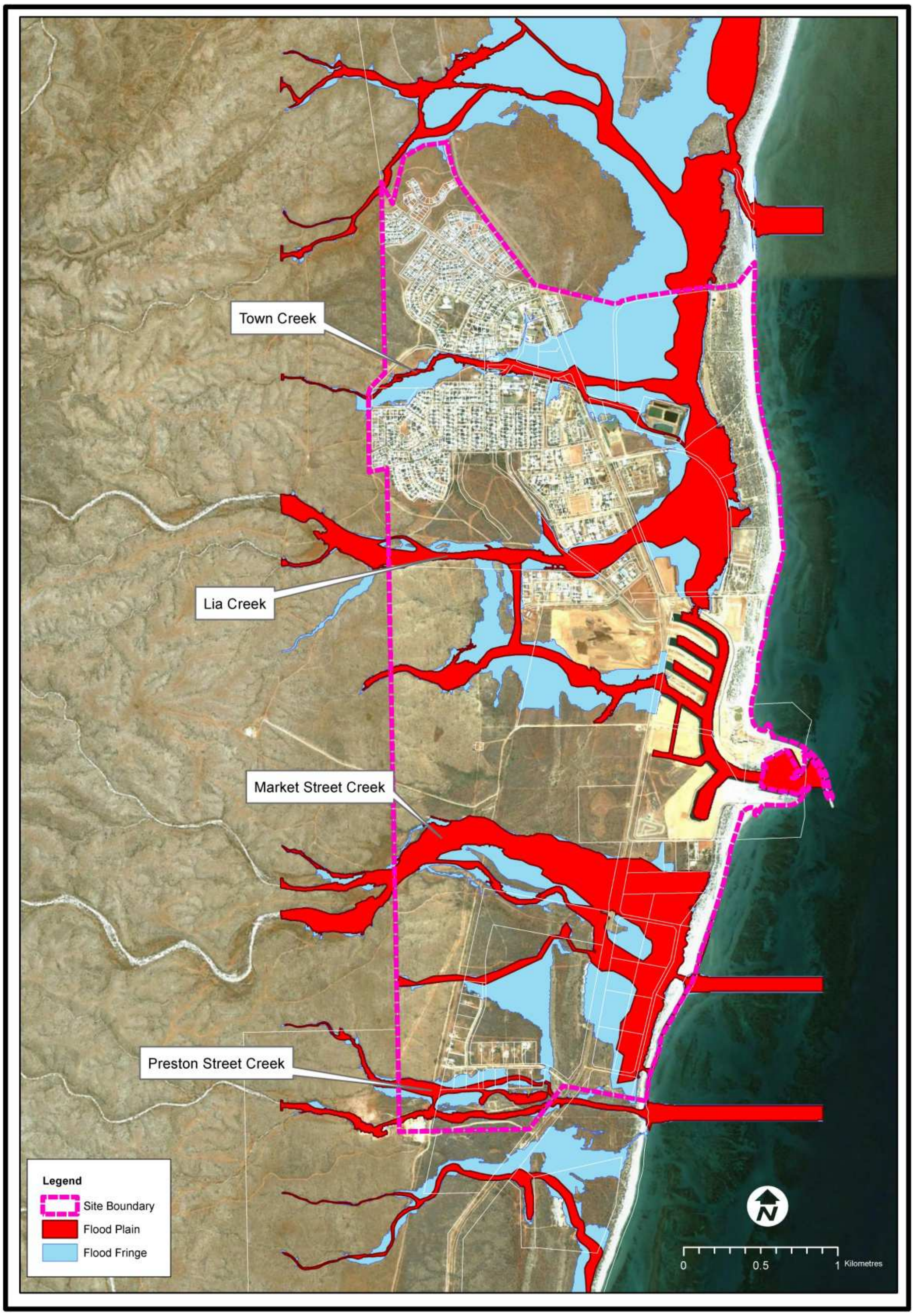

Figure 5 Major Waterways within the Townsite and Associated Flood Zones

Flood history summarised in the EFMS states that flood events in March 1999 and June 2002 are notable in magnitude. These events reflect both cyclonic flooding (March 1999) and flooding associated with heavy winter rainfall (June 2002). Both events are notable for being one of the most powerful cyclones (Cyclone Vance) recorded in Australia and the wettest June day on record in

Western Australia, respectively. Both these events resulted in out of bank flooding within the upstream catchments of the Townsite.

The EFMS established the floodplain extent for a 100 year Annual Recurrence Interval (ARI) event throughout the Townsite (**Figure 5**).

2.2.4.2 Surface Water Quality

Across the Exmouth Townsite there are no permanent surface water bodies. As detailed above there are a number of ephemeral creek lines, however, these only flow during the wet season for short periods of time, conveying stormwater.

2.2.4.3 Groundwater Levels and Quality

The *Exmouth Water Reserve Drinking Water Source Protection Review* (DoW, 2011) details a number of production boreholes which are located to the west of the Exmouth Townsite within Crown Reserve Land. Regular monitoring of these boreholes is undertaken by the Water Corporation (WC) for aesthetic related characteristics (non-health related) and health related characteristics. A summary of the results of this monitoring is provided in **Table 2**. It should be noted that these results are compared against the Australian Drinking Water Guidelines (ADWG) as a conservative approach, however, the water tested undergoes further treatment prior to being released to the general public of Exmouth.

Table 2 Summary of Long Term Water Quality Monitoring (Water Corporation)

Parameter	Units	ADWG Guideline Value	Median Result
Aesthetic Characteristics			
Chloride	mg/l	250	260
Hardness as $CaCO_3$	mg/l	200	330
Iron (unfiltered)	mg/l	0.3	<0.003
Sodium	mg/l	180	135
Total Filterable Solids	mg/l	500	831
Turbidity	NTU	5	<0.1
pH	No unit	6.5-8.5	7.3
Health Characteristics			
Nitrate (as Nitrogen)	mg/l	11.29	1.8
Nitrite (as Nitrogen)	mg/l	0.91	<0.002
Nitrite + Nitrate (as Nitrogen)	mg/l	11.29	1.9
Fluoride	mg/l	1.5	0.2

A review of the DoW database identified that there is no long term groundwater level and quality monitoring data available for the site.

2.3 Potable and Wastewater

2.3.1 Water Supply

The Townsite extracts circa. 832,000kl/yr of groundwater from the unconfined Tulki and Trealla Limestone Aquifers within the Cape Ranges. This water is abstracted via 40 boreholes to the west and south of the existing town. Prior to distribution the water is treated through aeration and filtration to remove iron and manganese to stabilise the pH, and disinfected through chlorination to ensure microbiological quality is maintained.

Potential land uses within the bore field include livestock grazing and limestone mining, both of which have the potential to cause contamination of the water supply. To limit the potential for contamination, a number of BMP have been detailed within the Exmouth Water Reserve (2011) document and will generally be managed through the borehole licensing application process and through guidance such as:

- Water Quality Protection Note 35: Pastoral Activities in Rangelands; and
- Statewide Policy No 13: Policy and Guidelines for Recreation within Public Drinking Water Source Areas on Crown Land.

2.3.2 Wastewater

WC is responsible for the provision of wastewater services within the town centre. Currently Exmouth is serviced by a Wastewater Treatment Facility (WWTF) within the town boundaries. In the future this WWTF will be relocated to the periphery of the town. Where connection to the WC serviced sewer is not available, septic tank sewerage is provided.

2.4 Contamination

A search of the DEC's Contaminated Sites database on the 18th of July 2011 indicated that there are nine known contaminated sites that have been identified for remediation within the Townsite (**Figure 6**). These sites are located within existing developed areas, including:

- 23 and 29 Pelias St, Exmouth (Contaminated – remediation required);
- 24 Nimitz St, Exmouth (Contaminated – remediation required);
- 4, 6 and 8 Huston St, Exmouth (Contaminated – remediation required);
- 12 and 16 Christie St, Exmouth (Contaminated – remediation required); and
- 8 Murat Road, Exmouth (Contaminated – remediation required).

Landcorp have also identified an old waste disposal site located south of Welch Street as historically containing chemical storage or potentially contaminating land uses. Landcorp are due to remediate this area prior to development.

An existing petrol station located on the corner of Murat Road and Maidstone Crescent also raises concerns. This site is located within a mapped floodway and has the potential to result in contamination transport during a significant rainfall and flooding event.

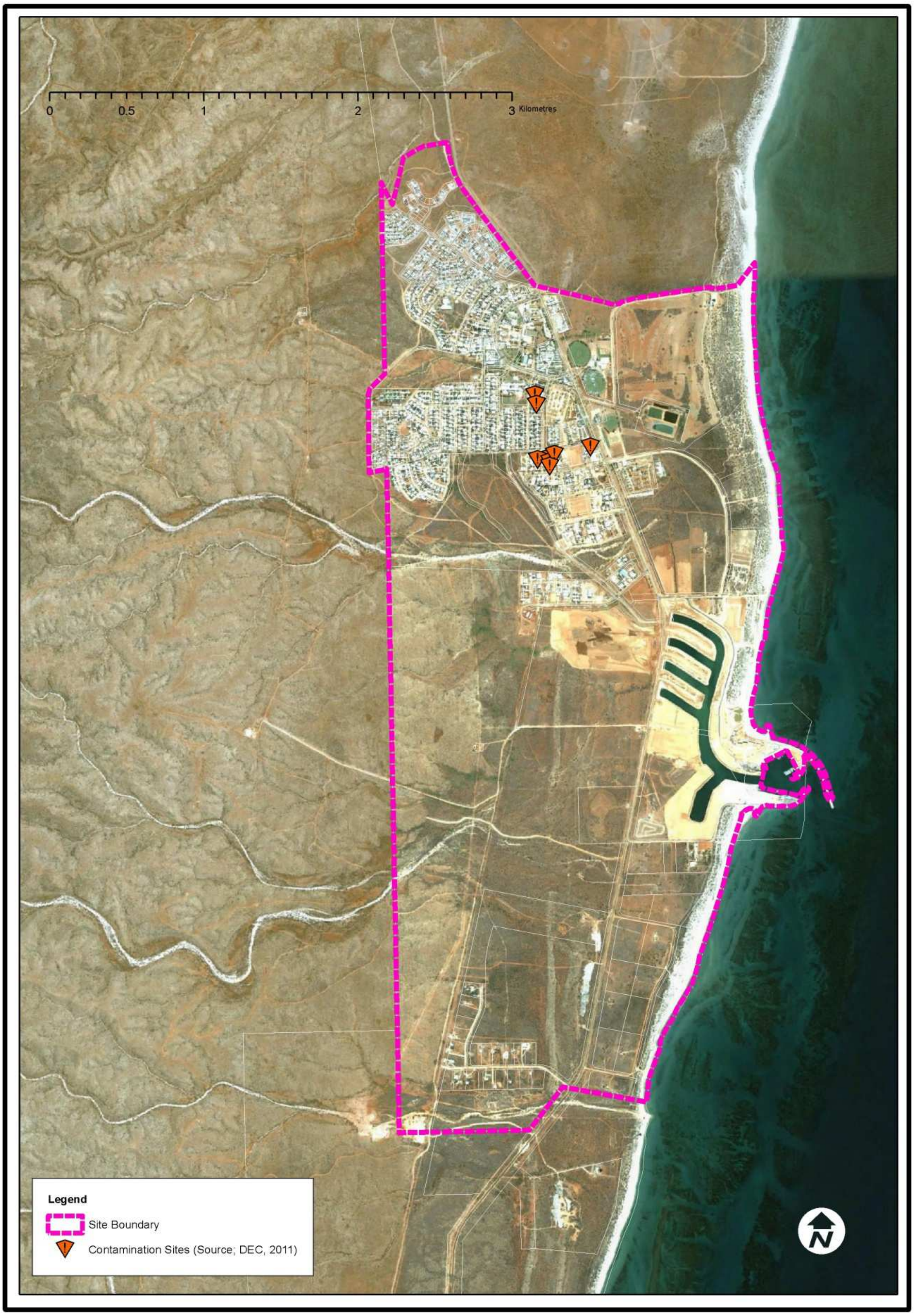

Figure 6 Contaminated Sites

2.5 Heritage Land Uses

2.5.1 Aboriginal Heritage

A search of the Department of Indigenous Affairs (DIA) database on the 18th of July 2011 for known sites of Aboriginal significance indicates that there are no known locations of significance within the Townsite (**Figure 7**). However, three sites of significance were identified adjacent to the site, and include:

- DIA 6115 Exmouth North-East; Skeletal material/Burial;
- DIA 6116 Exmouth South-West; Skeletal material/Burial; and
- DIA 19839 Waterhole, Exmouth; Artefacts/Scatter, Water Source.

2.5.2 European Heritage

A search of the Heritage Council of Western Australia's database (Heritage Council of WA, 2011) found that there are eight known sites of European Heritage that are located within the Townsite (**Figure 7**). The known heritage sites include:

- Community Hall (3053), Corner of Maidstone Crescent and Learmonth Street, Exmouth;
- Exmouth Fire Station (14506), Payne Street, Exmouth;
- Exmouth Police Station and Lockup (17339), Maidstone Crescent, Exmouth;
- Exmouth War Memorial (12290), Maidstone Crescent, Exmouth;
- First Trees planted in Exmouth (10622), Maidstone Crescent, Exmouth;
- Shire Library (10632), Maidstone Crescent, Exmouth;
- Staff House (10637), Corner of Bennett Street and Fyfe Street, Exmouth; and
- Transit House (10639), Lot 263 Christie Street, Exmouth.

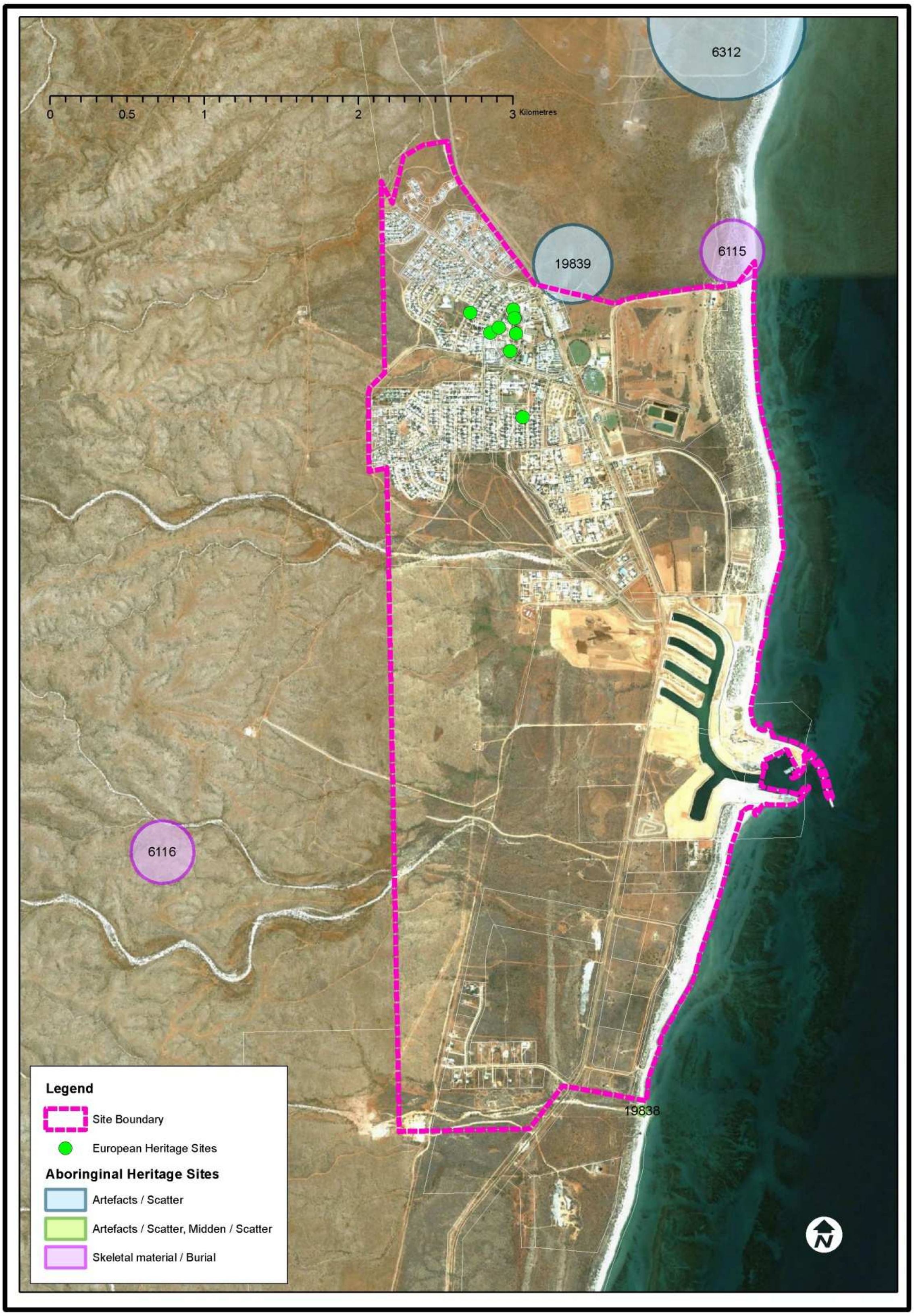

Figure 7 Heritage Land Use

3 Proposed Development

A DWMS is typically produced prior to or concurrently with the development of a DSP or LSP, so that the structure plan can use the information gathered in the DWMS investigation to facilitate the development of a design that best suits the existing natural environment, while ensuring sufficient space for water is provided.

In June 2011, the SoE released the Exmouth DSP (**Figure 8**). This DSP displays consideration of the current known constraints and opportunities of the Townsite. Additional knowledge gathered through future detailed Townsite investigation, however, may result in the structure plan undergoing some modification in the future.

The Exmouth Townsite DSP has classified the Townsite to comprise of a mixture of land uses, including:

- Residential Infill 1and 2 (RI);
- Multiple Use (MU) upgrade of 1 Reid Street to a 1 in 100 year storm event;
- MU zoning of 2 Murat Road;
- MU zoning of 3 Murat Road/Warne Street;
- Rural Residential (RR) of 1 Preston Street;
- Town Centre upgrade;
- Possible Harbour Extension to Residential 25 (R25);
- Introduction of three specialised tourism zoned sites, T1: Strategic Tourism Site, T2: Approved Site, T3: Zoned land for tourist accommodation;
- Murat Road Upgrade; and
- Minimum Lot Density of residential 17.5 (R17.5).

This will result in a total potential yield of 3078 dwellings for a total increase in 7076 residents, with 120ha available for residential and 8.1ha available for rural residential.

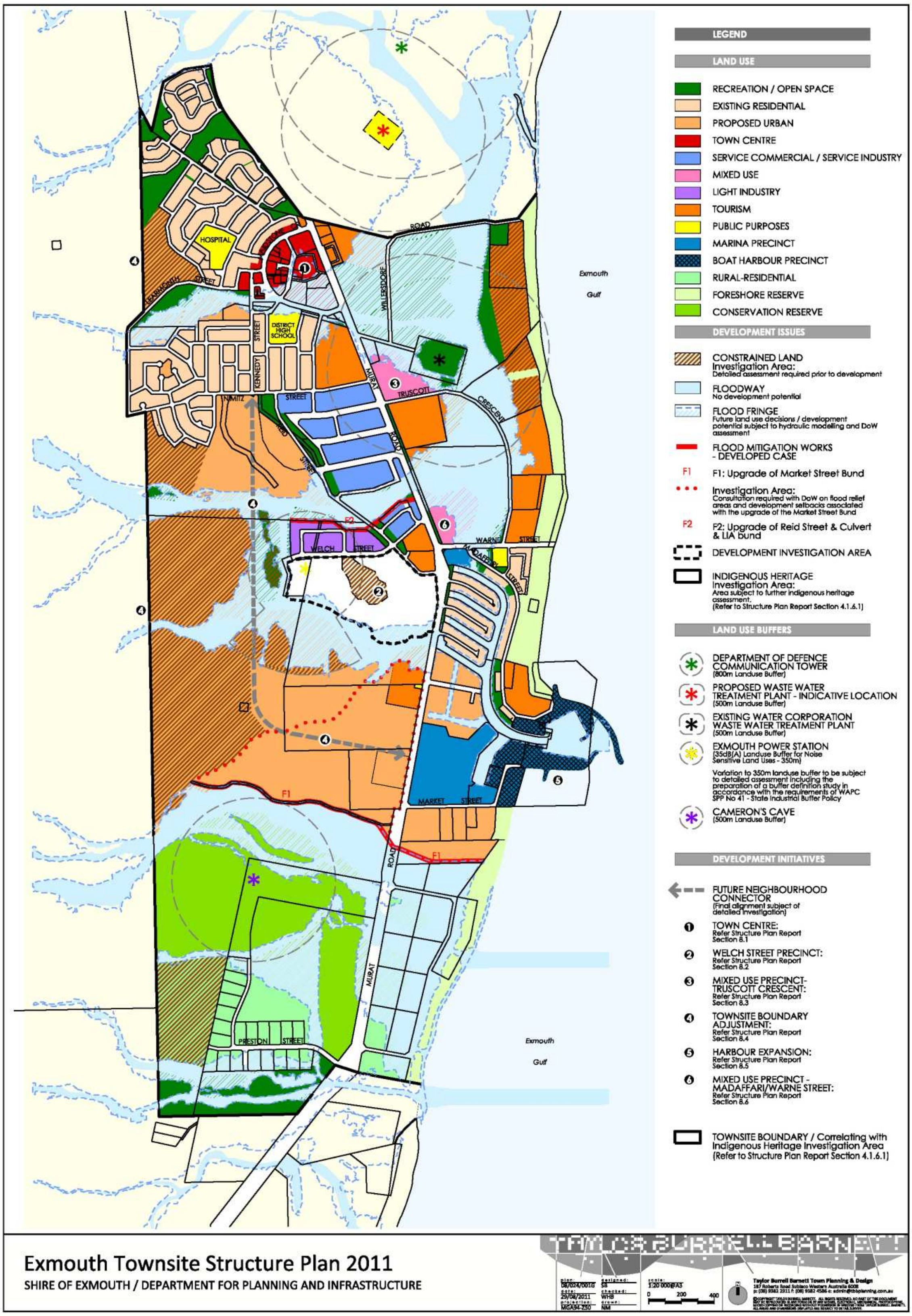

Figure 8 Exmouth District Structure Plan

4 Water Management Design Criteria and Objectives

4.1 Total Water Cycle Management for Water Conservation

The overall objective for preparing a total water cycle management plan for a proposed development is to minimise pollution and maintain an appropriate water balance. Therefore allocation and water use should be used sparingly where appropriate.

4.1.1 Wastewater Reuse

Wastewater should be recycled and used as potable or non-potable water depending on the quality of the treatment. Exmouth currently has a WWTF, with water utilised from non-potable sources for the irrigation of POS.

4.1.2 Grey Water Reuse

Grey water (wastewater used in the home, excluding toilets and potentially kitchens, with moderate concentrations of solids and nutrients) can be used for subsoil irrigation and in some other non-potable water uses. There is the potential for nutrient leaching if the water is used for irrigation, however, there are no wetlands within the site, therefore grey water could be used on a development scale to conserve water.

4.2 Stormwater Management

The overall guiding document for development of stormwater management strategies within urban areas is the *Stormwater Management Manual for Western Australia* (DoW, 2007). This is used in conjunction with the *Decision Process for Stormwater Management in WA* (DoW, 2009) as guidance to how urban development can achieve compliance within the objectives, principles and delivery approach. The *Stormwater Management Manual for WA* also provides guidance on the broad principles of WSUD.

4.2.1 Stormwater Quantity

Discussions undertaken with the DoW (personal communication 22 July 2011) determined the following key design criteria that should be adopted to manage stormwater quantity:

- Detain the first 15 mm of rainfall within lots where practical;
- Convey flood waters offsite without detention where practical;
- Stormwater quantity should be managed using open drains and roads rather than piped drainage;
- Culverts can be used where required to convey stormwater under roads;
- Minor roads should be set 0.3 m above the 100-yr ARI level;
- Major roads should be 0.5 m above the 100-yr ARI level; and
- Existing waterways and natural drainage lines should be retained with the aim of minimising changes to the pre-development hydrology. These waterways should also be restored where required.

4.2.2 Stormwater Quality

Water quality treatment systems and WSUD structures must be designed in accordance with the *Stormwater Management Manual for Western Australia* (DoW, 2007) and *Australian Runoff Quality* (Engineers Australia, 2006). The *Better Urban Water Management* (WAPC, 2008) principle outlines how existing surface and groundwater quality should be maintained as a minimum, and preferably improved prior to discharge from the development area. This will involve a water quality management approach that establishes pre-development water quality standards. Targets for post development scenarios that reflect the pre-development water quantity parameters can then be implemented as part of any Local Water Management Strategy (LWMS).

If catchment ambient conditions have not been determined, water quality targets should be derived from the *National Water Quality Management Strategy* (ANZECC, 2000). Pollutant outputs for pre-development environments are hard to determine, with limited opportunity to measure all of the runoff from the area within a sheet flow environment such as Exmouth. Stormwater treatment is possible, however, this will depend on the intended usage and treatment requirements.

4.3 Groundwater Management

Manipulation of groundwater levels can have a range of detrimental effects on the local Karst community, including increasing nutrient levels within superficial aquifers and ASS potential. BMPs for groundwater levels and quality presented within WSUD need to be considered within further planning. These principles should include:

- Minimising changes to the underlying groundwater levels as a result of development;
- Groundwater quality leaving the Townsite should be at least the same, or better, than the water entering the site;
- Subdivisional lots should have a separation distance from the Maximum Groundwater Level (MGL) of at least 1.2m to ensure protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels;
- Bio-retention systems and drainage inverts should operate as dry basins with a minimum clearance of 0.3m between the MGL and the invert of the basin; and
- If subsurface drainage is to be utilised it must:
  - Be installed at or above the MGL.
  - Be designed with free draining outlets.

5 Water Management Strategy

5.1 Potable Water Management

5.1.1 Introduction

Available water sources for the expansion of the Townsite are limited to what is available within the surrounding area and therefore will increase the dependency on efficient use and water sourcing. The objective of 'fit for purpose' water is to achieve the highest degree of efficiency and appropriate allocation of a water source for a particular application. The provision of a medium term water supply for the area was released in 2010 by the WC. The *System Planning: Exmouth Water Supply Planning 2010* identified that Exmouth water usage will increase over the coming years as follows:

- By 2015 the system is estimated to grow by around 390 services to a total of 1,865 services; and
- By 2023 the system is expected to grow by 950 services to a total of 2,425 services.

To allow for appropriate planning to ensure the continuation of available water, the fit for purpose strategy needs to be executed at every possible opportunity.

5.1.2 Design Objectives

Ensure the efficient use of all water resources and aim to achieve the highest value use of fit for purposes water in all new developments such as the use of grey water for subsoil irrigation and in other non-potable water uses where appropriate.

Maintain opportunities for future generations by using water more efficiently. This could be achieved by raising community awareness, regulation, facilitating the recognition of the true value of water and financial incentives.

5.1.3 Management Strategies

5.1.3.1 Retention of Rainwater

Tropical cyclones can generate large amounts of rain within a very short period of time. This degree of rain can be too large for gutters and downpipes to efficiently transport, having the potential to result in internal flooding. It is therefore recommended that roofs do not have gutters or downpipes installed, with the first 15mm of rainfall detained on the Townsite if practical.

Rainwater tanks are encouraged where possible, particularly in rural residential developments, for collection and storage of water for use within landscaping in place of reticulated water.

5.1.3.2 Water Efficient Appliances

Significant reduction in in-house water uses can be achieved with the use of water efficient appliances. **Table 3** gives an example of the water uses of typical appliances verses water efficient appliances. These water use rates have been used in the water balance investigation.

Table 3 Water Efficient Appliances

Appliance	Water Use	
	Standard Device	Water Saving Device
Toilet	12 Litres/Flush	4 Litres/Flush
Washing Machine	130 Litres/Flush	40 Litres/Flush
Shower Head	15-25 Litres/Minute	6-7 Litres/Minute
Taps	15-18 Litres/Minute	5-6 Litres/Minute

The water conservation strategy purposes that all dwellings use water efficient appliances. Water efficient shower heads and tap fittings are already mandated as part of the *Building Code of Australia* (ABCB 2011). However, uptake of the other devices will be encouraged through state government rebates as well as education and additional incentives from developers.

5.1.3.3 Water Efficient Gardens

Studies by the WC (WC, 2003) have found that for a typical Perth dwelling, 56% of water consumed by the lot is used on gardens. There is no published data of garden water usage for the Gascoyne region, however, water will be needed within gardens throughout the dry season. Therefore, reductions in water irrigation by employing water efficient garden measures can significantly reduce the total water usage of a development. The following water efficient measures could be used within development gardens:

- Installing an irrigation system that was designed and installed according to best water efficient practices;
- Irrigation controller must be able to irrigate different zones with different irrigation rates;
- Emitters must disperse coarse drops or be subterranean;
- Gardens should include large permeable areas such as lawn, gravel, dry creek bed features or swales;
- Limit the amount of turfed area within the design and consider the use of mulch or gravel as alternatives;
- Garden beds to be mulched to 75mm with a product certified to Australian Standard AS4454; and
- Strongly encourage gardens are planted with local plant species. Where required, soil shall be improved with soil conditioner certified to Australian Standard AS4454 to a minimum depth of 150mm where turf is to be planted.

Water conservation can also be reduced on a development scale within POS areas. As well as using the lot scale garden measures on POS gardens, the following additional measures should be utilised:

- Retention of remnant native trees where possible, reducing demands for water during establishment of POS areas;
- Minimal proportion of the POS areas will be turfed. Instead the POS will be largely vegetated with local native species to enhance the environmental values;
- Turf should be a low water and nutrient species;
- The adoption of Xeriscaped POS gardens, where garden beds within POS and community areas are landscaped using ‘waterwise plants’, which are local native species from regions with similar climates that require less water inputs than exotic species; and
- Managing irrigation practises within POS areas to minimise losses to evaporation (e.g. amount applied is not excessive, timing irrigation to avoid wastage, etc.).

5.1.3.4 Community Awareness and Education

Each development should provide a strategy which will be implemented to ensure future occupants of the Townsite are appropriately educated on possible water saving strategies applicable to the development. This should include the provision of reputable reference material from sources such as the WC's *Waterwise Programme* (2011) and the *Your Home* initiative (Commonwealth of Australia 2011).

5.1.3.5 Groundwater Allocation

The availability of freshwater is limited across the Townsite, therefore requires careful control and management. The Exmouth Area is divided into five sub areas (Exmouth West, North, Town, Central and South) and is managed by DoW in accordance with the *Groundwater Allocation Plan: Exmouth Groundwater Subarea* (WRC 1999). Currently the Exmouth North and Town sub areas are over allocated, with no further allocations for access made available. Exmouth Central and South have groundwater available, with new applications to be made available with further developments. New applications for groundwater access will have to involve total water cycle management principles to achieve a more efficient use of water application and detail the rate at which groundwater is planned to be extracted.

5.2 Wastewater Management

5.2.1 Introduction

Within Exmouth's DSP, it is intended to move the WWTF from its current location to the north west of the Townsite.

5.2.2 Principle

Minimise the use of potable water for non-essential use such as irrigation and industry. This should be undertaken through a commitment to meet the WC's target consumption of 40-60kl/person/year.

5.2.3 Design Objectives

Where possible recycle wastewater and use as potable or non-potable water depending on the level of treatment.

5.2.4 Management Strategies

5.2.4.1 Septic Tank Use

Where feasible further wastewater treatment should be implemented through the mandating of septic tanks and Aerobic Treatment Units (ATU) within individual housing developments. These systems are able to treat effluent to the Department of Health (DoH) standards, allowing disposal of the liquid fraction of the waste via leach drains or onsite irrigation. Only DoH approved ATUs should be used within developments.

5.2.4.2 Leaching Prevention

Where required, future Urban Water Management Plan (UWMP) will propose methodologies which ensure systems have a minimal potential for nutrients to leach from the systems installed. These measures would typically include the importation of an amended sand medium that has a high Phosphorous Retention Index (PRI) while retaining adequate infiltration characteristics. Where required, the future UWMP will need to specify the ongoing management requirements for these systems (e.g. maintenance regime for irrigation/leach drain areas). The DoW's water quality protection note *Wastewater Treatment: Onsite domestic systems* (DoW, 2010) should be referenced when implementing systems at the UWMP stage.

5.3 Stormwater Management Strategy

5.3.1 Introduction

A stormwater management strategy principally should maintain the existing hydrology through retaining and detaining surface flows and the infiltration of stormwater runoff as close to source as possible. This ensures the peak discharges and volumes of runoff in main drainage corridors do not increase through the introduction of impermeable areas associated with development, which could lead to flooding downstream.

Developments typically have a high proportion of impervious surface area (roads, paths and roofs) when compared to the pre-development environment. The increased imperviousness results in:

- Increased total volume of runoff;
- Increased maximum runoff rate (peak discharge); and
- Decreased time for runoff to occur.

Sufficient groundwater and surface water monitoring should be undertaken to provide "proof of concept" for the development.

5.3.2 Principle

5.3.2.1 Stormwater Quantity

Preserve and enhance where possible the natural function of the floodplain to convey flood waters and sustain flood events. This should be achieved by limiting the impact of new development on the existing floodways through sustainable appropriate development.

5.3.2.2 Stormwater Quality

Reduce the loads of stormwater pollutants discharged by developments into the groundwater system through the removal of gross pollutants and reduction, where possible, of dissolved pollutants within the groundwater discharged from all developments/subdivisions.

5.3.3 Design Objectives

5.3.3.1 Stormwater Quantity

- *Detain the first 15mm of rainfall within lots where practical;*
- *Convey flood waters off site without detention where practical;*
- *Stormwater quantity should be managed using open drains and roads rather than piped drainage;*
- *Culverts can be used where required to convey stormwater under roads;*
- *Minor roads should be set 0.3m above the 100yr ARI level;*
- *Major roads should be 0.5m above the 100yr ARI level; and*
- *Existing waterways and natural drainage lines should be retained with the aim of minimising changes to the pre-development hydrology. These waterways should also be restored where required.*

5.3.3.2 Stormwater Quality

Existing surface and groundwater quality should be maintained as a minimum, and preferably improved prior to discharge from the development area.

5.3.4 Management Strategies

5.3.4.1 Stormwater Quantity

The basic principle of stormwater quantity management is to slow down the stormwater runoff and infiltrate as much as possible, mimicking the existing environment.

The design criteria specified in **Section 5.1.2** can be achieved through the use of various WSUD strategies. As a minimum, detention basins are required to achieve the discharge requirements, however, the size of these basins can be reduced through the introduction of various WSUD techniques. Typical WSUD techniques are discussed below, however, further investigation and negotiation with the DoW should be completed and presented in future LMWS documents.

Lot Soak wells

The large impermeable roof area of each lot produces considerable runoff. This surface water runoff can be reduced at source by the promotion of infiltration using soak wells, where ground conditions permit.

Rainwater Tanks

Rainwater tanks used for stormwater management are designed to create a dedicated air space within the rainwater tank to ensure that storage is available as needed. While not practical within a town centre development, rain tanks may be used within a more rural setting on advice from the SoE.

Roadside Swales

Swales and buffer strips are vegetated conveyance corridors that typically have slopes ranging between 1% to 4%. This gradual slope combined with the increased roughness provided by vegetation reduces the stormwater runoff rate. The swales also provide some storage and infiltration capacity, thus reducing the total volume of runoff.

Flush Kerbing and open drains

Contemporary street drainage uses hard kerbing and pits draining the stormwater runoff to a sub-surface pipe network. This pipe network quickly transports the runoff through the development causing increased peak discharges from the area. Flush and intermittent kerbing allows most of this runoff to be directed to roadside swales, where it is more slowly conveyed or infiltrated. Flush kerbing should direct overland flow into open drains and roads rather than piped drainage. This is furthered by the use of culverts to convey stormwater under roads. The location of flush kerbing must be approved by SoE Engineers.

Flood Storage Areas (FSA)

FSAs are designed to store runoff during large rainfall events, typically incorporated into POS areas and retained for recreational purposes for the majority of the year. A FSA can be designed to either retain or detain the runoff from the development. In detaining or “holding back” runoff, the FSA is designed to reach maximum capacity in a designated storm event and discharge excess runoff at a reduced rate. Conveyed flood waters of downstream areas are not to be affected by the proposed development.

Porous Pavement and Non-porous Area Reduction

The majority of rain that falls on non-porous pavements will form stormwater runoff. The use of porous pavement or reduced area of non-porous pavement area can have a significant reduction in the total volume and peak discharge of the runoff. Large sustained rainfall events can result in increased sedimentation. As rainwater is not treated and no pipe systems are present, sedimentation may result in the clogging of porous pavement areas.

Junction Chamber Infiltration

Bottomless junction chambers can allow infiltration of water resulting in a reduction in the total stormwater runoff volume. Bottomless junction chambers are only suitable in locations with high infiltration rates and where the superficial aquifer is lower than the pipe junction inlet. Due to low infiltration rates and lack of a pipe network this technique is unlikely to be viable in the Exmouth area.

5.3.4.2 Stormwater Quality

The effective management of urban stormwater quality typically focuses on the treatment of frequent, low intensity stormwater events. Due to Exmouth's latitude and presence of tropical cyclones, conventional stormwater quality management techniques may not be applicable. Sedimentation and erosion are two key influences that can severely degrade stormwater quality. Strategies that will be adopted to minimise erosion and control sediment transport include:

- Vegetation will be retained on Townsite for as long as possible;
- The development will be cleared in stages to minimise erosion opportunities; and
- Ground disturbance activities will be avoided during intense rainfall events.

WSUD techniques should be investigated for the ability to improve the surface runoff water quality and presented in a future LWMS.

5.3.5 Demonstration of Compliance

5.3.5.1 Post-Development Drainage Strategy

The DWMS has utilised detention basins within catchments where new development is proposed to detain stormwater from the site. In catchments were development is existing, it has been assumed that stormwater detention has been included within the current layout and therefore was not included within modelling undertaken within this DWMS. Where no new development has been proposed stormwater detention has not been calculated as there will be no change to existing conditions.

In order to adhere to the design criteria stated in **Section 5.3.3.1**, the detention basins were sized to detain the 'first flush' 15mm of stormwater. This equates to a 2yr 15min storm event.

Flood Modelling

It has been assumed that the Flood Study undertaken (SKM 2007) accurately delimits the floodplains associated with the four major watercourses which flow through the development area. No additional modelling of these watercourses was undertaken as part of the work.

Modelling Parameters

The rate of runoff from an area is determined by the slope and roughness (Manning's n) of the surface. The total volume of runoff is determined by the amount of rainfall less the losses (e.g. infiltration, storage).

An "initial loss – continuing loss" infiltration model was adopted for the catchments, with loss values chosen based on Cardno's experience with similar vegetation, soil types and residential development modelling. The loss rates used are presented in **Table 4**.

Table 4 Initial and Continuing Loss Parameters for Hydrological Modelling

Infiltration Land Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Urban	1	0.1
Rural residential	21.5	2.5
POS	12.5	2.5
Coastal reserve	17.5	2.5
Conservation Reserve	21.5	2.5

The infiltration rates were predominantly based on the following assumptions:

- POS areas will likely contain dense vegetation and turf over a sand base. This turfed area will become compacted over time and this will reduce the initial loss rates.
- Garden areas will have high infiltration rates as it is likely that sand or loamy soil will be used. Rural residential developments within the Townsite are anticipated to have relatively large lots. These are likely to have small landscaped gardens with the remainder of the lot unmodified. For these reasons, it is anticipated that the average initial loss and continuing loss for the remainder of the lot will be the same as for sparsely vegetated areas.
- There will be no infiltration on roads, pavement and driveways (considered urban). There will however be some minor absorption storage loss and this is reflected in an initial loss of 1mm and continuing loss of 0.1mm/hr.

Not all neighbourhoods within the Townsite are proposed to undergo new development. For these neighbourhoods, and for the purpose of surface water modelling, the area of each land use type shall remain consistent with the methodology described above. At this district scale, the area of each land use within proposed new developments must be estimated.

Modelling Results

The XPSWMM computational modelling programme was used to calculate the rate of runoff generated by each catchment. **Figure 9** illustrates the boundaries of post-development catchments. Many of these catchments do not experience a change in land use between pre-development and post-development and will not require storage.

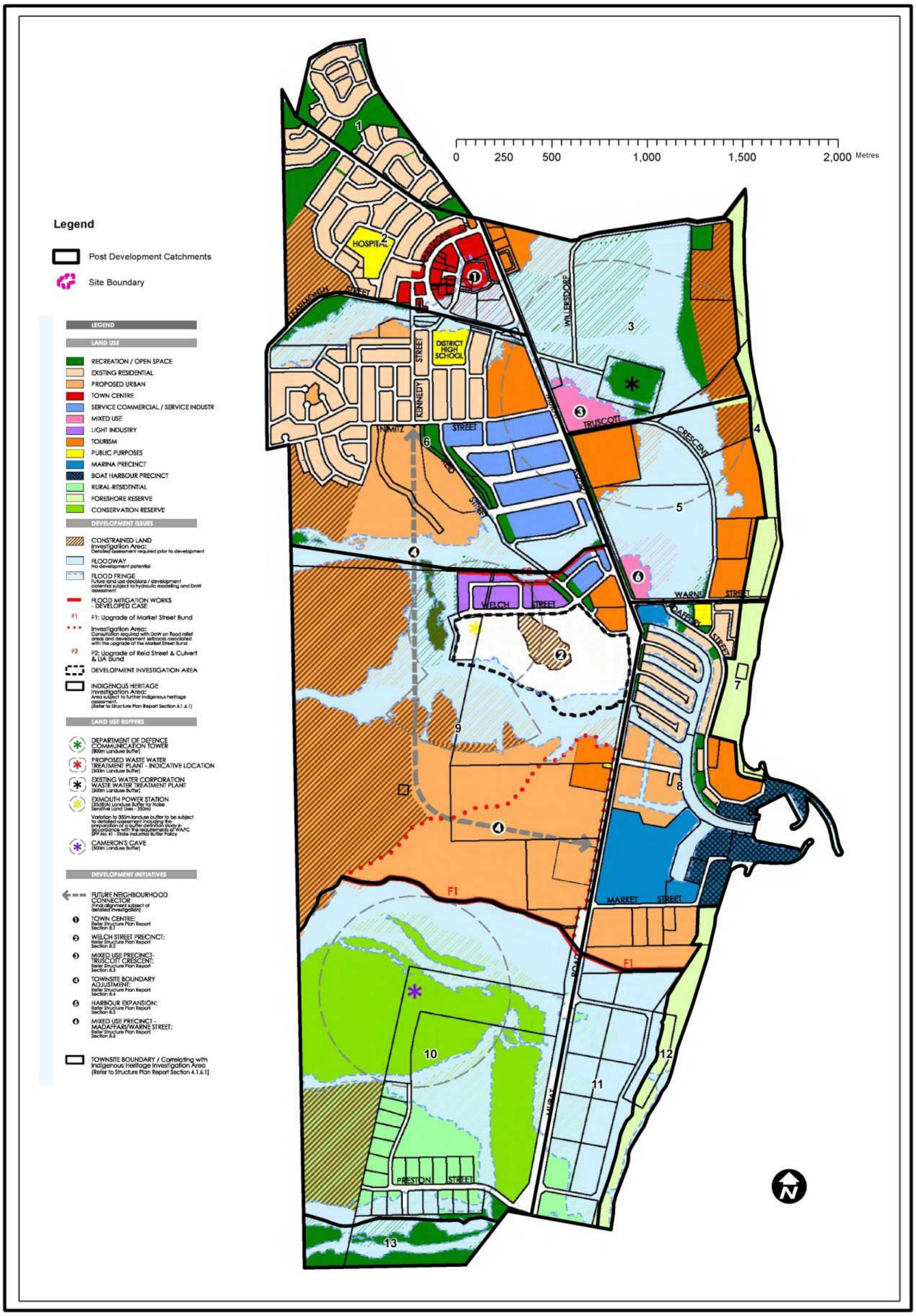

Figure 9 Post Development Catchments

Ground conditions across the Townsite vary with infiltration unlikely in the upland catchment areas, however, anecdotal evidence of flood waters infiltrating to ground near the foreshore suggest underlying ground conditions are likely to be conducive to infiltration. Consequently, infiltration through sides and base of basins was incorporated into the design in low lying catchments. It should be noted that infiltration rates are based on technical experience of typical infiltration to sand. Prior to detailed design infiltration testing should be undertaken *in situ* to determine actual ground infiltration rates.

Table 5 details the total detention requirements for all catchments where development is proposed. This volume should be used when developing a masterplan for each catchment area to ensure sufficient space for water is provided within the design. As detailed below this could be provided within lot gardens and POS areas. It is not recommended that a single flood storage area is designed for each catchment.

Table 5 Detention Structure Dimensions

Catchment	Total Catchment Area (ha)	Infiltration (m/s)	Basin Area (m^2)		Volume (m^3)
			Base Area	Top Area	
2	81.6	-	1,078	2,010	1,520
3	109.6	$5x10^{-5}$	6,635	8,733	7,660
5	80.4	$5x10^{-5}$	4,300	6,018	5,135
6	200.0	-	10,002	12,546	11,250
8	114.7	$5x10^{-5}$	12,581	15,417	13,975
9	290.7	-	36,747	41,491	39,095

Detention basins are nominally designed to have 1:6 side slopes and a depth of 1m. These basins may be modified in future detailed designs as appropriate. Due to the lack of detailed masterplanning at this stage of the planning process, the volume detailed in **Table 5** details the total volume required to detain the first 15mm of rainfall from road reserves and from lots within each catchment**.**

It is noted and understood that in future drainage designs the scheme will separate detention of this first flush event with lots detaining this rainfall within gardens and rainwater tanks, where appropriate, and road drainage within swales and POS area. This will decrease the volume of detention structures, but will increase the overall surface area required for successful detention and retention of stormwater.

The locations of detention and retention structures will be affected by the structure plan layout, the final approach to earthworks across the Townsite and the nature of the downstream receiving environment. It is most likely that detention structures will be located at the low point of each individual catchment, precinct, structure planning or development area. The locations of these structures should be specified within the LWMS through consideration of the LSP and earthworks plan (as stated in **Section 6.2.1.11**). All detention structures would be constructed during the subdivision stage.

5.4 Groundwater Management Strategy

5.4.1 Introduction

Manipulation of groundwater levels can have a range of detrimental effects on the local Karst community, including increasing nutrient levels within superficial aquifers and ASS potential. BMPs for groundwater levels and quality presented within WSUD need to be considered within further planning.

5.4.2 Design Objectives

Groundwater management objectives principles should include:

- *Minimising changes to the underlying groundwater levels as a result of development;*

- *Subdivisional lots should have a separation distance from the MGL of at least 1.2m to ensure protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels;*
- *Bio-retention systems and drainage inverts should operate as dry basins with a minimum clearance of 0.3m between the MGL and the invert of the basin;*
- *If subsurface drainage is to be utilised it must:*
  - *Be installed at or above the MGL.*
  - *Be designed with free draining outlets; and*
- *Groundwater quality leaving the Townsite should be at least the same, or better, than the water entering the site.*

5.4.3 Management Strategies

5.4.3.1 Groundwater Level

Minimising Groundwater Level Changes

Developments can have reduced infiltration of rainfall into the underlying groundwater due to increased impervious areas (e.g. roads and buildings). Due to the impervious soils present within the site, infiltration to groundwater is not considered to be a dominant factor within the environmental water balance of the system. The use of WSUD techniques should prevent lowering the underlying groundwater levels due to reduced recharge. To ensure groundwater systems are not adversely affected, infiltration will be maintained via the use of FSAs where appropriate.

It is critical that groundwater levels are maintained in the long term as a number of subterranean fauna exist within the Townsite which rely on existing conditions to survive.

Subsoil Drainage

If there are any areas with less than 1.2m of separation distance, the groundwater level would need to be artificially controlled to an acceptable depth or ground level fill is required. Where additional fill is required subsoil drainage should be 0.3m above MGL.

Due to the low permeability within the Townsite, subsoil drainage may be required underneath bioretention areas and FSAs. This subsoil drainage is not positioned to lower groundwater levels, rather it would be aimed at ensuring the bioretention areas and FSAs empty within an adequate time period.

Drainage of WSUD Features

As the hardpan soil has a low hydraulic conductivity the bioretention areas and FSA would remain wet after a storm event as minimal water would infiltrate into the groundwater. This then would create issues for the next storm event as well as providing habitats for mosquito and midge breeding. An imported permeable base layer will be required to ensure infiltration within the bioretention areas and FSAs.

5.4.3.2 Groundwater Quality

The Exmouth Gulf, located to the east of the Townsite, receives both surface water runoff and groundwater that originates from the site. It is important that the quality of this water entering the Gulf is comparable to the pre-development environment and where possible, improved.

The DWMS aims to encourage infiltration at source to maintain the existing groundwater hydrology. At source infiltration may not be possible within some areas due to soil characteristics. A geotechnical report is required to determine where this technique is appropriate. The soil profile and imported fill with high PRI soils will treat infiltrated water and remove phosphorous through natural processes. The approaches identified in **Section 5.3.4.1** will aim to infiltrate stormwater runoff, improving the quality of water infiltrating to the groundwater system. The Townsite drainage system should be designed to achieve the objectives and criteria stated in **Section 4.3**.

5.4.3.3 Perched Groundwater

As identified in **Section 2.1.3**, the Townsite is situated within a Karst environment. Karst environments where the limestone is near surface and has undergone secondary porosity, or partial dissolution, may allow for sinkholes to develop, which can lead to the deterioration of housing foundations and road surface pavement. A detailed geotechnical investigation will aim to identify the existence of clay layers and/or porous limestone within the soil profile. Subsoil drainage and/or imported fill will be used to mitigate the effects on the development from perched groundwater areas identified within the Townsite. The extent of these measures will be determined in context of the findings from the detailed geotechnical investigation, the LSP and the proposed earthwork strategy.

6 Requirements for LWMS & UWMP

6.1 Introduction

The development of the DWMS has been undertaken with the intention of providing a structure for subsequent development to be consistent with the total water cycle management approach described in this document. It is also intended to provide overall guidance to the general stormwater management principles for the area and to guide the development of the future LWMS and UWMP documents as outlined in Better Urban Water Management (WAPC 2008).

It is anticipated that future LWMS documents will be undertaken for all Precinct developments and UWMP at lot/subdivision scale. It is the responsibility of the land owner/developer to undertake these documents and for these documents to provide sufficient detail to the requirements outlined below and within this document, along with any additional requirements of the DoW or SoE.

6.2 Design and Management Objectives

As detailed in **Section** 5 a number of specific objectives have been presented in this document. **Table 6** below summarises these key principles (Armadale Redevelopment Authority, October 2006).

Table 6 Summary of WSUD Principles and Design Objectives

Key Guiding Principles

- Facilitate implantation of suitable best practice in Urban water management
- Encourage environmentally responsible development to meet the intent and recommendations of the UWMS
- Provide clarity for agencies involved with implantation
- Facilitate adaptive management responses to the monitored outcomes of development
- To minimise public risk, including risk of injury or loss of life
- To maintain the total water cycle

Category	Principals	Objectives
Water Supply	• Consider all the potential water sources in water supply planning • Integration of water and land use planning • Sustainable and equitable use of all water sources having consideration of the needs of all users, including community, industry and environment • To maximise the reuse of stormwater • Minimise use of potable water where drinking quality water is not essential	• Residential consumption target for portable water of 40-60 kL/person/year
Surface Water and Groundwater	• To retain natural drainage systems and protect ecosystems health • To protect from flooding and waterlogging • To implement economically viable stormwater systems • To ensure stormwater management recognises and maintains social aesthetic and cultural values • Post development annual discharge volume and peak flow rates to remain at predevelopment levels or defined EWRs • Minimise change in peak winter levels at groundwater dependant wetlands due to change in groundwater flux associated with urbanisation	• For ecological protection, 1 in 1year ARI volume and peak flow rates maintained at predevelopment conditions • Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the DoE/DoW • For flood management, manage up to the 1 in 100 year ARI event within the development area to predevelopment peak flows unless otherwise negotiated with Water Corporation • Post development end of winter operating levels at wetlands maintained at pre-development levels, unless otherwise determined by EWR's
Surface Water Quality	• To maintain or improve surface water quality within development areas • Reduce the average annual load of stormwater pollutants discharged by development compared to if it used a traditional piped conveyance system.	• As compared to a development which does not actively manage water quality: 60% reduction in TSS (annual loads) 60% reduction in TP 45% reduction in TN 70% reduction in Gross Pollutants
Groundwater Quality	• To maintain or improve groundwater quality within development areas • Where waterways/open drains intersect the water table, minimise the discharge of pollutants from groundwater to the waterway • Where development is associated with an ecosystem dependent upon a particular hydrological regime, minimise discharge or pollutants to shallow groundwater and receiving waterway and maintain water quality and habitat in specified environment	• Where waterways/open drains intersect the water table, as compared to a development which does not actively manage water quality: 60% reduction in TP (annual loads) 45% reduction in TN • Where development associated with sensitive environment, as per DoE/DoW

The LWMS must be written making reference to the requirements of Better Urban Water Management (WAPC, 2008). In addition, where appropriate, the following aspects of stormwater management should be considered:

- Sensitive Environments
- Flora survey
- Geotechnical investigation
- Acid sulphate soils
- Groundwater monitoring
- Water Sensitive Urban Design
- Coastal vulnerability study
- Soil contamination and remediation
- Aboriginal heritage Building Standards
- Demonstration of Compliance
- Design and Location of Drainage Structures
- Water Consumptions Strategies
- Non-Structural Measures

6.2.1 Design Objectives

6.2.1.1 Sensitive Environments

Development of Precincts should be undertaken taking into account any requirements to manage or mitigate stormwater or flooding found at the site. Flood modelling has been undertaken (SKM, 2007) across the extent of the DWMS Townsite (see **Figure 5**). Any proposed development within flood prone areas is required to ensure the following has been considered;

- Adequate flood protection from a 100year ARI flood;
- Habitatable floor levels should be set a minimum of 0.5 m above the 100 year ARI flood level; and
- The development does not detrimentally impact on the existing flooding regime of the general area.

Where developments are proposed within the floodway the DoW assess the appropriateness of each development on a case by case basis. The factors examined by the DoW include:

- Depth of flooding;
- Velocity of flooding;
- The effect of the development on existing flood flow paths;
- Possible structural and flood damage potential evacuating during a major flood; and
- The regional benefits of the development.

6.2.1.2 Flora Survey

For all newly proposed developed areas it is recommended that Flora and Vegetation Surveys are undertaken in accordance with EPA Guidance Statement No. 51 *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia*.

Any areas of remnant mangrove habitat identified in future Flora and Vegetation Surveys should be managed in line with the EPA Guidance Statement No. 1 *Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline*.

It is recommended that the Flora and Vegetation surveys be used to determine if a fauna assessment is necessary. This will be based on potential for suitable habitat for significant fauna species. The flora survey should be undertaken by the landowner and developer of each parcel of land.

6.2.1.3 Geotechnical Investigation

A geotechnical investigation will need to be conducted to confirm the regional geological mapping discussed in the DWMS and assist in the protection of Karst formations that support subterranean fauna species (as required by EPA Guidance Statement No. 54 *Consideration of subterranean fauna in groundwater and caves during Environmental Impact Assessment in Western Australia*). A number of test pits will be required to be installed at depths just below the ground surface (usually ~2.5m) to determine the soil characteristics and how this could impact on the proposed development. The investigation should include appropriate locations for onsite disposal of stormwater (flood detention structures and soakwells), soil types, suitability of soils for development and if treatment is required, settlement tests, bearing ratios and the hydraulic conductivity, which governs infiltration rates.

6.2.1.4 Acid Sulfate Soils

Given the soils and the hydrological characteristics at the site, it is recommended that a Preliminary Townsite Assessment for ASS is undertaken, especially if dewatering or excavation is required to facilitate development. This should to be undertaken by the landowner and developer of each parcel of land and is most applicable at the UWMP Stage.

6.2.1.5 Flood Risk

The DoW recommends that development is not undertaken within areas of the Townsite identified in **Figure 5** and that landfilling is not permitted within the floodplain. A Flood Emergency Response Plan should be submitted as part of the LWMS if the development is shown to be located near a flood prone area of the Townsite.

6.2.1.6 Water Sensitive Urban Design

The SoE mandate the use of WSUD across future development within the Townsite to allow for flood conveyance and minimise construction of impermeable surfaces. All stormwater drainage systems should be designed in accordance with *Guidelines and Specification for Design and Construction of Stormwater Drainage Systems* (SoE, March 2006). A summary of the main requirements relating to WSUD design principles is provided below:

- Road alignments should follow contours where possible to reduce stormwater flow velocities;
- Runoff from impermeable surfaces should discharge to detention basins and soft landscaping features prior to discharge offsite should be incorporated into the scheme design;
- Maximum flow velocities within unlined open drains should be limited to $1ms^{-1}$ and $2ms^{-1}$ in lined drains:
- All stormwater basins should be designed to hold a 10 year ARI storm event;
- Where stormwater management is within POS areas the whole POS should be subject to an agreement with the SoE to the extent and design of landscaping and grassing;
- Finished floor levels within developments should be 0.5m above the crown of adjacent roads where floodwater are discharged;
- Flood mitigation measures may be required, advise should be sought from the SoE;
- Building envelopes should be located to provide effective onsite stormwater detention, minimise peak flows and improve the quality of discharged water;
- Detailed consideration should be given to the nature, location, effectiveness and staging of stormwater management systems; and
- Visible stormwater management works should be constructed in keeping with the character of the area.

6.2.1.7 Coastal Vulnerability Study

The storm surge during Cyclone Vance was measured to be 3.6m and caused severe erosion of the marina and inundation of the beachfront. Developments proposed along the coastal fringe of the SoE are required to undertake appropriate consideration of possible storm surges, with coastal vulnerability studies recommended where development is proposed within or immediately behind the dunal systems.

6.2.1.8 Soil Contamination and Remediation

It is recommended, that should the developed lots that have been identified as contaminated sites undergo redevelopment, a Preliminary Townsite Investigation is undertaken.

6.2.1.9 Aboriginal Heritage

At present, Aboriginal heritage stakeholder consultation has been undertaken with the DIA. It is recommended that ethnographic and archaeological surveys be undertaken by developers to determine any additional areas of Aboriginal significance.

6.2.1.10 Building Standards

Flood protection infrastructure is a key criterion of all developments. The standard DoW requirement is for 0.3m above the 100 year flood level within subdivision roads and 0.5m above major waterways flood levels. This criterion is to be detailed within a LSP for individual developments.

6.2.1.11 Design and Location of Drainage Structures

This DWMS has provided preliminary volume requirements for flood detention structures (see **Table 5**). These are based on broad-scale assumptions. It is expected that as future investigations are undertaken, the designs developed will accommodate any constraints identified. The preliminary flood detention structure configurations should be reviewed to ensure that the stormwater management system can achieve all of the required objectives and blend into the surrounding environment. The DWMS has not provided indicative locations for these structures. The DWMS has recommended flood detention structures be located prior to, but nearby, the catchment discharge. Such details and design refinements should be presented in future LWMS.

6.2.1.12 Water Consumption Strategies

A number of potential measures have been discussed that can assist in achieving the state water conservation target (see **Section 4.1**). It is expected that future LWMS will clarify which measures are proposed to be integrated into the future built system. Additionally, Greenfields developments and most urban infill developments must verify that the measures will achieve the objective through an appropriate water balance.

Further investigation should be undertaken into the viability of the potential water sources available, where these are proposed to be utilised. The LWMS will need to provide a more detailed assessment of likely water requirements to maintain POS areas. A licence will need to be submitted and approved by the DoW for extraction of groundwater for non-potable uses.

6.2.2 Management Objectives

6.2.2.1 Water Balance

A detailed water balance will be undertaken as part of the LWMS strategy for all developments. This should include, but not be limited to, information on the following:

- Details of the Infrastructure requirements of the development and if appropriate allocation is available;
- Projected demand of potable and wastewater demand for the development;
- Where potable water and wastewater supplies will be serviced from; and
- How water will be used efficiently to maintain supply for future generations.

6.2.2.2 Groundwater Monitoring

Currently there is limited information on groundwater levels and quality within the site. It is recommended groundwater monitoring be conducted for a period of two years capturing two groundwater peak levels for each development Townsite as a proof of concept for the development. This is to be supported by conceptual design and flow paths and should be undertaken by the landowner and developer of each parcel of land. It is recommended this monitoring commences at the LWMS stage extending to the UWMP.

This may not be required if observation bores indicate there is sufficient 'groundwater to natural surface separation' that will not cause waterlogging. These observations will allow for the determination of active levels, degree of infill required and quality measurements. This is to include conceptual designs and flow paths.

6.2.2.3 Demonstration of Compliance

Modelling of local road drainage networks will need to be undertaken to demonstrate compliance with water quantity management criteria. Calculations supporting sizing of treatment retention structures and flood detention structures will need to be provided, such that detailed designs can proceed from this point and future water planning stages (i.e. UWMP) can demonstrate compliance with the design criteria via appropriate computational modelling of the proposed design.

6.2.2.4 Non-Structural Measures

Guidance for the development and implementation of non-structural water quality improvement measures is provided within the *Stormwater Management Manual of Western Australia*. Some measures will be more appropriately implemented by SoE, such as street sweeping, however many can be implemented relatively easily within the design and maintenance of the subdivision and the POS within it.

It is expected that future LWMS and UWMP documents will provide reference to measures such as public education. It is also expected that future UWMP will provide detailed management and maintenance plans that will set out maintenance actions (e.g. rubbish removal from swales and vegetated retention structures), timing (e.g. who will be responsible for carrying out the actions), locations (e.g. exactly where it will occur) and responsibilities (e.g. who will be responsible for carrying out the actions).

Given that approval from the SoE and DoW will be sought for the proposed measures, it is anticipated that consultation with these agencies will be undertaken and referral to guiding policies and documents will be made.

6.2.2.5 Financial Contributions

All subdivision/new development will be subject to financial contributions towards the provision of outfall drains/upgrading of drainage capital works wherever a development/subdivision drains into a Shire controlled (constructed, to be constructed, upgraded etc.) drainage system.

To minimise the cost and impact on the Shire drainage infrastructure construction and maintenance programmes should be prepared where necessary.

6.3 Monitoring

Appropriate monitoring regimes both pre-development and after construction are an integral part of the whole water cycle approach required by *Better Urban Water Management* (WAPC 2008). Pre-development monitoring allows existing conditions to be assessed ensuring that appropriate compliance limits for groundwater quality are set and that accurate groundwater level data is available for detailed design. This allows water quality to be appropriately managed during the construction and long term life of the development.

6.3.1 Pre-Development Monitoring

Pre-development monitoring within the Townsite has not previously been undertaken, however, monitoring of groundwater level and quality data is available from bores to the west of the Townsite. While this information may give an indication of regional groundwater levels and quality prior to development Townsite specific groundwater data will be required.

Two rainy seasons of data is required, as such, it is proposed that this monitoring is undertaken prior to development. Groundwater level peaks to be recorded during the rainy season to provide the seasonal fluctuation of the Townsite. The pre-development groundwater quality data will be used in defining appropriate trigger values for the Townsite.

6.3.2 Post-Development Monitoring

Post-development monitoring aims to demonstrate compliance with design objectives and criteria.

The post-development monitoring programme should be conducted for at least two years from practical completion. It should be tailored to the development, quantifying potential impacts on surface water quality, surface water flows, groundwater levels, seasonal fluctuation and quality, where applicable. The monitoring results can then provide:

- A trigger for contingency action, as per the contingency action plan guide ongoing management of open space and other landscape areas;
- An interim internal assessment tool of the monitoring programme;
- The monitoring programme should be designed in conjunction with DoW advice and consistent with the *Stormwater Management Manual for Western Australia* (DoW, 2007) to ensure data is of an appropriate standard for analysis and interpretation;
- Monitoring should follow the Australian Standards AS/NZ 5667 series of water quality sampling guidance notes. A NATA accredited laboratory is required to perform water quality testing (DoE, 2001) and analytes selected should be consistent with those pollutants of concern; and
- The Sampling and Analysis Plan for the post-development monitoring programme will be prepared and outlined within future LWMS/UWMP documents.

6.4 Reporting

The results of pre-development monitoring should be provided within future LWMS. Where monitoring is proposed to continue beyond this, final pre-development data should be included, and taken into account within future UWMP.

The monitoring reporting framework will need to be established within the LWMS phase to report on the pre-development conditions of the Townsite and this will facilitate development of appropriately refined management strategies. Post-development monitoring methodologies should be further developed and documented within the UWMP.

6.5 Staging

The modelling associated with the DWMS has assumed the planning of the development will be undertaken as multiple projects. As portions of the Townsite are developed in isolation to the rest of the development, the LWMS and UWMP documents associated with the parcel of land will need to be consistent with the criteria identifies in the DWMS. In particular the structural measures such as bioretention areas and FSAs will need to be designed and implemented in each isolated land parcel to ensure appropriate stormwater attenuation is provided.

6.6 Technical Review

It is not expected this DWMS will be reviewed unless there are significant changes made to the Exmouth DSP.

The LWMS should be submitted to the SoE with an appropriate structure plan. The SoE will then ensure all appropriate stakeholders are consulted.

This process is consistent with Better Urban Water Management (WAPC 2008).

6.7 Roles and Responsibility

This Exmouth DSP DWMS provides a framework that the future developers of the land can utilise to assist in establishing stormwater management methods. These have been based on site-specific investigations, relevant State and Local Government policies and have been endorsed by the SoE. The responsibility for working within the framework established within the DWMS rests with developers, although it is anticipated that future LWMS/UWMP will be developed in consultation with stakeholders (see **Table 7**) and in consideration of other relevant policies and documents. The future LSP will need to be supported by a LWMS and will require approval from the Shire of Exmouth and the DoW.

Table 7 Major Stakeholders

Stakeholder	Component required for Specialist Consideration	Funding/Responsible
DoW	Stormwater management Floodplain management Groundwater abstraction	Developer
DEC	Wetlands Vegetation ASS	Developer
Water Corporation	Drinking water and wastewater infrastructure Environmental issues	SoE
DoH	Where septic tanks are considered	SoE
SoE	Submission to planning service Developer contribution Drainage maintenance Wetland and vegetation	SoE

7 References

Armadale Redevelopment Authority, October 2006, Wungong Urban Water Master Plan District Water Management Strategy, Volume 1 of 2: Main Report.

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000, *National Water Quality Management Strategy*, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Canberra.

Australian Building Codes Board (ABCB), 2011, *Building Code of Australia*.

Commonwealth of Australia, 2011, Your Home, Available from: <http://www.yourhome.gov.au/> [August 2011].

Department of Environment and Conservation (DEC), 2011a, *Acid Sulfate Soil Mapping*, Viewed July 2011, Available online at http://www.dec.wa.gov.au/content/category/31/790/1653/.

Department of Environment and Conservation (DEC), 2011b, *Threatened and Priority Ecological Communities database*, information prepared by the Department of Environment and Conservation, Perth.

Department of Indigenous Affairs (DIA), 2011, *Aboriginal Heritage Inquiry System*, Viewed July 2011, Available Online at http://www.dia.wa.gov.au/en/Site-Search/Aboriginal-Heritage-Inquiry-System/.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), 2011, *Protected Matters Search Tool*, Viewed July 2011, Available Online at http://www.environment.gov.au/epbc/pmst/index.html.

Department of Water (DoW), 2007, *Stormwater Management Manual for Western Australia*, Perth.

Department of Water (DoW), 2009a, *Rezoning and Subdivision of Land in Public Drinking Water Source Areas*, Perth.

Department of Water (DoW), 2009, *Decision Process for Stormwater Management in Western Australia*, Perth.

Department of Water (DoW), 2010, *Water Quality Protection Note 70: Wastewater Treatment and Disposal – Domestic Systems*, Perth.

Department of Water (DoW), 2011, *Exmouth Water Reserve Drinking Water Source Protection Review.* Perth.

Engineers Australia, National Committee for Water Engineering, 2006, *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*, Canberra.

Government of Western Australia, 2003a, *Securing our Water Future: A State Water Strategy for Western Australia*, Perth.

Government of Western Australia, 2003, *Hope for the Future: The Western Australian State Sustainability Strategy*, Department of Premier and Cabinet, Perth.

Government of Western Australia, 2007, *State Water Plan*, Perth.

Heritage Council of WA 2011, *Places Database*, Viewed July 2011, Available Online at http://www.heritage.wa.gov.au/.

Shire of Exmouth, March 2006, *Guidelines and Specification for Design and Construction of Stormwater Drainage Systems*, SoE

Sinclair Knight Merz (SKM), 2007a, *Exmouth Floodplain Management Study: Flood Modelling Report*, Department of Water, Perth.

Sinclair Knight Merz (SKM), 2007b, *Exmouth Floodplain Management Strategy: Floodplain Management Strategy*, Department of Water, Perth.

Sinclair Knight Merz (SKM), 2010, *Exmouth Water Supply Planning 2010, Existing System Capacity Assessment*.

Taylor Burrell Barnett, 2011, *Proposed Exmouth Townsite Structure Plan*.

Water and Rivers Commission, 1999, *Groundwater Allocation Plan: Exmouth Groundwater Subarea*, Perth.

Water Corporation, 2003, *Domestic Water Use Study – In Perth, Western Australia 1998-2001*, Perth.

Water Corporation, 2011, *Being Waterwise*, Available from: <http://www.watercorporation.com.au/W/waterwise_index.cfm> [August 2011].

Western Australian Planning Commission (WAPC), 1997, *Statement of Planning Policy No. 4.1 State industrial Buffer Policy*.

Western Australian Planning Commission (WAPC), 1998, *Exmouth-Learmonth (North-West Cape) Structure Plan*, Perth.

Western Australian Planning Commission (WAPC), 2003, *Statement of Planning Policy No. 2 Environment and Natural Resources Policy*.

Western Australian Planning Commission (WAPC), 2003, *Statement of Planning Policy No. 2.6 State Coastal Planning Policy*.

Western Australian Planning Commission (WAPC), 2003, *Statement of Planning Policy No. 2.7 Public Drinking Water Source Policy*.

Western Australian Planning Commission (WAPC), 2004, *Statement of Planning Policy No. 6.3 Ningaloo Coast*.

Western Australian Planning Commission (WAPC), 2004, *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*, Perth.

Western Australian Planning Commission (WAPC), 2006, *Statement of Planning Policy No. 2.9 Water Resources*.

Western Australian Planning Commission (WAPC), 2006, *Statement of Planning Policy No. 3 Urban Growth and Settlement*.

Western Australian Planning Commission (WAPC), 2008, *Better Urban Water Management*, Perth.