Oakajee Industrial Estate
Structure Plan

District Water Management Strategy

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LANDCORP

Government of **Western Australia**
Department of **State Development**

GHD

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1. Executive Summary

GHD Pty Ltd were contracted by LandCorp to prepare a District Water Management Strategy (DWMS) for the Oakajee Industrial Estate. District water management is a component of integrated water cycle management that recognises 'water supply, stormwater and sewage services are interrelated components of catchment systems' (DoW 2004).

This DWMS investigation is based on the latest Structure Plan being prepared for the site by RPS Environment and Planning Pty Ltd and focuses on the Strategic Industrial Area and the two smaller General Industrial Areas.

The Oakajee Industrial Estate (OIE) development is considered a district scale scheme under State Government Planning. This DWMS will inform LandCorp and the Shire of Chapman Valley of the proposed water and drainage implications of the development so responsibilities can be fulfilled under Section 6 of *State Planning Policy 2.9 Water Resources* (2006).

The relevant water related planning documents that relate to the development include the *Shire of Chapman Valley Town Planning Policies* (Shire of Chapman Valley), *Town Planning Scheme No. 1, Amendment 18* (Shire of Chapman Valley 2000), *Town Planning & Development Act 1928* (Shire of Chapman Valley), *Shire of Chapman Valley Local Rural Strategy 2002* (Shire of Chapman Valley) and the Subdivision and Planning Development Guidelines (2009).

The site is currently used for farming and its topography is slightly undulating, with 3 north-south ridges running through it. Twenty-one monitoring bores were installed by Rockwater in 1996 and water levels in these ranged from 6 – 65 mBGL. Groundwater quality was generally brackish and elevated levels of nitrate and arsenic were encountered in some bores. The source of the nitrates is likely to be farming activities, whilst the arsenic is thought to be naturally occurring.

Up to 37 GL/yr has been forecasted as the total water demand for the OIE when fully developed. To ensure reliable and water efficient supply to the development, alternative water sources not considered conventional potable sources (scheme), were investigated.

Substituting scheme water with an alternative source for non-potable uses can result in significant savings in scheme water and in the associated chemicals and energy required to treat and deliver water to drinking water standard. It is therefore preferred that scheme water not be provided for non-potable demands within the (OIE).

Consequently, water source options for the site were investigated with the objective of reducing total potable water demand. These options currently include:

- Remote deep groundwater from Casuarina, Tumblagooda, Allanooka and local artesian aquifers;
- Desalination (reverse osmosis);
- Recycled industrial wastewater from a proposed Water Recycling Factory;

- Recycled treated organic wastewater from a future Waste Water Treatment Plant (WWTP).

Surface and groundwater management strategies are recommended to ensure the best management of water within the development and protection of downstream ecological communities. Water management (quality and quantity) will be the responsibility of each proponent for areas located within their lot boundaries, whilst LandCorp will be responsible for water management in public areas (road drainage). Specific surface water management strategies are presented below:

1 yr ARI

- To retain and treat the 1 year ARI event, rooves will be connected to soak wells and where they are adopted, to rainwater tanks.
- All stormwater will be contained within each lot and any which is contaminated will be treated prior to discharge / infiltration.
- Road runoff will be infiltrated as close to source as practicable using water sensitive urban design (WSUD) measures including roadside swales / table drains.

10 yr ARI

- Road runoff will be infiltrated as close to source as practicable using water sensitive urban design (WSUD) measures including roadside swales / table drains / bioretention structures.
- Bioretention structures within individual lots will treat and infiltrate stormwater runoff.

100 yr ARI

- Provision via overland flow paths will enable discharge of stormwater from each lot such that it will not exceed 100 yr ARI pre-development (existing environment) peak flows.

In order to ensure ongoing protection of groundwater, groundwater monitoring by individual development proponents will check against contamination.

2. Introduction

GHD were commissioned by LandCorp to deliver a District Water Management Strategy (DWMS) for the development of the Oakajee Industrial Estate (OIE). The site occupies land across the entire Oakajee area, in addition to parts of the Buller, Howatharra and White Peak localities.

This document focuses on the areas of land contained within the Strategic Industrial Area (SIA) and General Industrial Areas (GIA).

2.1 Site location and description

The OIE is approximately 6,400 hectares in area, located 23 km north of Geraldton in Western Australia. The site is on the coast within the Shire of Chapman Valley. The northern boundary is Coronation Beach Road, Buller River is the southern boundary and the foothills of the Moresby Range are the eastern boundary (Figure 1).

The OIE comprises the following four areas:

- Strategic Industry Area (SIA): covers an area of 1,100 ha on a plateau adjoining the coastal dunes and escarpment;
- General Industry Area (GIA): occupies 80 ha east of the (SIA) and another 110 ha land to its south;
- Buffer: serves as a buffer zone for the Strategic Industry Area, with its 4,000 ha located to the north, east and south of the industrial precincts; and
- Coastal Area: a 950 ha coastal strip bounded by the Strategic Industry Area in the east and the Buffer Area in the north and south.

The site is currently being developed to accommodate a range of processing industries for the Mid West of Western Australia. As part of the development, a deep water port is proposed near the centre of the Coastal Area to cater initially for iron ore exports, with other resources and products from the OIE likely to follow in the future.

Figure 1 Site location

2.2 Total water cycle management – principles and objectives

Total water cycle management, also referred to as integrated water cycle management, 'recognises that water supply, stormwater and sewage services are interrelated components of catchment systems and therefore must be dealt with using a holistic water management approach that reflects the principles of ecological sustainability' (DoW 2004-07, *Stormwater Management Manual for Western Australia*).

The *State Planning Policy 2.9: Water Resources* (WAPC 2004) outlines the key principles of integrated water cycle management as:

- Consideration of all water resources, including wastewater in water planning;
- Integration of water and land use planning;
- The sustainable and equitable use of all water sources, giving consideration to the needs of all water users, including the community, industry and the environment;
- Integration of human water use and natural water processes; and
- A whole of catchment integration of natural resource use and management.

The principles and objectives for managing urban water as stated in the *Stormwater*

Management Manual for Western Australia (DoW 2004-07) are as follows:

- Water Quality: to maintain or improve the surface and groundwater quality within the Development Areas relative to pre-development conditions;
- Water Quantity: to maintain the total water cycle balance within the Development Areas relative to the pre-development conditions;
- Water Conservation: to maximise the reuse of stormwater;
- Ecosystem Health: to retain natural drainage systems and protect ecosystem health;
- Economic Viability: to implement stormwater management systems that are economically viable in the long term;
- Public Health: to minimise the public risk including risk from injury or loss of life to the community;
- Protection of Property: to protect the built environment from flooding and water logging;
- Social Values: to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater; and
- Development: to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

2.3 Planning background

The planning framework for land and water planning is illustrated in Figure 2 (WAPC 2008). The DWMS demonstrates how water resources can be considered in the land use planning system and ensures consistency with *State Planning Policy 2.9: Water Resources* (WAPC 2004).

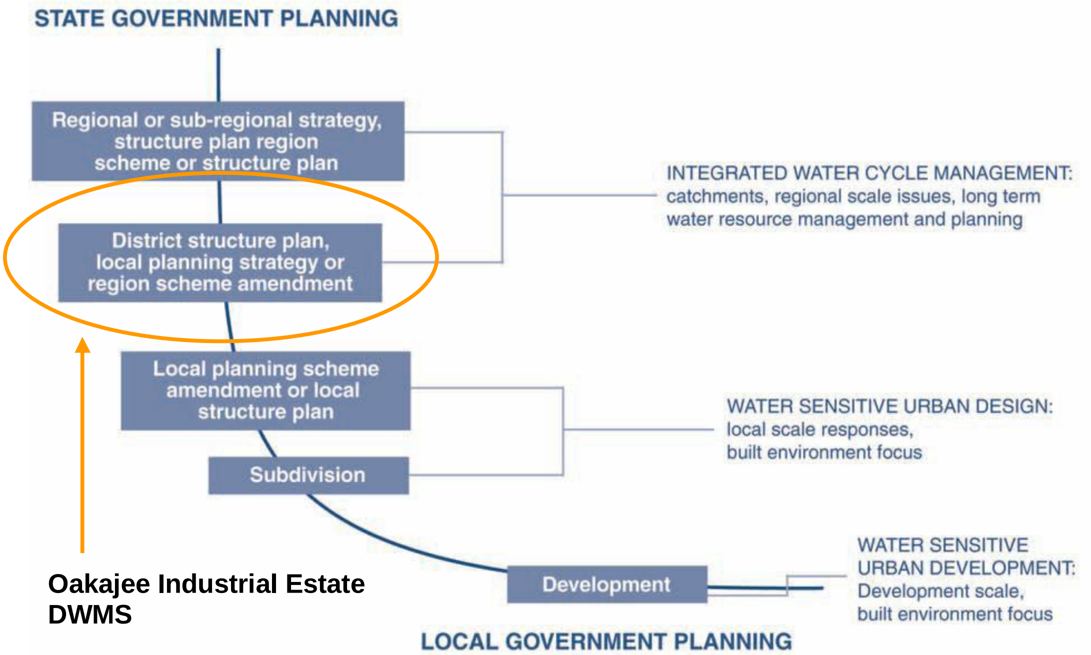


Figure 2 Planning framework for integrating the drainage planning with land planning

2.4 Previous studies and recommendations

Relevant documentation pertaining to the OIE and this DWMS is listed below:

Site Investigations

- *Oakajee Hydrology Report* (Jim Davies & Associates 1993)
- *Oakajee Site Hydrogeology: Site Investigation* (Jim Davies & Associates 1993)
- *Flora & Fauna Assessment: Oakajee Proposed Industrial Site* (Dames & Moore 1993)
- *Oakajee Hydrogeological Investigation* (Rockwater 1996)
- *Re-Evaluation of Flora and Fauna: Oakajee Proposed Industrial Estate and Quarries* (Muir Environmental 1997)
- *Vegetation Monitoring: Oakajee Industrial Estate* (Mattiske Consulting 2000)
- *Oakajee Industrial Park Groundwater and Surface Water Monitoring Results* (Rockwater 2000)
- *Oakajee Industrial Park Background Groundwater and Surface Water Monitoring Results* (Rockwater 2001)
- *Oakajee Industrial Park Groundwater Monitoring Results* (Rockwater 2003)
- *August 1997 Re-Evaluation of Flora & Fauna: Proposed Narngulu to Oakajee Railway* (Muir Environmental 1997)

- *Oakajee Pipeline Route Flora and Fauna Study: Desktop Review & Field Survey* (Landcare Services 1998)

Planning Documents

- *Better Urban Water Management* (Western Australian Planning Commission 2008)
- *Town Planning Scheme No. 1, Amendment 18* (Shire of Chapman Valley 2000)
- *Town Planning & Development Act 1928* (Shire of Chapman Valley)
- *Shire of Chapman Valley Town Planning Scheme No. 1* (Shire of Chapman Valley)
- *Shire of Chapman Valley Local Rural Strategy 2002* (Shire of Chapman Valley)
- *Residential Design Codes 2002* (Shire of Chapman Valley)
- *Shire of Chapman Valley Town Planning Policies* (Shire of Chapman Valley)

3. Design and Management Objectives

The following design criteria have been adapted from the Generic Design Objectives presented in *Better Urban Water Management* (WAPC 2008). These design criteria are methods for improving water management, and should, where possible, be implemented wherever possible by the developer. It is the Shire's intent that these design criteria be incorporated into the Local Water Management Strategy.

3.1 Water conservation and efficiency

- No potable water should be used outside buildings, with use of water to be as efficient as possible;
- Water supply to be fit for purpose, with reuse and recycling of wastewater to be adopted where suitable;
- All new fittings to meet 5 Star Plus provisions;
- The use of native plants is to be promoted, with native species constituting a minimum of 95% of total Public Open Space (POS) areas. It is noted that POS areas will be minimal, with 95% of the total open spaces to be dryland vegetation.

3.2 Water quantity management

- Post-development annual discharge volume and peak flow rates to be maintained relative to pre-development (existing environment) conditions, unless otherwise established through determination of ecological water requirements for sensitive environments;
- For the critical one year Average Recurrence Interval (ARI) event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development (existing environment) conditions in all parts of the catchment;
- Maintain runoff for up to the 1 in 100 year ARI event in the development area at pre-development (existing environment) peak flow rates; and
- Protect the built environment from flooding and waterlogging.

3.3 Water quality management

- Maintain surface and groundwater quality at pre-development (existing environment) levels (winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located;
- If pollutant outputs from the development (measured or modelled concentrations) exceed catchment ambient conditions, the proponent shall achieve water quality improvements in the development area or, alternatively, arrange equivalent water quality improvement offsets

inside the catchment. If these conditions have not been determined, the development should meet relevant water quality guidelines stipulated in the *National Water Quality Management Strategy* (ANZECC and ARMCANZ, 2000);

- Ensure that all runoff contained in the drainage network receives treatment prior to discharge and infiltration to a receiving environment consistent with the *Stormwater Management Manual for Western Australia* (DoW 2007).

3.4 Stormwater modelling criteria

If it is proposed to use a stormwater modelling tool to demonstrate compliance with design objectives, the modelling parameters recommended are those stated in Better Urban Water Management (WAPC 2008) (comparison is with a development that does not actively manage stormwater quality):

- At least 80 per cent reduction of total suspended solids;
- At least 60 per cent reduction of total phosphorus;
- At least 45 per cent reduction of total nitrogen; and
- At least 70 per cent reduction of gross pollutants.

3.5 Disease vector and nuisance insect management

To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours.

Permanent water bodies are discouraged but, where accepted by the Department of Water, must be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of the Department of Water and the Department of Health.

4. Pre-Development Environment

4.1 Climate

The OIE experiences a Mediterranean climate characterised by mild, wet winters and hot, dry summers. Mean daily temperatures fluctuate seasonally, ranging from 30°C in the summer to 8°C in winter.

Table 1 and Figure 3 summarise climate statistics for Oakajee obtained from the Bureau of Meteorology (BoM). The nearest BoM climate station is Geraldton Airport (008051), which is about 23 km south-west of the site. For comparison purposes, rainfall data from the Howatharra station (008168) has also been included in Table 1. The Howatharra station is located approximately 5 km north-east of the site and measures rainfall only.

Rainfall data dating back to 1975 has also been collected by the Department of Water at the Buller River gauging station (508025). Owing to its proximity to the site, rainfall data from this station is considered representative of rainfall over the entire site. Rainfall recording ceased in 2003, but the records nevertheless display a similar rainfall pattern to records from the Howatharra station. Monthly rainfall statistics from the Buller River gauging station are also shown in Table 1.

Table 1 Climate statistics near the Oakajee Industrial Estate (Department of Water 2009, Bureau of Meteorology 2009)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (°C)	31.6	32.5	30.9	27.6	24.0	20.9	19.5	20.0	22.0	24.4	27.1	29.4	25.8
Mean minimum temperature (°C)	18.3	19.1	17.9	15.4	12.9	11.0	9.5	8.9	9.2	10.9	13.8	16.3	13.6
Mean rainfall (mm)													
◗ Buller River (1974-2003)	5.4	8.6	19.9	27.4	66.0	83.4	73.9	53.4	30.9	15.7	9.4	3.5	388.9
◗ Geraldton Airport (1941-2009)	5.7	11.0	15.9	24.1	69.9	100.4	92.7	64.5	32.5	19.0	9.2	5.4	448.9
◗ Howatharra (1911-2009)	5.6	8.5	14.7	25.0	71.4	107.1	95.9	63.8	30.5	18.1	8.4	3.2	455.2
Mean daily evaporation (mm)	10.8	10.7	9.3	6.5	4.6	3.4	3.0	3.2	4.3	6.4	8.5	10.1	6.7
Mean monthly evaporation (mm)	335	300	288	195	143	102	93	99	129	198	255	313	2450

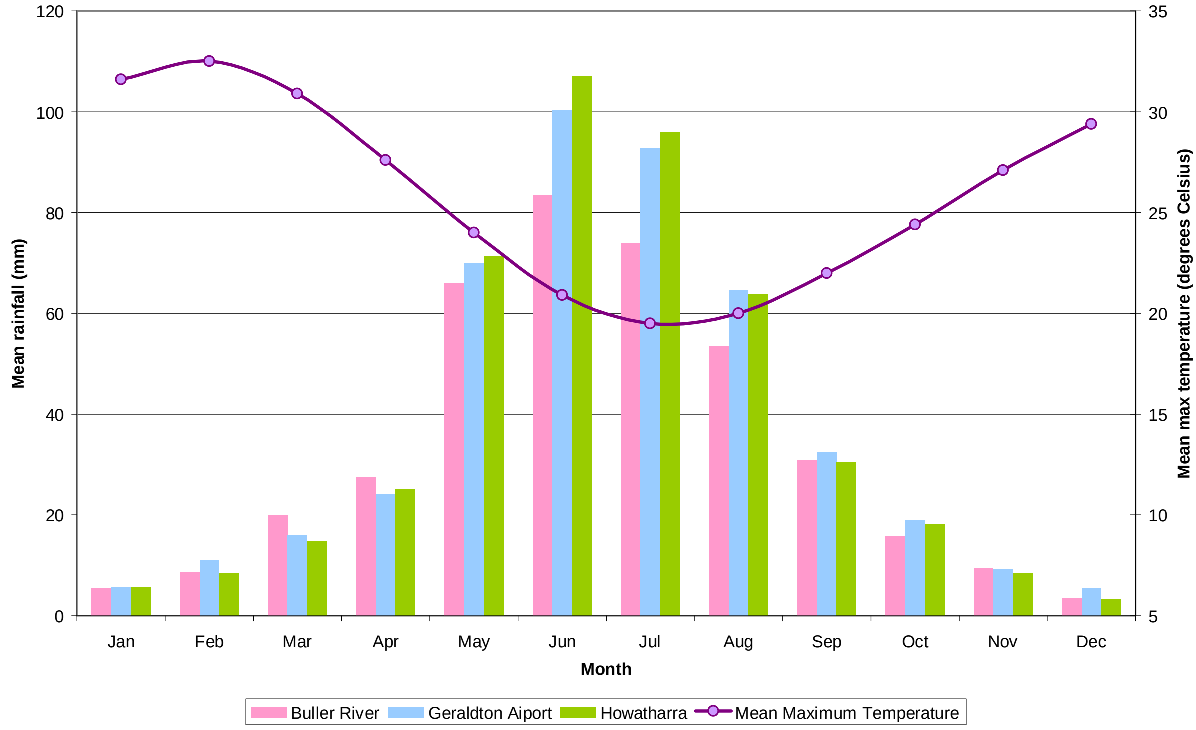


Figure 3 Climate statistics from Geraldton Airport (Bureau of Meteorology 2009)

Rainfall at Oakajee is fairly low, with the majority of rainfall occurring between May and August. The mean annual rainfall is approximately 388 mm, whilst the mean annual evaporation is 2,450 mm. With the exception of June and July, evaporation exceeds rainfall at all times of the year.

4.2 Topography

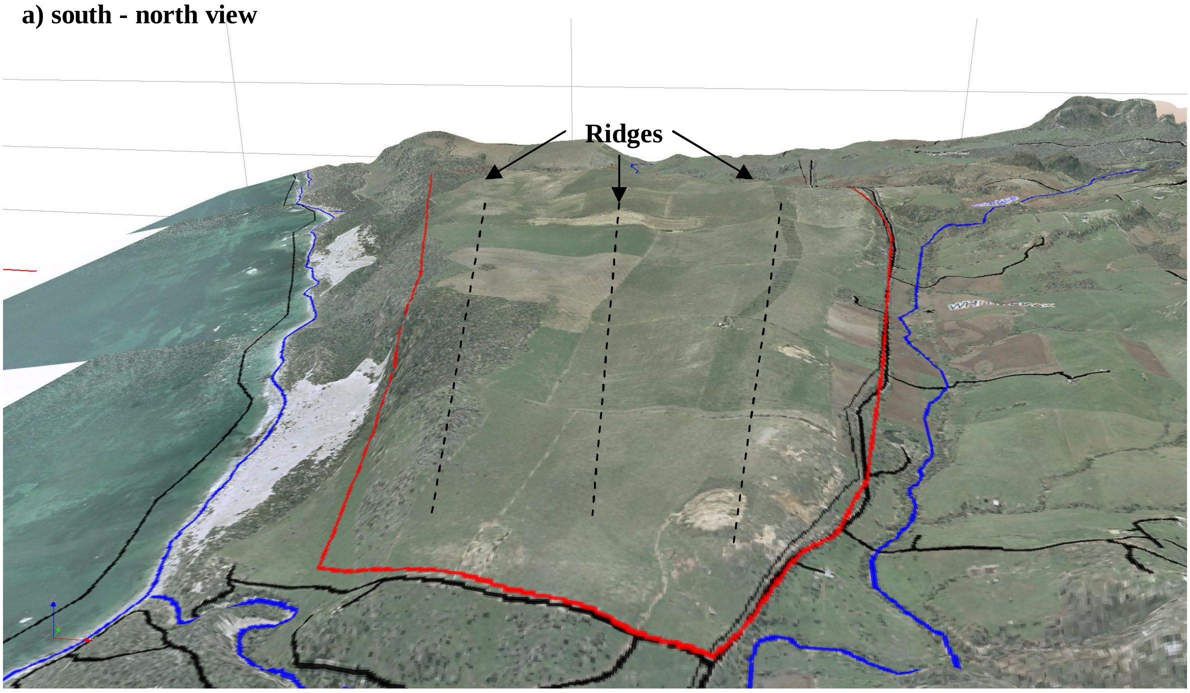
The SIA is located on a gently undulating coastal plateau. Elevation of the plateau ranges from RL 105 mAHD in the east to RL 70 mAHD in the west. To the west of the plateau is a steep limestone escarpment which drops to coastal dunes behind the beach. To the north, the plateau drops steeply to the Oakajee River, while to the east and south it drops more gently towards the Buller River.

The northern buffer is characterised by hilly terrain that drops through a coastal escarpment to dunes and the coast in the west, and descends more gently to the Oakajee River in the south.

Three low, distinct ridges running north-south traverse the plateau, with the eastern-most ridge screening the industrial areas from the Buffer to the east. The ridges are separated by two shallow depressions approximately 1 km wide which drain internally (Figure 4). The crests of the ridges are 10 to 15 m above the floor of the intervening depressions, with side slopes of 1:15 to 1:20. The floors of the depressions have only a gentle gradient (1:100 or less). It is anticipated these landforms may be modified to accommodate development of the site (Quilty Environmental 1998).

The natural ridges and depressions are illustrated in 3D form in Figure 4a and b, whilst the topography of the site is illustrated in Figure 5.

a) south - north view



b) north – south view

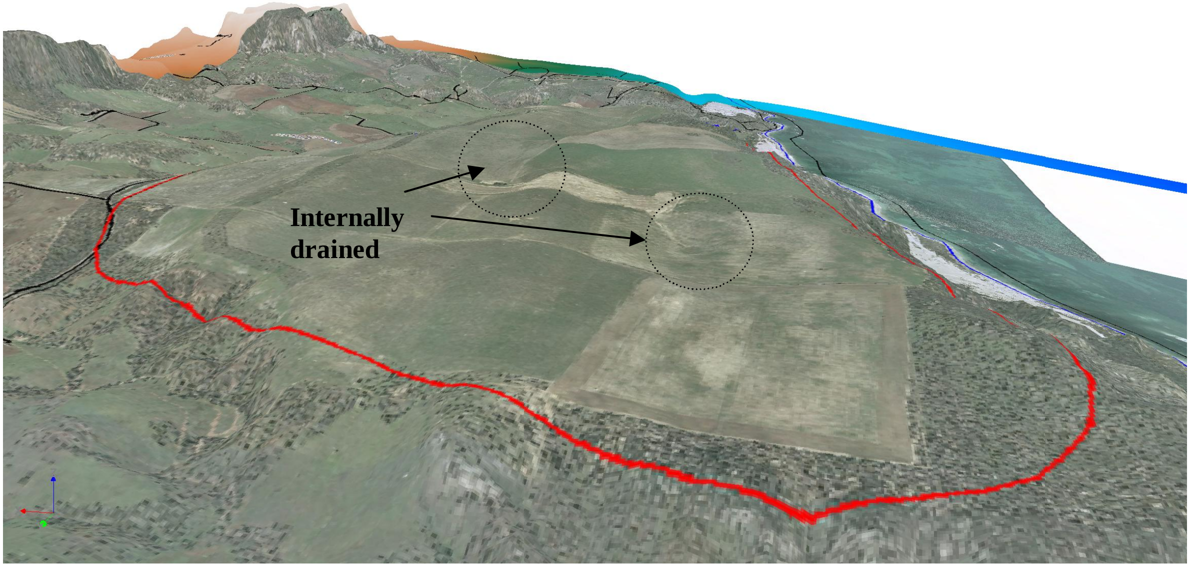


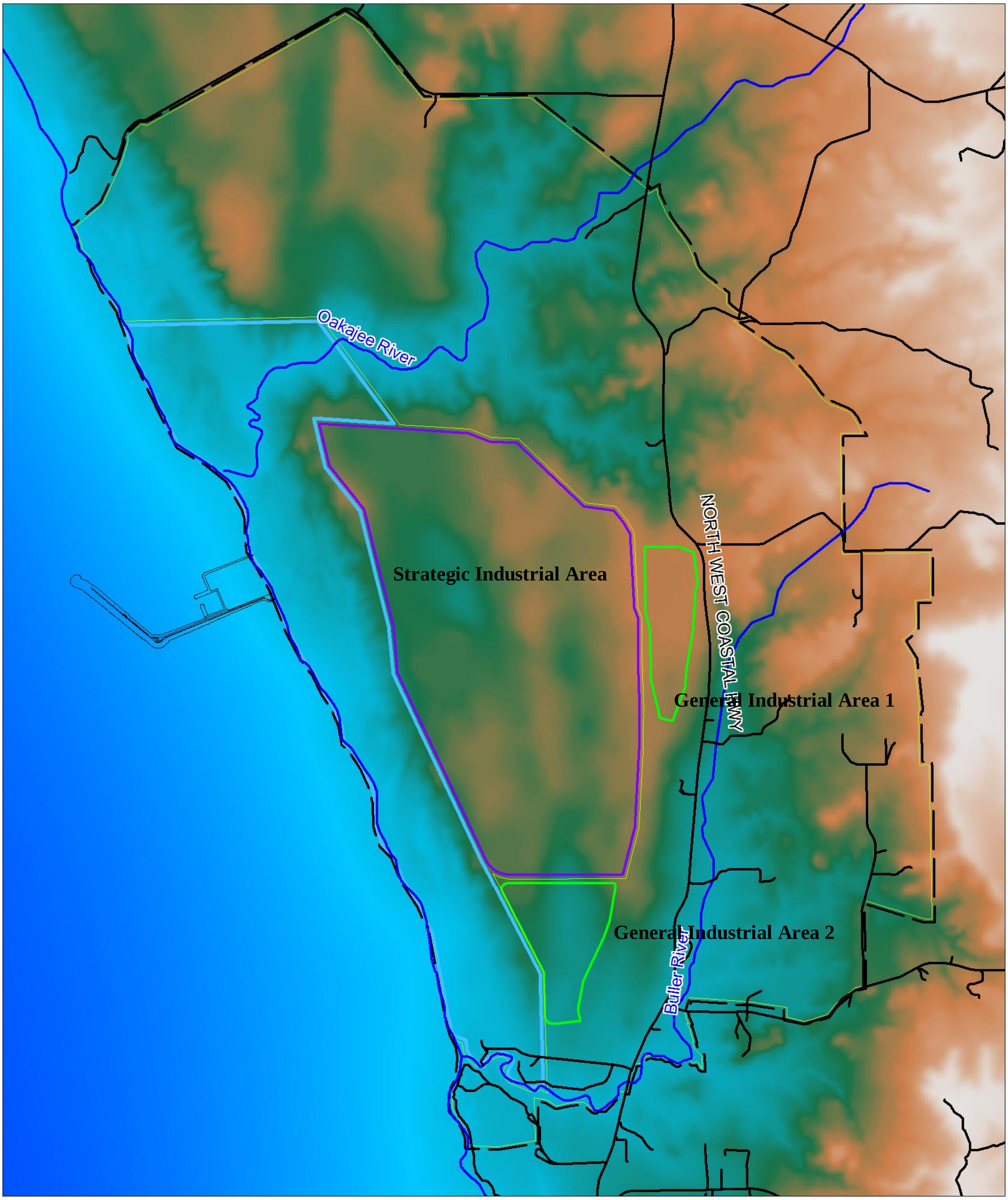
Figure 4 3D images of Oakajee Site (5x vertical exaggeration)

4.3 Geology and soils

Oakajee lies mainly on the Tamala Limestone Formation, which is comprised of a calcarenite core with a capping of secondary limestone or capstone (GHD 1993). Safety Bay Sand occurs on the coastal strip to the west. The dominant geomorphological processes in the area include transport of sediment to the shore by waves, formation of coastal sand dunes by wind, and transport of sand inland by wind (Koltasz Smith 2007).

Freely draining yellow sandplain overlying limestone makes up the bulk of the soils within the SIA and GIA. Near the coastal escarpment in the west, red Spearwood sands occur over limestone. These too are freely draining and are more fertile than the yellow sandplain soils (Rockwater, 1996). The surface geology of the site is illustrated in Figure 6.

Soils within the site are largely free from any risks of acid sulphate occurrence (Figure 6). A small area with moderate to high risk of acid sulphate occurrence is located near the centre of the Coastal Area, outside the industrial precincts which are the subject of this DWMS. Other potentially affected sites are the Oakajee and Buller Rivers, where soils close to the rivers pose a low to moderate risk. The risk level elevates to moderate to high at locations near the river mouths. These too fall outside the industrial precincts and will not be disturbed by their development.



LEGEND

Major Roads
Natural Drainage Lines
Coastal Zone
General Industrial Areas
Strategic Industrial Areas
Buffer Zone

Elevation (mAHD)

185	110	80	45
150	95	75	10
125	88	65	0

0.5 0 0.5 1 1.5
Kilometers
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

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CLIENTS | PEOPLE PERFORMANCE

Client Name: LandCorp
Project Name: Oakajee Industrial Estate
District Water Management Strategy

Job Number 612461102
Revision A
Date 26082010

Topography

Figure 5

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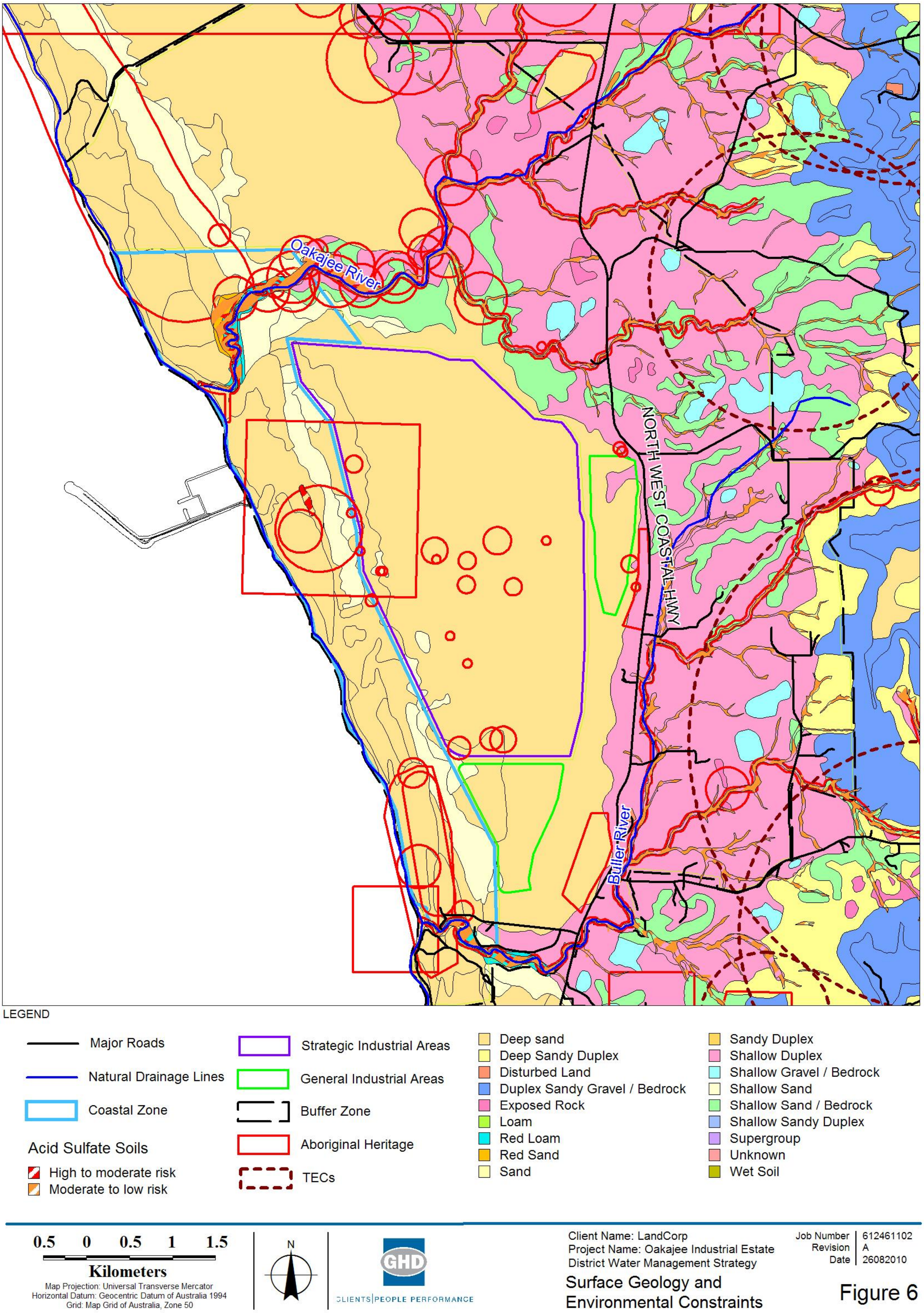

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Client Name: LandCorp
Project Name: Oakajee Industrial Estate
District Water Management Strategy

Job Number | 612461102
Revision | A
Date | 26082010

Surface Geology and Environmental Constraints

Figure 6

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4.4 Flora

Several flora assessments have been undertaken within the OIE. The two of most recent relevance are:

- Geraldton Regional Flora and Vegetation Study (Department of Planning 2010); and
- OPR PER Vegetation and Flora Survey (Ecologia 2010a)

According to these recent investigations, there are 82 ha of remnant vegetation on the western side of the SIA and within the southern GIA. These comprise Geraldton Regional Flora and Vegetation Survey (GRFVS) communities 10 (Near Coastal *Acacia rostellifera*), 12 (Ridge *Melaleuca cardiophylla*), and 13 (Sandplain *Banksia prionotes*), comprising areas of 39 ha, 25 ha and 18 ha respectively.

The investigations indicate no Declared Rare Flora (DRF) within these precincts, although there are three priority species towards the western boundary of the SIA and GIA and a further 30 within the Buffer. Within the SIA these species are located in areas that are likely to be cleared for the Oakajee Port and Rail's (OPR) rail alignment.

Table 2 summarises Priority Flora encountered within the SIA and GIA.

Table 2 Priority Flora found within the Strategic and General Industrial Areas

Species name	Status
Malaleuca huttensis	Priority 1
Grevillea triloba	Priority 3
Lasiopetalum oppositifolium	Priority 3

No Threatened Ecological Communities (TECs) were identified within the SIA or the GIA. Five Priority 1 areas were identified to the east of Oakajee listed as 'plant assemblages of the Moresby Range system.' These areas are illustrated in Figure 6.

4.5 Fauna

The most recent fauna assessment was undertaken by Ecologia Environmental (2010a) for the Oakajee Port and Rail (OPE) Public Environmental Review (PER).

A total of 22 mammals, 161 birds, 105 reptiles and 15 frog species were found in the wider area, none of which were located within the SIA or GIA. Of these, 32 are species of recognised conservation significance, including:

- Four EPBC Act listed migratory bird species – Fork-tailed Swift, Eastern Osprey, White-bellied Sea-eagle and Rainbow Bee-eater;
- Two Priority 4 bird species listed by DEC – White-browed Babbler and Australian Bustard;
- One Priority 4 species listed by the DEC – Western Carpet Python;

- Northern and southern forms of the Fossorial skink, an undescribed worm lizard currently awaiting classification, and several fauna species at or near the northern limit of their range.

Within the SIA and GIA, some species of short range endemic invertebrates were identified. These include:

- Two millipede species (*antichiropus* 'Geraldton' and *Podykipus* sp.1) on the north western and south western boundary of the SIA and in the vegetated portion of the southern GIA;
- Trapdoor spider (*Aname* sp. 1) in remnant vegetation in the north west of the SIA and in the north west section of the southern GIA;
- Land snail (*Bothriembryon* sp.) in the north west of the southern GIA.

Subterranean Fauna

Troglobites are fauna that inhabit caves or other subterranean habitats. While troglobite is a term which can be applied to obligate subterranean species of both terrestrial and aquatic habitats, the term stygobite is used in preference for subterranean aquatic fauna species (Finalyson & Hamilton-Smith 2003). In the context of this DWMS, the presence of stygobites in groundwater is of relevance.

The occurrence of stygobites within the OIE has been assessed through a baseline stygofauna survey of groundwater bores at the site. A total of three species, representing two Classes and three Orders, were recorded in the survey. According to Ecologia Environment (2009), it is likely all three species are new to science. In addition, the elevated nature of the plateau suggests the underlying aquifers are unlikely to be connected to the surrounding aquifers, thus restricting the stygofauna species to the site (Ecologia 2009).

From physio-chemical data gathered during groundwater sampling, the subterranean environment at the site was found to be suitable stygofauna habitat (Ecologia 2009).

The site has been radically altered over the past 60 years, with wholesale clearing of the Oakajee plateau beneath which the stygofauna have been located and subsequent grazing, cropping and groundwater extraction from this area for stock supplies. This land use has seen no containment of nutrients or other pollutants infiltrating to groundwater from farming and grazing activities, and no management of groundwater levels which would have risen following clearing and have varied since according to seasonal conditions. Against this background, allowing for depth to groundwater (15 – 65 mBGL) beneath the plateau, and assuming Best Management Practices (BMP) are adopted with respect to management of water within the industrial site, future developments are unlikely to negatively impact stygofauna or troglofauna and may see improved management of site groundwater compared with what has obtained over the past 60 years of farming and grazing.

This is supported by a Stygofauna Risk Assessment report (PB 2010) which assessed likely impacts of the proposed development on subterranean fauna. The study concluded the impact on stygofauna from likely industrial activities within the SIA and the GIA will be 'very low' if mitigation measures proposed in this DWMS are implemented.

4.6 Land use

Land use within the general Oakajee area is predominantly rural, with wheat production and grazing of livestock. Soils are generally average to good quality and the preferred land use is broad-acre agriculture (Welker Environmental Consultancy 1997).

The OIE is zoned 'Industrial Investigation' under the *Shire of Chapman Valley Town Planning Scheme No. 1 District Zoning Scheme*. The SIA and GIA have been extensively cleared for agricultural purposes, with vegetation retained around the perimeter only. In the past, wind erosion degraded some areas of the cleared ground.

Land surrounding the industrial areas is largely zoned 'General Farming' with lot sizes ranging from 5 ha upwards. In areas to the south-east, 'Special Rural' allotments have been created through subdivision.

Recreational opportunities and/or existing recreational use have been identified at the Buller River mouth and the adjoining coast to the south and at Coronation Beach to the north

4.7 Aboriginal and European heritage

The Department of Indigenous Affairs' register indicates that there are a number of Aboriginal heritage sites within the OIE (Figure 6). These include the Buller River and Oakajee River, which are both considered mythological sites. The Oakajee River is also populated with approximately twenty artefact sites along its fringes and there are a further eight sites to the north.

Nine Aboriginal heritage sites are registered within the Oakajee Coastal Area, four of which are burial sites. The proposed port coincides with three heritage sites, whilst the 'Buller River North Reburial' site overlaps with the western portion of the SIA.

The register also indicates 25 other artefact sites through the industrial precincts and two sites near North West Coastal Highway.

To address development impacts on these and any further sites which may be identified, LandCorp is currently preparing an Aboriginal Heritage Management Plan for Oakajee in consultation with the three Aboriginal claimant groups.

The Heritage Council of Western Australia's *State Register of Heritage Sites* lists four European heritage sites within the boundaries of the Oakajee buffer. All are in the northern buffer, in areas that will remain undisturbed.

4.8 Surface water

The Buller and Oakajee Rivers are the only significant surface drainage features near the OIE. The site has been subdivided into sub-catchments, which are further described in Section 7.

The only location where long term surface water monitoring has occurred is the Buller River stream gauging site (701006) near the mouth of the Buller River. Daily streamflow information was collected from 1974 to 2001. Findings are summarised in Figure 7 and Figure 8.

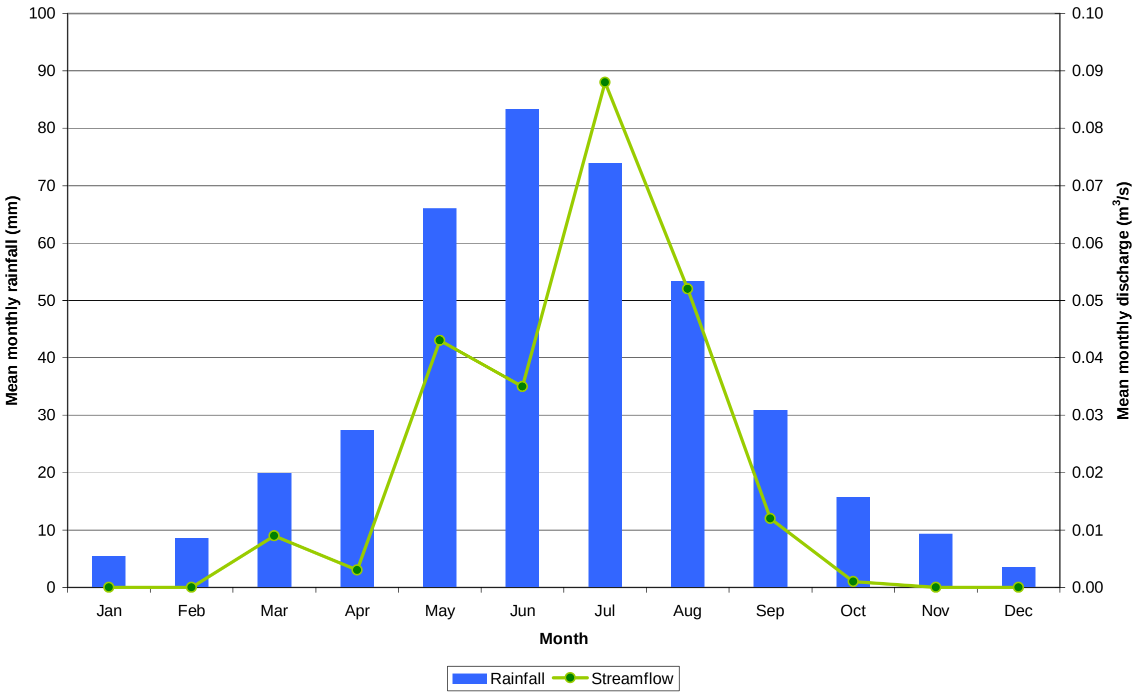


Figure 7 Monthly rainfall and streamflow statistics of Buller River (Department of Water 2009)

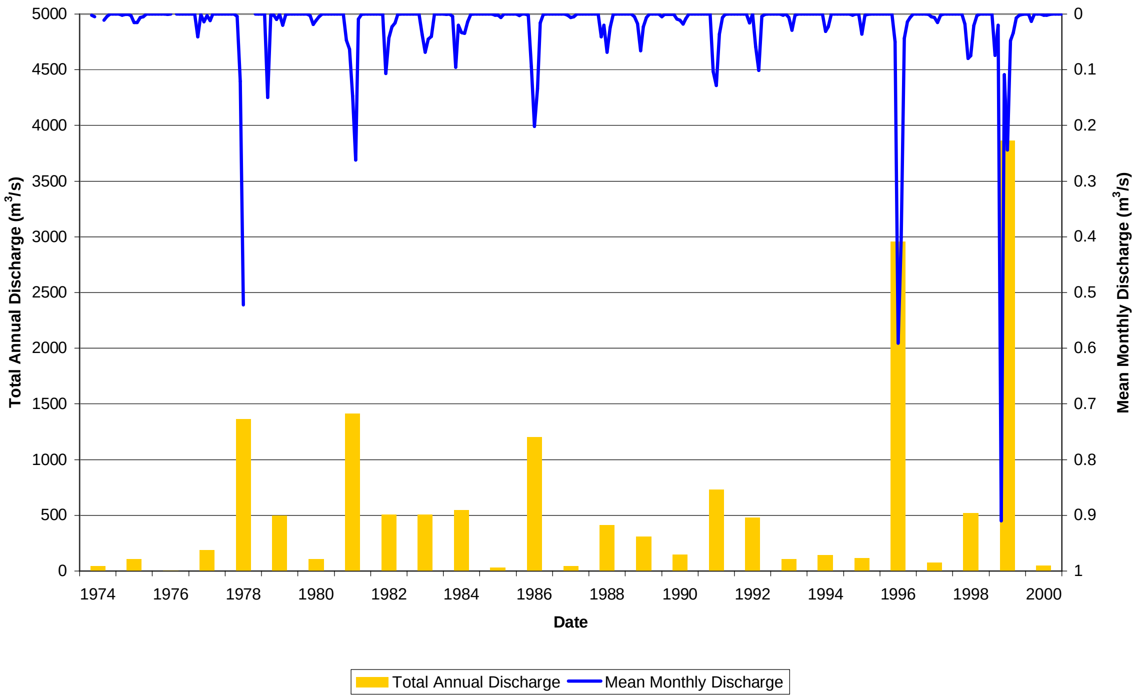


Figure 8 Annual and monthly streamflow statistics at Buller River (Department of Water 2009)

A comprehensive surface water monitoring study at the site was conducted by Greenbase EIC over a two-year period from 1999 to 2000. Streamflow data suggests the Buller River is dry for most of the year (Greenbase EIC 2001).

Despite both rivers having similar catchment characteristics, discharge volumes from the Oakajee River were considerably higher than from the Buller River for both study years (Greenbase EIC 2001). Variations in discharge were attributed to the contribution of baseflow in the two rivers. From 1999 to 2000, baseflow in the Buller River amounted to approximately 3 % of the annual discharge volume (Greenbase EIC 2001), compared to the Oakajee River where baseflow represented 5 - 6% of the annual discharge volume (Greenbase EIC 2001). This implies the Buller River catchment is likely to contain a higher proportion of area contributing to direct surface runoff; while the Oakajee River appears to have a higher degree of influence from groundwater recharge and discharge (Greenbase EIC 2001).

Surface water quality sampling undertaken by Greenbase EIC between 1999 and 2000 revealed elevated levels of sodium, chlorine, potassium and magnesium which are the main chemical constituents of saline groundwater. Metal constituents were generally below detectable limits, with the exception of low arsenic and zinc levels at the Oakajee sampling sites and infrequent low nickel and zinc levels at some Buller sampling sites (Greenbase EIC 2001). Nitrate levels were above guideline values for aquatic ecosystems in undisturbed lowland rivers, but were within the guideline limit for livestock drinking water (Greenbase EIC 2001).

Sediment analysis for both rivers revealed concentrations of zinc, lead and chromium that are normally found in environments with a history of agricultural land use (Greenbase EIC 2001). The total phosphorus concentration in sediments was high at both rivers, probably due to agricultural activities (Greenbase EIC 2001). No pesticides were detected in any of the sediment samples, but most constituents, with the exception of mercury and cadmium, were present in detectable quantities (Greenbase EIC 2001). As a result of the infrequent sampling program, Greenbase EIC advised that the sediment analysis results should not be considered as definitive.

4.9 Groundwater

Groundwater at the Oakajee Industrial Estate occurs in unconfined aquifers 15 to 65 m below ground level (Rockwater 2003; Figure 9). The aquifers are recharged by rainfall and comprise locally weathered bedrock and overlying siltstone (Chapman Group), Tamala sand and superficial sand (Rockwater 1996). There is no saturated aquifer at the north-western edge of the plateau due to impermeable granite bedrock rising above the groundwater table here (Rockwater 1996).

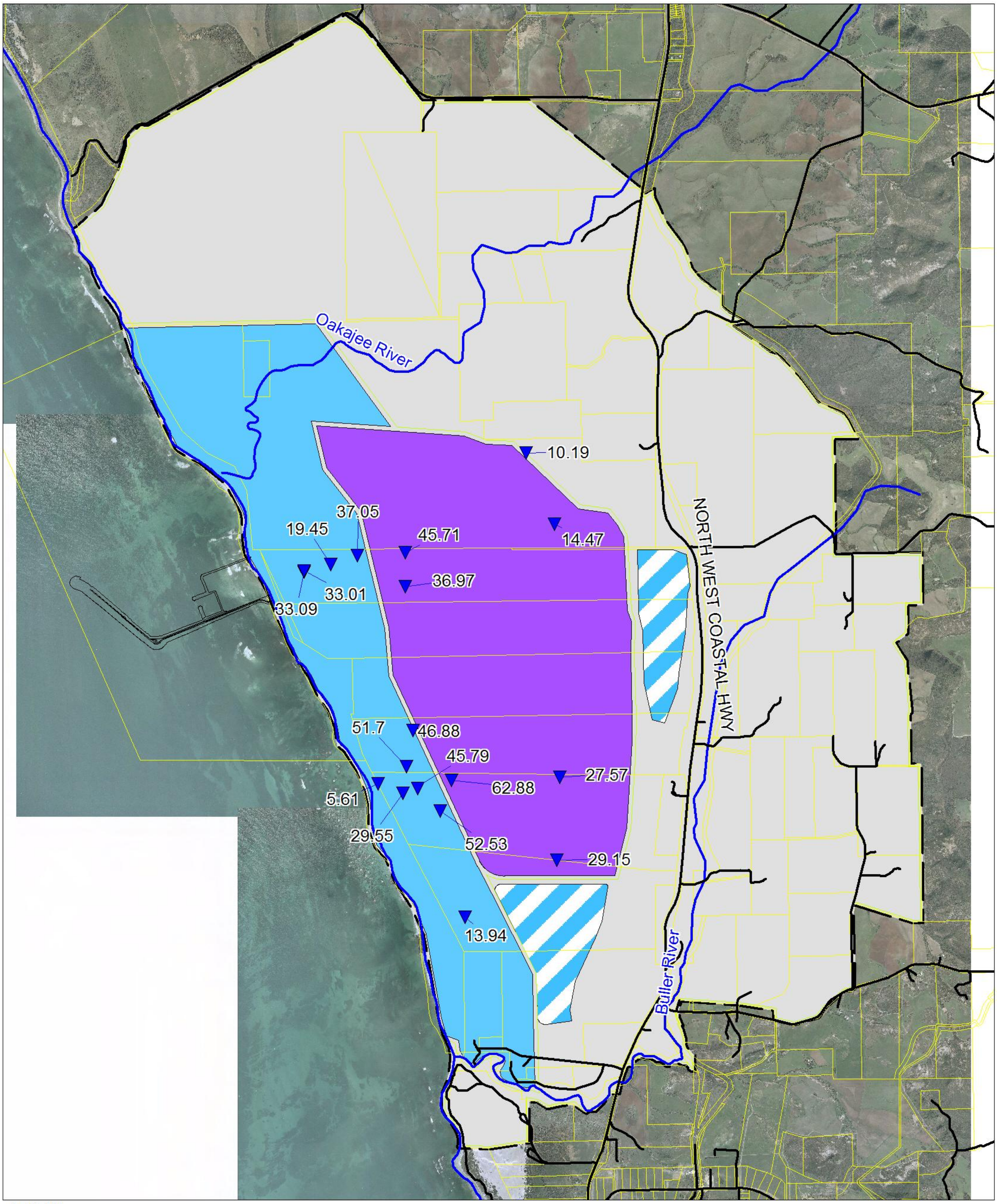
Groundwater level contours indicate groundwater levels ranging from about 80m AHD at the north-east of the plateau to less than 1 m AHD at the coast (Rockwater 2003). Groundwater from the site flows predominantly in a westerly or south-westerly direction towards the coast, passing though the Tamala sand and Chapman Group sediments (Rockwater 2003).

The granite bedrock in the plateau's north-west inhibits groundwater flow towards the coast in this particular sector. Consequently, higher groundwater levels are observed along the eastern side of this granite and slight depressions occur on its western side (Rockwater 1996).

Groundwater sampling at the site was carried out by Rockwater from May 1999 to December 2000 and from September 2001 to April 2003. Results indicated that the groundwater is essentially free of contamination, with the exception of high nitrate concentrations and low arsenic levels (Rockwater 2003).The elevated nitrate levels were probably the result of agricultural activities, with the highest concentrations occurring at the western side of the plateau (Rockwater 2003).

Arsenic levels above guideline limits were detected at two bores installed into the Tamala sand aquifer (Rockwater 2003). Parsons Brinckerhoff (2010) advise that the arsenic in the local groundwater may be a natural occurrence as a result of mobilisation from sediments during rainfall infiltration (O'Shea et al. 2007). Rockwater (2003) also noted that it is possible minor groundwater contamination by arsenic could have come from agricultural compounds such as sheep dip, feed additives or pesticides.

The groundwater beneath the site is brackish, with salinities ranging from 1,000 – 3,500 mg/L, but typically ranging from 700 – 1300 mg/L. Nitrate levels ranged from 19 – 150 mg/L in six bores selected for water quality monitoring. Total phosphorous levels were below reporting limits (<0.05 mg/L).



LEGEND

- Major Roads
- Natural Drianage Line
- Groundwater Level (mBGL)
- Cadastre
- Coastal Zone
- General Industrial Area
- Strategic Industrial Area
- Buffer Area

0.5 0 0.5 1 1.5

Kilometers

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

GHD CLIENTS | PEOPLE | PERFORMANCE

Client Name: LandCorp
Project Name: Oakajee Industrial Estate
District Water Management Strategy

Water Features

Job Number	612461102
Revision	A
Date	26082010

Figure 9

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239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by: GIS Operator

5. Proposed Development

The proposed development will be based on the Structure Plan prepared by RPS.

5.1 Key elements of the structure plan

The Structure Plan can be broadly divided into the following zones, as illustrated in Figure 10.

Strategic Industry Area and General Industrial Areas

The structure plan contains three industrial areas that are relevant to this DWMS. They include the Strategic Industry Area (SIS) (1,144 ha) and two General Industry Areas (GIA) located immediately to the east and south of the SIA and comprising 80 and 107 ha respectively. The SIA is planned for heavy industrial purposes such as ferrous mineral processing, whilst the GIA are intended for general industrial activity supporting the industries within the SIA.

Coastal Area

The Coastal Area covers 947 ha and is proposed for a port and port-related industry. Possible industries include iron-ore stockpiling, grain storage and handling, marine construction, fuel storage and an intermodal facility.

Buffer

The buffer has been defined to contain impacts of industry and to exclude land uses such as residential development which could constrain future industrial development.

5.2 Transport Corridors

The Structure Plan allows for integrated transport and service corridors entering the estate through Wokatherra Gap to the east.

Road

Three separate access roads are proposed to allow access to the OIE and Port from the North West Coastal Highway; the Southern, Central, and Northern Access Roads.

The Central Access Road will provide the primary entrance to the Strategic Industrial Area from the North West Coastal Highway, which runs past the estate, and will also provide access to the Port. The Southern Access Road will provide access to both the SIA and the Port, while the proposed Northern Access Road will provide access to the Port only.

Rail

Since industries which will locate in the OIE and their needs for rail transport are unknown, multiple rail options have been proposed to facilitate the best access opportunities to the site.

A multi-product railway is proposed that enters the estate through Wokatherra Gap and loops around the boundary of the SIA. Another rail link is proposed from Wokatherra Gap running up to the northern buffer before swinging back to the Port.

5.3 Potential Development Impacts

The Oakajee development will modify the current environment which has in turn been substantially modified compared to the pre-European environment. Development modifications to the current setting will require management to ensure there are no unacceptable impacts to the environment.

Stormwater runoff will increase due to increases in impervious areas. The combination of reduced vegetation cover and increased stormwater runoff will result in more groundwater infiltration. This may result in local groundwater mounding beneath local areas of point infiltration.

The land use change from dryland agriculture to industrial has potential to lead to contamination of stormwater and groundwater. Stormwater will need to be managed carefully through appropriate treatment measures. A treatment train approach, which incorporates multiple treatments in series, is considered most appropriate.

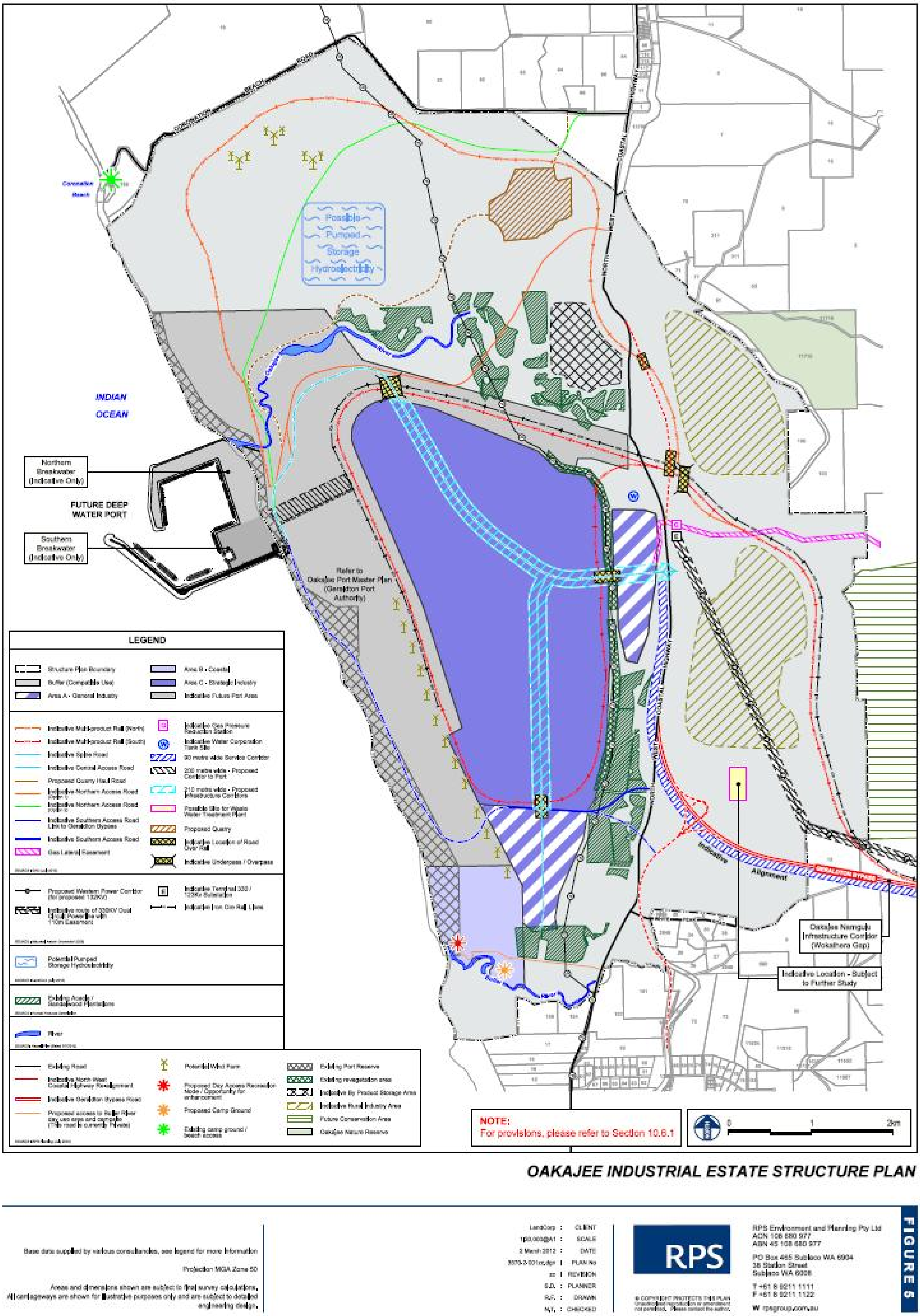


Figure 10 Preliminary (draft) Oakajee Industrial Estate structure plan (prepared by RPS 2010)

6. Fit-For-Purpose Water Source Planning

This section outlines a combination of generic and site specific water source planning strategies relevant to the OIE. These strategies provide options for utilising alternative sources of water within the site and identify the infrastructure required.

A preliminary site water balance based on water demand projections has been prepared to quantify water supply and demand for the site and to assist in identifying ways to improve water efficiency within the site.

A surface water hydrological assessment detailing pre and post-development flows and required storages to maintain pre-development flows has also been undertaken and is presented in Section 7, which also addresses management principles.

6.1 Water allocation

Substituting scheme water with an alternative source for non-potable uses can result in significant savings in scheme water and in associated chemicals and energy required to treat and deliver water to drinking water standard. It is preferred that scheme water not be provided for non-potable demands within the OIE.

Potential supply options for non-potable uses include roof runoff, groundwater, stormwater (runoff from impervious surfaces) and wastewater re-use. A non-potable system cannot be established without a detailed investigation into associated risks. Possible risks associated with such systems largely relate to public health and the environment, particularly as the water is generally of poorer quality than potable water.

Use of roof runoff and/or groundwater is currently adopted widely across Perth and in regional Western Australia, and is not difficult to implement. Indirect reuse of stormwater also occurs on the Swan Coastal Plain by infiltrating stormwater through sands and subsequently abstracting it as groundwater. The direct reuse of stormwater and reuse of treated wastewater (either directly or indirectly) have not yet been approved for any projects in Western Australia, although they are occurring in some developments in the eastern states and overseas.

It is necessary to evaluate potential public health risks, environmental impacts, financial costs, technical practicability, source viability and attitude of the local community against probable benefits of implementing a non-potable water supply system. Alternative water supply systems should be established only in areas where potential benefits outweigh potential risks.

Typically, the use of rainwater tanks is encouraged in urban developments to capture rainwater as a substitute for scheme water for in house non-potable use and garden irrigation. Rainwater tanks could also be used for these purposes in the Oakajee Industrial Estate, but consideration should be given to efficiency of water capture and reuse.

In the OIE case, industrial water demands far outweigh domestic potable demands. Consequently, stormwater runoff from industrial roofs and hardstand areas is likely to represent a small component of the total water demands. Dust suppression in particular is likely to require large water volumes. This water will initially be sourced from desalination of sea water.

The relative difficulty of implementing non-potable water use in Perth, as related to level of treatment required, availability and costs is summarised in Table 3. The implementation process for Oakajee may be more difficult than indicated below due to its remote location, but still warrants consideration due to the environmental benefits.

Table 3 Relative ease of implementation of non-potable water use under current regulatory framework

Water Source	**In House**			**Domestic Irrigation**	**Public Open Space Irrigation**	**Aquifer Recharge**
	Hot Water	Toilet Flushing	Washing Machine Cold Water Inlet			
Roof runoff	Difficult to implement. Not currently approved by health department as hot water is classified as a drinking water use	Easy to implement	Easy to Implement	More effort to implement	More effort to implement	Easy to Implement
Stormwater (urban runoff)		Difficult to implement	Difficult to implement	Difficult to implement	Difficult to implement	Easy to Implement
Domestic Grey water		Difficult to implement	Difficult to implement	Significant effort to implement	Significant effort to implement	More effort to implement
Treated Wastewater		Difficult to implement	Difficult to implement	Significant effort to implement	More effort to implement	Significant effort to implement

The technical feasibility and health implications of these alternatives have been considered in developing the proposals which follow.

6.2 Alternative Water Source Options

Forecast total water demand for the entire OIE is 37 GL/yr when fully developed. To meet this demand, alternative water sources will need to be accessed. Alternative sources are discussed below but will require further investigation to identify the most viable and cost effective options.

Roof Runoff (Rainwater)

Rainwater tanks have the potential to supply a reasonable proportion of domestic requirements within administration buildings.

Unconfined Groundwater

Unconfined groundwater typically occurs at shallow depths, can be abstracted by bores and is extensively used in some areas of Perth for irrigating parks and gardens. Groundwater is considered to be the easiest and usually the most cost effective alternative to scheme water for irrigation. Local groundwater in particular can represent a viable water source, particularly in industrial sites, where recharge to groundwater is increased as a result of increases in impervious areas.

There are, however, no proposals to extract groundwater from beneath the industrial precincts of the OIE where earlier work by Rockwater indicates a limited resource with TDS values ranging as high as 3000 mg/L. Extraction may, however, occur from bores within the buffer if suitable resources are identified there.

Confined Groundwater

Generally high quality groundwater has been identified in confined aquifers which might be available for use within the OIE. They are in locations removed from the estate; two from the Yarragadee North aquifer and the others from the Carnarvon and Perth Tumblagooda aquifers (Table 4). These groundwater sources have the potential to supply both potable and high and low quality industrial feedwater demands.

Table 4 Identified deep groundwater sources for the Oakajee Industrial Estate*

Groundwater Area	Sub area	Aquifer	Allocation Limit (GL/yr)	Current Availability (GL/yr)
Arrowsmith	Allanooka	Perth – Yarragadee North	28.5	6.5
Gascoyne	Casuarinas	Perth – Yarragadee North	10	4.4
Gascoyne	Kalbarri / Eurardy	Carnarvon - Tumblagooda	5	2
	Northampton / Galena	Perth - Tumblagooda	1	1

* Figures current as of 23rd November 2010 and should be used as a guide only

The Casuarinas groundwater aquifer is located on the mid northern boundary of the Arrowsmith groundwater area, at the northern-most extent of the North Perth Basin. Drilling of this aquifer is in progress to secure additional data that will allow an improved understanding of this water resource. The investigation is due for completion in 2012.

Additional Groundwater Assessment

A desktop assessment has been completed aimed at improving the understanding of groundwater sources in the area, assessing publically available information and liaising with relevant parties from local and state government organisations. A summary of results of the desktop assessment is presented in Table 5.

Table 5 shows that for water demands up to 37 GL/year there is probably limited groundwater close to the OIE. Anecdotal information regarding high groundwater yields from the deep Perth Aquifer 20 km east of Oakajee is unsubstantiated and discussions with relevant stakeholders suggest the resource is likely too limited to support development within OIE. However, this source may be able to support short term water supply, for example for construction purposes.

Significant groundwater resources are inferred in areas removed from the Oakajee development (40 to 50 km to the north and east) where major sedimentary basins exist, including the Carnarvon and North Perth Basins. These may be prospects for future development and allocation for water supply purposes, but further investigation would be required to determine their potential and resource allocation limits.

Closer appraisal of groundwater resources is alsom warranted to better quantify water resources close to Oakajee (coastal aquifer, granite aquifer and sedimentary aquifer -overlying granite). These aquifers may be suitable for short term water supply (e.g. construction), or investigations may indicate the presence of deeper aquifers which may support increased groundwater demands.

Table 5 Summary of Desk Top Groundwater Assessment

Aquifer	Location	Salinity (mg/L)	Interpreted Resource Potential
Surficial - Coastal (Sands/limestone 10 to 30m thick overlying granites)	Underlying SIA/GIA and extending north and south in coastal areas	1200 - 3000	Limited water supply of brackish quality, unlikely to be sufficient for use within the estate Coastal supply north and south of Oakajee likely similar but unconfirmed.

Granite/Gneissic (Fracture flow in weathered granites)	Areas immediately east of SIA/GIA, extending 40 km eastwards	Variable (500 – 10,000)	Traditionally understood as a limited resource, but in some locations increased groundwater resources may be found in weathered and fractured zones.
Sedimentary (Jurassic sediments overlying granites	Areas immediately east of SIA/GIA, extending 40 km eastwards	1,000 – 5,000	Understood as a limited resource (locally important) sediments overlying granites, possible presence of deeper aquifers (e.g. paleo-channels incised in granites)
Sedimentary (Multi layered Northern Perth Basin.	30 to 50 km east of Oakajee	Unknown	Major groundwater resource deep sedimentary aquifers
Sedimentary (Multi-layered South Carnarvon Basin)	30 to 50 km north of Oakajee	Unknown	Major groundwater resource deep sedimentary aquifers

Domestic Grey Water

Domestic grey water is potentially available for reuse at the individual lot scale and collectively at the subdivision scale. If grey water is to be considered for in-house commercial property use, it must meet Class A (DoH 2005) standards for toilet flushing and washing machine use, and potable standards for hot water systems. Grey water for in-house uses would probably be too costly to consider as a mandatory requirement, and regulatory approvals would be difficult to obtain due to requirements for management to ensure adequate maintenance and operation of systems.

The volume of grey water generated from the OIE is likely to be small. Due to its general inability to meet irrigation requirements, together with costs associated with installing grey water systems, it is not considered appropriate to recommend grey water systems for OIE.

Stormwater

Stormwater is mainly generated from roads and other impervious surfaces. It is generally considered as wastewater and can contain relatively high concentrations of contaminants, including nutrients, hydrocarbons, metals and pathogens. The lack of barriers to exposure and the inability to control raw water quality make stormwater a difficult option for direct reuse, as it requires a high level of treatment. Furthermore, given the length of the dry season at Oakajee, stormwater is unlikely to be available to meet summer irrigation demands without installation of a costly storage, treatment and distribution network.

The most appropriate option for stormwater is considered to be indirect reuse via infiltration to shallow water tables. Stormwater from hardstand areas within development sites will receive treatment via a treatment train approach using multiple treatments in series to remove contaminants prior to infiltration. This treatment train may include use of gross pollutants traps, prior to stormwater discharge to vegetated swales which may be treated with soil amendments.

Desalination

Desalination has been identified as a possible future alternative water source for the OIE, capable of treating seawater and brackish groundwater. A Seawater Reverse Osmosis Desalination Plant (SWRO) can produce large volumes of potable and non-potable water. MWH (2009) indicated the following capacity (GL/yr) and capital costs for three SWRO Plants:

- 10 GL/yr capacity - $325 million;
- 25 GL/yr capacity - $560 million; and
- 50 GL/yr capacity - $925 million.

A desalination plant is currently proposed to supply Oakajee Port and Rail (OPR). The plant is initially planned to supply 3.7 GL/yr for dust suppression. There may be potential for upgrade of the plant to increase capacity to meet both high quality and low quality industrial water demands.

Treated Wastewater / Effluent

There are significant challenges in managing health risks posed by recycling treated wastewater. The cost of managing these risks generally increases the cost of recycled wastewater above that of other water sources.

A waste water treatment plant (WWTP) is proposed within OIE to process domestic effluent pumped from the northern suburbs of Geraldton. Treatment and reuse of this effluent has the potential to supply large annual volumes of water for industrial requirements. The WWTP will initially provide only basic technology in the form of settling ponds. It will be located close to a services corridor for easy incorporation of a pipeline to the industrial precincts.

A Water Recycling Factory is also proposed either inside the SIA or adjacent to the WWTP to receive and process wastewater from industrial processes. The Water Recycling Factory will have capacity to receive various non-potable waters, low quality groundwater and treated organic wastewater (from the WWTP). The configuration of both the Water Recycling Factory and the WWTP is unknown, but they may feed into each other to operate as a primary and a secondary water treatment train.

Investigation and development of these options should be given priority and has the potential to significantly reduce total potable and non-potable water demand from other sources. The capacity of both treatment systems is likely to be small initially, but will increase as staged development increases non-potable water demand within the estate.

In the event of delays in the development of a Water Recycling Factory and a WWTP, it will be the responsibility of each proponent to provide onsite treatment and recycling of organic effluent and process wastewater.

6.3 Infrastructure

6.3.1 Water

The current fresh water supply to Oakajee will not meet the total water demands of the proposed development. The closest developed water resource is the borefields at Allanooka, located approximately 40 km south-east of Geraldton. The Water Corporation's Draft Groundwater Management Plan for Allanooka indicates a sustainable yield of 28.8 GL/yr of which 22.1 GL/yr is listed as allocated, committed or requested (including an increase from the current 12 GL/yr to 18 GL/yr for public water supply), implying a maximum of only 6.5 GL/yr is available to meet any new demand.

If groundwater from Allanooka were to be supplied to Oakajee, it would require construction of a new 500 mm supply main from the Allanooka borefields to the site. The responsibility for its construction and management would reside with the Water Corporation.

6.3.2 Wastewater

As previously indicated, a WWTP is proposed in the south eastern Buffer. This will be capable of treating sewage from Oakajee and also from the northern residential precincts of Geraldton. Timing of this development is, however, uncertain, and if industrial development occurs prior to development of the WWTP, each large industry will be required to provide on-site treatment of its own wastewater. Development and management of the WWTP will be the responsibility of the Water Corporation or private investors.

Treated wastewater from on-site package treatment plants could be disposed by irrigation or through on-site evaporation ponds. Private contractors would be required for sludge removal, or the sludge might be used for certain industrial operations.

For industries on smaller lots, wastewater disposal could be incorporated into initial development via septic tanks and leach drains provided by individual lot owners.

6.3.3 Electricity

Electric power at the OIE will be supplied either by power lines from the Western Power inter-connected grid or from a private gas fired power station at the site. Power will be reticulated through the site on a needs and "as required" basis.

Power reticulation throughout the site will utilise service corridors and road reserves, with provision of distributed substations.

6.4 Responsibilities

With a range of possible water source options available to maximise water efficiency within the OIE, it is important to identify responsibilities associated with their development and ongoing management. Table 6 summarises the likely distribution of responsibilities.

Table 6 Responsibility of utilities supply to development

Development Option	Result	Responsibility
Potable mains water supply	Potable scheme water supply to the development	Water Corporation
Roof rainwater collection / infiltration / re-use through local abstraction	Increased water supply to local shallow groundwater	Individual proponent
Deep groundwater supply	Potable quality water supply to the development	Water Corporation / Department of Water
Desalination	Large volumes of potable quality water supply to the development	Water Corporation / Private Investors
Water Recycling Factory	Onsite treatment of industrial wastewater for reuse within the development	LandCorp / Water Corporation / Private Investors
Waste Water Treatment Plant	Onsite treatment of organic wastewater from industrial development and from Geraldton for possibly recycling to industry	Water Corporation / Private Investors
Electricity	Electricity supply to the development	Western Power

6.5 Site Water Balance

A site water balance was developed to identify and quantify likely water supply and water demands within Oakajee. The objective was to identify potential shortfalls in water supply against preliminary staged development scenarios to assist in determining required alternative water supply volumes. Climate change has not been considered within this water balance analysis.

The water balance is a high level assessment to estimate total water inputs and outputs. More detailed investigations may yield a different set of numbers to those presented herein. Thus the figures presented should be used as a guide only.

The OIE is to be developed with a mix of heavy, general and light industrial uses. Consequently, water supply is expected to be split into two types based on water quality with projected water demands for these two types presented in Table 8:

1. High quality feedwater (100 – 200 mg/L TDS) will be required for certain areas of industrial processing
2. Low quality feedwater (800 – 1000 mg/L TDS) will be required for such uses as industrial cooling and dust suppression

Table 7 Projected high quality feedwater demands

OIE precincts	Indicative forecasted high quality industry feedwater use (ML/a)									
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Strategic Industrial Area	798	2,395	3,992	5,589	7,186	8,783	10,380	11,977	12,775	12,775
General Industrial Area 1	1	3	6	9	12	16	16	16	16	16
General Industrial Area 2	6	28	56	84	113	141	169	197	209	209
Coastal Zone	5	26	53	79	105	132	158	184	211	211
Buffer Zone	0	0	0	0	0	0	0	0	0	0
Total Oakajee Industrial Estate	**810**	**2,453**	**4,107**	**5,762**	**7,416**	**9,071**	**10,723**	**12,374**	**13,210**	**13,211**

Table 8 Projected low quality feedwater demands

OIE precincts	Indicative forecasted low quality industry feedwater use (ML/a)									
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Strategic Industrial Area	1,427	4,280	7,133	9,986	12,839	15,692	18,545	21,398	22,825	22,825
General Industrial Area 1	1	7	15	22	29	37	38	38	38	38
General Industrial Area 2	6	29	58	87	116	145	174	203	215	215
Coastal Zone	11	53	107	160	214	267	321	374	428	429
Buffer Zone	30	149	298	447	596	745	893	1,011	1,011	1,011
Total Oakajee Industrial Estate	**1,474**	**4,518**	**7,610**	**10,702**	**13,794**	**16,886**	**19,971**	**23,024**	**24,516**	**24,517**

At this stage it is difficult to accurately predict the industries likely to establish at Oakajee and to estimate the timing of their development. Consequently the forecasts in the above tables were based on water demands in similar industrial developments elsewhere, including Kwinana, adopting the following assumptions:

- Volumes are indicative high level estimates and are subject to change;
- There is no certainty about development rates;
- Estimates are subject to industry mix;
- Estimates do not take account of ongoing industry expansions, or of increasing efficiencies and technology developments over time;
- Estimates cover operation of industries but do not allow for possible higher demands during

construction.

Water balance modelling considered the forecast demands listed above. Due to uncertainty in the level and timing of development, water balance scenarios were undertaken for the developed years 2020 and 2060 to represent an early stage of development scenario (2020) and the fully developed estate (2060):

- Current State – this assumes the site is undeveloped;
- Future State 2020 – This assumes a partly developed site with desalinated water supplies of 3.7 GL/yr for both low and high quality feedwater uses as indicated by the Engineering Services Report (GHD 2010) and with remaining water demand is supplied from alternative water sources (probably remote groundwater).
- Future State 2060 – This assumes the desalination plant has been upgraded to a capacity of 15 GL/yr for both low and high quality feedwater uses, and identifies the water volumes required to meet the remaining demands for the estate. Assuming a water factory is operational, only water from the SIA is available for recycling back to the water factory.

The following lists the basic assumptions used to define inputs to the water balance model:

- The land coverage areas were assumed to be 75% open space (dryland), 5% irrigated land (POS), 10% hardstand and 10% roof area for the Future State 2020 scenario (assumes 20% development progress using the ratio of *2020 total water demand : 2060 total water demand*);
- The land coverage areas were assumed to be 15% open space (dryland), 5% irrigated area (POS), 40% hardstand and 40% roof area for the Future State 2060 scenario.
- The water balance considered water transition by runoff coefficients through the following means - 1) direct evaporation; 2) surface runoff; and 3) direct infiltration;
- Monthly average rainfall (annual mean 389 mm/yr) and evapotranspiration were used as input data and taken from Bureau of Meteorology Geraldton Airport (site 008051) and the Buller River rainfall station;
- Pervious Recharge = infiltration to groundwater from open pervious areas only;
- Roof Recharge = direct infiltration to groundwater through soak wells from roof surfaces only;
- Hardstand Recharge = runoff from hardstand (paved) areas directed to treatment train infiltration devices;
- Surface Water Runoff = runoff generated from pervious areas, irrigation areas and hardstand areas;
- Net Groundwater Addition = Surface Water Runoff + Pervious Recharge + Roof Recharge + Hardstand Recharge.

A further component of the water balance was estimation of evapotranspiration. This was calculated using the following equation to assist in determining total groundwater recharge volumes (Zhang et al 1999).

$$\frac{ET}{P} = \frac{1 + w\frac{E_o}{P}}{1 + w\frac{E_o}{P} + \left(\frac{E_o}{P}\right)^{-1}}$$

ET – Evapotranspiration (mm)

P = Precipitation (mm)

E_o = Potential evapotranspiration (mm)

w = Plant available water coefficient (ranges from 0.5 for crops to 2.0 for forest)

Potential evaporation (E_o) was calculated using the Priestley and Taylor (1972) method:

$$\mathrm{PET} = \frac{\alpha}{\lambda}\frac{\Delta}{\Delta + \gamma}(R_n - G)$$

R_n – Net radiation (MJ m^{-2} day^{-1})

G – Soil heat flux (assumed to be 0)

Δ - Slope of the vapour pressure – temperature curve (kPa K-1)

Y – Latent heat of evaporation (~$2.5x10^6$ J mm-1)

a - Empirical factor of 1.26

Table 9 Oakajee Industrial Area water balance for 2020 scenario (ML/yr)

Inputs	**Current State**	**Future State 2020**	**Future State 2060**
Rainfall (389 mm/year)	5,254	5,254	5,254
Domestic Potable (scheme)	0	19	108
Industrial Irrigation	0	422	846
High Quality Feedwater	0	2,468	13,313
Low Quality Feedwater	0	4,367	23,383
Total Inputs	**5,254**	**12,530**	**42,904**
Alternative Water Supply groundwater, water recycling plant, WWTP)	*0*	*3,557*	*22,542*
Minimum Potable Scheme Water Supply	*0*	*19*	*108*
Desalination (SWRO) Supply	*0*	*3,700*	*15,000*
Outputs	**Current State**	**Future State 2020**	**Future State 2060**

Evaporation and Evapotranspiration	4,152	3,588	1,759
Surface Water Runoff	53	256	860
Pervious Recharge	1,049	1,201	959
Roof Recharge	0	420	1,681
Hardstand Recharge	0	210	841
Total Industrial Wastewater	0	5,371	34,391
Strategic Industrial Wastewater (to sewer/water recycle factory)	*0*	*2,871*	*18,394*
General Industrial Wastewater (to sewer)	*0*	*2,500*	*16,007*
Industrial Process Losses	0	1,484	2,413
Total outputs	**5,254**	**12,530**	**42,904**
Available wastewater for recycling	*0*	*2,871*	*18,394*
Net Groundwater Addition	*1, 102*	*2,087*	*4,341*

6.5.1 Water Balance Outcomes

Results from the water balance assessment provide a high level overview of total water demands and are useful in quantifying water volumes required from non-potable sources to reduce demands from scheme water supply. The key outcomes of the water balance assessment have identified the following:

- An additional 3.5 GL/yr of water will need to be sourced to meet industrial water demand by 2020;
- An additional 22.5 GL/yr of water will need to be sourced to meet industrial water demand by 2060;
- Desalinated water (3.7 GL/yr) will be able to meet 85% of the low quality feedwater demand in 2020 and will form a critical component of total water supply;
- Additional water might be sourced from Allanooka bore field, which has a current availability of 6.5 GL/yr;
- Further water sources will need to be secured to meet total water demands for the site after 2020, as the site is fully developed;
- If a water recycling factory is developed, there should be sufficient industrial wastewater available in 2020 and 2060 to meet total water demands when combined with water from a desalination plant; and
- An additional 3.3 GL/yr of water will be infiltrated to groundwater by 2060 compared to the

current state as a result of increases in impervious areas and increased direct infiltration.

7. Water Management

7.1 Flood management

A key objective of surface water management for the OIE is protection of property and infrastructure through safe conveyance of excessive runoff from minor and major storm events. This includes management of surface water from the development and mitigating impacts on downstream waterways.

Key focus areas for flood management of the proposed development are:

- Maintaining the natural peak discharge to receiving waterways resulting from 10 year and 100 year average recurrence interval (ARI) events;
- Conveyance of major 100 year ARI events via natural overland flow paths away from development;
- Ensuring all proposed development is at least 0.3 m above the 100 year ARI flood level.

These requirements will be addressed in detail within the Local Water Management Strategy.

7.2 Surface Water Hydrology

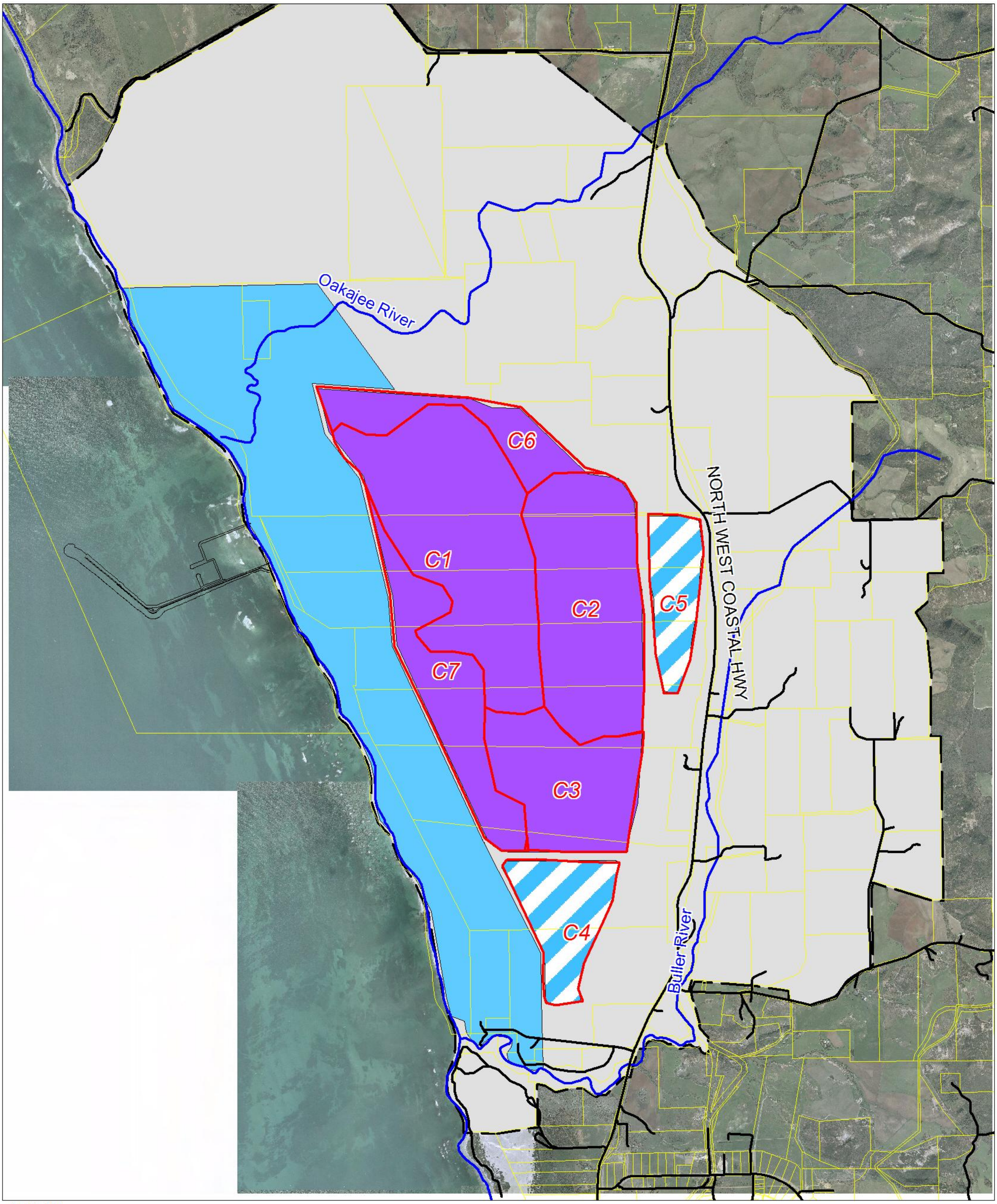
A surface hydrological assessment was undertaken for the OIE to calculate pre and post development surface water flows. These calculations were undertaken to provide a guide for sizing of surface water detention structures such as swales and infiltration basins.

Runoff control within the OIE will be through a combination of the following structural measures to carry runoff from low frequency storms (10 yr ARI), with provision for overland flow paths (100 yr ARI):

- Open swales;
- Open drains;
- Infiltration / bioretention basins;
- Culverts,
- Roof soak wells;
- Rainwater tanks.

Calculation of flows requires catchment delineation within the site. Based on site topography, seven catchments were delineated (Figure 11).

Catchments 1 and 2 are internally drained and all post development surface water will be detained within them. Pre and post development peak water flows were calculated for the 1, 5, 10 and 100 yr ARI event. Required storages were determined so that throttled flows from storage structures was equal to the pre development peak flows for each corresponding design rainfall event.



LEGEND

Major Roads	Cadastre	General Industrial Area	Project Boundary
Natural Drianage Line	Coastal Zone	Strategic Industrial Area	Surface Water Catchments

0.5 0 0.5 1 1.5
Kilometers
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

GHD
CLIENTS | PEOPLE PERFORMANCE

Client Name: LandCorp
Project Name: Oakajee Industrial Estate
District Water Management Strategy

Job Number 612461102
Revision A
Date 26082010

Surface Water Catchments

Figure 11

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by: GIS Operator

Table 10 Pre- and post-development flows for Oakajee Industrial Estate

Catchment	Development	Flows (m^3/s)			
		1 Year ARI	5 Year ARI	10 Year ARI	100 Year ARI
1	Pre Dev.	0	0.58	1.73	8.75
	Post Dev.	15.20	28.1	32.6	55.1
2	Pre Dev.	0	0.28	0.83	4.18
	Post Dev.	7.69	14.4	17.2	30.1
3	Pre Dev.	0	0.33	0.98	4.99
	Post Dev.	8.5	15.7	18.2	30.2
4	Pre Dev.	0	0.13	0.39	2.00
	Post Dev.	3.69	7.11	8.36	14.2
5	Pre Dev.	0	0.13	0.38	1.93
	Post Dev.	3.41	6.58	7.74	13.1
6	Pre Dev.	0	0.27	0.81	4.01
	Post Dev.	5.68	10.4	11.9	19.4
7	Pre Dev.	0	0.48	1.41	7.07
	Post Dev.	9.79	17.9	20.6	33.4

Table 11 Total storage required to maintain pre-development flows

Catchment	Required Storage (m^3/ha)			
	1 Year ARI	5 Year ARI	10 Year ARI	100 Year ARI
1	88	152	184	283
2	78	141	164	262
3	83	143	154	209
4	71	128	143	203
5	71	127	142	200

6	84	139	149	179
7	88	144	155	187

7.3 Surface Water Management

Stormwater within Oakajee should be managed readily. Groundwater at depth and permeable sands across the site favour infiltration. Further, the site is not constrained by land availability, so traditional pit and pipe drainage networks commonly employed on urban roads will not be required.

Specific surface water management strategies for Oakajee are detailed below:

1 yr ARI

- To retain and treat the 1 year ARI event, rooves will be connected to soak wells and, where appropriate, to rainwater tanks.
- All stormwater will be contained within each lot and any which is contaminated will be treated prior to discharge / infiltration.
- Road runoff will be infiltrated as close to source as practical using water sensitive urban design (WSUD) measures including roadside swales / table drains.

10 yr ARI

- Road runoff will be infiltrated as close to source as practical using water sensitive urban design (WSUD) measures including roadside swales / table drains / bioretention structures.
- Bioretention structure within individual lots will treat and infiltrate contaminated stormwater using soil amendments to improve quality;

100 yr ARI

- Provision via overland flow paths will enable discharge of stormwater from each lot such that it will not exceed 100 yr ARI pre development (current environment) peak flows.

7.3.1 Stormwater Management at Lot Scale

Due to the uncertainty of future development at Oakajee, lot sizes and their configuration are unknown. It is therefore appropriate that stormwater management responsibility rests with each proponent. The following management actions are applicable to each proponent:

- Separation of uncontaminated stormwater from potentially contaminated stormwater;
- Chemical storage and handling areas should be located within secondary containment areas that allow maximum recovery of any spilt chemicals;
- Paved areas exposed to rainfall where dust, litter or spilt substances accumulate should be regularly cleaned, avoiding drainage or leaching into the surrounding environment. Litter, oil and sand traps (as appropriate to the site) are recommended at drain entry points. First flush

water diversion should be considered for dusty outdoor areas to capture initial stormwater runoff after extended dry periods;

- Turbidity should be controlled and, where necessary, stormwater should be treated and, in order of preference, be used as a process water source, be disposed onto vegetated areas, or be infiltrated via onsite soak pits or infiltration basins;
- Chemical solvents and non-degradable detergents used to clean equipment or pavements should not be released into stormwater systems;
- Stormwater should not be released from chemical storage compounds, unless first tested and found to be uncontaminated; and
- Stormwater from some industries may require containment in settling ponds and testing prior to discharge / infiltration.

7.4 Groundwater Management

Groundwater investigations and monitoring have been undertaken for the OIE by Rockwater and are reported as follows:

- Oakajee Hydrogeological Investigation (Rockwater 1996);
- Oakajee Industrial Park Background and Surface Water Monitoring Results (Rockwater 2000);
- Oakajee Industrial Park Background and Surface Water Monitoring Results (Rockwater 2001); and
- Oakajee Industrial Park Groundwater Monitoring Results (Rockwater 2003).

The initial investigation by Rockwater drilled 21 bores that recorded static water levels in Feb 1996 ranging from 6 – 64 mBGL.

Groundwater monitoring is currently being undertaken by Parsons Brinckerhoff who recently installed three additional bores and are now monitoring all site bores for a two-year period.

Due to the depth of groundwater below the natural ground surface, direct infiltration of stormwater is recommended. Assuming BMPs (treatment train approach) are adopted with WSUD measures, there is unlikely to be any negative impacts on groundwater levels and quality.

Overlying sedimentary deposits include Tamala limestone, Tamala sand and Chapman group sandstone and siltstone. Permeability of these sediments ranges from 0.03 to 240 m/d according to Rockwater (1996). Consequently the potential for stormwater contamination, particularly within each industrial lot, should be carefully managed and any contaminated stormwater treated to avoid groundwater contamination prior to its recycling for use or infiltrartion to groundwater

Due to the potential for high rates of infiltration and low rates of nutrient retention, it is recommended Phosphorous Retention Index (PRI) testing is undertaken at all point infiltration structures. Soils with low PRI are generally poor for retaining nutrients such as phosphorous and nitrogen, resulting in direct transfer of these to groundwater. In the event PRI is measured at < 10, addition of soils with a high PRI such as red clays is recommended at points of infiltration.

The above practices together with use of vegetated roadside swales to capture road runoff will ensure groundwater levels and groundwater quality are not adversely affected by developments within the OIE. They will be explored in greater detail within Local Water Management Strategies and future groundwater investigations.

7.5 Drinking water conservation and efficiency of use

Additional water saving strategies relating to in-house water use and irrigation are discussed below:

Potable use

Use of potable water should be minimised where water of drinking water quality is not essential, particularly outside buildings.

The State Government has identified demand reduction and efficient use of potable water as a priority. The *State Water Plan* (Government of Western Australia 2007) sets household consumption targets of less than 100 kilolitres per person per year (kL/person/year) for consumers within Perth of which not more than 40 to 60 kL/person/yr is to be scheme water.

Regional household consumption targets are yet to be reviewed, so application of targets to Oakajee is not determined at this stage. Nonetheless, measures to reduce water consumption should be encouraged.

It is recommended that only highly rated water efficient appliances and fittings be used within the estate. Applying the Water Use in House Code Stage 1 while not specifically targeted at industrial developments, will assist in reducing consumption of scheme water.

This Code requires all tap fittings other than bath outlets and gardens taps to be a minimum 4 stars Water Efficiency Labelling and Standards (WELS), showerhead to be a minimum 3 stars WELS rated and all sanitary flushing systems to be a minimum 4 stars WELS rated dual flush (DoHW 2007).

Water-using products covered by the WELS Scheme and their proposed ratings are set out in Table 12.

Table 12 Specifications for fixtures and fittings

Product	Minimum WELS rating
Clothes washing machines	4
Dishwashers	4

Product	Minimum WELS rating
Toilet (lavatory) equipment	4
Showers	3
Tap equipment	6
Urinal equipment	3

Landscaping and irrigation efficiency measures

Gardens (private and public) and public open space areas should be waterwise in design to minimise irrigation requirements. Low water requirement plants should be predominantly used and turf areas should be kept to a minimum.

Any POS irrigation should be restricted to the times where wind conditions are low and evaporation is at a minimum.

Landscaping within Oakajee will be largely dryland, but where irrigated landscaping is proposed, water requirements can be reduced by using rain and soil moisture sensors, soil conditioners, wetting agents and mulches

7.6 Responsibilities

With a range of surface water and groundwater management strategies recommended across the OIE, it is important to identify responsibility for implementation of each strategy. Table 13 below summarises responsibilities associated with water management within Oakajee.

Table 13 Responsibility of water management

Water Management Implementation	Responsibility
Water management outside lot boundaries (road table drains)	LandCorp, Shire of Chapman Valley or Main Roads
Water wise landscaping outside lot boundaries	LandCorp
Roof and hardstand runoff capture and re-use at the lot scale	Individual Proponent
Construction and management of infiltration structures at the lot scale	Individual Proponent
Onsite treatment of wastewater	Individual Proponent
Offsite wastewater treatment	Water Corporation / Private Investors

Supply of offsite potable / non-potable water	Water Corporation / Department of Water

8. Implementation Framework

8.1 Local planning

Developments commonly progress after the District Planning phase to a Local Structure Plan (LSP), but this is unlikely at Oakajee due to the uncertain nature and timing of development. Consequently, each proponent will be required to prepare cell based Local Water Management Strategy (LWMS), incorporating strategies proposed in this DWMS to address various aspects of water management.

The cell based LWMS documents will define best-practice solutions for water quantity/quality management, information relating to water use (potable and non-potable), water initiatives including the use of recycled water where appropriate, surface water and groundwater management, including best-practice solutions for stormwater quality treatment, and regard for practices including a secondary sedimentation basin network. Site specific environmental information and any available water monitoring data will be used to select the most appropriate WSUD BMP for local conditions.

The LWMS will need to include, but not be limited to, the following:

- Stormwater concept design;
- Site water balance;
- Land improvement conditioning if and where warranted; and
- A contingency action plan and appropriate trigger levels.

8.2 Monitoring

To date there is a good record of both surface and groundwater monitoring at and surrounding the Oakajee site. Groundwater is at depth and there are no prominent surface water features within the industrial estate. Monitoring undertaken to date is considered sufficient to satisfy the requirements for a minimum 18 months pre-development monitoring. Further monitoring is nonetheless currently occurring.

Continued monitoring is recommended for the site both during construction and post development to maintain a check on contaminants and on surface water and groundwater regimes.

A sample pre and post-development monitoring program is presented in Table 14.

Table 14 Monitoring programme summary

Monitoring	Sites	Frequency	Parameters
Surface water	Development inflow and outflow locations Detention storages inflow and outflow Water bodies	Site specific	flows and water levels
		Monthly grab of samples while flowing, to be reviewed after the first year of monitoring	**In-situ:** pH, EC and temperature. **Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals **Filtered sample**: nitrate/nitrite and PO_4,
Groundwater	Network of monitoring bores providing a suitable spatial representation of the study area inclusive of areas outside the site.	Monthly	water levels
		Quarterly (typically Jan, Apr, July, Oct)	**In-situ:** pH, EC and temperature. **Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals **Filtered sample**: nitrate/nitrite and PO_4

8.3 Requirements for following stages

State planning policy 2.9: water resources (Government of WA, 2006) requires that planning should contribute to the protection and wise management of water resources through local and regional planning strategies, structure plans, schemes, subdivisions, strata subdivisions and development applications. Better Urban Water Management (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts by Essential Environmental Services, 2008) provides guidance on implementation of State planning policy 2.9. It identifies the requirements for water management strategies and plans that must be developed to accompany the land use planning and approvals process in the OIE at each stage of the planning process.

In summary, all local structure planning should incorporate a LWMS consistent with the strategies and objectives of this OIE DWMS. Subsequent subdivision applications should be accompanied by an urban water management plan (UWMP) where required by DoW and the Shire of Chapman Valley, and/or should be consistent with any approved local water management strategy and with the strategies and objectives of this DWMS.

Guidelines for LWMS and UWMP documents are available from the DoW website or by contacting the DoW regional office. Developers are encouraged to contact the DoW and the Shire of Chapman Valley early in the planning process to discuss specific water management requirements for proposals

8.4 Funding and responsibilities

8.4.1 Funding

Funding for the design and construction of both flood management measures and water quality measures can be sourced from a variety of stakeholders depending on the type of work being undertaken and the point in time at which the funding is required. For example, swales and bioretention swales form part of the road reserve and are a substitute for structural engineering pits and pipe networks. They may therefore be funded by the developer of the road infrastructure as they are simply an alternative drainage solution and not an addition to what is normally required.

Maintenance and renewal of bioretention swales and biofiltration pockets will be required after the developer's involvement has concluded, so funding and responsibility for this work will need to be decided in advance.

8.4.2 Responsibilities

The key stakeholders responsible for implementing this DWMS are:

- LandCorp;
- Department of Water;
- Western Australian Planning Commission (WAPC);
- Shire of Chapman Valley (SoC);
- Main Roads WA; and
- Developers.

Table 15 DWMS Implementation and Funding

Stakeholder	Responsibilities	Funding
LandCorp (Developer)	◗ Implement environmental monitoring program; ◗ Implement DWMS ◗ Coordinate and confirm preferred water source options with Department of Water and Water Corporation	◗ LandCorp ◗ LandCorp ◗ LandCorp
Department of Water	◗ Finalise DWMP to guide water source planning and LWMS ◗ Recommend approval of DWMS by WAPC ◗ Recommend approval of subsequent LWMS by WAPC	◗ DoW ◗ N/A ◗ N/A
Western Australian Planning Commission	◗ Approve DWMS ◗ Approve LWMS	◗ N/A
Shire of Chapman Valley	◗ Approve DWMS and subsequent LWMS's	◗ N/A
Developers	◗ Prepare LWMS/UWMP through consultant that will identify detailed drainage management for each development proponent ◗ Continue environmental monitoring if recommended ◗ Implement DWMS	◗ Landowners ◗ Landowners ◗ LandCorp / Landowners

8.5 DWMS Technical review

It is preferred that this DWMS be reviewed within ten years (or earlier if deemed necessary).

The review should be undertaken by the DoW, with endorsement from the Environmental Protection Agency, Western Australian Planning Commission, Shire of Chapman Valley and the Water Corporation. The review should cover, but not be limited to the following:

- Assessment of impacts of development; and
- Design objectives.

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