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Oranjemund Water Sustainability Study

Report

Version - 2

14 October 2016

Freedthinkers

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GLOSSARY OF TERMS

Alluvial aquifer	A groundwater-bearing rock unit (mainly sand and gravel) found along rivers and also fed (recharged) by the rivers
Aquifer	A body of water-bearing permeable rock which can contain and easily transmit groundwater. Water is extracted (abstracted) from an aquifer by means of a borehole or shaft
Blue water	Fresh water obtained from rivers, lakes and aquifers
Conjunctive Water Use	The practice of storing surface water in groundwater aquifers in wet periods and withdrawing it from the aquifer during dry periods
Desalination Plant	A facility, usually located near the sea, that is developed to turn salt water into potable water. With the aid of designated machinery and equipment, seawater undergoes a treatment processes to remove minerals from the saline water
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
E10 to E90	Values that are likely to be exceeded in 10% to 90% of years
Electrical Conductivity	The ability of water to conduct electricity. The **Electrical Conductivity** (EC) of groundwater is used to estimate the amount of Total Dissolved Solids (TDS) in the water
Greywater	Wastewater (used household water) collected from handbasins, showers, baths, washing machines and kitchen sinks, but excludes water collected from toilets
Groundwater abstraction	The process whereby water is extracted or removed from the ground, often by means of a borehole or shaft
Groundwater Basin	An area that is underlain by permeable rocks (groundwater reserve) capable of yielding or storing a significant amount of groundwater. The groundwater basin may comprise of a single aquifer or a group of linked aquifers

Helsinki Convention	An international convention encompassing various measures for the prevention and elimination of pollution of the Baltic Sea
Hydrogeological units	Rock units that are categorised based on their potential to contain or transmit groundwater
IWRM	Integrated Water Resources Management **(IWRM**) is a process that promotes the coordinated development and management of water, land and related resources
Monitoring borehole	A hole drilled into the ground with the purpose of monitoring the quality and/or quantity of groundwater in a certain area
Namdeb	Namibia De Beers Diamond Mine Company
NamWater	Namibia Water Corporation Parastatal responsible for the bulk distribution of water in Namibia
ORASECOM	Orange-Senqu River Commission **(ORASECOM) is a** commission appointed to promote the equitable and sustainable development of the resources of the Orange-Senqu River.
Primary aquifer	An aquifer in which groundwater is contained and transmitted through the original voids spaces or pores of the rock units (pores or openings that were formed at the same time as the rock unit) - these aquifers are also called porous aquifers
Production borehole	A hole drilled in the ground that is used to abstract water for a specific purpose, for instance; water for human consumption, agricultural or industrial use
Ramsar Convention	An international treaty for the conservation and sustainable use of wetlands
Secondary aquifer	An aquifer in which groundwater is contained and transmitted through the secondary opening / voids spaces or pores of the rock units (pores that formed after the rock units were formed) - these aquifers are also called fractured or karstified aquifers

Tsau // Khaeb	The Tsau // Khaeb is a protected mining area in the south of Namibia, encompassing a total area of 26,000 km^2. It falls within a global 'hotspot' of biological diversity and has consequently been named a Protected Area and has restricted access
Transfrontier management	Cooperation and ecosystem-based management across borders between countries
Water borehole (well)	A hole drilled into the ground to a certain depth in order to locate water, either for water abstraction, monitoring or any other purpose
Wellfield	An area surrounding permitted (authorised) wells where water is pumped (extracted / abstracted) from an aquifer
WWF	World Wide Fund for Nature

EXTENDED EXECUTIVE SUMMARY

Background / Introduction

Freedthinkers requested that GCS Water and Environment (Pty) Ltd undertake a desktop study to address the water challenges experienced by the town of Oranjemund for input into a larger sustainability plan. Oranjemund is a diamond mining town located in the extreme southwest of Namibia that extracts water from the Orange River for domestic and mining purposes (Namdeb, 2016). The lower Orange sub-basin, into which Oranjemund's water sources fall, is an area in which evaporation is far greater than rainfall (WRC, 2015), and climatic changes are likely to have water resources management implications. This document provides a high-level water strategy and footprint assessment for the town and surrounding areas, where applicable, in order to evaluate the water supply and demand for the town and immediate surrounds, and the implications for water resource management in the area. This document further assesses potential water-related risks and associated mitigation measures, as well as opportunities for the area.

Philosophical approach based on local knowledge/environment

The climate study was mainly desktop-based but also involved the analysis of hydrological data in order to gain an improved understanding of the current status of water resources in the area. The analysis provided an understanding of the inflows, outflows and losses within the catchment. The Oranjemund regional climate is characterised by a low Mean Annual Precipitation of 42mm, high Mean Annual Evaporation of 2401mm and consequently low Mean Annual Runoff of 0.00136mm.

According to reports compiled by the Namibian Department of Water Affairs, Oranjemund uses between 6.57 million m^3 (DWAF, 2006) and 6.85 million m^3 of water (Van der Merwe *et al.*, 2006) per annum, originating largely from what is known as the Fehlman Well and boreholes tapping from the Orange River Alluvium Aquifer. Namdeb has traditionally provided this water to Oranjemund at no cost (van der Merwe *et al.*, 2006) but The Namibian Government Gazette No. 5533 states that water tariffs should have been implemented from July 2015 (Namibia, 2014). According to a resident of Oranjemund (Jason Ndipwashimwe, pers comm, 9 September 2016), water tariffs will be implemented once the Oranjemund Town Council tariff system has been finalised. According to a Namdeb (Namibia De Beers Diamond Mine Company) representative (Jack Wasserfall, pers comm, 26 September 2016), water meters have already been installed and trial runs of the tariff system will be undertaken by the end of October 2016 to ensure that the system functions without unforseen difficulties. The actual implementation of the system will likely commence in January 2017.

According to the Namibian Ministry of Agriculture, Water and Forestry's Water Demand Management document of 2010 (MAWF, 2010); the Namdeb, Skorpion and Rosh Pinah Mines – all within 100 kms of Oranjemund - use about 10 million m^3/year of Orange River water in conjunction with seawater which is also used for mining purposes at Oranjemund. Oranjemund Mine used close to 6 Mm^3 and the others use the remaining 4Mm^3.

The Oranjemund area falls within the Southern Namib and Naukluft groundwater basin and the groundwater potential of rock bodies is very limited in this region (Christelis and Struckmeier, 2001). There are two types of aquifers in this groundwater basin; the shallow alluvial primary aquifers along the Orange River, and a variety of deeper hard rock secondary (heavily karstified) aquifers. Alluvial aquifers are generally only recharged by surface water and Oranjemund's low mean annual rainfall means that groundwater recharge from rainfall is minimal, making the Orange River the main source of recharge to the alluvial aquifers through seepage. Groundwater resources are very limited in the study area and the depletion of groundwater would have many adverse impacts including the drying up of shallow water wells, deterioration of water quality and a lowering of groundwater levels. Over-abstraction would also have negative impacts on the surrounding environment, especially the natural ecosystem supported by groundwater and The Orange River in the area of abstraction.

Surface water in the area is of good quality (Volschenk *et al.*, 2005) (de Wet, 2010). Based on the available monitoring borehole data, the water quality of the alluvial aquifer from which all of Oranjemund's water is sourced is classified within Group A, which is water of excellent quality suitable for human consumption, yet Koch *et al.* (2011) warns that the water quality of the Orange River in the Oranjemund region is declining and that the main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities. A desktop-based Ecological Reserve determination study concluded that the Ecological Reserve for the Orange River Estuary classifies as Ecological Category D+, which is described as a largely modified area (Taljaard *et al.*, 2005). Further to this, there is a considerable tidal/seawater influence on the Orange River mouth, and groundwater intrusion is currently increasing the salinity of some surface water sources in areas close to the sea (NACOMA, 2015).

A water balance calculated for Oranjemund within this study based on one year's worth of measured abstraction and water supply data, indicates that a considerable amount of water (482172 m^3/annum) is lost within the town generally. A total of 53630 m^3/annum constitutes wastewater, which is largely re-used to irrigate lawns in public parks, the Oranjemund golf course and trees lining the boundary of the Oranjemund Town. This wastewater volume was calculated as a residual of measured Sewage Treatment Plant inflows and the system's retention or storage. The total volume of water in circulation within the combined Oranjemund Town and Mine is approximately 5477195 m^3 per annum.

The Vision for Oranjemund

A preliminary, scenario-based approach was taken to this desktop study, in order to potentially establish for how long the calculated current supply can potentially meet the calculated current demand at Oranjemund when accounting for:

- Potential climatic changes such as temperature increases;
- Increased upstream water use and
- Legislation changes affecting water quotas.

As this is a literature-based study and limited information is available, no definitive numbers could be concluded, but the study does give an indication of the potential effects of the abovementioned changes on Oranjemund's ability to meet its demands going forward, as well as the cumulative impact thereof.

The lower Orange sub-basin has been identified as an area where anticipated climate change impacts - including excessive evaporation - are likely to have wide-ranging water resource management implications (Schulze *et al.*, 2005) (NACOMA, 2015). This would reduce runoff and the subsequent amount of water reaching the Lower Orange River basin over time (NACOMA, 2015). The aquifers that are recharged by the Orange River could thus have their water tables lowered and the combination of sea level rise and lowered water tables will likely trigger salt water intrusions. Under these circumstances these aquifers would no longer be able to supply the current volumes of fresh water, potentially requiring additional investment in desalination (NACOMA, 2015). Rising seas and increasingly intense high water events will place added stress on the sea walls established by Namdeb, which, if they are breached, will move the current coastline closer towards its natural position approximately 1.7km from the town (NACOMA, 2015).

Water use upstream of Oranjemund is increasing and is likely to continue to increase, leaving less water available for Oranjemund (van de Merwe *et al.*, 2006). There is a high possibility that boreholes currently being used will not recharge in the future as much as they have in the past, due to decreasing flows already being observed in The Orange River (Van der Merwe *et al.*, 2006), and this lower flow has been attributed to the infrastructure along the Orange River – largely upstream in South Africa and Lesotho (Van der Merwe *et al.*, 2006), and upstream water demands from the Orange River will likely increase as a result of growing demand in South Africa and Lesotho (NACOMA, 2015) and in Namibia where a significant increase in agriculture is envisaged and planned (Jack Wasserfall, 2016 pers. comm.).

As Namibia is a signatory to a number of progressive pieces of environmental legislation and Oranjemund both falls within the protected Tsau // Khaeb area and is a dry mining town whose current water resources are under threat, it is likely – and advisable – that water will increasingly be metered, charged-for and limited in the future, as gazetted and planned (Namibia, 2014), once the Oranjemund Town Council tariff system is in place. This will significantly change water use practices; the IWRM Plan Joint Venture Namibia (2010) states that the practice of not paying for water by the residents of Oranjemund has led to significant figures of water consumption of up to 16m^3 per household per day and that this quantity of water represents a significant proportion of the 40-50 Mm^3/annum initial entitlement of water from the Orange River for Namibia (IWRM Plan Joint Venture Namibia, 2010). Koch *et al*. (2011) states that both the water quantity and quality of the Orange River in the Oranjemund region are declining and that the main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities.

It is likely that climatic changes will lead to more erractic weather patterns and higher evaporation rates, that development upstream of Oranjemund will continue to increase and that water use in Oranjemund will increasingly be metered and charged-for going forward. Cumulatively this scenario will put significant pressure on Oranjemund's freshwater resources but the metering of freshwater use will help to curb wasteful usage.

While it is impossible to calculate this figure with any degree of accuracy based on a literature review, it is estimated that, should the current freshwater supply remain stagnant, Oranjemund could run out of fresh water by 2050. This is purely based on the assumption that the population growth rate will remain as it has for the past 14 years and that this is driving increased demand, not mining. Based on the current demand (mining and town related uses only) as a function of population growth - holding other variables constant, including supply - the population growth factor (which becomes the water demand factor) was determined to be 0.4. Through a trial and error approach it was determined that, at the current supply level, the available freshwater resources would last for 34 years without being depleted. The 35th year would result in a freshwater deficit of 6976 m^3 per annum. Again – no decisions should be based on this figure and it should be recalculated once considerably more water use figures become available (and are measured).

Drivers

The identified drivers of change for Oranjemund centre on the resource-conscious legislation governing the greater area and the water-related risks that Oranjemund faces.

Legislation

Namibia is a signatory to a number of progressive pieces of legislation and frameworks centred on protection of the natural environment and the responsible use of water resources. According to the Namibian constitution, all water in Namibia belongs to the State, which regulates and permits its use. Namibia's water resource management legislation provides for the management, protection, development, use and conservation of water resources; to provide for the regulation and monitoring of water services and to provide for incidental matters. The Namibia Water Corporation Act was mandated to establish the Namibia Water Corporation (NamWater), which has taken over the bulk water supply function of the DWA. The Local Authorities (LAs) Act spells out the functions and duties of LAs in rendering water supply and wastewater disposal services. In the case of Oranjemund, however, water has traditionally been supplied directly to the Town and Mine by Namdeb free of charge (van der Merwe *et al*., 2006). Although bulk water abstraction by Namdeb from the Fehlman Well and from a series of production boreholes is metered and documented, volumes used by individual households are not known due to lack of household water metering. This anomaly will be addressed when the Oranjemund Town Council water tariff system is operational, probably in January 2017 (Jack Wasserfall, pers comm October 2016).

Locally

Important legislative frameworks, policies and Acts guiding water demand and resource management relevant to Oranjemund are listed below. Key to these is the abovementioned Namibian Government Gazette No. 5533 that states that water tariffs should be implemented in Oranjemund. Oranjemund Town Proclamation, Land Ownership, Land Rights, Land Use Zoning and Title Deed documents include The:

- Oranjemund Town Planning Scheme 2013;
- Draft Oranjemund Structure Plan 2015 -2030;
- Draft Urban and Regional Land Use Planning Bill 2016;
- Namibia's National Land Policy, April 1998;
- The Regional Councils Act (No. 22 of 1992);
- Environmental Management Plan for the Town of Oranjemund; and
- Various Institutional Capacities.

Nationally

Frameworks, policies and Acts guiding water demand and resource management at a national level relevant to Oranjemund are listed below. The include The:

- Constitution of the Republic of Namibia, 1990;
- Water Resources Management Act, 2013 (No. 11 of 2013);
- Namibia Water Corporation Act (Act No. 12 of 1997);
- Local Authorities Act (Act 23 of 1992);
- Draft Integrated Pollution Control and Waste Management Bill; and
- Draft Wetland Policy, 2003.

Internationally

Namibia is a signatory to a number of international agreements. In order to improve management of the shared watercourses, various institutional bodies have been established. The following collaborations were formed for the Orange-Senqu system:

- The Permanent Water Commission (PWC) between Namibia and South Africa was established in September 1992;
- A parastatal Joint Irrigation Authority- established during the signing of the Treaty of the Vioolsdrift and Noordoewer Joint Irrigation Scheme between Namibia and South Africa
- The Interim Fish River Forum was formed with the aim of establishing a Basin Management Committee (BMC) as prescribed in the Water Resources Management Act (No. 11 of 2013); and
- The Orange-Senqu River Commission (ORASECOM) was established by the Governments of Botswana, Lesotho, Namibia and South Africa through the "Agreement for the Establishment of the Orange-Senqu Commission" on 3 November 2000.

Other important legislative frameworks, policies and Acts guiding water demand and resource mangment at an International level relevant to Oranjemund are listed below:

- The Ramsar Convention on Wetlands of International Importance (Ramsar Treaty), 1971;
- United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, 1997;
- Convention on the protection and use of transboundary watercourses and international lakes (Helsinki Convention), 1995; and
- Protocol on Shared Watercourse Systems in the SADC Region, 1995.

Risks

Oranjemund faces many water-related risks. The water quality of the surface water is both intrinsically linked to that of the groundwater and declining (Taljaard *et al.,* 2005) (Koch *et al.*, 2011) (NACOMA, 2015), making this a threat to groundwater resources. The boreholes used to supply Oranjemund are also vulnerable to salt water intrusion due to their proximity to the coast and the inflow of salt water back up the Orange River (van der Merwe *et al.*, 2006). There is a high possibility that the boreholes will not recharge in the future as much as they have in the past due to decreasing flows observed in The Orange River. This lower flow has been attributed to increased infrastructure upstream along the Orange River in South Africa and Lesotho (van der Merwe *et al.*, 2006) and will be exacerbated by the significant increase in agriculture as envisaged and planned in the Namibian side of the Lower Orange basin (Jack Wasserfall, 2016 pers. comm.).

Risks associated with surface water resources in the Oranjemund Region include the abovementioned water quality deterioration (Taljaard *et al.,* 2005) (Koch *et al.*, 2011) (NACOMA, 2015); variable, low rainfall; very high evaporation; occurrence of flash floods and droughts (NAMWATER, 2013). There is a lack of reliable, updated runoff records for the Oranjemund area as well as a lack of measured abstractions or water use demands. This comes with the threat of unsustainable overuse of the resource. The Oranjemund Town also experiences challenges in the form of a lack of expertise, data and incentives to enforce tariffs to water users within its jurisdiction. The threat of a shortage of freshwater to the town during the summer months further exists (Namdeb, 2003) and pollution from landfill sites in the Oranjemund Town and mine is a further potential threat to water resources in the region (NACOMA, 2015).

A high-level risk assessment was undertaken based on data obtained from the WWF Water Risk Filter website and based on 20 risk indicators (WWF, 2016). The following were deemed to be high risk; sea level rise, drought, freshwater biodiversity, government strategy, establishment of a Catchment Management Agency and the cultural or religious importance of local water resources, as well as water quality deterioration risks specific to Oranjemund. These risks agree well with those found elsewhere in the literature. From the findings of the risk assessment, these risks can generally be split into administrative, policy and management-related risks, and into climate and nature-related risks. In the case of the latter, some of the risks cannot be controlled, such as sea level rise and drought occurrence. These are processes that cannot be mitigated against at a local or regional scale.

One of the key administrative risks is managing the water resources in and around Oranjemund without a dedicated Catchment Management Agency (CMA). A CMA typically ensures that the mandate of water resource management agents is implemented, and the function of the CMA should be regularly monitored. Those tasked with implementing the CMA policies would need to implement regular monitoring of ecological functions in the Orange River and ensure that the Ecological Reserve is maintained as far as possible (WWF, 2016).

Key Recommendations for Oranjemund

As a first step, water use in Oranjemund should be metered (as proposed commencing in January 2017) so that it can be accounted-for. Once metered, tariffs should be assigned to this usage in order to curb wasteful use of water.

Bearing in mind that the wellfield that supplies the majority of Oranjemund's water is recharged directly from the Orange River, a sustainable conjunctive use plan should be put in place that accounts for likely climatic changes such as increased evaporation and sea level rise. An Integrated Water Management Planning approach should be adopted generally, as this would encourage water use sectors in Oranjemund to consider consumption by other users when calculating their water budgets, and lessen the likelihood of double accounting of water resources.

To obtain a clear picture of Oranjemund's water demands, it is recommended that various sectors that use water within the area either undertake their own water balances or add to the water balance provided with this document, in order to quantify all inflows and outflows within the various water uses. The water balance studies should include flow meters at selected key points in order to accurately measure water flowing between process units. Although bulk water abstraction is being measured, household use should also be measured and documented in order to update the water balance. Conjunctive (surface and groundwater) water quality monitoring should be undertaken at selected key points to detect incidences of water pollution before they deteriorate.

In order to preserve ecosystems within the Oranjemund Estuary, no development should occur within flood lines of specific return period such as the 1:50-year and 1:100-year flood events. These flood lines should be calculated.

Effective, legally-compliant stormwater management should also be prioritised, thus Storm Water Management Plans should be developed for mines and other institutions within the Oranjemund area in order to ensure the separation of clean and dirty water resources in the area.

The residents of the town of Oranjemund should start to view water as the scarce and valuable resource that it is. A voluntary approach to demand management should be encouraged, using water educational measures to inform the water users in Oranjemund and surrounding areas of the importance of using water sparingly. Further to this, strategic thinking around alternative supplies of water should be encouraged, including desalination and expanding the re-use of greywater. Despite the fact that the rainfall in Oranjemund is very low, rainwater harvesting is a further option that should be investigated, as an effective system based on a large roof area can provide a significant additional amount of water that can be used for domestic purposes, irrigation and for livestock watering. Unlike desalination, this is a simple and inexpensive manner in which to obtain additional clean water, so could be implemented in the near future along with reuse of greywater. Although desalination is a possible long-term water supply alternative, it has the following challenges:

- It is very expensive as the power cost involved can be 70% of the cost;
- Filtering membranes are expensive; and
- Brine disposal can be problematic.

The local fresh water/seawater interface should be monitored to ensure that any salt water intrusion is detected and corrected in time.

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1 INTRODUCTION

1.1 Study Background

The Oranjemund Region, which houses the coastal mining town of Oranjemund in the extreme southwest of Namibia, is in need of a water strategy and footprint assessment. Freedthinkers requested that GCS Water and Environment (Pty) Ltd undertake a desktop study to address some of the water challenges experienced by the town of Oranjemund for input into a larger sustainability plan that includes the surrounding area up to Hohenfels (see Figure 1-1). This desktop study involved a considerable amount of literature review and data gathering and outlines the status quo of Oranjemund's water availability. It further provides a literature-based indication of potential water supply options for various developments within the region. This includes a high-level review of the town's water availability and footprint, including the mine's water demand, and proposes preliminary ways in which to potentially address the town's current water challenges, based on the available data and literature.

1.2 Study Site Background

The mining town of Oranjemund is adjacent to the South African quaternary catchment D82L which is located within the Lower Orange Water Management Area 14, as can be seen in Figure 1-1. While Oranjemund itself does not fall into this area, the water source for the mine and town does. Oranjemund was established in 1936, after the discovery of significant alluvial diamond deposits by Hans Merensky on the north bank of the Orange River and the adjacent northern coastline. The Oranjemund Diamond Mine is a joint venture between the Government of Namibia and De Beers Holdings (Pty) Ltd. The town's climate is dominated by the South Atlantic high pressure cell, which drives the Benguela Current northwards past the town. The lower Orange sub-basin is an area in which climatic changes are likely to have water resources management implications (Schulze *et al.*, 2005). Household water use is not metered in the town, so is not used efficiently, making demand management difficult (NACOMA, 2015). This is in the process of changing as the Oranjemund Town Council tariff system will likely be operational in January 2017.

The Orange River Mouth is recognised as a Ramsar site or wetland of international importance. In September 1995 the salt marsh on the south bank of this Ramsar site was identified to be in a severely degraded state and the Ramsar site was placed under the Montreaux Record which is a list of Ramsar sites around the world that are in a degraded state (Taljaard *et al*, 2005).

ORANJEMUND SUSTAINABILITY WATER STUDY: LOCALITY

Figure 1-1 Locality of the Oranjemund Region

2 METHODOLOGY AND INFORMATION COLLECTION

A scenario-based approach was taken to this largely desktop study, in order to establish for how long current supply can meet current demand at Oranjemund when accounting for:

- Potential climatic changes such as temperature increases;
- Increased upstream water use and
- Legislation changes affecting water quotas.

As this is a literature-based study, no definitive numbers can be concluded, but the study does give an indication of the potential effects of the abovementioned changes on Oranjemund's ability to meet its demands going forward.

Although the study is desktop-based, it also involved the analysis of available hydrological and geohydrological data in order to gain an improved understanding of the current status of water resources in the area.

2.1 Legislation and Institutional Frameworks

The legal and institutional environment within which water is managed in Namibia was ascertained through an assessment of the relevant international frameworks, national legislation and local agreements.

The key international frameworks that were considered are The:

- Ramsar Convention on Wetlands of International Importance (Ramsar Treaty), 1971
- United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, 1997
- Convention on the protection and use of transboundary watercourses and international lakes (Helsinki Convention), 1995
- Protocol on Shared Watercourse Systems in the SADC Region, 1995

Land ownership and rights in Oranjemund are managed by the Oranjemund Town Planning Scheme of 2013, The Draft Oranjemund Structure Plan (2015 -2030) and the Town Planning Ordinance (No 18 of 1954). These documents were reviewed in order to establish land ownership rights in Oranjemund.

2.2 Climate

Recent climate data obtained from the Water Resources of South Africa study of 2012 (WRC, 2012) were analysed to determine the Mean Annual Precipitation (MAP), Mean Annual Evaporation (MAE) and the Mean Annual Runoff (MAR) for the region. The data used is a 90-year time series record of rainfall and runoff from 1920 to 2009. The WR2012 study is a comprehensive national water resources assessment study undertaken in South Africa that is widely used in Southern Africa for water resources assessment.

2.3 Water Quality

Water quality information was obtained from previous reports for the region which included the following:

- Situation analysis of problems for water quality management in the Lower Orange Region with special reference to the contribution of the foothills to salinisation (Volschenk *et al.*, 2005)
- A specialist report on the determination of the preliminary ecological reserve at a rapid level for the Orange River Estuary (Taljaard *et al*, 2005);
- Environmental consideration of the Orange River (Heath and Brown, 2007); and
- Orange River Mines Environmental Impact Assessment: River Ecology Study (de Wet, 2010).

2.4 Water Demand Analysis

Current water demand for the Oranjemund Town was estimated from a water accounts report for 2001/2002 compiled by the Namibian Department of Water Affairs and Forestry (DWAF, 2006). The current demand was calculated as a proportionate function of population growth from 2002 to 2016. The 2002 and 2016 population figures were obtained from the Namibia Statistics Agency (NSA) (Namibia Statistics Agency, 2011; Namibia Statistics Agency, 2002) and City Population (City Population, 2016) and the Oranjemund Town Council websites (Oranjemund Town Council, 2016), respectively.

2.5 Water Balance

The water balance was calculated using 9 months of measured abstraction data from January 2016 to September 2016 for a series of production boreholes and the Fehlman Well (see Figure 4-5) (Namdeb, 2016). Based on the observed water use trend for the 9-month abstraction period, a total annual (12 months) abstraction volume was calculated. Measured collective water use/supply were obtained for the same 9-month period. Measured sewage treatment plant inflow data were obtained for the period January 2013 to October 2016 (Namdeb, 2016) No sector-specific water use data were obtained so the water balance was calculated as a 'black box' (non-detailed) inflow-outflow system.

Based on a demand factor calculated as a function of population growth and water use trends, future water demand was projected from the current year (2016). The population growth and the water demand trend analyses used in the projection process are for the years 2002 and 2016 (Namibia Statistics Agency, 2011; City Population, 2016; Oranjemund Town Council, 2016)

2.6 Geohydrology

The town of Oranjemund is supplied with groundwater from the Fehlman Well (fed from the Orange River via alluvial processes) and from 10 production boreholes (Namdeb, 2016). According to Namdeb (2016) the Fehlman Well is a concrete-lined shaft with a diameter of 2.9 metres and is 17.05 metres deep. The well is fed by ten lateral pipes (each 40 metres long) which radiate horizontally from the bottom of the well. Water in the alluvial sediments drains via the lateral pipes into the shaft from where it is extracted by 4 turbine pumps powered by 160- kilowatt motors.

The 10 production boreholes augment the bulk water supply at Oranjemund. Water is pumped to the surface by six stage submersible pumps powered by 45- kilowatt motors. Groundwater is abstracted daily from the production boreholes and the Fehlman Well (Namdeb, 2016). Details of the Fehlman Well and the production boreholes are presented in Table 2-1. The coordinates are given in the Modified Clarke 1880, L017 projection system (ESRI, 1995).

Table 2-1 Fehlman Well and production boreholes at Oranjemund

Borehole ID	GPS Coordinates		Depth (m)
	X	Y	
BH3	+3160085.686	+42182.180	25.90
BH7	+3160015.857	+47759.190	21.09
BH14	+3159792.783	+47349.514	33.78
BH15	+3159755.440	+47257.065	32.02
BH16	+3159787.588	+47195.114	27.19
BH17	+3159723.412	+47162.219	29.71
BH18	+3159761.696	+47106.029	34.42
BH19	+3159690.844	+47039.636	28.14
BH20	+3159745.016	+47039.437	37.32
WW36337	+3158944.558	+45107.474	40
WW36344	3159554.792	+46688.488	40
WW36345	3159494.942	+46817.793	40
WW36338	3159582.357	+46950.637	40
Fehlman Well	+3159983.9370	+47474.9830	17.05

(Source: Namdeb, 2016)

2.7 Water Risk Assessment

The water risk assessment methodology was twofold: risks identified based on the literature reviewed and data analysed were elaborated upon, and a high-level water risk assessment of the area was undertaken based on the World Wide Fund (WWF) for nature risk assessment methodology (WWF, 2016). The WWF risk assessment was based on 20 risk indicators which included: Annual blue water scarcity; Groundwater abstraction; Temperature change; Rainfall change; Climate change; Sea level rise; Historical drought; Occurrence of floods; Present ecological status; Freshwater biodiversity; Ecosystem vulnerability; Government strategy; Sophistication and clarity of legal framework; Establishment of Catchment Management Agency; Cultural and/or religious importance of local water resources; Access to drinking water; Dependency of hydropower; Municipal functionality; Enforcement of legislation; Access to improved sanitation and History of protests by residents against any water management strategies within the municipality.

In principle, each risk indicator has 5 potential levels, and each level resulted in a score from 1 to 5 where 1 = No or very limited risk, 2 = Limited risk, 3 = Some risk, 4 = High risk, and 5 = Very high risk.

3 WATER LEGISLATION, INSTITUTIONAL FRAMEWORKS AND USE

3.1 International Legislation and Bodies

Namibia is a signatory to a number of international agreements. In order to improve management of shared watercourses, various institutional bodies have been established. For the Orange-Senqu system these include:

- The Permanent Water Commission (PWC) between Namibia and South Africa was established in September 1992 at Noordoewer. Its purpose is to deal with water matters of mutual concern, concentrating its activities on the Orange River Basin (University of Maryland, 2008).
- A parastatal Joint Irrigation Authority was established during the signing of the Treaty of the Vioolsdrift and Noordoewer Joint Irrigation Scheme between Namibia and South Africa in September 1992 at Noordoewer. This was established to operate the irrigation project located on both sides of the Orange River at Vioolsdrift and Noordoewer (University of Maryland, 2008).
- The Interim Fish River Forum was formed with the aim of establishing a Basin Management Committee (BMC) as prescribed in the Water Resources Management Act. The role of the BMC is to "*provide scope for addressing various issues affecting water resources in the basin, ranging from efficient water use to monitoring the health of the basin*" (MAWF, 2010).
- The Orange-Senqu River Commission (ORASECOM) was established by the Governments of Botswana, Lesotho, Namibia and South Africa through the "Agreement for the Establishment of the Orange-Senqu Commission" on 3 November 2000 in Windhoek.

3.1.1 Ramsar Convention on Wetlands of International Importance (Ramsar Treaty), 1971

The Ramsar Treaty calls for national action and international cooperation for the conservation and wise use of wetlands and their respective resources. The requires a) the formulation of plans that promote conservation of wetlands in their territory, b) consultation with other contracting parties regarding the implementation of the convention's obligations (University of Maryland, 2008). The Orange River Mouth was designated a Wetland of International Importance on 23 August 1995. In terms of Article 3.2, this makes Namibia responsible for ensuring that the convention secretariat is informed at the earliest possible time if the ecological character of the Orange River Mouth wetland is likely to change as the result of technological developments, pollution or other human interference.

The Orange River Mouth's status extends to both sides of the border between Namibia and South Africa, making it a transfrontier Ramsar site. The entire Tsau // Khaeb, including the Orange River mouth, is recognised as an Important Bird Area and an Important Plant Area (Stubenrauch Planning Consultants (SPC), 2015).

3.1.2 UN Convention on the Law of the Non-Navigational Uses of International Watercourses

The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997) applies to uses of international watercourses and their waters for purposes other than navigation, and to measures of protection, preservation and management related to the uses of those watercourses and their waters.

In determining the relationship and order of priority between different uses of a shared watercourse, the Convention provides that two considerations apply: a) in the absence of agreement or custom to the contrary, no use of an international watercourse enjoys inherent priority over other uses. b) In the event of a conflict between uses of an international watercourse, it shall be resolved with special regard being given to the requirements of vital human needs (University of Maryland, 2008). In terms of Namibia's 2008 Water Supply and Sanitation Policy (WASSP), uses of national waters are prioritised with water for domestic use being afforded the highest priority.

3.1.3 Convention on the protection and use of transboundary watercourses and international lakes

The objective of the Helsinki Convention (1995) is for signatories to take measures to prevent, control and reduce any transboundary impact by ensuring a) transboundary waters are managed in a rational, environment-friendly manner, b) transboundary waters are used in a reasonable and equitable way and c) conservation restoration of ecosystems (University of Maryland, 2008).

3.1.4 Protocol on Shared Watercourse Systems in the SADC Region, 1995

This Protocol on Shared Watercourse Systems in the SADC Region is based on the conviction of "the need for coordinated and environmentally sound development of the resources of shared watercourse systems in the SADC region in order to support sustainable socio-economic development".

The Declaration Treaty and Protocol on the establishment of the Southern African Development Community (SADC) was signed on 17 August 1992 in Windhoek, Namibia. The activities of SADC have been divided into ten different areas of co-operation, called Sectors, each of which has been allocated to one of the member countries. Water is one such area and the SADC member country responsible for the Water Sector co-ordination is Lesotho. A Water Sector Co-ordination Unit (WSCU) that has been established in Maseru performs the function of secretariat.

3.2 Water Sharing and Joint Management

The objective of water sharing and joint management is to ensure the equitable sharing of benefits of the system for all involved (Lower Orange River (LOR) Consultants, 2005). Upstream development has altered the natural flow patterns and reduced annual average flows in the Lower Orange. LOR Consultants (2005) identifies the following principles to safeguard against vested interests and country sovereignty:

- *Water produced should be clearly defined with a known assurance and cost of supply, together with its point of delivery. ·*
- *Water provided should be available at the point of delivery as modelled in the analysis.*
- *Abstractions should be metered.*
- *The benefits of the development option should be achieved in practice, i.e., it should be ensured, that water assessed to be available, should in practice, reach the consumers for whom it is meant.*

3.2.1 Allocation of Water

South Africa is the largest user of water from the Orange-Senqu River basin, using approximately 97%, with Lesotho utilizing 1%, Namibia 2% and Botswana <1% (Orange-Senqu River Basin Commission (ORASECOM), 2016). Agriculture is the most significant water user in the mid to lower reaches of the Orange-Senqu River system, whereas industrial, mining and domestic uses dominate the upper reaches (ORASECOM, 2016). Namibia has an agreement with South Africa to abstract at least 70 Mm^3/year, however, according to ORASECOM (2016), in 2000 this figure was close to 44 Mm^3/year.

3.2.2 Authorizations and Permits

Abstraction permits are used as a tool to control water use, promoting equity and protecting environmental flow requirements. A permit to use the water from the river is only issued by the relevant authority (in this case the Department of Water Affairs at the Ministry of Agriculture, Water and Forestry) once all water demands, including the environmental water demands have been determined for the river. The demand is then compared against the reserve before a permit is issued.

3.3 National Legislation and Bodies

According to the Namibian constitution, all water in Namibia belongs to the State, which regulates and permits its use. Relevant Acts in the water sector are described below:

3.3.1 Constitution of the Republic of Namibia, 1990

Provisions relating to the environment are contained in Chapter 11, article 95, which states that the Republic of Namibia shall – "*actively promote and maintain the welfare of the people by adopting, inter alia, policies aimed at … maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilisation of living natural resources on a sustainable basis for all Namibians, both present and future*".

3.3.2 Water Resources Management Act, 2013 (No. 11 of 2013).

The Act provides for the management, protection, development, use and conservation of water resources; to provide for the regulation and monitoring of water services and to provide for incidental matters. It establishes a Water Advisory Council, a Water Regulator and a Water Tribunal, as well as Basin Management Committees and Water Point Committees. It provides for an Integrated Water Resources Management Plan and a Water Pricing Policy, and covers licencing for water services providers and for water abstraction and use. Amongst the other topics it addresses are management of internationally shared water resources, protection of groundwater, and control of water pollution, dams, flood management and wetlands. This Act will replace the Water Act 54 of 1956 but these two are currently being used together.

> *(2) The international agreements relating to shared water resources binding on Namibia in relation to which regulations contemplated in subsection (1) may be made, are the following:*

Establishment of the Orange-Senqu River Commission (ORASECOM) agreement entered into on 3 November 2000 between the Kingdom of Lesotho, the Republic of Botswana, the Republic of South Africa and the Republic of Namibia.

3.3.3 Namibia Water Corporation Act (Act No. 12 of 1997)

This Act establishes the Namibia Water Corporation (NamWater), which has taken over the bulk water supply function of the DWA.

3.3.4 Local Authorities Act (Act 23 of 1992)

The Local Authorities (LAs) Act spells out the functions and duties of LAs in rendering water supply and wastewater disposal services.

3.3.5 Draft Integrated Pollution Control and Waste Management Bill

The purpose of this Bill is to regulate and prevent discharge of pollutants to the air, water and land in Namibia, and to enable the country to fulfil its international obligations in this regard. The draft Bill forbids any person from discharging or disposing any water without a water pollution license (aside from the discharge of domestic waste from a private dwelling or the discharge of pollutants or waste to a sewer or sewage treatment works).

3.3.6 Draft Wetland Policy, 2003

The Wetland Policy of 2003 aims to integrate sustainable management into decision-making at all levels by stating that "*Namibia shall manage national and shared wetlands wisely by protecting their biodiversity, vital ecological functions and life support systems for the current and future benefit of people's welfare, livelihoods and socio-economic development.*"

3.3.7 Water Act, 54 of 1956

This law addresses the control, conservation and use of water for domestic, agriculture, urban and industrial purposes. It makes provision for the control, in certain respects, of the use of seawater for certain purposes and for the control of certain activities on or in water in certain areas. The Namibian Water Act Number 54 of 1956 governs water use in Namibia.

3.3.8 Responsible Agencies for Water Management in Namibia

The present responsibilities for environmental management of watercourses in Namibia are divided between a number of organisations that include the Departments of Environmental Affairs, Water Affairs, Agriculture and Minerals and Energy.

3.3.9 National Government

- The Directorate of Resources Management within the Ministry of Agriculture, Water and Forestry (MAWF) is responsible for overall water resource inventory, monitoring, control, regulation and management

3.3.10 Regional Governments and Local Authorities (LAs)

- Directorate of Rural Water Supply (DRWS): Decentralizing responsibilities
- Regional Governments and LAs: Responsible for Water Supply & Sanitation. These councils buy water from NamWater or supply their own water from boreholes for delivery to end users.

At the encompassing watercourse level:

- River Basin Management Committees

Bulk water supplies:

- NamWater (in terms of the NamWater Act) abstracts water from primary sources, including the River, aquifers and dams and supplies to some end-users directly.

Self-providers include:

- Commercial farmers
- Tour operators
- Mines
- Conservation parks

These are subject to appropriate agreements and licences and supply their own water.

Operating analyses for the Orange River System are undertaken on an annual basis to determine available surplus or deficit in the system for the next year. Surpluses are allocated to generate additional hydropower over and above that generated by normal releases for downstream users. When there is a deficit in the system, curtailments are imposed (ORASECOM, 2016).

3.3.11 Institutional Capacities

The administrative capacities of the various organs of state in terms of Namibia's land tenure system is described below:

- National Planning Commission (NPC) - responsible for coordinating and directing national development planning.
- Ministry of Urban and Rural Development (MURD) - responsible for spatial land use planning at a regional level.
- Ministry of Lands and Resettlement (MLR) - in charge of land use planning for communal and commercial land in rural areas.
- State owned land is controlled by the Ministry of Works, Transport and Communications but the Ministry does not routinely undertake land use planning.
- Ministry of Environment and Tourism - undertakes land use planning in respect of areas designated for nature conservation such as the Tsau // Khaeb. The development of the Tsau // Khaeb Land Use Plan included extensive planning.

3.3.12 Land use planning in the Tsau // Khaeb

Planning in the Tsau // Khaeb is administered by the Tsau // Khaeb Land Use Plan. The various zonings proposed in the Tsau // Khaeb area were also investigated to determine which areas along the Orange River can be utilized and the legal process for initiating a project in the protected area. The Tsau // Khaeb includes the Atlantic Ocean-facing coast from Oranjemund northwards, on the border with South Africa, to around 72 kilometres north of Luderitz (see Figure 1-1). Mining takes place in five percent of the Tsau // Khaeb, with most of the area acting as a buffer zone (Encyclopedia Britannica, 2016). Members of the public are banned from entering most of the area, despite the creation of a national park there in 2008 (Conservational International, 2016).

According to Schneider & Walmsley (2004) the need for land use planning in the Tsau // Khaeb was driven by the necessity:

- *“to protect the fragile desert, coastal and riverine environments within a development context;*
- *to allow sustainable development based on the inherent qualities of the area and within its carrying capacity; to ensure planned development according to agreed land use suitability criteria;*
- *to allow for the integration of multiple users where practical and possible; to prevent unsuitable land use and environmental degradation caused by a lack of proper planning;*
- *to develop the area so that it can ultimately be integrated into the vision of a Protected Area Network spanning three countries, namely South Africa, Namibia and Angola; and*
- *to ensure that the area has a long-term benefit for the whole of Namibia, and the southern regions in particular, integrated development, with maximum protection of the environment”*

The Land Use Plan (Ministry of Environment and Tourism, 2000) gives land use options and guidelines for such options, including prospecting, mining, tourism, conservation, research, agriculture, mariculture, aquaculture, power generation and transmission, education and training (Schneider & Walmsley, 2004).

The preliminary zonings of the Tsau // Khaeb plan are based on the sensitivity, importance and development potential of individual areas. It is divided into

a) strict nature reserves,
b) national park areas,
c) wilderness areas,
d) natural monuments,
e) habitat/species management areas,
f) protected landscapes/seascapes and managed resource protected areas.

Based on the descriptions provided by Schneider & Walmsley (2004) the following descriptions apply to the various zonations:

- *“The zonation of Natural Monument applies to the conservation of specific natural features and currently only include the Bogenfels Arch and the Roter Kamm Meteorite Crater.*

- *Habitat/Species Management Areas comprise the Ramsar Site at the Orange River Mouth and the offshore islands. These are areas that should be managed mainly for conservation, and may require management interventions, for example manipulation of flows in the Orange River to ensure that minimum flow requirements are met.*
- *The zonation Protected Landscape/Seascape applies to the Diamond Coast Recreation Area near Lüderitz and the recreation areas around Oranjemund, in which a broader spectrum of recreational activities occur and private vehicle access is allowed.*
- *Managed Resource Protected Areas are to be managed for the sustainable use of natural ecosystems, including mining. This zoning includes the entire western part of the Tsau // Khaeb, as well as an area north of the Orange River. Proper rehabilitation of these areas could mean that ultimately they would be available for some other type of land use in the future, consistent with the goals of the proposed National Park."*

In order to develop in the Tsau // Khaeb, Mr Ndokosho (Deputy Director for the Parks Division at MET) (pers. comm.) indicated that a proposal or request is to be submitted to the Minister of Environment and Tourism since it falls on state land. The Minister will launch an inquiry to determine whether the proposed activity is in line with the Park Regulations and Land Use Plan. Should the proposal be approved by the Ministry, it is submitted to the Attorney General for scrutiny in order for the Government to proclaim the portion of the portion of the park for the proposed land use activity.

3.4 Local Legislation and Bodies

3.4.1 Town proclamation, land ownership, land rights, land use zoning, title deeds – Oranjemund

Until recently, Oranjemund was a closed mining town constrained by the presence of diamond licence areas surrounding the town. Because of these restricted access areas, expansion of the town is limited to the current townlands, and any development outside of this area requires approval from the mining license holder (i.e. Namdeb (Namibia De Beers Diamond Mine Company)). According to SPC (2015) it is expected that - based on Namdeb's current work plan - these areas will be cleared by 2050.

In order to facilitate development and reduce the dependency on diamond mining, Oranjemund was proclaimed as a Town in 2011 (Government Gazette No. 4736, June 2011). This allowed outside citizens the opportunity to migrate to Oranjemund and own land in the town. Consequently the need for the development of new townships has increased. According to SPC (2015) it is expected that by 2025 the majority of the usable townlands would have been planned. It is notable, however, that very little private ownership outside of Namdeb has been realised since Oranjemund was given town status in 2011.

The objective of the development of the town is to encourage investment and ensure that sufficient, serviced erven are available to encourage diversification of the economy. One of the key factors in attracting investors is to provide them with a choice, whether it is for an informal investor or a formal investor. Secondly, an opportunity must be attractive for an investor, and Council must make sure that erven are serviced, as an investor will not invest in a town where there are no serviced erven (SPC, 2015).

Currently there is no legislation in Namibia that requires the preparation of a coherent, national and regional land use framework. This might change with the enactment of the Draft Urban and Regional Planning. In the absence of this legislation, the establishment of towns and the subdivision of land are regulated by the Townships and Division of Land Ordinance of 1963 while the development and application of town planning schemes is regulated by the Town Planning Ordinance 18 of 1954. Both these Ordinances should be read with the Local Authorities Act 23 of 1992. A brief description of some of the key regulations and laws associated with land ownership and rights in Namibia are provided below:

3.4.2 Oranjemund Town Planning Scheme 2013

The Oranjemund Town Planning Scheme contains provisions to coordinate and harmonise development within the Scheme Boundary of Oranjemund and it is governed by the Oranjemund Town Council. The Scheme provides details regarding the way land is to be used and developed, classify areas for land use and include provisions to coordinate infrastructure and development within the Local Authority area. It makes specific reference to land ownership, land rights, land use zoning and title deeds.

3.4.3 Draft Oranjemund Structure Plan 2015 -2030

The Structure Plan, although in a draft stage still, aims to inform the Oranjemund Town Council so that an integrated and holistic future-orientated planning approach can be adopted on the sustainable use of the available resources (natural and man-made), on the allocation of land for urban expansion, as well as on maximising the development potential of Oranjemund within a regional context (SPC, 2015).

3.4.4 Town Planning Ordinance (No 18 of 1954)

The Town Planning Ordinance makes provision for the preparation and carrying out of town planning schemes. The Ordinance aims to ensure that every town planning scheme shall have for its purpose the coordinated and harmonious development of the area to which it relates "in such a way as will most effectively tend to promote health, safety, order, amenity, convenience and general welfare, as well as efficiency and economy in the process of development and the improvement of communications.

3.4.5 Draft Urban and Regional Land Use Planning Bill 2016

It is envisaged that the current system of land use planning and development controlled in Namibia will be comprehensively reformed by the enactment of the draft Urban and Regional Planning Bill and regulations made under it. The Bill provides for the establishment of national, regional and urban structure plans, and the development of zoning schemes. It also deals with a variety of related land use control issues such as the subdivision and consolidation of land and the establishment and extension or urban areas.

3.4.6 Namibia's National Land Policy, April 1998

The National Land Policy is aimed at addressing the need for access to land and security of land tenure, both on rural and urban land, in order to redress past social and economic injustices. The Policy sets out a list of fundamental principles, which, amongst others, call for a unitary land system, provides security and protection to all legally held land rights irrespective of the form of tenure, and requires environmentally sustainable land and natural resource use. The Policy reaffirms the position that all land (and water) belongs to the State unless otherwise lawfully owned. It also stipulates that tenure rights allocated under the Policy will include all renewable natural resources on the land, conditional to sustainable use and subject to sectoral policies and legislation.

3.4.7 Local Authorities Act (Act 23 of 1992)

This Act provides for the determination of local authorities and the establishment of local authority councils. It also sets forth the powers, duties and functions of such councils. Local authorities are given wide-ranging powers such as, "*to supply water to residents; to provide and maintain sewerage and drainage systems; to provide waste removal services; to supply electricity or gas to residents; to establish and operate sand, clay, stone or gravel quarries; and to promote tourism.*"

3.4.8 The Regional Councils Act (No. 22 of 1992)

From a land use and project planning point of view, the duties of elected representatives include, as described in Section 28 "to undertake the planning of the development of the region for which it has been established with a view to physical, social and economic characteristics, urbanisation patterns, natural resources, economic development potential, infrastructure, land utilisation pattern and sensitivity of the natural environment."

3.4.9 Environmental Management Plan for the Town of Oranjemund

The purpose of the EMP is to identify various activities of people and organisations in the town impact on the town environment and the surrounding area. Within this document there is a brief description of the impacts associated with the main activities of the town, and detailed mitigation measures for these impacts. By implementing these actions the town (and its citizens) will demonstrate its commitment to minimising its impact on the environment and ensuring a sustainable future for forthcoming generations.

3.5 Water Use – Oranjemund

Before proclamation, residents of Oranjemund were supplied with free water by Namdeb as part of their employment packages. This resulted in virtually no restrictions on water use and whilst Namdeb regularly monitored the aquifer from which water was abstracted as part of an early warning sign, no penalties were enforced for non-adherence. Because the houses were not equipped with water meters, there was no way of monitoring water use (Boonzaier, 2000). Water is still free currently but water tariffs will be implemented in January 2017 in Oranjemund.

The IWRM Plan Joint Venture Namibia (2010) states that the practice of not paying for water by the residents has led to significant figures of water consumption of up to $16m^3$ per household per day. In Windhoek it is found that the consumption averages about 0.2 m^3 (200 litres) per person per day. If the average household has 6 persons, this leads to a consumption of $1.2m^3$ per household per day, which is $15.8m^3$ (13 times) lower than in Oranjemund. This quantity of water represents a significant proportion of the 40-50 Mm^3/annum initial entitlement of water from the Orange River for Namibia (IWRM Plan Joint Venture Namibia, 2010).

In addition to uncontrolled water consumption in Oranjemund, the aging water distribution infrastructure installed close to 80 years ago (Brandt, 2014) contributes to high water demand due to transmission losses in the area (refer to Section 5.3). There are no strategically-located water meters and isolation vales, thus water losses can only be identified once the leak appears above ground, after considerable volumes of water have been lost.

Approximately 22% of the Oranjemund Town area is covered by large, green, open spaces constituting public parks, lawns and the golf course (NACOMA, 2015). The golf course is irrigated using around 50% freshwater obtained directly from the Orange River while the remainder comes from reuse of greywater (Charnelle Fortuin, 2016, pers. comm.). Greywater is also used to irrigate windbreak trees lining the periphery of the Oranjemund Town. As the green spaces in the Oranjemund Town are irrigated, these constitute a considerable water use even though freshwater is augmented by greywater for this irrigation. Further to this, if freshwater use in the town is reduced, less greywater will be available for such irrigation.

4 REGIONAL WATER SOURCES

This section addresses the status of water resources in the Oranjemund region and includes a description and characterisation of surface water and groundwater resources. While the groundwater abstracted for Oranjemund is fed by the Orange River – essentially making these one resource – the surface and groundwater sources have been described separately in this section for the purpose of simplification, and have been brought together in the concluding sections of this document.

4.1 Surface Water

The Oranjemund surface water assessment involved the analysis of rainfall, runoff and evaporation to determine the Mean Annual Precipitation, Mean Annual Runoff and Mean Annual Evaporation for the site. This provided an understanding of surface water inflows, outflows and losses within the catchment.

4.1.1 Hydro-meteorology

The average annual temperature in Oranjemund is 16.9°C. The warmest month (January), on average, has an average temperature of 19.2°C while the coolest month (August), on average, has an average temperature of 14.3°C (Weatherbase, 2016). The Köppen Geiger Climate Classification subtype for the Oranjemund regional climate is Bwk which represents a Tropical and Subtropical Desert Climate (Weatherbase, 2016). This type of climate is characterised by low rainfall and runoff and high evaporation, as shown when analysing the WR2012 hydrological data for the site. The site has a Mean Annual Precipitation of 42mm, a Mean Annual Runoff of 0.00136 mm and a Mean Annual Evaporation of 2401 mm. The monthly average values of these parameters indicate that Oranjemund experiences dry weather conditions with very low rainfall and limited to no runoff (See Table 4-1).

Table 4-1 Rainfall, Evaporation and Runoff for quaternary catchment D82L

Month	Rainfall(mm)	Runoff (mm)	Evaporation(mm)
Oct	2.38	0.00362	228.10
Nov	1.73	0.00034	269.39
Dec	2.39	0.00001	307.81
Jan	1.55	0.00293	313.57
Feb	2.61	0.00034	263.87
Mar	3.78	0.00172	247.30
Apr	4.72	0.00138	177.67
May	4.86	0.00138	119.09
Jun	5.60	0.00069	89.80
Jul	5.46	0.00276	87.88
Aug	4.80	0.00121	122.93
Sept	2.39	0.00000	173.59
Total	**42.28**	**0.00136**	**2401.00**

(Source: WRC, 2012)

The probability rainfall distribution of quaternary catchment D82L will likely be as indicated in Figure 4-1. The terms E10 to E90 represent values that can be exceeded in 10 to 90% of years. An average of 24.5 days of precipitation, with the most precipitation occurring in June with 3.0 days and the least precipitation occurring in January with 1.1 days, were recorded at Oranjemund (Weatherbase, 2016) (See Table 4-1). These figures were obtained for a record length of 112 years.

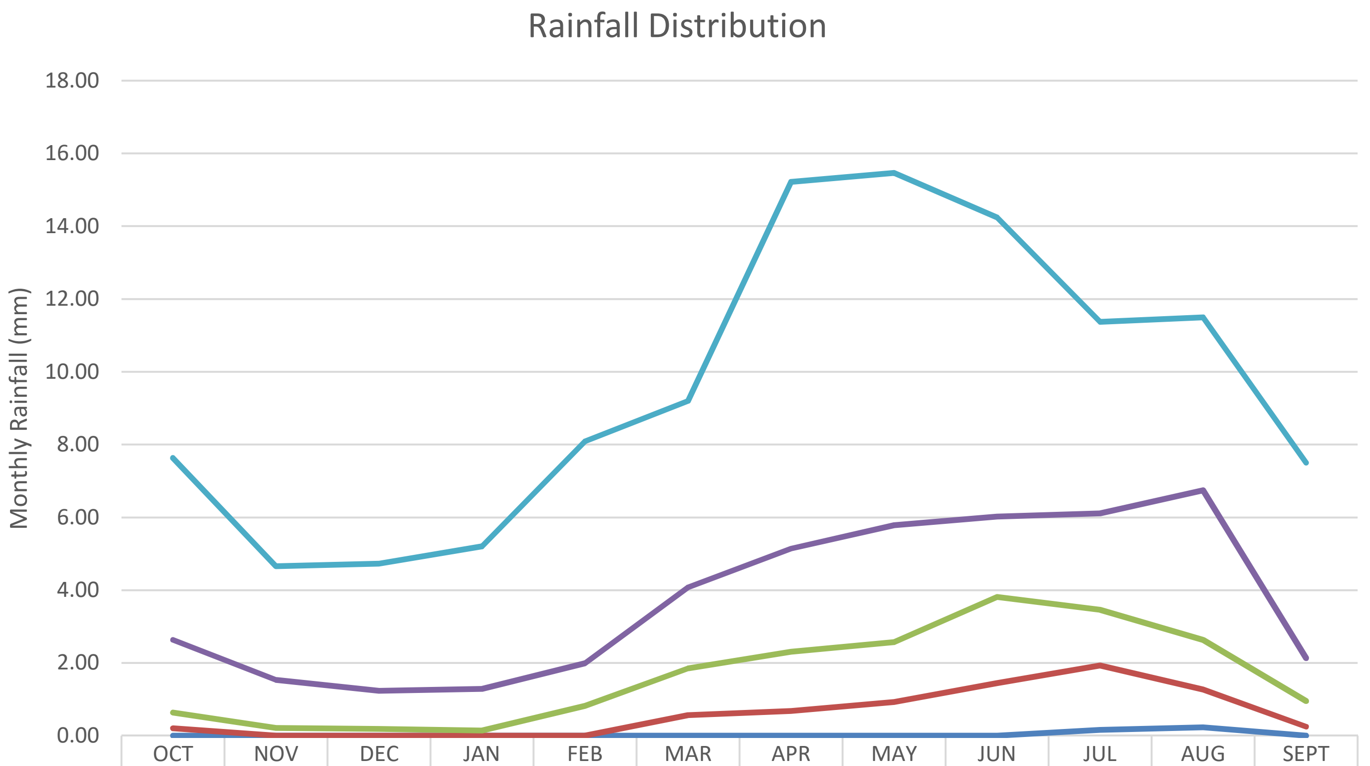
Table 4-1 Average number of rain days in the Oranjemund region

Average Number of Days With Precipitation for 112 Years												
Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
24.5	1.1	1.2	1.7	2.2	2.3	3.0	2.7	3.0	2.1	2.6	1.4	1.2

(Source: Weatherbase, 2016)

The average monthly runoff for the Oranjemund region is likely to be distributed as indicated in Figure 4-2. The highest average flow is indicated to be 0.01 mm/month for the month of December while the lowest flow is 0.003 mm/month and will typically occur in the month of November.

The monthly average evaporation values viewed against rainfall for the Oranjemund region are indicated in Figure 4-3. It is clear that evaporation exceeds rainfall by a large margin in this region and that runoff values are consequently very low.



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
E90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.00
E70	0.20	0.00	0.00	0.00	0.00	0.57	0.68	0.93	1.45	1.93	1.27	0.25
E50	0.63	0.22	0.18	0.14	0.83	1.85	2.31	2.57	3.81	3.47	2.63	0.96
E30	2.64	1.53	1.23	1.29	1.99	4.08	5.15	5.79	6.03	6.11	6.75	2.13
E10	7.63	4.66	4.73	5.20	8.09	9.20	15.22	15.47	14.24	11.37	11.50	7.50

Figure 4-1 Monthly rainfall distribution for quaternary catchment D82L

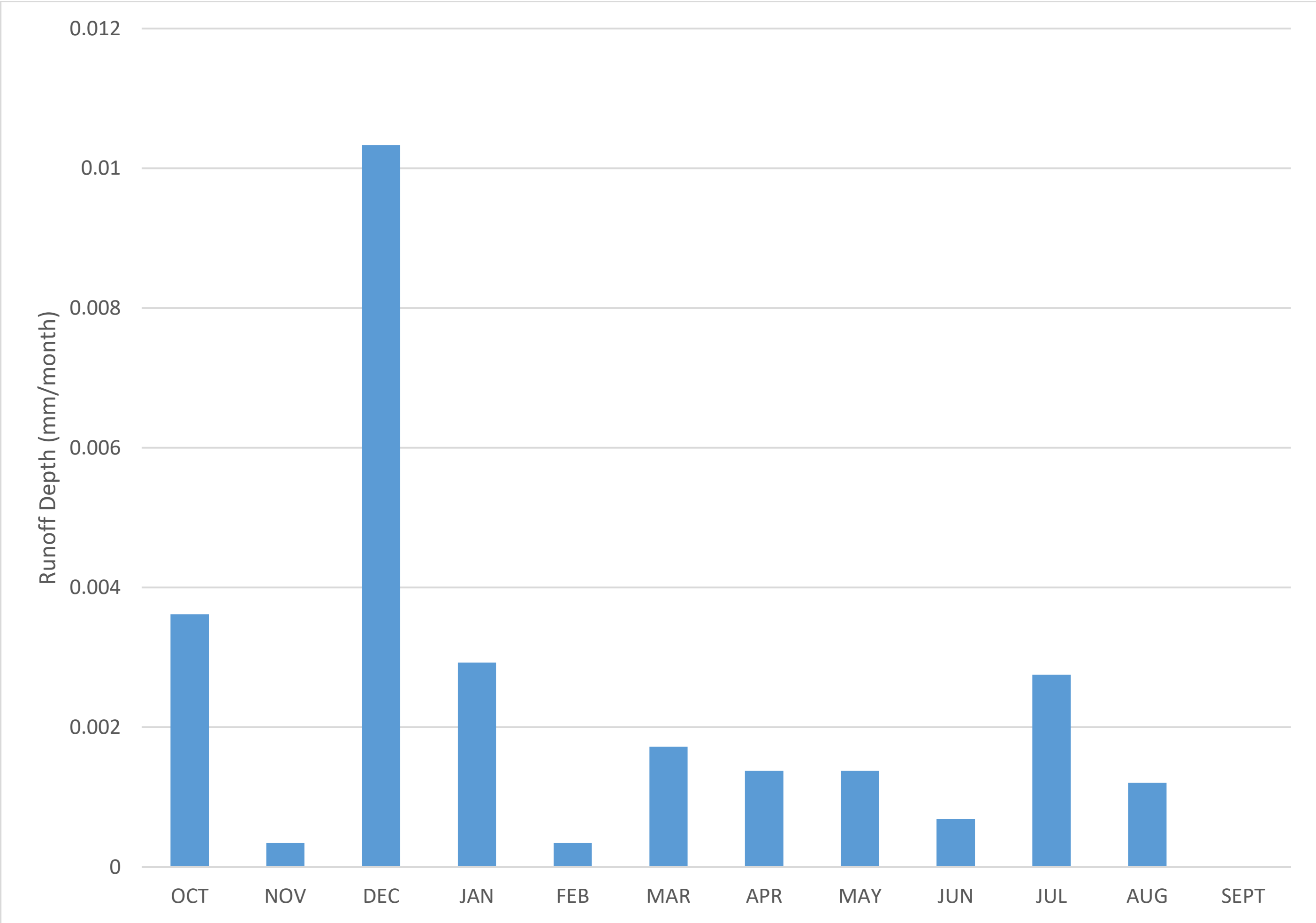


Figure 4-2 Average monthly runoff for Oranjemund region

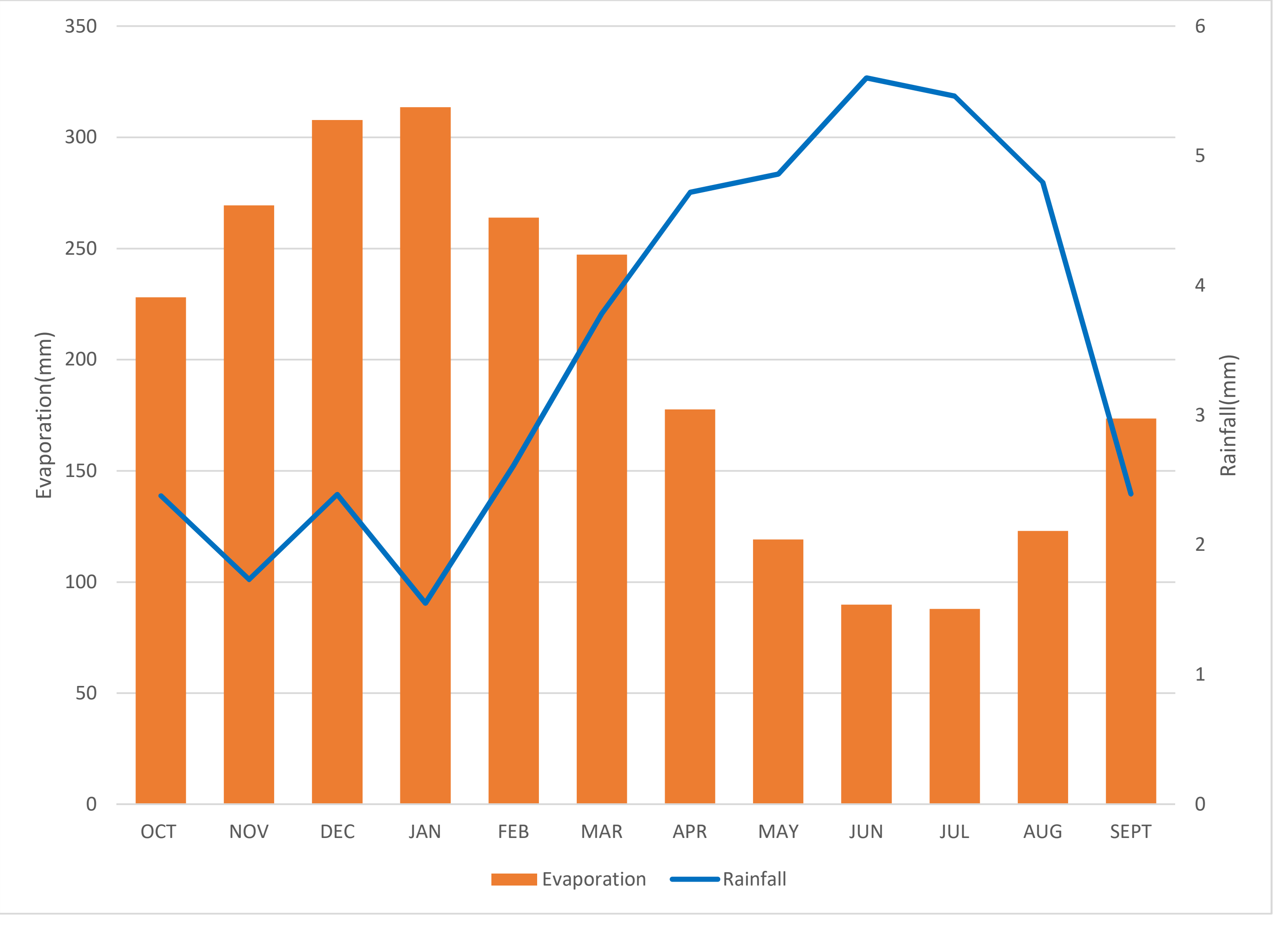


Figure 4-3 Rainfall and evaporation for quaternary catchment D82L

4.1.2 Surface Water Supply

Discussion with various stakeholders supported the literature presented in the previous sections. According to Michael Gaingob (pers comm, October 2016); a Namdeb employee based at Oranjmemund, there are no direct surface water abstraction from the Orange River for use in the Town or Mine. The Orange River, however, provides indirect recharge to aquifers tapped by production boreholes and the Fehlman Well which are the main sources of freshwater supply for Oranjmeund. The Orange River also supplies water to Scorpion and Rosh Pinah towns (see Figure 4-4). Namdeb abstracts this water for the Oranjemund Town and Mine at no cost (van der Merwe *et al.*, 2006), but, as mentioned, this will change with the implementation of proposed tariffs in January 2017. The water used for the Mine and Town abstracted from the Fehlman Well and a series of production boreholes can be seen in Figure 4-4 (DWS, 2016). Seawater is also used in Oranjemund for mining purposes without prior purification (van der Merwe *et al.*, 2006). An account of the volumes associated with these abstractions is provided in Section 5.

4.1.3 Surface Water Quality

Surface water quality in the Oranjemund region - according to long-term measurements of Electrical Conductivity, sodium adsorption rates and cation and anion concentrations - is of good quality and is not expected to pose any serious problems regarding salinity, sodium toxicity (Volschenk *et al.*, 2005). The classification of the sodium adsorption rate data for the lower Orange River water indicated that the probability that sodium toxicity will develop in plants sensitive to sodium through root uptake is limited (Volschenk *et al.*, 2005).

Groundwater intrusion is increasing salinity of some surface water sources in areas close to the sea, however (NACOMA, 2015). Higher saline conditions may be a result of runoff over salty sandy soils due to high evaporation rates in the area (de Wet, 2010).

Water samples collected along the Lower Orange River indicated that the water quality is within the DWA standard limits for domestic use, irrigation livestock watering and for aquatic ecosystem as well as within the SANS 241-2:2015 drinking water standard limits. These results are supported by findings of a previous Orange River Ecology Study (de Wet, 2010) which affirms that the Lower Orange River water at Oranjemund is suitable for human consumption, industry and agriculture. This study further predicted that the salinity (measured as a function of Total Dissolved Solids, TDS) of the water at Oranjemund may increase to 514 mg/l by the year 2030 due to evaporation towards the river mouth. This figure will still be below the DWA and the SANS standards limits.

A River Ecology study was conducted which also analysed Dissolved Oxygen (DO), pH and *E.coli* concentrations. The findings were that the DO in the river was greater than 70% saturation, the pH of 8.2 was acceptable and that the *E.coli* count of less than 100 counts per 100 ml was acceptable for full contact recreational use.

Koch *et al*. (2011), however, states that the water quality of the Orange River in the Oranjemund region is declining and that the main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities. Proposed landfills (see Figure 4-4) could pose further threats to water quality in the area surrounding Oranjemund (NACOMA, 2015).

Figure 4-4 The Orange River Estuary and Landfill sites at Oranjemund

4.2 Groundwater

This sub-section addresses the literature reviewed centred on groundwater at the study site.

4.2.1 Aquifer Description

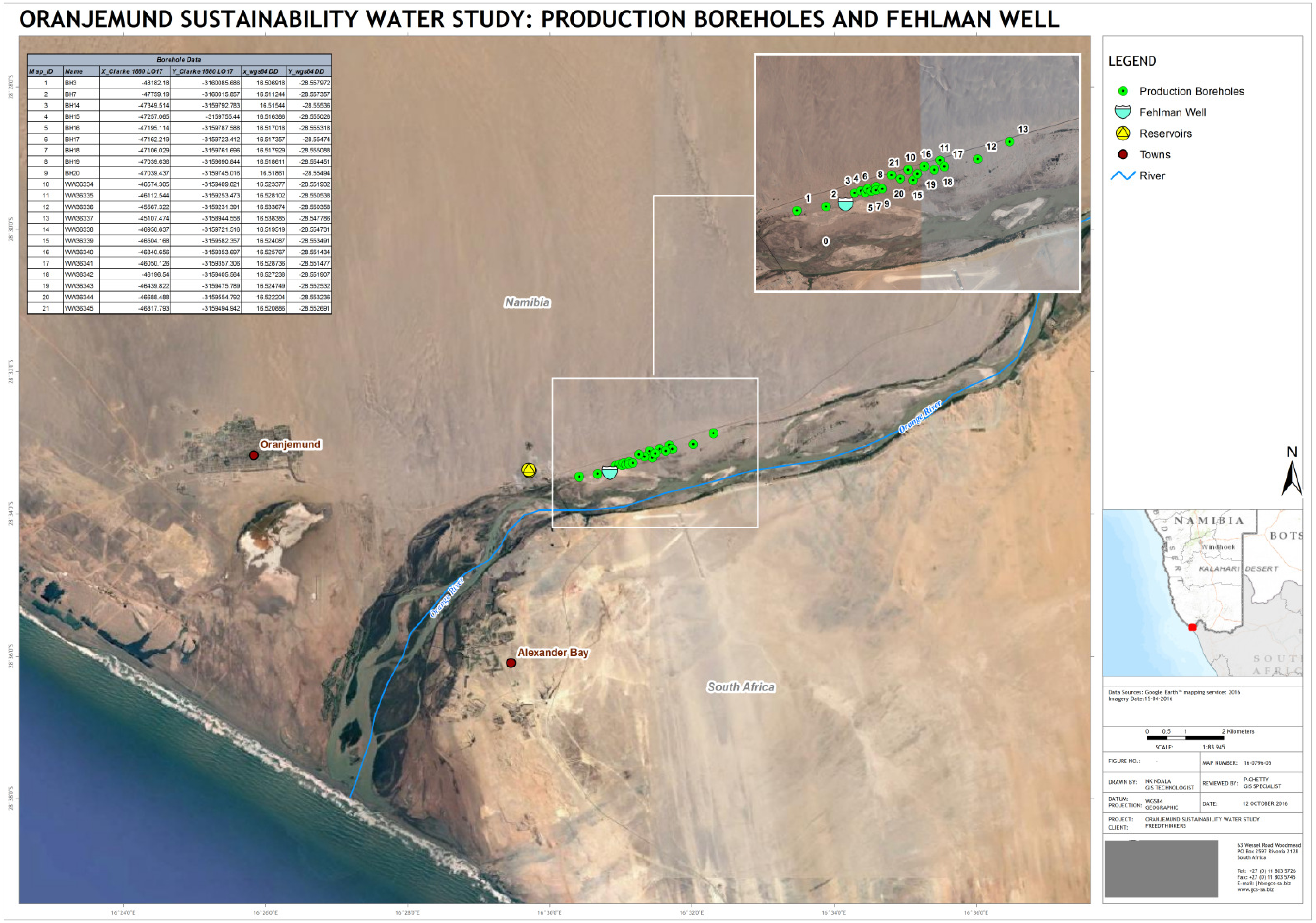
Hydrogeologically the Oranjemund area falls within the Southern Namib and Naukluft groundwater basin (Christelis and Struckmeier, 2001). The groundwater potential of aquifers in this basin is very limited, with low recharge rates often being the limiting factor.

The main hydrogeological units at Oranjemund are carbonate rocks of the Kalahari Group and Gariep Group, comprising unconsolidated to semi-consolidated sand and gravel, locally calcrete, and deeper, older bedrocks of marble, sandstone and quartzite of the Cretaceous period. Younger alluvial deposits (Recent to Quaternary) are also deposited along the Orange River. The main exploited aquifer units in the area are the shallow alluvial primary aquifers along the Orange River. On the broader area of Oranjemund is a variety of deeper hard rock of Cretaceous sandstone (secondary karst) aquifers.

The alluvial aquifers in southern Namibia are generally only recharged by surface water runoff. According to Christelis and Struckmeier (2001), the occurrence of exploitable groundwater resources in the Namib Desert is closely linked to the existence of alluvial aquifers created by perennial, ephemeral or even fossil rivers. The only abundant and reliable source of groundwater in the Tsau // Khaeb is the alluvial aquifer along the Orange River, which provides a secure water supply to Oranjemund. This supplies water to the towns of Oranjemund and Rosh Pinah (see Figure 1-1), to mines and for agricultural and tourism projects. As the Oranjemund area receives so little annual rainfall (see Sub-section 4.1.1), groundwater recharge from rainfall is minimal, limiting the aquifer potential of the other aquifers in the area.

4.2.2 Oranjemund Groundwater Supply

As mentioned, the Fehlman Well is the biggest groundwater supply of freshwater to the town of Oranjemund, producing approximately 800 m^3 (800 000 litres) of water per hour (Namdeb, 2016). Under optimum conditions, the wellfield of production boreholes produces 640 m^3 (640 000 litres) of water per hour. (See Figure 4-5 for location of production boreholes and the Fehlman Well).



Borehole Data					
Map_ID	Name	X_Clarke 1880 LO17	Y_Clarke 1880 LO17	x_wgs84 DD	Y_wgs84 DD
1	BH3	-48182.18	-3160085.686	16.506918	-28.557972
2	BH7	-47759.19	-3160015.857	16.511244	-28.557357
3	BH14	-47349.514	-3159792.783	16.51544	-28.55536
4	BH15	-47257.065	-3159755.44	16.516386	-28.555026
5	BH16	-47195.114	-3159787.588	16.517016	-28.555316
6	BH17	-47162.219	-3159723.412	16.517357	-28.55474
7	BH18	-47106.029	-3159761.696	16.517929	-28.555088
8	BH19	-47039.636	-3159690.844	16.518611	-28.554451
9	BH20	-47039.437	-3159745.016	16.51861	-28.55494
10	WW36334	-46574.305	-3159409.821	16.523377	-28.551932
11	WW36335	-46112.544	-3159253.473	16.528102	-28.550538
12	WW36336	-45567.322	-3159231.391	16.533674	-28.550358
13	WW36337	-45107.474	-3158944.558	16.538385	-28.547786
14	WW36338	-46950.637	-3159721.516	16.519519	-28.554731
15	WW36339	-46504.168	-3159582.357	16.524087	-28.553491
16	WW36340	-46340.656	-3159353.697	16.525767	-28.551434
17	WW36341	-46050.126	-3159357.306	16.528736	-28.551477
18	WW36342	-46196.54	-3159405.564	16.527236	-28.551907
19	WW36343	-46439.822	-3159475.789	16.524749	-28.552532
20	WW36344	-46688.488	-3159554.792	16.522204	-28.553236
21	WW36345	-46817.793	-3159494.942	16.520886	-28.552691

Figure 4-5 The Fehlman Well and production boreholes at Oranjemund

The amount of water abstracted from the boreholes and the Fehlman Well is combined to give total monthly water supply. Table 4-2 shows the amount of water supplied to Oranjemund town including water extraction limits from 16 December 2015 to 26 September 2016 (Namdeb, 2016). The total abstraction and supply volumes at Oranjmeund for the 9 months of monitoring are indicated to be 4 063 205m^3 and 4 504 109 m^3, respectively. These figures show that Oranjemund Town's water abstraction volumes comply with their permit limit for this period. During the months of January and February, the water demand was equal to the abstracted volume (See Figure 4-6), meaning that there was no water storage in the Town's reservoirs. Daily water demand, however, decreased from the month of March to the 16th of September 2016, which means there is temporary storage of surplus water in storage reservoirs (Figure 4-5) at the Town.

Table 4-2 Abstraction volumes from the Fehlman Well and production boreholes

Date	Groundwater Supply (m^3)			
	Monthly Abstraction	Monthly Permit Limit	Daily Abstraction	Daily Permit Limit
Dec-2015/Jan-16	508 244	509589.04	16438.36	22000.00
Feb-16	508 624	509589.04	16438.36	22000.00
Mar-16	463103	460273.97	16438.36	22000.00
Apr-16	482 853	509589.04	16438.36	22000.00
May-16	410 425	493150.68	16438.36	22000.00
Jun-16	419 249	509589.04	16438.36	22000.00
Jul-16	405 255	493150.68	16438.36	22000.00
Aug-16	431 594	509589.04	16438.36	22000.00
Sep-16	433 858	509589.04	16438.36	22000.00
Totals	4 063 205	4504109.57	147945.24	198000
Surplus/Shortfall	440904.57		50054.76	

(Source: Namdeb, 2016)

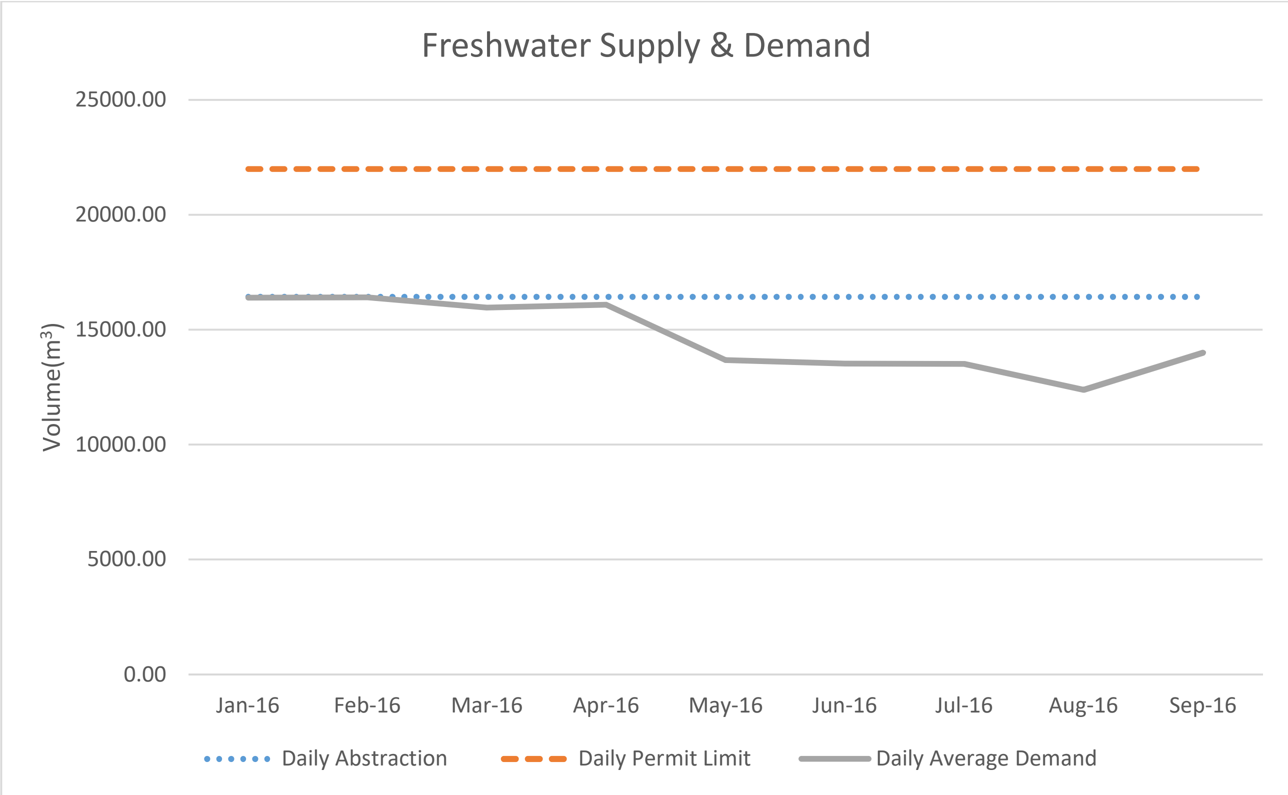


Figure 4-6 Freshwater abstraction and demand at Oranjemund

4.2.3 Groundwater Quality and Water Level Monitoring

In the alluvial sediments there are twelve capped and equipped non-production boreholes between Oranjemund and Hohenfels (Namdeb, 2003a). These boreholes are used for groundwater level and quality monitoring. The water levels in the monitoring boreholes typically range from 4 to 10 metres below collar (Namdeb, 2003a). According to the available borehole information obtained from Namdeb's groundwater database, the 12 boreholes had been profiled for Electrical Conductivity (EC) between January 1999 and December 2003. Conductivity readings have also been taken from the taps at the production boreholes to provide an early warning of possible deterioration in the quality of the water supplied. The EC values of the monitoring boreholes water increased with depth, ranging from 0.10 to 0.60 mS/m, which indicates that the water quality is suitable for drinking. The groundwater quality in Namibia is classified based on the Total Dissolved Solids (TDS). Based on the available monitoring boreholes' data, the water quality of the alluvial aquifer is classified Group A, which is water of excellent quality and suitable for human consumption (Namdeb, 2003b).

5 EXISTING WATER FOOTPRINT

A water footprint is regarded as an indicator of the appropriation of freshwater resources (both surface and groundwater) defined by direct and indirect water uses. This section addresses water uses by ecosystems (denoted as the Ecological Reserve), household use, other uses (including industrial use) and losses (which include leakage and evaporation losses).

5.1 Ecological Reserve

The Ecological Reserve is an allocation of water specified as a volume and quality underpinned by flow and duration requirements to sustain the specified river ecosystem (Van Wyk *et al.*, 2006). The Ecological Reserve for the Orange River Estuary (see Figure 4-4) was determined in a joint previous study conducted for the mining town of Oranjemund by the South African Department of Water Affairs and Forestry (now the DWS) and the Namibian DWA (Taljaard *et al*, 2005). In this study, the Orange River Mouth (recognised as a Ramsar wetland of international importance (South African Wetlands Conservation Programme, 2014) was classified as Ecological Category D+, which is described as a largely modified area.

The Ecological Reserve of Oranjemund - given as percentiles - can be seen in Figure 5-1. A percentile indicates a value below which a given percentage of observations in a group of observations falls. For example; the 20th percentile (20%ile) is the value below which 20% of the Ecological Reserve flows for a catchment may be found. As indicated in Figure 5-1, 90% of the Ecological Reserve flows for Oranjemund fall below 923039.04 m^3/month while 1% of Ecological Reserve flows are found below 31344.72 m^3/month (Taljaard *et al*, 2005). These percentiles were obtained from a desktop and rapid (low confidence) assessment, since no Ecological Reserve studies have been undertaken on specific river reaches to provide high confidence values for Oranjemund (Heath and Brown, 2007). This Ecological Reserve distribution represents a scenario in which the catchment inflow is 157.53 million m^3/ month (Taljaard *et al*, 2005). This catchment inflow figure is far higher than the Mean Annual Runoff calculated from the WR2012 database for quaternary catchment D82L which stands at 0.02 million m^3. This discrepancy is likely due to the following reasons:

- Increased upstream development in South Africa and Lesotho has resulted in higher water demands thereby decreasing runoff volumes that reach the Orange River mouth between the 2005 study and the current date.

- The Ecological Reserve study was not conducted on a detailed reach-to-reach basis but was a desktop and rapid (low confidence) assessment which only provides indicative information on which no planning conclusions should be based.
- The estimation of inflows for estuaries requires the modelling of the catchments upstream of the estuaries including all water uses involved (Van Niekerk *et al.*, 2015). This also explains why the mean annual runoff for Oranjemund is smaller than that used to estimate inflows into the Orange River mouth which comprises all upstream quaternary catchments rather than the immediate catchment draining the Oranjemund area.

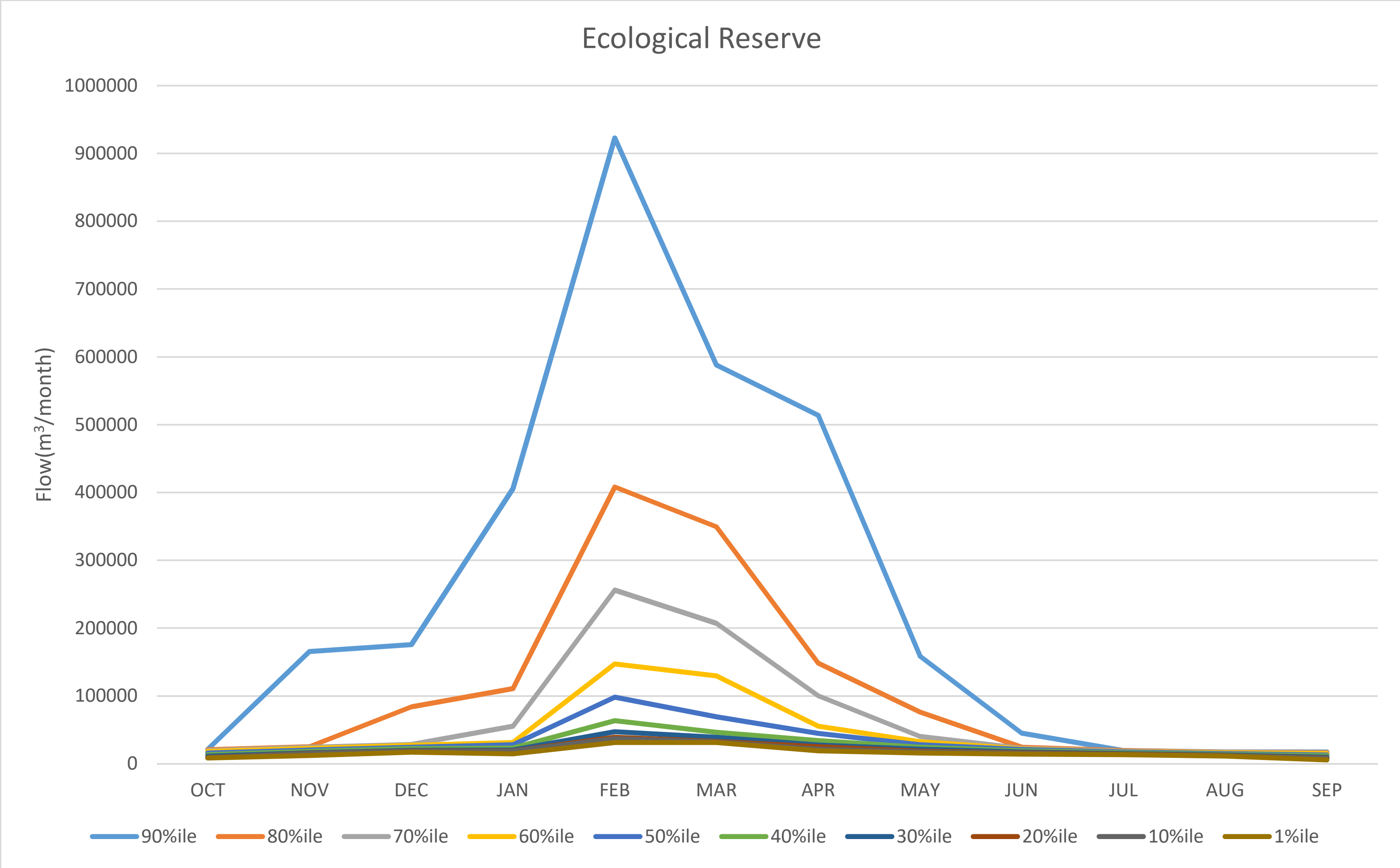


Figure 5-1 Ecological Reserve for Oranjemund

5.2 Oranjemund Tidal Information

The Waverider tidal information station was set up in 1978 to gather information for the design of a piled jetty in the surf zone in the Oranjemund mining area and the Council for Scientific Industrial Research (CSIR) has analysed the data (CSIR, 1986). As the Waverider does not record wave direction, use had to be made of available Voluntary Observing Ships' records that were collected between 1960 and 1979 for the whole of Southern African coast (CSIR, 1986). These data were correlated to characterise the beach behaviour and the study concluded the wave climate is fairly severe, with a once/year significant wave height of 5.6m (CSIR, 1986).

The available wave data for the area clearly show a strong predominance of waves with a high angle of incidence from the south to the south-west. The gross longshore transport sediment in the area is about 1.9 million cubic metres per year, with a net of 1.3 million cubic metres per year northbound. These extremely high values, which are the result of the high angles of incidence referred to previously, have been verified by comparison with the rate of up-drift infill at the first sea-wall, which was constructed in 1971 at Oranjemund (CSIR, 1986). The relevance of this (albeit old) information for the current study is there is a considerable tidal/seawater influence on the Orange River mouth, and groundwater intrusion is currently increasing the salinity of some surface water sources in areas close to the sea (NACOMA, 2015).

5.3 Current Water Use Practices in Oranjemund Town

As mentioned, abstractions from the Fehlman Well and from production boreholes that tap from the Orange River alluvial aquifer are being measured and monitored at Oranjemund. Since residential areas are yet to be metered, no records of household water uses are available at Oranjemund. The Namibian Government Gazette No. 5533 states that water tariffs should have been implemented from July 2015 (Namibia, 2014). According to a resident of Oranjemund (Jason Ndipwashimwe, pers comm, 9 September 2016), the water metering system is being installed and once it is in place, water tariffs will be implemented. According to a Namdeb representative (Jack Wasserfall, pers comm, 26 September 2016), water meters have already been installed and trial runs of the tariff system will be undertaken by the end of October 2016 to ensure that the system functions without unforseen difficulties. For the current situation, demand management is difficult since residents are unaware of their water usage and are usually ignorant of the consequences of water wastage (NACOMA, 2015). The mining sector of the Oranjemund Town mainly uses seawater which results in freshwater savings in the town (NACOMA, 2015).

5.4 Water Balance for the Oranjemund Town and Mine

According to reports compiled by the Namibian Department of Water Affairs, Namdeb Mine and Town together use between 6.57 million m^3 (DWAF, 2006) and 6.85 million m^3 of water (DWA n.d.) per annum, originating from the Fehlman Well and from a series of production boreholes tapping from the Orange River Alluvium Aquifer. As mentioned, Namdeb provides this water to Oranjemund at no cost (van der Merwe *et al.*, 2006). According to the Namibian Ministry of Agriculture, Water and Forestry's Integrated Water Resources Management document of 2010; the Namdeb, Skorpion and Rosh Pinah Mines – all within 100 kms of Oranjemund - use about 10 million m^3/year of Orange River water in conjunction with seawater used for mining purposes at Oranjemund. No separate surface water data from the Orange River or seawater figures for the Namdeb Mine and Oranjemund Town were found.

5.4.1 Development of the Water Balance

Data sources used for calculation of the water balance can be seen on the cover page accompanying this document.

Within the water balance calculated for Oranjemund, the water supply was deemed to come from the Fehlman Well and from a wellfield of production boreholes. These sources supply water amounting to 5 417 606.7 m^3, a figure which is obtained from 9 months of measured data (Namdeb, 2016), upscaled to 12 months. Data for collective water use were also obtained for the same 9-month period (Namdeb, 2016). Sewage Treatment Plant inflow data were obtained for the period January 2013 to October 2016 (Namdeb, 2016). No sector-specific water use data were obtained so the water balance was calculated as a 'black box' (non-detailed) inflow-outflow system. The water process flow diagram for Oranjemund - based on the water use information gathered in the literature as well as on information gathered through stakeholder consultation in the area - is indicated in Figure 5-2. This process flow diagram was used to generate the water balance for Oranjemund which is presented in Table 5-1. The water balance indicates that a considerable amount of water (482172 m^3/annum) is lost within the town generally. A total of 53630 m^3/annum constitutes wastewater (greywater), which is mainly re-used to irrigate lawns in public parks, the golf course and trees lining the boundary of Oranjemund Town. This wastewater volume was calculated as a residual of measured Sewage Treatment Plant inflows and the system's retention or storage. The total volume of water in circulation within the Oranjemund Town and Mine is approximately in the order of 5477195 m^3 per annum.

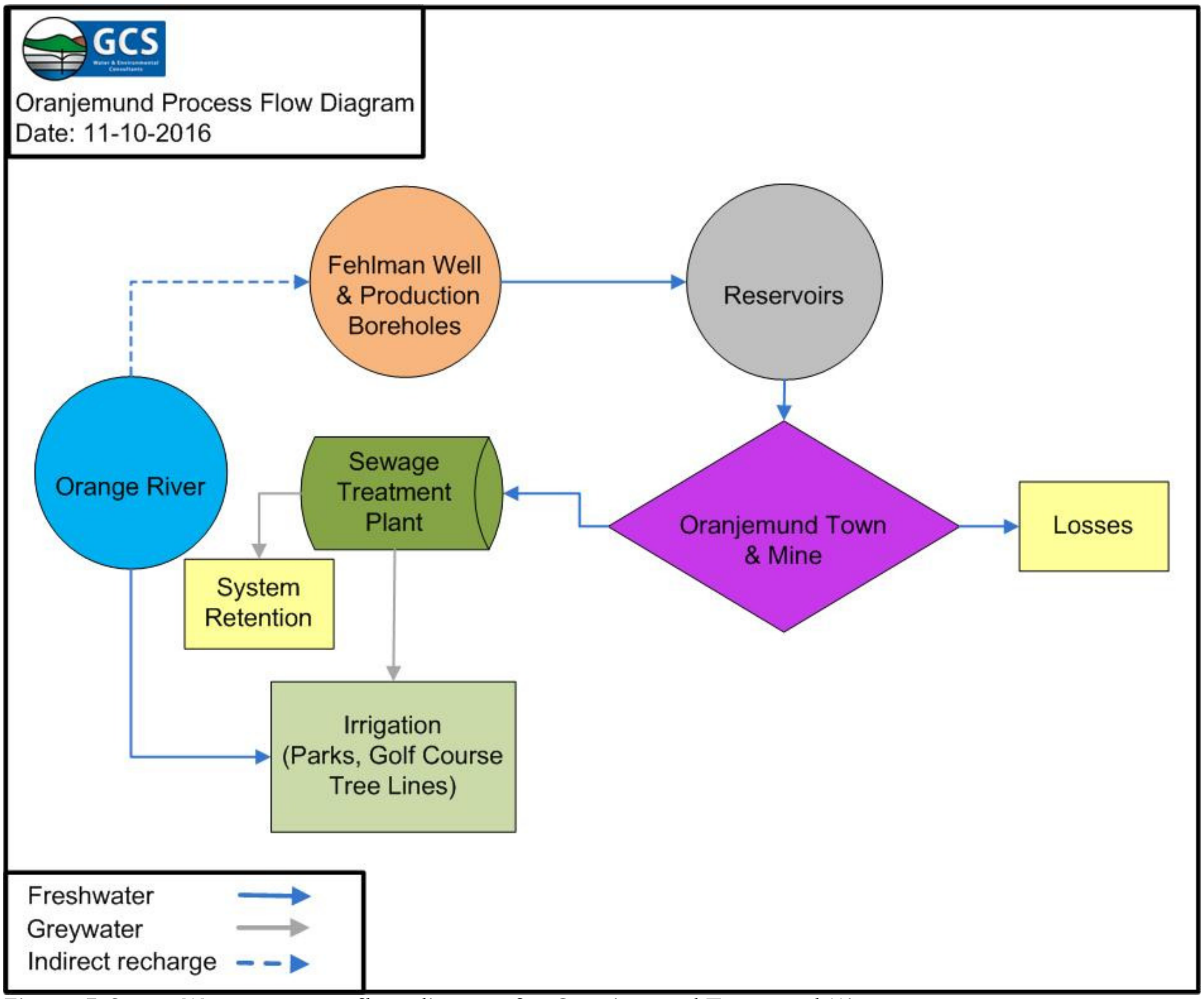


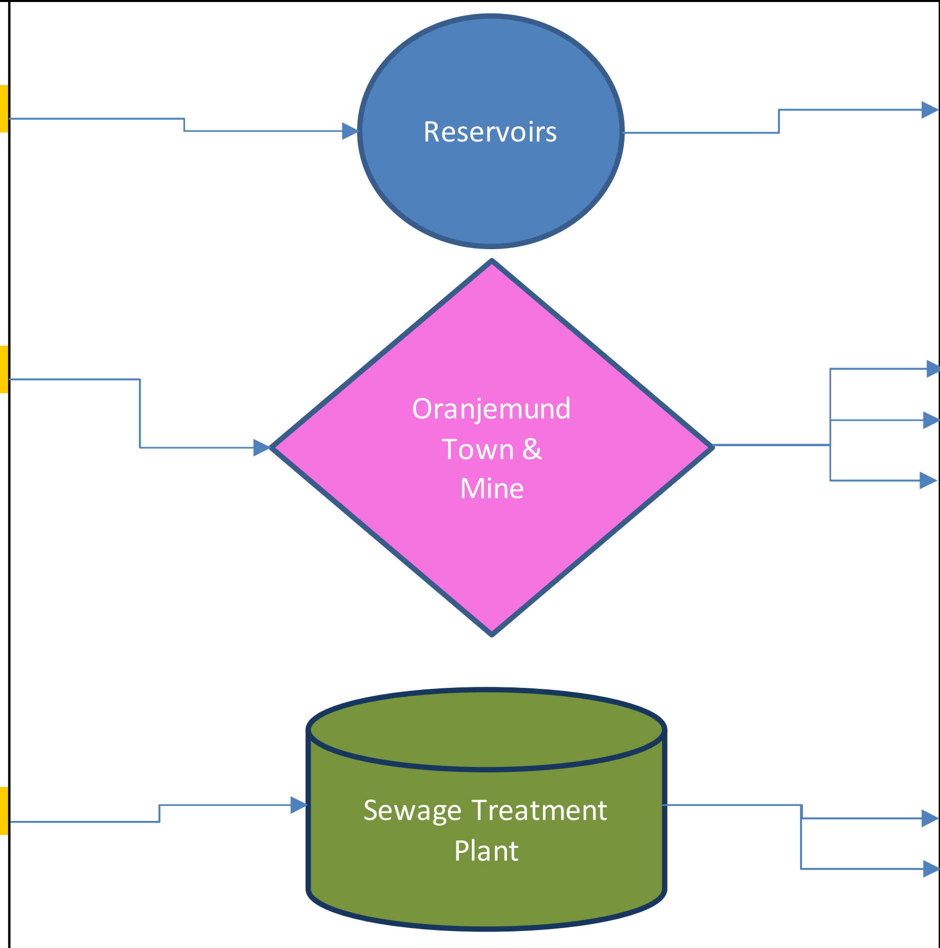
Figure 5-2 Water process flow diagram for Oranjemund Town and Mine

Table 5-1 Annual average water balance for the Oranjemund Town and Mine

ORANJEMUND

AVERAGE ANNUAL WATER BALANCE

IN			OUT		
From: Orange River (Fehlman Well & Boreholes)	5417607	m^3/annum	To: Oranjemund Town & Mine	5417607	m^3/annum
From: Reservoir	5417607	m^3/annum	To: Sewage Treatment Plant	59589	m^3/annum
			To: Losses	482172	m^3/annum
			To: System Retention/Use	4875846	m^3/annum
From: Oranjemund Town & Mine	59589	m^3/annum	To: Irrigation (Golf Course, Parks & Trees)	53630	m^3/annum
			To: System Retention	5959	m^3/annum
	10894802	m^3/annum	**TOTAL**	**10894802**	m^3/annum



Calculated from measured water supply	(yellow)
Calculated to balance the water balance	(blue)

6 WATER RISK ASSESSMENT

The water risk assessment methodology was twofold: risks identified based on the literature reviewed and data analysed were elaborated upon, and a high-level water risk assessment of the area was undertaken based on the World Wide Fund (WWF) for nature risk assessment methodology (WWF, 2016).

6.1 Risks Identified in the Literature

6.1.1 Threats and Limitations to the Orange River Alluvial Aquifer Source

As mentioned, the water quality of the surface water is both intrinsically linked to that of the groundwater and declining, making this a threat to groundwater resources. The boreholes used to supply Oranjemund are also vulnerable to salt water intrusion due to their proximity to the coast and the inflow of salt water back up the Orange River (DWA n.d.).

There is a high possibility that the boreholes will not recharge in the future as much as they have in the past due to decreasing flows observed in The Orange River (van der Merwe *et al.*, 2006) This lower flow has been attributed to the infrastructure along the Orange River upstream in South Africa and Lesotho (DWA n.d.).

6.1.2 Threats and Limitations to Surface Water Resources

The limitations associated with surface water resources in the Oranjemund Region include variable, low rainfall, very high evaporation, occurrence of flash floods and droughts (NAMWATER, 2013). There is a lack of reliable, updated runoff records for the Oranjemund area as well as a lack of measured abstractions or water use demands, as described in more detail in Section 4. This comes with the threat of unsustainable overuse of the resource. The Oranjemund Town also experiences challenges in the form of a lack of expertise, data and incentives to enforce tariffs to water users within its jurisdiction. The threat of a shortage of freshwater to the town during the summer months exists and was experienced during the period September 2002 to January 2003 as described below (Namdeb, 2003):

During winter water consumption in Oranjemund is around 400 000 m^3 (400 million litres) of water per month, which increases dramatically in the summer months when the highest daily water consumption recorded (on the 30th December 2002) was 21 123 m^3. The total water usage for the month of December 2002 was 513 932m^3 (513 932 000 litres) indicating an increase of more than 100 million litres of water. It was also noted that the Orange River levels dropped from 2.95 metres on the 30th September 2002 to 0.65 metres on the 3rd January 2003. This highlights that, if the town depletes the water held in the aquifer and the River when it is at its lowest level (which is the case in the summer months), the Oranjemund community will be faced with a water shortage.

As mentioned, pollution from propoesd landfill sites in the Oranjemund Town and mine is a further potenital threat to surface water resources in the region (Nambed, 2016).

6.2 Sustainability of The Overall Resource

Sustainability is a measure of the availability and accessibility of a resource which thus accounts for both surface and groundwater quantity and quality. The current status of water supply and demand management in Oranjemund is not sustainable. This is largely because there is no monitoring of the demand by way of water use measurement (although this is proposed to change) in this low rainfall, high eveporation region. If demand is not known and monitored, the risk of running short of water supply cannot be ruled out. Further to this, according to Koch *et al*. (2011), the apparent abundance of water in the Orange River is misleading, since both the water quantity and quality are declining. The main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities. The Orange River water quality is deteriorating as a result of return flows from irrigation farms (in South Africa and Namibia) which carry high loads of pesticides and leached fertilisers. The pesticides and fertilisers in the water threaten the ecological integrity of the Orange River (see Section 5.1), particularly the river mouth which, as highlighted previously, is recognised as a wetland of international importance.

6.2.1 Climate Change

The potential climatic change impacts on water resources within the Oranjemund region have been broken into specific climate change-related risks in this section.

6.2.1.1 Sea Level Rise and Beach Erosion

The town currently lies approximately 6.3km from the Atlantic Ocean and is not (with the exception of The Oranjemund Yacht Club) considered susceptible to the rising sea levels predicted to result from climatic changes (NACOMA, 2015). However, rising seas and increasingly intense high water events will place added stress on the sea walls established by Namdeb, which, if they are breached, will move the current coastline closer towards its natural position (approximately 1.7km from the town) (NACOMA, 2015).

6.2.1.2 Reduced Runoff and Future Supply

The lower Orange sub-basin has been identified as an area where anticipated climate change impacts including excessive evaporation are likely to have wide-ranging water resource management implications (NACOMA, 2015). Upstream water demands from the Orange River will likely increase as a result of growing demand in South Africa and Lesotho. The increasing upstream water demands, coupled with excessive evaporation due to climate change will reduce runoff and the subsequent amount of water reaching the Lower Orange River basin over time (NACOMA, 2015).

6.2.1.3 Reduced Aquifer Table and Salt water Intrusion

As explained, climate change impacts result in reduced runoff within the Lower Orange Basin. The aquifers which are recharged by the Orange River will have their water tables lowered and the combination of sea level rise and lowered water tables will likely trigger salt water intrusions. These aquifers would no longer be able to supply fresh water, potentially requiring additional investment in desalination (NACOMA, 2015).

6.3 WWF Risk Assessment

In terms of examining overall water risk, the World Wildlife Fund (WWF) recently developed a water risk assessment tool (WWF, 2016) which can be used to assess water-related risks based on a geographic location. The Water Risk Filter aims to cover all relevant aspects of water risks, and uses the best available global data source for physical, regulatory and reputational risk indicators (WWF, 2016). In the case of South Africa, local high resolution data are available. The risks associated with Quaternary Catchment D82L have been assessed within this section. The water footprint calculated for the whole of the Orange River Basin using these data can be seen in Appendix A.1.

Each risk indicator will result in a score from 1-5:

- **1: No or very limited risk;**
- **2: Limited risk;**

- 3: Some risk;
- **4: High risk; and**
- **5: Very high risk.**

Water risk can be categorised into the following:

- **Physical risk:** Relates to water quantity (scarcity and flooding) and water quality that is unfit for use (pollution). Physical risk may mean that there is not sufficient good quality water available.
- **Regulatory risk:** Relates to the imposition of restrictions on water use by government. This may include the pricing of water supply and waste discharge, licenses to operate, water rights and quality standards.
- **Reputational risk**: Reputational risk manifests itself through tensions and conflict around access to water or the degradation of local water resources. In a highly globalised information economy, public perceptions can emerge rapidly around decisions that are seen to impact on aquatic ecosystems or local communities' access to clean water.

Therefore, to examine Oranjemund's water risk, indicators were selected based on the WWF water risk indicators (WWF, 2016) and are summarised in the following tables for Quaternary Catchment D82L and for Oranjemund itself.

The water risk indicators for D82L are summarised in Table 6-1 and those for Oranjemund are summarised in Table 6-2.

From the findings of the risk assessment, these risks can generally be split into administrative, policy and management-related risks, and into climate and nature-related risks. In the case of the latter, some of the risks cannot be controlled, such as sea level rise and drought occurrence. These are processes that cannot be mitigated against at a local or regional scale. For the Oranjemund-specific analysis, very high risk is associated with water quality deterioration and consequent impacts on the ecological reserve.

One of the key administrative risks is managing the water resources in and around Oranjemund without a dedicated Catchment Management Agency (CMA). A CMA typically ensures that the mandate of water resource management agents is implemented, and the function of the CMA should be regularly monitored. Those tasked with implementing the CMA policies would need to implement regular monitoring of ecological functions in the Orange River and ensure that the Ecological Reserve is maintained as far as possible.

Table 6-1 Water Risk Assessment for D82L

Indicator	Description	Magnitude	Data Source
Physical Risk			
Water Scarcity and maximum net water depletion	Water Availability = No shortage > 10 years	Very Limited Risk	DWS, 2015
Groundwater Scarcity	Groundwater Use/Groundwater Recharge 0 - 50%	Very Limited Risk	DWS, 2015
Climate change temperature impact	1-2 = 25% of quaternaries with the least predicted temperature change"	Very Limited Risk	Engelbrecht *et al.*, 2016
Climate change sea level change	Area is located on the coastline	Very high risk	
Meteorological drought index	Extreme/Exceptional droughts in the last 3 years	Very high risk	Villholth *et al.*, 2013
Flood risk index	< 5 days with streamflow greater than 2mm/day	Very Limited Risk	Schulze *et al.*, 1997
Present ecological status around the facility	Moderate risk of surface water contamination	Some Risk	Vörösmarty *et al* 2010
Threat to freshwater biodiversity threat around the facility	Contains a sub-quaternary catchment which is a River FEPA or contains Endangered or Critically Endangered Fish	Very High Risk	Nel *et al* 2015
Vulnerability of water ecosystems	Wetlands and rivers ecosystem types = vulnerable	Some Risk	National Biodiversity 2011
Regulatory Risk			
Water strategy of local, national and upstream governments, including drought and flood management plans where appropriate	No strategy in place	Very High Risk	The DWS All Towns Reconciliation strategy
Sophistication and clarity of water related legal framework	Somewhat sophisticated, strict and subjective	Some Risk	WWF & Tecnoma (TYPSA Group)
Municipal functionality	Municipal Functionality as reported by Department of Cooperative Governance and Traditional Affairs = Municipality Functioning	Some Risk	COGTA, 2016
Enforcement of water related legal framework	The Blue Drop 2011 and Green Drop 2012= Moderate compliance	Some Risk	DWS, 2016
Establishment of a catchment management agency (CMA)	No Catchment Management Agency	Very High Risk	DWS, 2016
Reputational Risk			
Cultural and/or religious importance of local water sources	RAMSAR (66 quat) and SADC Springs (44 quat)	Some Risk	RAMSAR, SADC HYDROGEOLOGICAL MAP, NFEPA and SANBI
History of protests	No service delivery Protests	Very limited Risk	Institute for Security Studies
Access to safe drinking water	Adequate access	Very limited risk	Census, 2011
Access to improved sanitation	Inadequate access- 40 - 60% of the quaternary catchments that do not have access to flush sanitation	Limited Risk	Census, 2011

Table 6-2 Water Risk Assessment for Oranjemund

Indicator	Description	Magnitude	Data Source
Physical Risk			
Quantity			
Annual average monthly net water depletion (WaterGap)	Water Availability = Very low depletion (<5%) [Basin Level Indicator]	Very Limited Risk	Brauman, KA, BD Richter, S Postel, M Malby, M Flörke. (2016)
Number of months per year net water depletion exceeds <60% (WaterGap)	0 months [Basin Level Indicator]	Very Limited Risk	Brauman, KA, BD Richter, S Postel, M Malby, M Flörke. (2016)
Net water depletion in the month in which net water depletion is the highest in this river basin (Water Gap)	Very low depletion [Basin Level Indicator]	Very Limited Risk	Brauman, KA, BD Richter, S Postel, M Malby, M Flörke. (2016)
Aridity	Arid [Grid Level Indicator]	High Risk	Trabucco, A., and Zomer, R.J. (2009)
Forecasted impact of climate change	Vulnerability Index: 2 of 4: Limited impact [Grid Level Indicator]	Limited risk	Yohe, G., E. Malone, A. Brenkert, M. Schlesinger, H. Meij, X. Xing, and D. Lee. 2006
Estimated occurrence of droughts (2013-2016)	10-25% of the country affected by a severe drought in the last 3 years [Grid Level Indicator]	Some Risk	Vicente-Serrano S.M., Santiago Beguería, Juan I. López-Moreno, (2010)
Estimated occurrence of droughts (2014-2016)	>25% of the country affected by a severe drought in the last 2 years [Grid Level Indicator]	High Risk	Vicente-Serrano S.M., Santiago Beguería, Juan I. López-Moreno, (2010)
Estimated occurrence of droughts (2015-2016)	10-25% of the country affected by a severe drought in the last 12 months [Grid Level Indicator]	Some Risk	Vicente-Serrano S.M., Santiago Beguería, Juan I. López-Moreno, (2010)
Estimated occurrence of floods	Rare: 1-2 floods reported between 1986 and 2016 [Grid Level Indicator]	Limited Risk	The Flood Observatory Tool; University of Colorado
Quality			
General situation of water pollution around the facility	Very high risk of surface water contamination [Grid Level Indicator]	Very High Risk	Vörösmarty et al 2010
Nitrogen loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Phosphorus loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Pestizide loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Soil salination	Score: 0.275 [Grid Level Indicator]	Limited Risk	Vörösmarty et al 2010
Organic loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Sediment loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Mercury loading	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Potential Acidification	Score: 0.1 [Grid Level Indicator]	Limited Risk	Vörösmarty *et al* 2010
Thermal alteration	Score: 0.875 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Ecosystem Health			
Threat to freshwater biodiversity threat around the facility	Very High Threat to Biodiversity: 0.825 - 1.0 [Grid Level Indicator]	Very High Risk	Vörösmarty *et al* 2010
Vulnerability of water ecosystems in the country	Resilient (EVI <215) [Country Level Indicator]	Very Limited Risk	Environmental Vulnerability Index; South Pacific Applied Geoscience Commission (SOPAC), United Nations Environment Programme (UNEP)
Access to safe drinking water (% of population)	90-95% of population [Country Level Indicator]	Limited Risk	World Health Organization (WHO) and United Nations Children's Fund (UNICEF)
Access to improved sanitation (% of population)	<60% of population [Country Level Indicator]	Very High Risk	World Health Organization (WHO) and United Nations Children's Fund (UNICEF)
Regulatory Risk			
Water strategy of local, national and upstream governments, including drought and flood management plans where appropriate	The national government has no water strategy, however policies regarding some important water topics exist [Country Level Indicator]	High Risk	WWF & Tecnoma (TYPSA Group)
Sophistication and clarity of water related legal framework	Somewhat sophisticated, strict and subjective [Country Level Indicator]	Some Risk	WWF & Tecnoma (TYPSA Group)
Enforcement of water related legal framework	Some (irregular) enforcement [Country Level Indicator]	Some Risk	WWF & Tecnoma (TYPSA Group)
Official forum or platform in which stakeholders come together to discuss water-related issues of the basin	Yes, a forum exists, however is not yet in the position to influence [Country Level Indicator]	Some Risk	WWF & Tecnoma (TYPSA Group)
Reputational Risk			
Cultural and/or religious importance of local water sources	Water is considered somewhat important by the local culture and/or religion	Some Risk	WWF & Tecnoma (TYPSA Group)
Exposure of this country to local/national media coverage reporting on criticizing on possible water	Occasionally (>1 per 6 months)	Some Risk	WWF & Tecnoma (TYPSA Group)
Exposure of this country to global media coverage reporting on criticizing on possible water issues	Occasionally (>1 per 6 months)	Some Risk	WWF & Tecnoma (TYPSA Group)

(Source: WWF, 2016)

7 SCENARIO-BASED WATER AVAILABILITY ASSESSMENT

As mentioned, without measuring and modelling surface and groundwater flows for the region, volumes of water availability going forward cannot be given, but an indication of the likely risks under five scenarios are provided in this section.

7.1 Potential climatic changes

As highlighted in Section 6, The lower Orange sub-basin has been identified as an area where anticipated climate change impacts - including excessive evaporation - are likely to have wide-ranging water resource management implications (Schulze *et al.*, 2005) (NACOMA, 2015). This will reduce runoff and the subsequent amount of water reaching the Lower Orange River basin over time (NACOMA, 2015). A study by de Wet undertaken in 2010 (de Wet, 2010) predicted that the salinity (measured as a function of Total Dissolved Solids, TDS) of the water at Oranjemund will increase to 514 mg/l by the year 2030 due to evaporation towards the river mouth. This figure will still be below the DWA limits for human consumption, industry and agriculture and the SANS drinking water standards limits, however.

7.2 Increased upstream water use

Water use upstream of Oranjemund is increasing and is likely to continue to increase, leaving less water available for Oranjemund (van der Merwe *et al.*, 2006). There is a high possibility that boreholes currently being used will not recharge in the future as much as they have in the past, due to decreasing flows already being observed in The Orange River (DWA n.d.), and this lower flow has been attributed to the infrastructure along the Orange River – largely upstream in South Africa and Lesotho (DWA n.d.) and upstream water demands from the Orange River will likely increase as a result of growing demand in South Africa and Lesotho (NACOMA, 2015). Upstream development has altered the natural flow patterns and reduced annual average flows in the Lower Orange. It's been found that Agriculture is most significant water user in the mid to lower reaches of the Orange-Senqu River system, whereas industrial, mining and domestic uses dominate the upper reaches. These activities span across South Africa, Namibia, Botswana, and Lesotho as they all share the resources of the Orange River.

7.3 Legislation changes affecting water quotas

As Namibia is a signatory to a number of progressive pieces of environmental legislation and Oranjemund both falls within the protected Tsau // Khaeb area and is a dry mining town whose current water resources are under threat, it is likely – and advisable – that water will be metered, charged-for and limited in the future. As mentioned, Namdeb has traditionally provided this water to Oranjemund at no cost (van der Merwe *et al.*, 2006) but The Namibian Government Gazette No. 5533 states that water tariffs should have been implemented from July 2015 (Namibia, 2014). As mentioned, according to a resident of Oranjemund (Jason Ndipwashimwe, pers comm, 9 September 2016), water tariffs have not yet been implemented as the relevant system is still being rolled out, but that tariffs will be implemented once the meters and the system are in place, and according to a Namdeb representative (Jack Wasserfall, pers comm, 26 September 2016), water meters have already been installed and trial runs of the tariff system will be undertaken by the end of October 2016 to ensure that the system functions without difficulties. This will severely change water use practices; as previously mentioned the IWRM Plan Joint Venture Namibia (2010) states that the practice of not paying for water by the residents of Oranjemund has led to significant figures of water consumption of up to 16m^3 per household per day and that this quantity of water represents a significant proportion of the 40-50 Mm^3/annum initial entitlement of water from the Orange River for Namibia (IWRM Plan Joint Venture Namibia, 2010). As highlighted in Section 6, Koch *et al.* (2011) states that both the water quantity and quality of the Orange River in the Oranjemund region are declining and that the main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities.

7.4 Cumulative impact – Likely Scenario

It is likely that climatic changes will lead to more erractic weather patterns and higher evaporation rates, that development upstream of Oranjemund will continue to increase and that water use in Oranjemund will be metered and charged-for going forward. Cumulatively this scenario will put significant pressure on Oranjemund but the implementation of water tariffs will help to curb wasteful use.

7.5 Oranjemund Running Out of Water

While it is impossible to calculate this figure with any degree of accuracy based on the data used within this study, it is estimated that, should the current freshwater supply remain stagnant, Oranjemund could run out of fresh water by 2050. This is purely based on the assumption that population growth rate will remain as it has for the past 14 years and that this is driving increased demand, not mining. Based on the current demand (mining- and town-related uses only) as a function of population growth, holding other variables constant including supply, the population growth factor (which becomes the water demand factor) was determined to be 0.4. Through a trial and error approach it was determined that, at the current supply level, the available freshwater resources would last for 34 years without being depleted. The 35th year would result in a freshwater deficit of 6976 m^3 per annum. Again – no decisions should be based on this figure and it should be recalculated once considerably more water use figures become available.

8 OPPORTUNITIES

There are a number of opportunities for better water management for the town of Oranjemund. These include – first and foremost - monitoring of household water uses through installation of flow meters and levying tariffs to all water users. This will help to understand the available water resources after accounting for demand and to deter overuse of water resources through the payment of tariffs. This is an opportunity that is likely to be implemented from the beginning of January 2017.

There are also a number of opportunities to potentially improve water sustainability within the greater Oranjemund region. These could include a system of conjunctive surface- and groundwater usage, including developing groundwater aquifers for water supply to augment current supplies – but detailed studies into the sustainability of these resources is essential.

8.1 Alternative Potential Water Sources

As existing sources of water are under threat in the region, alternative sources of water will need to be investigated. Potential alternative water sources for Oranjemund could include desalination, greywater re-use, building of a small, covered reservoir and rainwater harvesting. Key to this way of thinking is to build awareness around water as a scarce resource.

8.1.1 Desalination

Although mines within the vicinity of Oranjemund use raw seawater for their operations, seawater desalination has been widely proposed in water forums and in the media in Namibia to supply potable water. The construction of a desalination plant at the coast could provide water to arid regions like Karas (see Figure 1-1), the central areas of Namibia and towns like Oranjemund in order to augment current supply.

Currently only Erongo Desalination Plant north of Wlotzkasbaken - approximately 690 km from Oranjemund - is in operation, which is wholly-owned by Areva Resources Namibia and operated by Aveng Water Treatment Namibia. The plant supplies NamWater with five million cubic metres (5 Mm^3) of water per year. The desalination plant is said to have relieved the burden of water supply in the Swakopmund region and has the ability to maintain a sustainable supply. During the period between November 2015 and February 2016, Areva provided subsidised water to the Swakopmund Municipality when demand was too high to be met during the holiday season (Hartman, 2016).

Desalination could potentially provide a sustainable, long-term option for water supply to augment the groundwater and surface water resources in Oranjemund, however the infrastructure development and maintenance expenditure of a desalination plant could hinder the realisation of this option. The following challenges are associated with desalination:

- It is very expensive as the power cost involved can be 70% of the cost;
- Filtering membranes are expensive; and
- Brine disposal can be problematic.

8.1.2 Greywater Reuse

Use of greywater at the household level for irrigation is an inexpensive and simple alternative that could be practiced to a greater extent in Oranjemund. Greywater is wastewater (used household water) collected from handbasins, showers, baths, washing machines and kitchen sinks, but excludes water collected from toilets (Randwater, 2016). As seen in the Oranjemund water balance in Section 5, based on the figures available, wastewater makes up 9382845 m^3/annum, all of which could be reused for irrigation. It appears a significant portion of this water is currently used for irrigating the Oranjemund golf course, green areas and trees lining the town. It should be noted, however, that a decrease in the volumes of water used by the residents of Oranjemund will lead to a decrease in the volumes of available greywater.

8.1.3 Rainwater Harvesting

Despite the fact that the rainfall in Oranjemund is very low, rainwater harvesting is a further option that should be investigated, as an effective system based on a large roof area can provide a significant additional amount of water from a few rain events that can be used for domestic purposes, irrigation and for livestock watering. Unlike desalination, this is a simple and inexpensive manner in which to obtain additional clean water. Rainwater harvesting involves capturing and containment of rainwater for reuse. Rainwater can be collected from roofs directed to storage tanks as can be seen in Figure 8-1. Rainwater harvesting can be practiced both at a small scale by individuals and at larger scales by industries, including mines (DWA n.d.). The Oranjemund Municipality could raise awareness within the community about rainwater harvesting in order to start implementing a water saving mentality.

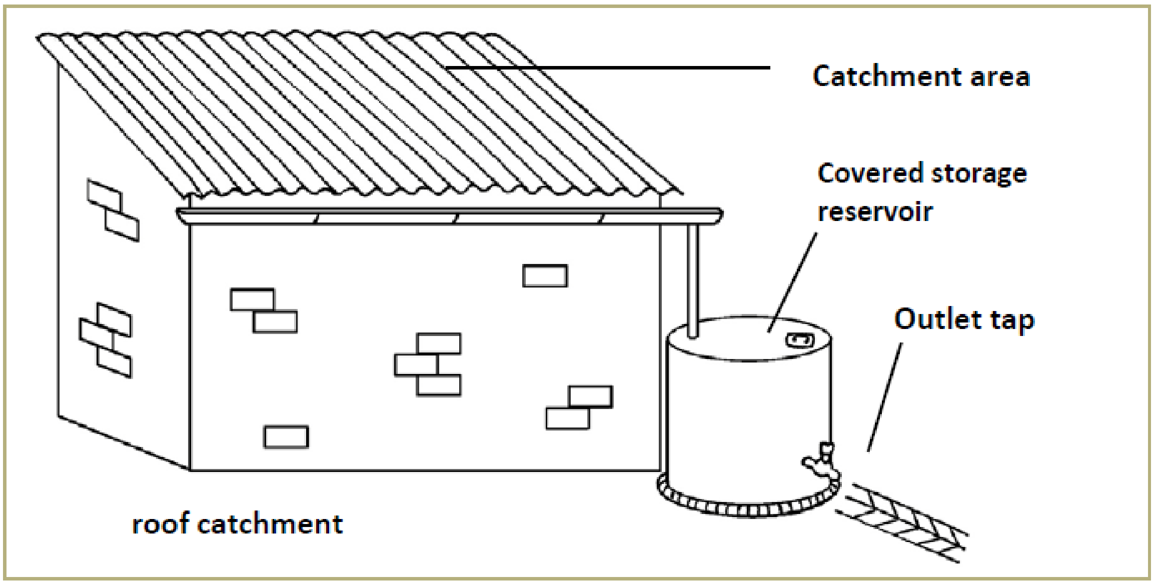


Figure 8-1 Illustration of a rainwater harvesting system

8.1.4 Building a Small Reservoir

Bearing in mind that the study area experiences low rainfall and very high evaporation conditions (see Section 4), investigation into the possibility of constructing a covered, off-channel water reservoir, or developing an existing one, if avaliable, could be undertaken.

8.1.5 Fog Harvesting

Fog harvesting was investigated as a potential water source but should not considered worthwhile at this point, owing to the small quantities collected. Fog harvesting feasibility was investigated at Gobabeb (Desert Research station in the Namib) in Namibia for a period of over 35 years. The findings were that during the wet 6 months (August – January) fog occurred on 45% of the days with an average yield of greater than 2 litres per day, while during the drier periods fog occurred on 15% of the days with average yield of less than 0.5 litres per day (Desert Research Foundation of Namibia, 1998).

9 WATER RESOURCE MANAGEMENT

This desktop assessment of the available surface and groundwater resources in the Oranjeumund region has led to the following water management and remedial action recommendations and subsequent, proposed management plan for the Oranjemund region.

9.1 Management Recommendations

9.1.1 Cross-industry water use planning

An Integrated Water Management Planning approach should be adopted for managing water resources in the Oranjemund area. This would encourage water use sectors to consider consumption by other users when calculating their water budgets, and lessen the likelihood of double accounting of water resources. This should take into consideration both surface and groundwater resources in the area since these resources are interconnected, as highlighted in Section 6, where the risks to surface water are clearly also risks to groundwater as the wellfields are largely fed by indirect recherge from the Orange River.

9.1.2 Strategic Planning

Oranjemund's water is currently sourced and managed by Namdeb. Startegically it would be preferable if Namwater controlled sourcing of the water from the Orange River alluvial wellfields and the municipality controlled distribution of the water to (what will soon be) ratepayers/households.

9.1.3 Remedial Actions

To get a clear picture of water demands, it is recommended that various sectors that use water within the area either undertake their own water balances or add to the water balance provided with this document, in order to quantify all inflows and outflows within the various water uses. The water balance studies should include flow meters at selected key points in order to accurately measure water flowing between process units. This would require monitoring and measurement of the water resources used, including potable water, industrial water, agricultural water and water for the mine, including all surface and groundwater abstractions.

Conjunctive (surface and groundwater) water quality monitoring should be undertaken at selected key points to detect incidences of water pollution before they get worse.

In order to preserve ecosystems within the Oranjemund Estuary, no development should occur within flood lines of specific return period such as the 1:50-year and 1:100-year flood events. These flood lines should be calculated.

Effective, legally-compliant stormwater management should also be prioritised, thus Storm Water Management Plans should be developed for mines and other institutions within the Oranjemund area in order to ensure the separation of clean and dirty water resources in the area.

9.1.4 An Alternative Approach

The residents of the town of Oranjemund should start to view water as the scarce and valuable resource that it is. A voluntary approach to demand management should be encouraged, using water educational measures to inform the water users in Oranjemund and surrounding areas of the importance of using water wisely. Further to this, planning around alternative supplies of water should be investigated, such as those in Section 8.

9.2 Management Plan

A management plan featuring short-, medium- and long-term strategies to sustain or prolong water supplies is described in this section. This essentially prioritises the aforementioned actions:

- Short-term strategies: The following should be undertaken:

(a) Water Balance calculations to quantify inflows and outflows within the municipality;

  - Installation of flow meters at selected key points identified during the water balance investigations to accurately determine an accurate water demand for various sectors within the municipality. The measured volumes should then be used to update a water balance.
  - The water balance should inform possible areas or sectors where water recycling or re-use can be implemented within and across sectors in the Oranjemund municipality.

(b) Storm Water Management Planning should be developed for the Oranjemund Landfill Site, mines and other development projects in the area;

- The Storm Water Management Plan should indicate the separation of clean and dirty runoff in order to minimise the chance of polluting freshwater resources.
- Containment of dirty water and effective disposal, recycling or re-use.

(c) Reparing leakages in water pipes and taps to ensure minimal water transmission losses.

- Medium-term strategies:

(a) Aquifer yield and groundwater exploration investigations should be undertaken in order to determine the possibility of further development of groundwater resources in the area.

- Water supply borehole sinking should be undertaken, guided by the yield and exploration findings.
- Conjunctive water use options should be explored where recharge of aquifers can be conducted during the rainy season for use during the dry season.

(b) Bearing in mind that the study area experiences low rainfall and very high evaporation conditions (see Section 4), investigation into the possibility of constructing a covered off-channel water reservoir, or developing an existing one, if avaliable, could be undertaken.

- This reservoir placed at a determined suitable location for water storage can be used by various sectors of the Oranjemund municipality at controlled supply conditions and tarrifs.

- Long-term strategies:

(a) Water quality monitoring

Monitoring should be undertaken at key points related to the landfill site, pollution control dams and at stormwater discharge points in order to identify pollution sources and address these before widespread contamination of freshwater resources occurs. The discharge points will be identified by comprehension storm water management plans which are one of the recommended management measures discussed.

(b) Paradigm-shift

Education around ways in which to view and save water, as well as the use of alternative sources of water, should be encouraged.

(c) Strategic Control of Resources

Control of water resources should be handed from Namdeb to Namwater (from the source) and the municipality (distribution to households).

10 CONCLUSIONS

10.1 Managing the now (what now)

10.1.1 General findings

Namibia is a signatory to a number of progressive pieces of legislation and frameworks centred on protection of the natural environment and the responsible use of water resources. According to the Namibian constitution, all water in Namibia belongs to the State, which regulates and permits its use. Namibia's legislation of water resource management provides for the management, protection, development, use and conservation of water resources; to provide for the regulation and monitoring of water services and to provide for incidental matters. The Namibia Water Corporation Act was mandated with establishing the Namibia Water Corporation (NamWater), which has taken over the bulk water supply function of the DWA. The Local Authorities (LAs) Act spells out the functions and duties of LAs in rendering water supply and wastewater disposal services. In the case of Oranjemund, however, water is supplied directly to the Town and Mine by Namdeb. This direct supply has lead to current water use for the Oranjemund Town and the Mine being unaccounted-for as water use in the area is unmetered. The use and demand quantities for the area are thus largely undocumented (NACOMA, 2015). This lack of water management and accountability is in direct contravention of the vision behind the legislation and frameworks to which Namibia is a signatory. Having said this, The Namibian Government Gazette No. 5533 states that water tariffs should have been implemented from July 2015 (Namibia, 2014), and, according to a resident of Oranjemund (Jason Ndipwashimwe, pers comm, 9 September 2016), water tariffs have not yet been implemented as the system is still being rolled-out, but that, according to a Namdeb representative (Jack Wasserfall, pers comm, 26 September 2016), water meters have already been installed and trial runs of the tariff system will be undertaken by the end of October 2016 to ensure that the system functions without unforseen difficulties, which will likely be in January 2017.

Oranjemund lies in a hot, dry area, making responsible water management even more important. According to reports compiled by the Namibian Department of Water Affairs, Namdeb Mine and Town together use between 6.57 million m^3 (DWAF, 2006) and 6.85 million m^3 of water (DWA n.d.) per annum, originating largely from boreholes tapping from the Orange River Alluvium Aquifer, while the remainder is abstracted directly from the Orange River. Groundwater for Oranjemund Town is abstracted from this well system (DWS, 2016) but otherwise

Surface and groundwater quality in the vicinity of Oranjemund is currently very good, but sources report that it may be deteriorating. According to Koch *et al*. (2011), the apparent abundance of water in the Orange River is misleading, since both the water quantity and quality are declining. Having said this, a desktop-based Ecological Reserve determination study concluded that the Ecological Reserve for the Orange River Estuary classifies as Ecological Category D+, which is described as a largely modified area (Taljaard *et al.*, 2005).

The water balance calculated based on limited measured abstraction and water supply data indicates that a considerable amount of water (482172 m^3/annum) is lost within the town generally. A total of 53630 m^3/annum constitutes wastewater, which is largely re-used to irrigate lawns in public parks, the golf course and trees lining the boundary of the Oranjemund Town. This wastewater volume was calculated as a residual of measured Sewage Treatment Plant inflows and the system's retention or storage. The total volume of water in circulation within the Oranjemund Town and Mine is approximately in the order of 5477195 m^3 per annum.

10.1.2 Specific findings

What	Why	How	Where	Implementation considerations (high level)	Dependencies	Sample Case Study (if applicable)
482 172 m^3/annum of freshwater is lost	Unmetered fresh water use	Through wasteful general usage	Oranjemund Town in general	Metering of Oranjemund's water usage	Legislation, good governance	
53630 m^3/ annum of wastewater re-used to a limited scale	Limited re-use of greywater. Possibly due to limited re-use plans or policies implemented	Through ignorance of water scarcity or just wasteful usage	Throughout Oranjemund	Further development of greywater reuse policy and plan implementation	Legislation, public awareness	

10.2 Creating the future (what if)

10.2.1 General findings

Without measuring and modelling surface and groundwater flows for the region, volumes of water availability going forward cannot be given, but an indication of the likely risks under five scenarios was given within this study.

The lower Orange sub-basin has been identified as an area where anticipated climate change impacts - including excessive evaporation - are likely to have wide-ranging water resource management implications (Schulze *et al.*, 2005) (NACOMA, 2015). This will reduce runoff and the subsequent amount of water reaching the Lower Orange River basin over time (NACOMA, 2015).

Water use upstream of Oranjemund is increasing and is likely to continue to increase, leaving less water available for Oranjemund (DWA, n.d). There is a high possibility that boreholes currently being used will not recharge in the future as much as they have in the past, due to decreasing flows already being observed in The Orange River (van der Merwe *et al.*, 2006), and this lower flow has been attributed to the infrastructure along the Orange River – largely upstream in South Africa and Lesotho (DWA n.d.) and upstream water demands from the Orange River will likely increase as a result of growing demand in Namibia, South Africa and Lesotho (NACOMA, 2015).

As Namibia is a signatory to a number of progressive pieces of environmental legislation and Oranjemund both falls within the protected Tsau // Khaeb area and is a dry mining town whose current water resources are under threat, it is likely – and advisable – that water will be metered, charged-for and limited in the future, as stated in the Namibian Government Gazette No. 5533. This will severely change water use practices; as previously mentioned the IWRM Plan Joint Venture Namibia (2010) states that the practice of not paying for water by the residents of Oranjemund has led to significant figures of water consumption of up to 16m^3 per household per day and that this quantity of water represents a significant proportion of the 40-50 Mm^3/annum initial entitlement of water from the Orange River for Namibia (IWRM Plan Joint Venture Namibia, 2010). Koch *et al.* (2011) states that both the water quantity and quality of the Orange River in the Oranjemund region are declining and that the main threats to the water resource are high water demands by mines and the risk of pollution from mines and agricultural activities.

It is likely that climatic changes will lead to more erractic weather patterns and higher evaporation rates, that development upstream of Oranjemund will continue to increase and that water use in Oranjemund will be metered and charged-for going forward. Cumulatively this scenario will put significant pressure on Oranjemund but the implementation of water tariffs will help to curb wasteful water use.

While it is impossible to calculate this figure with any degree of accuracy based on this desktop-based study, it is estimated that, should the current freshwater supply remain stagnant, Oranjemund could run out of fresh water by 2050. This is purely based on the assumption that population growth rate will remain as it has for the past 14 years and that this is driving increased demand, not mining. Based on the current demand (mining-and town-related uses only) as a function of population growth, holding other variables constant including supply, the population growth factor (which becomes the water demand factor) was determined to be 0.4. Through a trial and error approach it was determined that, at the current supply level, the available freshwater resources would last for 34 years without being depleted. The 35th year would result in a freshwater deficit of 6976 m^3 per annum. Again – no decisions should be based on this figure and it should be recalculated once considerably more water use figures become available (and are measured).

WATER RESOURCE MANAGEMENT

An Integrated Water Management Planning approach should be adopted for managing water resources in the Oranjemund area. This would encourage water use sectors to consider consumption by other users when calculating their water budgets, and lessen the likelihood of double accounting of water resources. This should take into consideration both surface and groundwater resources in the area since these resources are interconnected, as highlighted in Section 6, where the risks to surface water are clearly also risks to groundwater as the wellfields are largely fed by laterwater movement of water from the Orange River.

To get a clear picture of water demands, it is recommended that various sectors that use water within the area either undertake their own water balances or add to the water balance provided with this document, in order to quantify all inflows and outflows within the various water uses. The water balance studies should include flow meters at selected key points in order to accurately measure water flowing between process units. This would require monitoring and measurement of the water resources used, including potable water, industrial water, agricultural water and water for the mine, including all surface and groundwater abstractions.

Conjunctive (surface and groundwater) water quality monitoring should be undertaken at selected key points to detect incidences of water pollution before they get worse.

In order to preserve ecosystems within the Oranjemund Estuary, no development should occur within flood lines of specific return period such as the 1:50-year and 1:100-year flood events. These flood lines should be calculated.

Effective, legally-compliant stormwater management should also be prioritised, thus Storm Water Management Plans should be developed for mines and other institutions within the Oranjemund area in order to ensure the separation of clean and dirty water resources in the area.

The residents of the town of Oranjemund should start to view water as the scarce and valuable resource that it is. A voluntary approach to demand management should be encouraged, using water educational measures to inform the water users in Oranjemund and surrounding areas of the importance of using water wisely. Further to this, planning around alternative supplies of water should be encouraged.

10.2.2 Specific findings

What	Why	How	Where	Implementation considerations (high level)	Dependencies	Sample Case Study (if applicable)
Strategy 1: Integrated Water Resource Management Approach	To accurately account for water usage in order to use it more sustainably	Development of a Catchment Management Agency or water use forum	Oranjemund and surrounds	The area's Flood lines, water balance, storm water management planning, conjunctive use strategies	Namdeb Mine, industries, agriculture and residences providing accurate information	
Strategy 2: Water Use Education	To create a culture of responsible, sustainable water usage	Educational programmes and policy	Oranjemund and surrounds	Inclusion of individuals, industry, agriculture and the mine	Buy-in from individuals, industry, agriculture and the mine Policy documents	

10.3 KEY RISKS

Oranjemund faces many water-related risks. The water quality of the surface water is both intrinsically linked to that of the groundwater and declining, making this a threat to groundwater resources. The boreholes used to supply Oranjemund are also vulnerable to salt water intrusion due to their proximity to the coast and the inflow of salt water back up the Orange River (DWA n.d.). There is a high possibility that the boreholes will not recharge in the future as much as they have in the past due to decreasing flows observed in The Orange River (DWA n.d.). This lower flow has been attributed to the infrastructure along the Orange River upstream in South Africa and Lesotho (DWA n.d.).

Risks associated with surface water resources in the Oranjemund Region include variable, low rainfall, very high evaporation, occurrence of flash floods and droughts (NAMWATER, 2013). There is a lack of reliable, updated runoff records for the Oranjemund area as well as a lack of measured abstractions or water use demands. This comes with the threat of unsustainable overuse of the resource. The Oranjemund Town also experiences challenges in the form of a lack of expertise, data and incentives to enforce tariffs to water users within its jurisdiction. The threat of a shortage of freshwater to the town during the summer months further exists (Namdeb, 2003) and pollution from existing and planned landfill sites in the Oranjemund Town and mine is a further potenital threat to water resources in the region (Namdeb, 2016).

The lower Orange sub-basin has been identified as an area where anticipated climate change impacts including excessive evaporation are likely to have wide-ranging water resource management implications (NACOMA, 2015). Upstream water demands from the Orange River will likely increase as a result of growing demand in South Africa and Lesotho. The increasing upstream water demands, coupled with excessive evaporation due to climate change will reduce runoff and the subsequent amount of water reaching the Lower Orange River basin over time (NACOMA, 2015). The aquifers which are recharged by the Orange River will have their water tables lowered and the combination of sea level rise and lowered water tables will likely trigger salt water intrusions. These aquifers would no longer be able to supply fresh water, potentially requiring additional investment in desalination (NACOMA, 2015). Rising seas and increasingly intense high water events will place added stress on the sea walls established by Namdeb, which, if they are breached, will move the current coastline closer towards its natural position (approximately 1.7km from the town) (NACOMA, 2015).

A high-level risk assessment was undertaken based on data obtained from the WWF Water Risk Filter website and based on 20 risk indicators (WWF, 2016). The following were deemed to be high risk; sea level rise, drought, freshwater biodiversity, government strategy, establishment of a Catchment Management Agency and the cultural or religious importance of local water resources. These risks agree well with those found elsewhere in the literature.

From the findings of the risk assessment, these risks can generally be split into administrative, policy and management related risks, and into climate and nature-related risks. In the case of the latter, some of the risks cannot be controlled such as sea level rise and drought occurrence. These are processes that cannot be mitigated against at a local or regional scale.

One of the key administrative risks is managing the water resources in and around Oranjemund without a dedicated Catchment Management Agency (CMA). A CMA typically ensures that the mandate of water resource management agents is implemented, and the function of the CMA should be regularly monitored. Those tasked with implementing the CMA policies would need to implement regular monitoring of ecological functions in the Orange River and ensure that the Ecological Reserve is maintained as far as possible.

10.4 KEY FINDINGS

The key findings of the study centre on the fact that freshwater resources supplied to households in Oranjemund are currently unmetered and thus used wastefully, although plans are in place for this to be rectified commencing in January 2017.

Namibia is a signatory to many, progressive pieces of water legislation and frameworks centred on responsible use of environmental resources, yet freshwater is used wastefully in Oranjemund.

Aside from a limited volume of borehole water used to supplement supplies when necessary, Oranjemund's water is derived from a wellfield fed via seepage directly from the Orange River, or directly from The River, making it's surface and groundwater resources one and the same.

Information pertaining to volumes of household water use in Orangrmund is not readily available, making water use management very difficult and measurement essential.

The available water quantities in the Orange River are decreasing and the qualities deteriorating, making sustainable water management essential.

10.5 KEY OPPORTUNITIES

There are many opportunities for better water management for the town of Oranjemund. These include – first and foremost - monitoring of water uses through installation of flow meters and levying tariffs to all household water users. This will help to understand the available water resource after accounting for demand and to deter overuse of water resources through the payment of tariffs.

There are also a number of opportunities to potentially improve water sustainability within the greater Oranjemund region. These could include a system of conjunctive surface- and groundwater usage, including developing groundwater aquifers for water supply to augment current supplies – but detailed studies into the sustainability of these resources is essential.

As existing sources of water are under threat in the region, alternative sources of water will need to be investigated. Potential alternative water sources for Oranjemund could include desalination, more greywater re-use and rainwater harvesting. Although desalination is a possible water supply alternative, it is expensive.

The seawater interface should be monitored to ensure that any salt water intrusion is detected and corrected in time.

Key to this way of thinking is to build awareness around water as a scarce resource so that residence and all water users use the resource sustainably.

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12 APPENDICES

Appendix A.1 High-level Orange River Basin Water Footprint

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average(m^3/s)	Average (m^3/annum)
Natural Runoff (m^3/s)	693.4	866.2	838.6	541	301.3	188.9	127.9	119.4	120.3	135.3	206.3	330.1	372	11582499744
Blue Water Availability (m^3/s)	138.7	173.2	167.7	108.2	60.26	37.77	25.58	23.9	24.04	27.07	41.28	66.01	74	2316542976
Blue Water Footprint (m^3/s)	5.6	86.1	89.7	66.9	31.1	37.8	47.6	73.0	92.1	87.7	55.7	41.2	60	1852624224