CHAPTER 3

Supplementary Material: Specialist Report

Aquatic report

Main Consultant
CSIR

STRATEGIC ENVIRONMENTAL ASSESSMENT FOR THE PROPOSED BOEGOEBAAI PORT AND STRATEGIC ECONOMIC ZONE, NORTHERN CAPE, SOUTH AFRICA

WORK PACKAGE 1:

AQUATIC ECOSYSTEMS ASSESSMENT:

INLAND AQUATIC ECOSYSTEMS AND ESTUARIES

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Executive Summary

E1 Introduction

As part of South Africa's ambition to become a player in the globally emerging green hydrogen (GH_2) market, a substantial programme of greenfield infrastructure has been proposed in the Northern Cape consisting of three main components:

1. A new deepwater port at Boegoebaai, dry and liquid bulk berths, and multi-purpose terminals;
2. A mixed-use Special Economic Zone (SEZ) located in the region adjacent to the proposed Boegoebaai port; and
3. Expansive regional renewable energy (wind and solar PV) generation and transmission infrastructure.

The production of GH_2 at the scale envisaged could have multiple direct and indirect impacts, including on local economies, infrastructure, communities and natural ecosystems and resources. In order to consider these potential impacts, the Council for Scientific and Industrial Research (CSIR) has been appointed to undertake an independent Strategic Environmental Assessment (SEA). The overarching purpose of the SEA is to develop an integrated decision-making framework to guide the planning of the proposed Boegoebaai Port, Special Economic Zone, and wider Namakwa region in a sustainable manner (Schreiner *et al*. 2024).

The present report was commissioned to provide specialist assessment of the potential impacts of the proposed Boegoebaai Port and SEZ (termed Work Package 1) for aquatic ecosystems, namely **inland aquatic ecosystems** and **estuaries**.

E2 Study approach

The findings of this report were based mainly on desktop review of available literature and spatial mapping products, with limited time for ground-truthing / calibration of mapped wetland areas. Information gaps were identified, including the need for high-confidence investigation of surface / groundwater linkages driving the larger pan and associated wetland function and structure in the Visagiespan, Rietfontein and Rietfonteinpan systems; the need for identification and mapping of key temporary pan habitat in rocky outcrops; and the need for wet-season assessment of ephemeral wetland invertebrate faunal communities. These information gaps would need to be filled, in the event that the proposed development was considered in more detail, as part of an Environmental Impact Assessment and/or water use licence application.

E3 Summary of aquatic ecosystems assessed on and associated with the study area

The report provides an overview of inland and estuarine aquatic ecosystems on and in the vicinity of the proposed Boegoebaai Port and SEZ areas, highlighting their importance and sensitivity to various development-related aspects.

E3.1 Inland aquatic ecosystems

Overall, the assessment showed that the study area is not rich in inland aquatic ecosystems. However, given the aridity of the area, those ecosystems that do occur are likely to be of very high importance from a terrestrial faunal perspective (see Niemandt 2025), and the ephemeral pans in this area are assumed to support interesting and rare aquatic invertebrate communities, including crustacean zooplankton fauna, with potentially high levels of regional endemism. The larger pans (Visagiespan, Rietfontein and

Rietfonteinpan (BB1, BB2 and BB3 in Figure E1)) in particular afford substantial wetland and pan habitat, with (unquantified) links to primary and/or secondary aquifers, which form springs in at least Visagiespan, creating permanent standing water pools. These are clearly utilised by terrestrial fauna, either directly (as a brackish to saline water source) or indirectly, for grazing of wetland plants that are supported by perennial water supply in places. Other inland aquatic ecosystems of assumed high biodiversity importance include ephemeral pans located in rocky outcrops across the site, some of which are likely to support communities of invertebrates adapted to ephemeral conditions and with high conservation importance. These systems have however been mapped in this study with low confidence.

All of the inland aquatic ecosystems mapped are classified as **depressions** in the National Wetland Map (Version 5) of the 2018 National Biodiversity Assessment (NBA) (Van Deventer et al. 2018). The larger pans include wetland habitat and belong to the Namaqualand Sandveld Bioregion. Within this bioregion, depressions have been rated as Critically Endangered with a protection status of Not Protected.

E3.2 Estuarine ecosystems

There are no estuaries in the study area. However, two estuarine systems lie in close proximity to the study area, and could potentially be affected by impacts associated with the proposed development. These comprise the Orange River Estuary to the north of the study area and the Holgat River Estuary, immediately to the south.

E3.2.1 The Orange River Estuary

The Orange River Estuary flows into the sea between the coastal towns of Alexander Bay (South Africa) and Oranjemund (Namibia). The estuary covers an area of about 2700 ha, and comprises an (almost) permanently open river mouth; a 2 to 3 m deep tidal basin; a braided channel system (located between sand banks covered with pioneer vegetation); and a severely degraded saltmarsh on the south bank of the river mouth (DWS 2017a). It is a rare and unusual wetland type on the arid and semi-arid coastline of southern Africa, deriving its flows from a large catchment that begins in the Lesotho Highlands in Lesotho, some 2432 km upstream of Alexander Bay.

The estuary is important at both a national and international level, having been accorded Ramsar Wetland status and being one of only two estuaries on the Namibian coast. The condition of the Orange River Estuary does however fall well short of its Recommended Ecological Category, requiring active interventions to improve estuarine condition. This is important, because new developments, such as that proposed, that further threaten its condition, directly or indirectly, would have direct negative implications for meeting the estuary's Resource Quality Objectives.

E3.2.1 The Holgat River Estuary

The Holgat River enters the sea just south of the study area. The outlet has been highly modified by mining operations. The system is ephemeral, with river flows rarely passing into the estuarine area, which is classified as a micro-outlet, signifying its small and highly ephemeral character.

Figure E1 illustrates the inland aquatic ecosystems identified within the study area, while **Figure E2** presents the results of sensitivity mapping of inland and estuarine aquatic ecosystems associated with the study area, with specific regard to sensitivity to the kinds of impacts likely to be associated with the proposed development.

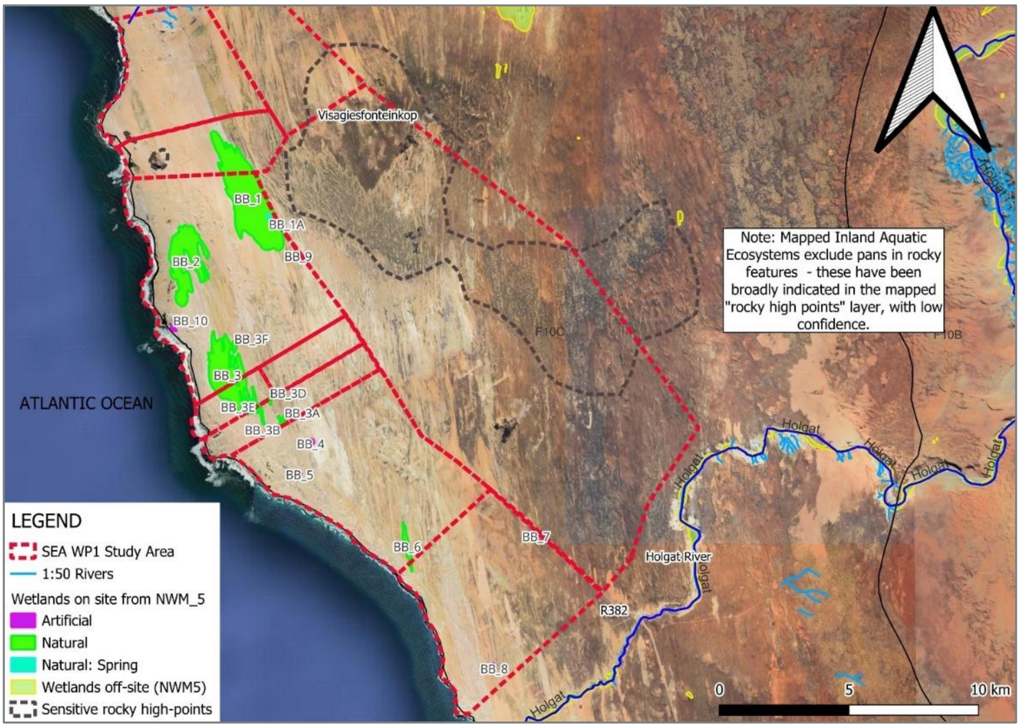

Figure E1

Coded, mostly ground-truthed inland watercourses in the study area, with extent based on that indicated in NWM Ver 5 (Van Deventer et al. 2018). Rocky high points mapped at desktop level with low confidence – the faunal specialist sensitivity layer should be prioritised for these areas.

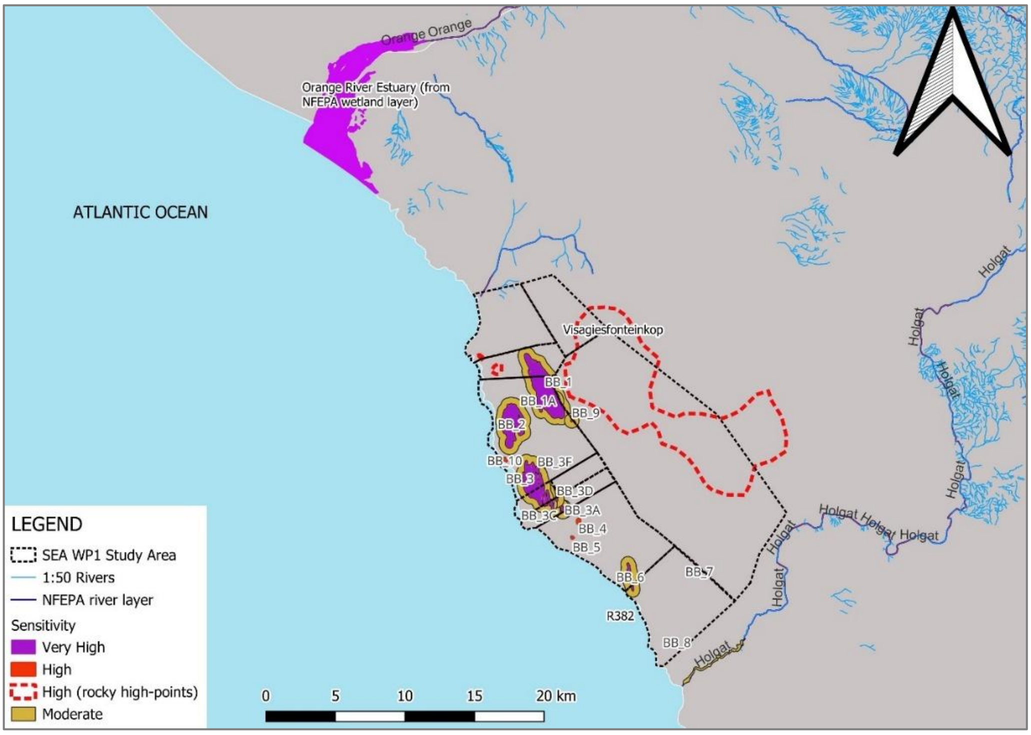

Figure E2

Inland and estuarine aquatic ecosystems sensitivity of the proposed Boegoebaai Port and SEZ study area. The figure includes recommended protective setbacks or buffer areas of 50 m and 500 m hydrological buffers, intended to protect recharge function, in the absence of more detailed information. Sensitivity assessments have been applied only to the watercourses on and immediately abutting the site. Grey areas have been rated as of Low sensitivity to the present proposed project

E4 Main Report findings

The proposed development would, in the conceptual layout presented for assessment in this study, result in potential loss of all of the inland aquatic ecosystems identified in the study area. Of these, natural pans and depression wetlands have been rated as Critically Endangered systems in the 2018 NBA (Van Deventer et al. 2018). The report thus recommends changes in development layout that could avoid these systems. It furthermore recommends the inclusion of ecological corridors that link between ecologically important terrestrial, coastal and (inland) aquatic areas across the site. Mitigation measures also include addressing potential impacts associated with concentrated stormwater flows through areas characterised by increasingly hardened surfaces, which could bypass dependent aquatic ecosystems.

Indirect impacts to the Orange River Estuary have also been flagged as potentially associated with the proposed development. The report recommends that, if the development were to be approved, it would need to allow (specifically) for increased human and financial resources at the Orange River Estuary, to control and police fishing, hunting and vehicle access and movement within the estuary, including its important saltmarshes. In addition, it would need to match any provision of fresh water from desalination plants to the Alexander Bay or other communities / urban areas with an equal increase in infrastructure and human resources capacity to treat the additional resultant waste water that would be generated from these areas, to a level that would not impact negatively on any receiving watercourse, and the Orange River Estuary in particular. This might mean far more stringent water quality treatment requirements than would normally be required.

Other required measures to address indirect impacts associated with expansion of urban areas as a result of the proposed development include the need for upgrading of solid waste management and attention to the design of new and/or upgraded external access roads, such that they do not result in downstream erosion or blockages of flows in flood conditions.

Finally, the report highlighted a number of information gaps that would need to be addressed if the proposed project is considered further and taken into Environmental Impact Assessment and/or Water Use License Application phases. These include detailed studies to unpack surface / groundwater interactions at the major pan / spring/ wetland areas (BB1, BB2 and BB3); wet-season assessment of ephemeral wetland invertebrate faunal communities; development of detailed stormwater management plans that take cognisance of the sensitivity of inland and estuarine aquatic ecosystems on and near the site; and details as to measures that can address the impact avoidance, mitigation and management measures outlined in the report.

The report concluded with a note that that there are no positive impacts to inland or estuarine aquatic ecosystems that would be associated with the proposed Boegoebaai Port and SEZ development, and substantial negative impacts could accrue, unless stringently addressed in development layout (avoidance), design and management.

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1 INTRODUCTION

1.1 Background

Green hydrogen (GH_2), and its derivative products (e.g. green ammonia and green methanol) potentially provide an opportunity to decarbonise the South African energy economy, generate new revenues, create jobs and skills and facilitate a Just Energy Transition (Schreiner *et al*. 2024). As part of South Africa's ambition to become a player in the globally emerging green hydrogen market, a substantial programme of greenfield infrastructure has been proposed in the Northern Cape consisting of three main components:

1. A new deepwater port at Boegoebaai, dry and liquid bulk berths, and multi-purpose terminals;
2. A mixed-use Special Economic Zone (SEZ) located in the region adjacent to the proposed Boegoebaai port; and
3. Expansive regional renewable energy (wind and solar PV) generation and transmission infrastructure.

The production of GH_2 at the scale envisaged could have multiple direct and indirect impacts, including on local economies, infrastructure, communities and natural ecosystems and resources. In order to consider these potential impacts, the Council for Scientific and Industrial Research (CSIR) has been appointed to undertake an independent Strategic Environmental Assessment (SEA). The overarching purpose of the SEA is to develop an integrated decision-making framework to guide the planning of the proposed Boegoebaai Port, Special Economic Zone, and wider Namakwa region in a sustainable manner (Schreiner *et al*. 2024) (see **Figure 1.1**).

The SEA has two outputs:

1. **Boegoebaai Port and Special Economic Zone (Work Package 1):** Local-scale SEA report concerned with assessing the sensitivities of the receiving environment around the proposed port and Special Economic Zone.
2. **Namakwa Region (Work Package 2):** Regional-scale SEA report covering the main sustainability issues associated with an expansive Northern Cape Green Hydrogen economy covering parts of the Namakwa District, delineated by the Richtersveld, Nama Khoi, Kamiesberg and Khâi Ma Local Municipalities.

The present report falls under Work Package 1, and comprises a specialist assessment of the potential impacts of the proposed Boegoebaai Port and SEZ for aquatic ecosystems, including inland aquatic ecosystems and estuaries.

1.2 Terms of reference

The aquatic ecosystems assessment (estuaries and inland aquatic ecosystems) is primarily a desktop study, supplemented by limited time on site, intended to calibrate desk-top mapping and obtain a broad understanding of the types of aquatic systems that occur on the site. The report is intended to:

- Describe the key characteristics of aquatic ecosystems in the study area and their conservation and other importance; landscape connectivity and links to important terrestrial ecosystems; links to groundwater;
- Describe the land-use dynamics and change trends of the receiving environment and broader region as it relates to aquatic ecosystems;
- Describe the local receiving environment per SEZ subzone (where relevant);
- Define and identify areas of high, medium and low sensitivity, to inform site development plans;
- Complete an aspects / impacts register for each impact identified;
- Recommend strategic management actions to enhance positive impacts and reduce negative ones; guide future Port / SEZ planning and layout; and guide future site and project-specific Environmental Impact Assessments in the study area.

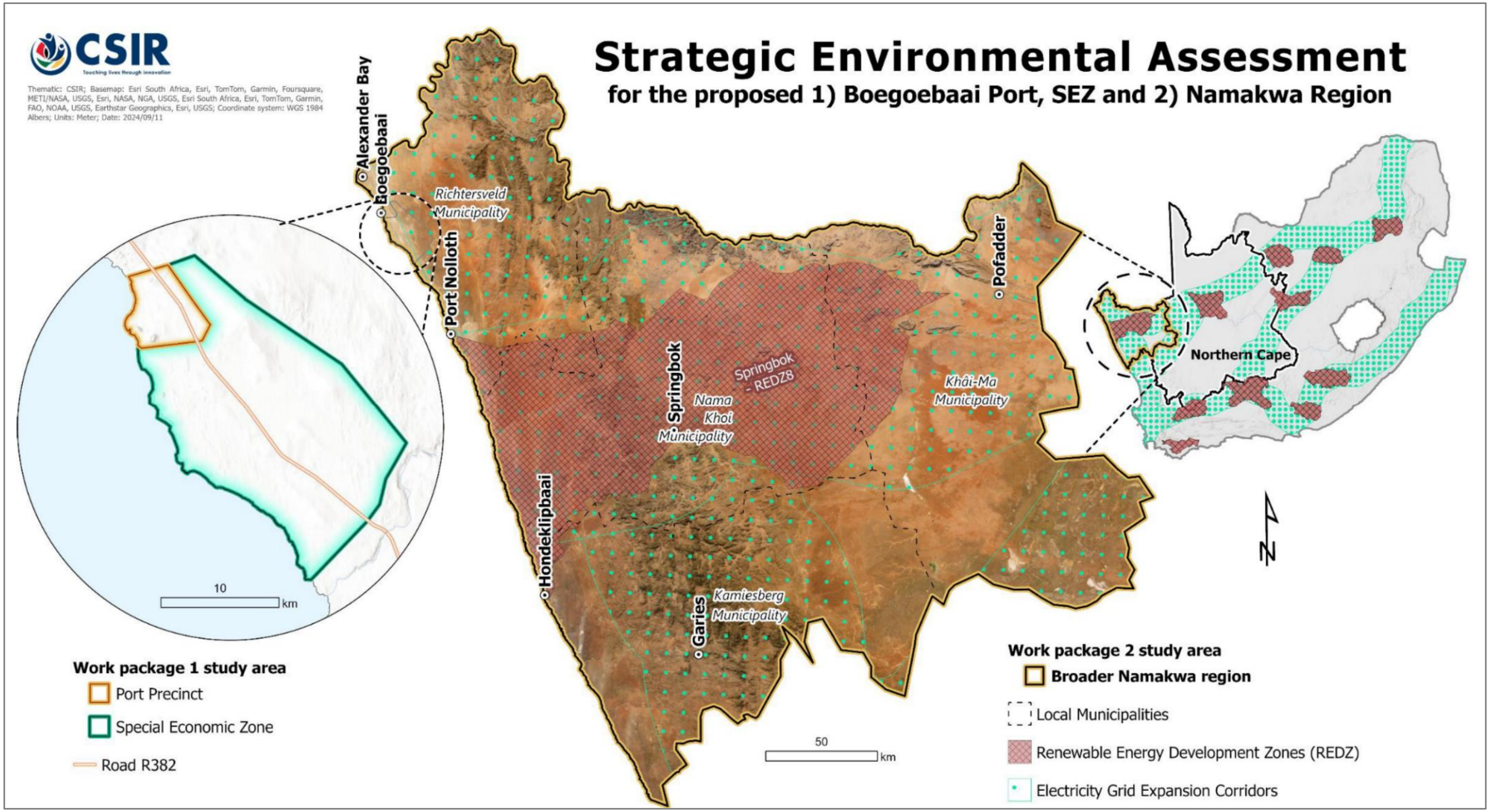

Figure 1.1
Spatial extent of the two work packages included in the GH_2 SEA (Figure after Schreiner *et al*. (2024).

1.3 Report informants

This assessment was informed by the following inputs and datasets:

- Spatial data:
    - National Freshwater Ecosystems Priority Area (NFEPA) project (Driver et al. 2011)
    - National Wetland Map (NWM Ver 5) (Van Deventer et al. 2018)
    - National Biodiversity Assessment (NBA) for aquatic ecosystem data (Van Deventer et al. 2018)
    - National 1:50 000 rivers and topographical GIS layers
    - National Strategic Surface and Groundwater Resources data
    - Ecoregion data
    - Bioregion and National Threat Status data (from the NWM dataset)
    - National Vegetation layer
    - The Northern Cape biodiversity spatial plan, including aquatic ecosystems
    - Boegoebaai disturbed and windblown sand layer (provided by CSIR)
- Relevant reports including (but not limited to):
    - Outputs from the (ongoing) Lower Orange River Classification and Resource Quality Objectives (RQOs)study
    - Geohydrological Impact Assessment for Alexkor Diamond Mine (Mavurayi 2014)
    - Surface water assessment (Hattingh 2016)
    - Ecological Water Requirement reporting for the lower Orange River (DWS 2017);
- A site visit (14-15th December 2023), during which watercourses highlighted during project ground-truthing were visited and a single water quality sample from a small spring within the study area was sampled and analysed for basic water quality parameters at BEMLAB laboratory in Somerset West.

1.4 Assumptions and limitations

- This report is primarily a broad-based desktop assessment, based on existing mapped data and available reports – no new biophysical data were collected as part of this study, other than once-off water quality data, of limited value.

- The assessment has relied on existing watercourse and estuary maps, included in the NFEPA and NWM Ver 5 datasets. These data are useful to inform broad conservation planning, but have not been ground-truthed sufficiently for high-confidence information of environmental impact assessments and for detailed development planning. This is a significant limitation in this assessment – the mapped extent of watercourses in the above datasets is not necessarily accurate.

- Although the current extent of most watercourses is discernible from aerial imagery, floodplain extent for major storm events is unknown.

- This report was not informed by a project-specific geohydrological report, which would have added considerably to the confidence with which surface/groundwater interactions were reported. Available geohydrological reports on the broader Alexkor Mining area (e.g. Mavurayi 2014) did not comment in any detail on groundwater interactions with any of the wetlands and/or springs within the current study area, making assessment of their hydrological drivers difficult and with low confidence.

1.5 Definitions

All reference to wetlands and watercourses in this document are based on the following definitions, taken from the National Water Act (NWA) (Act 36 of 1998):

“**watercourse**" means -

(a) a river or spring;

(b) a natural channel in which water flows regularly or intermittently;

(c) a wetland, lake or dam into which, or from which, water flows; and

(d) any collection of water which the Minister may, by notice in the Gazette, declare to be watercourse, and a reference to a watercourse includes, where relevant, its bed and banks;

“**wetland"** means -

land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

Government Notice (GN) 4167 of December 2023 furthermore defines:

“**Extent of a watercourse**” as:

(a) The outer edge of the 1 in 100 year flood line and/or delineated riparian habitat, whichever is the greatest distance, measured from the middle of the watercourse of a river, spring, natural channel, lake or dam; and

(b) Wetlands and pans: the delineated boundary (outer temporary zone) of any wetland or pan.

The National Environmental Management: Integrated Coastal Management Act, 2008 (as amended: 2015) defines an **estuary** as follows:

“estuary” means a body of surface water—

(a) that is permanently or periodically open to the sea;

(b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or

(c) in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water;

Aquatic ecosystems are defined in Ollis et al. (2013)’s National Classification System for wetlands and other aquatic ecosystems as including

- Inland systems (i.e. watercourses (as defined above) comprising rivers, wetlands, springs and pans
- Estuarine systems (as defined above); and
- Marine systems.

This report is concerned only with Inland and Estuarine aquatic ecosystems.

1.6 Study area location and extent

Figure 1.2 shows the location and extent of the area considered in this report (Work Package 1). The area includes a 33 500 ha area of land, comprising 3 378 ha for the proposed port and 30 122 ha for the proposed SEZ. The area is located some 14.75 km south of the small mining town of Alexander Bay, on the northern boundary of South Africa with Namibia. It is accessible off the R382 road to Alexander Bay, and via the Alexkor Mine, the entrance to which is located on the southern outskirts of Alexander Bay. The southern boundary of the site lies approximately 37 km north of the seaside town of Port Nolloth.

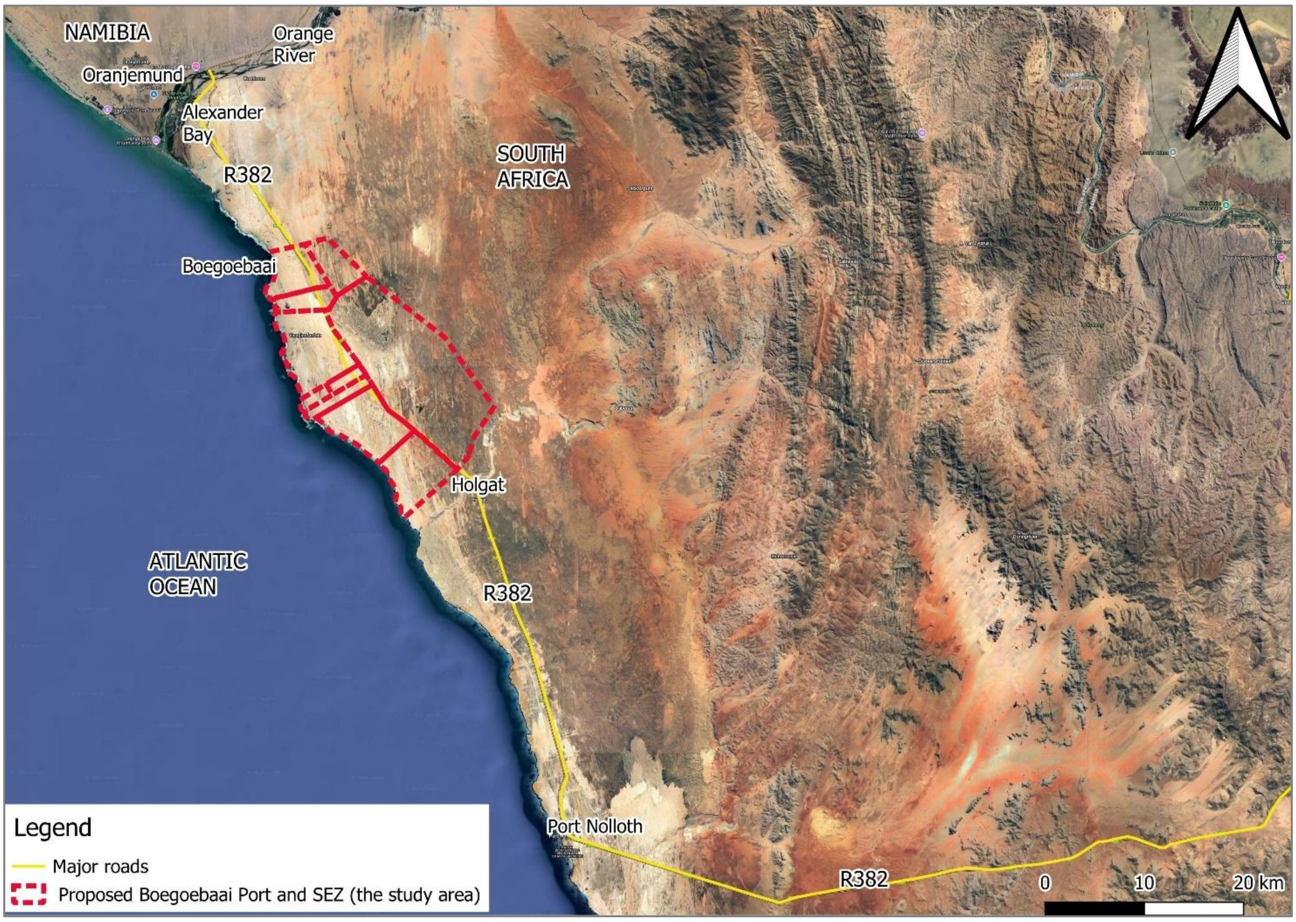

Figure 1-2
Study area for Work Package 1 of the Boegoebaai SEA.

2. DESCRIPTION OF THE RECEIVING ENVIRONMENT (INLAND AQUATIC ECOSYSTEMS AND ESTUARIES)

2.1 Overview

The study area is edged by a long rocky coastline, with large expanses of the inland areas having been disturbed by mining and other activities. Two rivers pass into the sea to the north and south of the site respectively, namely the Orange River, which enters the sea via its extensive estuary on the northern outskirts of Alexander Bay, and the ephemeral Holgat River, which opens into the sea some 2 km south of the boundary of the study area. Other drainage lines and watercourses within the study area peter out and dissipate into the sands, with no surface outlets into the sea. These are described in more detail in Section 2.11.

2.2 Climate

Climate is a major driver of inland aquatic ecosystems, and since freshwater flows are one of the key drivers of estuarine ecosystem function (Cadman 2016), climate is also an important consideration in estuarine assessment.

2.2.1 Rainfall

PRDW (2015) cites South African Weather Service (SAWS) data for Alexander Bay (noted as the driest station in South Africa at the time), with a mean annual rainfall of 46 mm per year. Hattingh (2016) confirms that rainfall is low and highly variable, with annual rainfall of around 41 mm, falling mainly during winter with no rain generally falling during summer months.

The above report also notes that there is some increase in rainfall with distance south, with Port Nolloth recording an average rainfall of 63 mm during the past few decades (data source not noted). Average annual evaporation rate is however high, and Hattingh (2016) cites an evaporation rate of 2 524 mm per year, resulting in extremely dry conditions across most of the site.

2.2.2 Fog

Fog contributes moisture that is an important water source to biota adapted to arid conditions (see terrestrial ecology reports) and may account for a greater volume of water than annual rainfall (Davis et al. 2016). Fog commonly occurs in the late afternoon till late morning (Hattingh 2016) . Data presented in PRDW (2015) indicate that fog appears to be most prevalent between January and May, with most fog periods lasting two to four hours, sometimes extending up to 10 hours.

2.2.3 Temperature

Hattingh (2016) cites average midday temperatures for Alexander Bay that range from 20.6°C in July to 27.5°C in January, noting that the region is coldest during July, with average night time minimum temperatures of 8.3°C. However, occasional hot, dry easterly katabatic winds in winter can result in increased temperatures up to 40°C, with daily temperature variations of up to 30°C.

2.2.4 Climate change context

Davis et al. (2016) assessed long-term weather data for five stations in Namaqualand, including Port Nolloth, just south of the current study area. With specific regard to data for Port Nolloth, which should be interpreted cautiously, given that annual rainfall may be higher in this area than in the present study area, the research made the following findings:

- Trends in annual maximum temperature indicated a significant increase at the Port Nolloth station of 0.3 °C per decade;
- The rate of increase in seasonal minimum temperatures is greater than that of maximum temperatures;
- The annual rainfall time series for the weather station demonstrated no significant change in rainfall over the last 30 years with strong inter-annual variability but no significant trend in the coefficient of variation, suggesting that inter-annual rainfall variability has remained relatively constant over the past decades, although a decrease in summer rainfall was statistically significant over Port Nolloth;
- Port Nolloth also experienced a decline in the maximum consecutive 5 day rainfall event;
- Areas along the coastline generally experienced an increase in evapotranspiration of up to 30 mm per decade over the study period (1901-2009);
- The occurrence of warm extremes has increased and the occurrence of cold extremes has decreased over Namaqualand, while there has been an increase in warm spell duration;
- The increase in temperature combined with observed increases in evapotranspiration is of concern, while the impact of these on fog occurrence is poorly understood;
- In addition to the above, climate change is predicted likely to increase sea levels and storm surge heights (noted in PRDW 2015). These changes may impact on inland and/or estuarine ecosystems (see Section 4.3).

2.3 Topography and geology

The study area comprises mainly gently undulating sands towards the coast, with steep rocky drop-offs down to the coastal zone. Extensive low-lying depressions occur between low dunes in places, although large-scale mining disturbance in some areas on the western part of the site means that the actual natural topography is now difficult to determine, with some areas having been mined down to hard-pan areas and others clearly recipients of dumped mining spoil.

The topography varies from a maximum of 240 m amsl on a high point near the eastern site boundary (Visagiesfonteinkop), dropping gently down to sea level along the coastal zones to the west. Rocky outcrops / inselbergs occur in places (e.g. the Boegoeberg Twins and Visagiesfonteinkop, as well as other unnamed rocky outcrops, the bases of which are generally covered in windblown sands with the upper areas comprising exposed rock).

Mavurayi (2014) presents a simplified geological map that includes the present study area, showing that most of the site comprises quaternary deposits (sand and calcrete), with rocks of the Holgat Suite (schist, gneiss, arenite and limestone) underlying parts of the site and protruding above the surface in some areas (e.g. Boegoe Bay area, including the Boegoeberg Twins formations (see **Figure 2.1**) and a number of higher-lying areas east of the R382, including Visagiesfonteinkop. These formations characterise the lower reaches of the Holgat River, just south of the study area, with the deep Holgat Canyon / river valley having been incised predominantly into greywackes (Mavurayi 2014). Infilled fossil drainage valleys also occur within the study area, and the above author notes that they are currently indicated by the presence of pans including those in the Rietfontein area of the present study area. These are discussed in Section 2.6.

Desmet (1996) notes that the largest of these fossil channels is in the region of Rietfontein, citing a suggestion by Keyser (1972) that this represents the palaeo course of the Holgat River, which was diverted into its present course during the Middle to Lower Pleistocene (ca. 100 000 BP).

Mavurayi (2014) further notes that, in areas where beaches and embayments occur along the coastline and correspond to old river valleys, the earlier, darker coloured sediments are overlain by light-coloured dune sands of marine origin, which are generally loose and are aligned more or less parallel to the main wind direction (SE-NW). These marine sands derive from fluctuations in ocean level that resulted in the formation of sequences of wave cut marine terraces and more extensive sand accumulation on those areas of the coastal plain. During periods of sea level retreat, these unconsolidated sediments were exposed to aeolian mobilisation, leading to dune field formation.

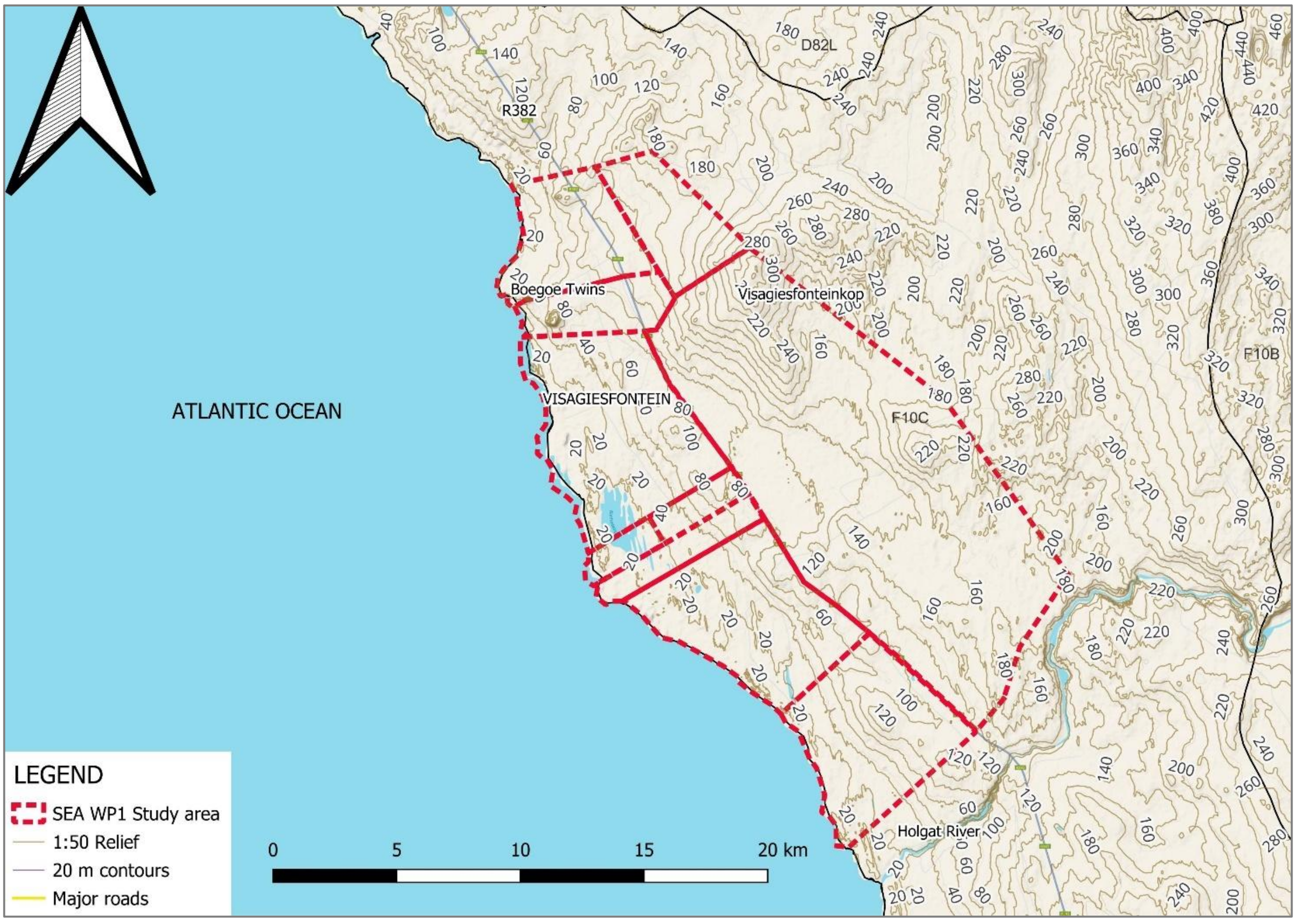

Figure 2.1
Map showing relief and main topographical features in and abutting the study area.

The conceptual cross-section shown in **Figure 2.2** shows that lenses of calcrete also occur in places on these old wave-cut platforms.

Calcrete formation is in fact linked to rainfall and evaporation in arid areas. When rain falls, it percolates into the soil, carrying with it dissolved minerals, including calcium carbonate from the soil and rocks, which react with carbon dioxide to form solutions of calcium carbonate. As the water moves through the soil it evaporates, increasing the concentration of calcium bicarbonate, which precipitates out as a a hard, crusty layer of calcium carbonate, over which water may collect. When these layers lie close to the surface, they can create perched wetlands.

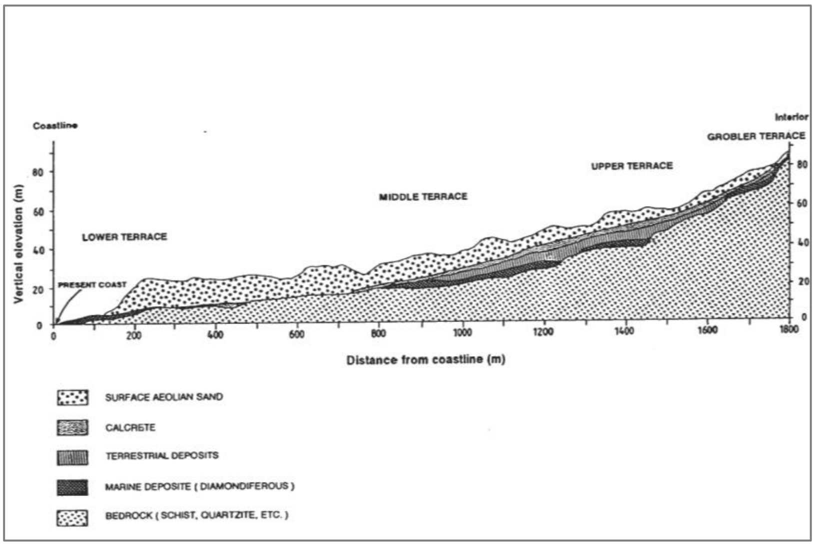

Figure 2.2
Conceptual cross-section (west to east) through the landscape in / near the present study area.
Figure after Burns (1994) as presented in Desmet (1996). Note that Rietfontein and Rietfonteinpan lies some 1 600 and 1 900 m from the coast, as estimated off Google Earth imagery.

2.4 Geohydrology

Background information provided in this section is based on reporting by Mavurayi (2014), who assessed the broader Alexkor mining site from a geohydrological perspective. However, in the absence of any boreholes within the current study area, the findings of that assessment can be broadly considered in this report, but do not assist with site-specific assessments of surface-groundwater interactions.

The report found that:

- As a result of the low rainfall, recharge of groundwater is limited (hence only small quantities can be abstracted on a sustainable basis);
- Primary aquifers are associated with the unconsolidated deposits comprising sand and gravel in the flood plain of the Orange River; and in paleao drainage channels and associated valleys. They vary in thickness from 0 m (bedrock outcrops) to about 30 metres below the surface;
- Secondary aquifers are associated with fractures and fissures in the bedrock of Gariep Complex consisting of schist, gneiss, arenite and limestone, in which secondary processes have improved their groundwater potential through fracturing and weathering;
- Groundwater quality is typical of arid regions and characterised by high salinity with electrical conductivity generally > 300 mS/m, attributed to:
    - Very low groundwater recharge (estimated at 0 to 5 mm per annum) and thus limited flushing out of old water,
    - Marine origin of gravels on terraces extending about 2 km inland and rising to about 90 m above mean sea level;
    - Leaching and dissolution of terrestrial salts originating from salt outfall from the sea;
    - Ancient water in palaeo-channels, recharged during periods of less arid regional climate in the past;
    - Excessive surface water evaporation relative to rainfall.
- A perched water-table is expected in the gravels in places where clay layers and other less permeable material exist.

The above information in part assists in explaining the presence of permanent but highly saline wetlands in parts of the site (see Section 2.7), which appear to occur, at least in part, in the infilled palaeo-channels described in Section 2.3. These wetlands include deep, permanent standing water areas, the persistence of which is not necessarily explicable by a perched primary aquifer, given the low rainfall and high evaporation rates, and might suggest a spring / link to the secondary aquifer. Geohydrological input is required in this regard.

2.5 Strategic surface and groundwater resources

No surface or groundwater Strategic Water Source Areas (SWSAs) are mapped within the study area (Le Maitre et al. 2018). The data presented in **Figure 2.3** indicate that the closest SWSA (groundwater) lies south of the study area, in the Port Nolloth area.

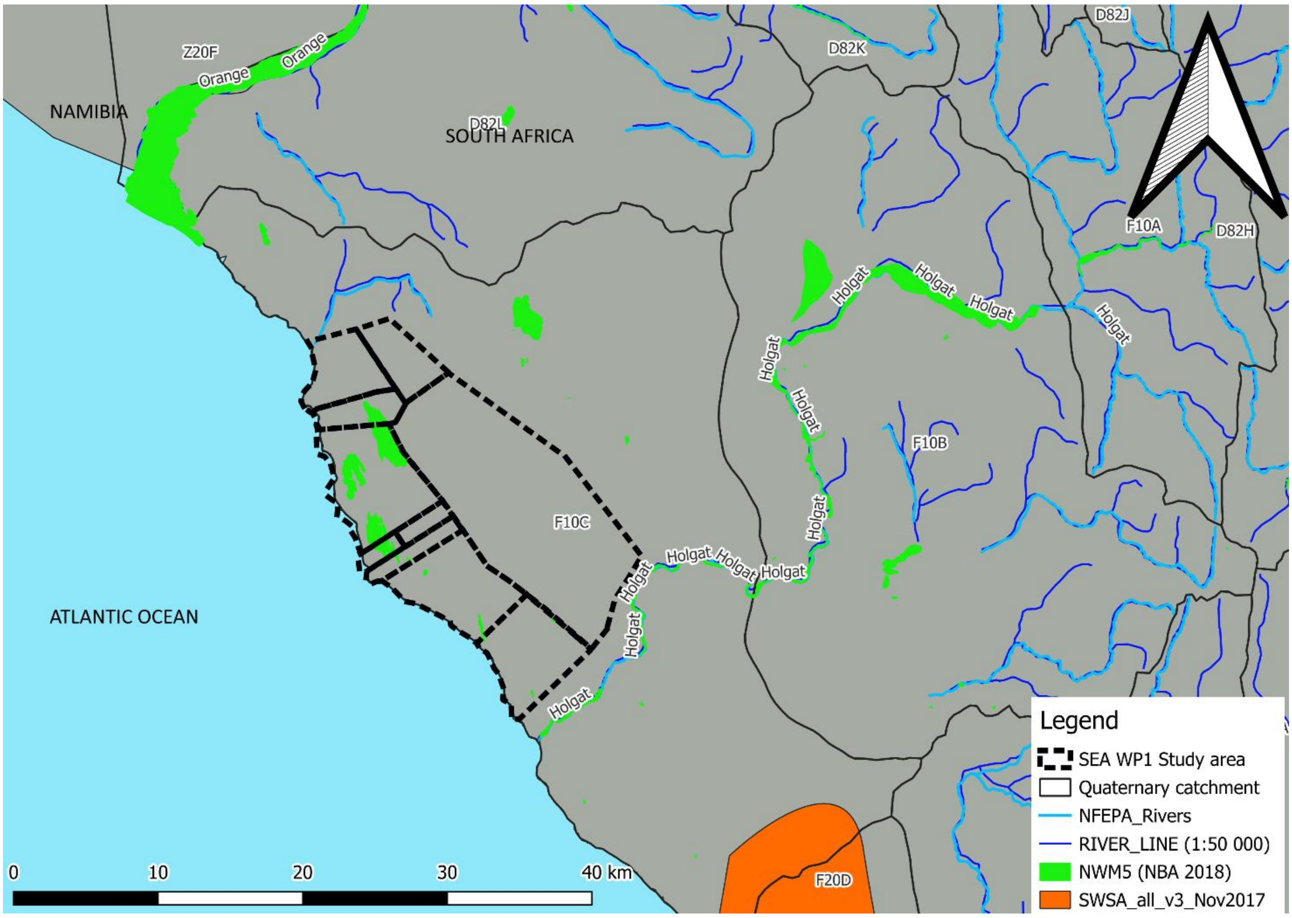

Figure 2.3
Study area in the context of the Strategic Water Source Area (surface and groundwater) data.
(Le Maitre et al. 2018).

2.6 Regional Vegetation types

Five vegetation units occur within the study area namely Namib Seashore Vegetation, Richtersveld Coastal Duneveld, Northern Richtersveld Yellow Duneveld, Richtersveld Sandy Coastal Scorpionstailveld and Western Gariep Plains Desert, the extents of which are indicated in **Figure 2.4**. Of these, two are listed as Critically Endangered (CR) under the revised Red List of Ecosystems (SANBI 2022b) (i.e. Namib Seashore Vegetation, Richtersveld Coastal Duneveld. The other three units are listed as of Least Concern(LC).

These units are described in detail in the terrestrial ecosystems reports for this study (Niemandt 2024) and are referred to in this report in the particular context of those that support wetlands or other aquatic ecosystems. Aquatic ecosystems are thus also indicated in **Figure 2.4**, and described later in Sections 2.9-2.11.

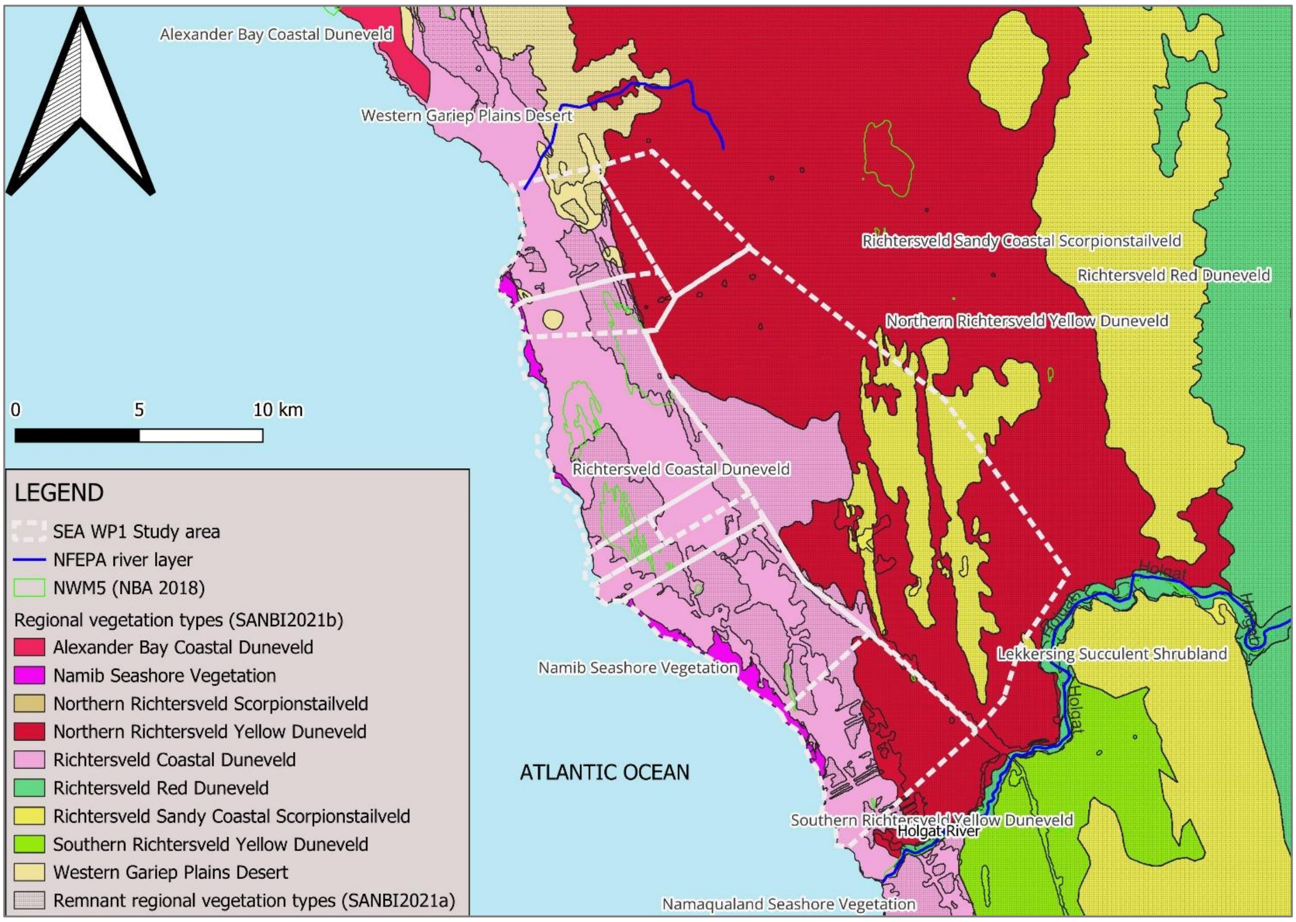

Figure 2.4
Regional vegetation types within and in the vicinity of the study area (data from SANBI 2022b), showing also inland and estuarine aquatic ecosystems from the NWM of the 2018 NBA (van Deventer et al. 2018). Hatched areas indicate remnant vegetation (SANBI 2022a).

The mapped wetlands shown in **Figure 2.4** occur almost wholly within the (Critically Endangered) Richtersveld Coastal Duneveld vegetation units. Other aquatic ecosystems not mapped in the National Wetland Map (NWM Ver 5) of Van Deventer et al. (2018) include ephemerally inundated depressions that occur in rocky outcrops.

2.7 Ecoregion context

An ecoregional classification produced by Kleynhans et al. (2005) divided the country's rivers into 31 distinct ecoregions, or groups of rivers which share similar physiography, climate, geology, soils and potential natural vegetation. **Figure 2.5** shows the present study area in the context of these ecoregions.

The figure indicates that the study area falls wholly within the Western Coastal Belt ecoregion.

The main characteristics of this ecoregion are summarised below (after Kleynhans et al. 2005), and not surprisingly correspond with the climatic data discussed in Section 2.2.

- **Western Coastal Belt ecoregion** characteristics:
  - Mostly low relief plains; some closed hills and mountains with moderate to high relief;
  - Vegetation consists mainly of Lowland Succulent Karoo;
  - Mean annual precipitation: Very low/arid (0-200 mm);
  - Coefficient of variation of annual precipitation: High to very high.
  - Drainage density: Low.
  - Stream frequency: Low/medium.
  - Slopes <5%: >80%.
  - Median annual simulated runoff: Very low.

The above characteristics suggest:

- Generally low rainfall (arid region);
- Few watercourses;
- High to very high variability in MAR between years;
- High discharge after rain events in some areas;
- Rainfall generally concentrated over a few months (winter).

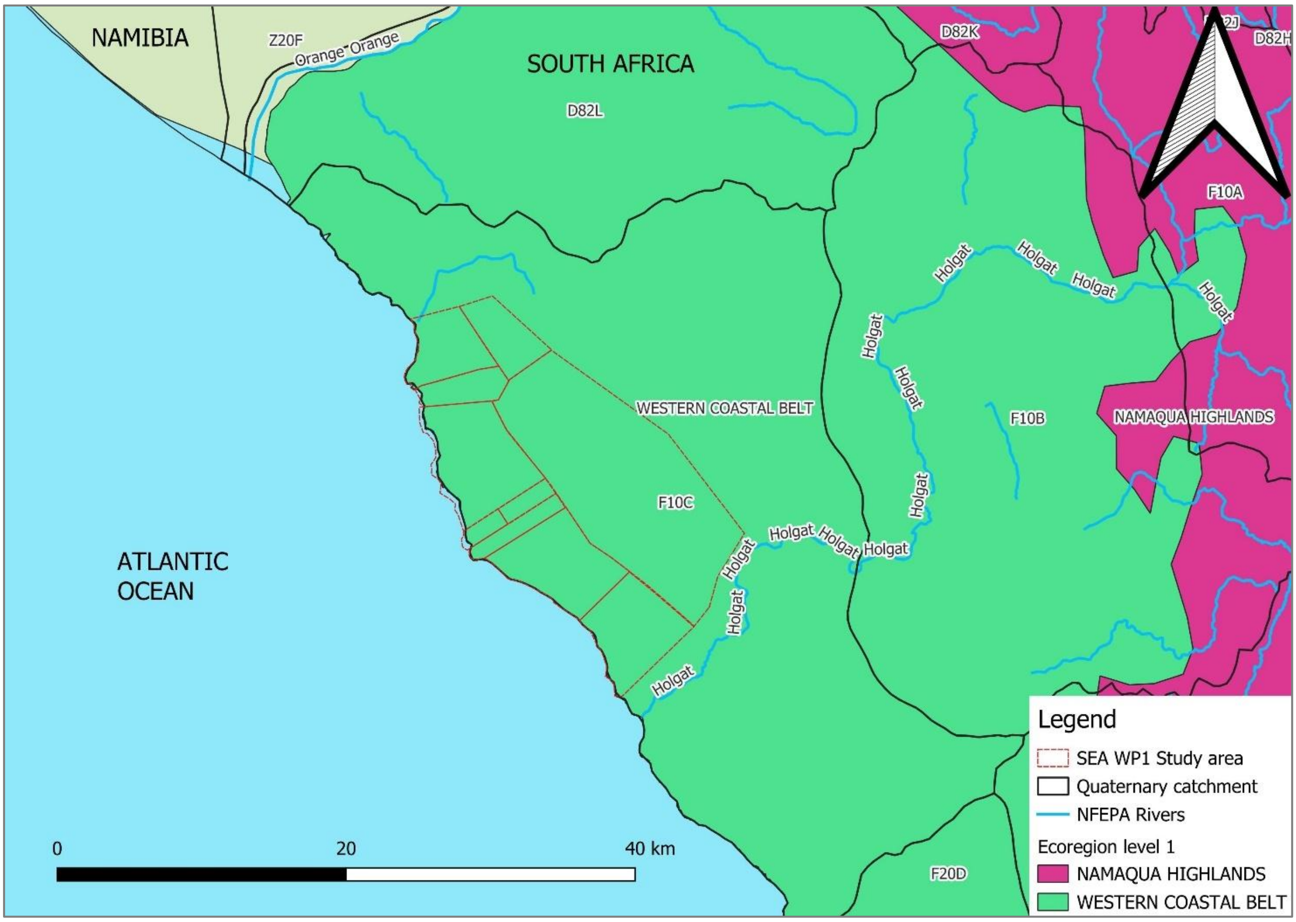

Figure 2.5
Ecoregion context of the study area. Data after Kleynhans et al. (2005).

2.8 Catchment[1] context

The study area lies wholly in the Department of Water and Sanitation (DWS)'s quaternary catchment F10C, within the Coastal Orange sub-Water Management Area (Sub-WMA), nested within the Lower Orange WMA, as shown in **Figure 2.6**. The Coastal Orange sub-WMA does not in fact drain into the Orange River, but drains west towards the coastline by way of multiple ephemeral watercourses (that is, rivers that are dry throughout most years, flowing irregularly and intermittently, without strong seasonal patterns). Most of these dissipate into the deep sands of the surrounding area.

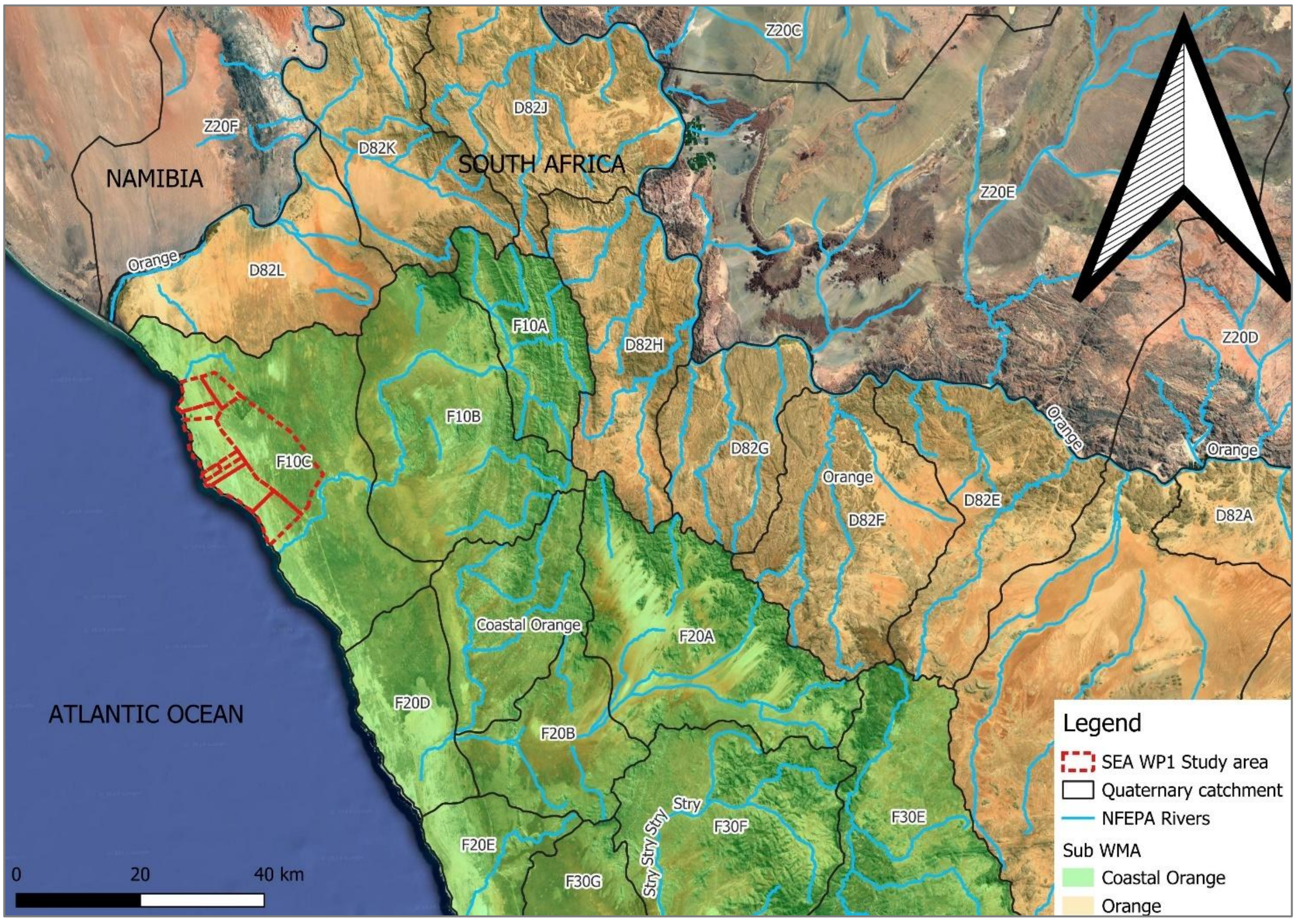

Figure 2.6
Catchment context of the proposed Boegoebaai Port and SEZ (the study area).

2.9 Inland aquatic ecosystem conservation planning context

2.9.1 FEPA status

The National Freshwater Ecosystem (NFEPA) Programme includes rated Freshwater Ecosystem Priority Areas (FEPAs). These are strategic priority subcatchments that are needed for conserving freshwater ecosystems and supporting the sustainable use of water resources (Driver et al. 2011). FEPAs have been determined for different river and wetland types throughout South Africa, on the basis of a number of

[1] The relevance of quaternary catchment identification is for purposes of water use licence authorisation and/or registration of water uses in future phases of the project. Identification of sub-WMAs contributes to an understanding of the broader water resources in the area.

criteria that included ensuring that there is an adequate extent of conservation of different river and wetland ecosystem types; that they represent adequate habitats to support threatened fish species and their migration corridors; that free-flowing rivers (i.e. rivers without major dams) are prioritised as FEPAs; that water supply areas in high-water yielding sub-quaternary catchments are maintained; and that ecological connectivity between systems is maintained as far as possible.

FEPAs are often tributaries or rivers that support “hard working” rivers downstream (that is, rivers that are heavily utilised or impacted by agricultural, industrial or other human activities). They need to stay (or get into) good condition to manage and conserve freshwater ecosystems and to protect downstream water resources for human use. Driver et al. (2011) stress however that FEPAs do not necessarily need to be protected from all human use. Rather, they should be supported by good planning, decision-making and management to ensure that human use does not impact on their condition or on the important resources they may protect downstream.

River FEPA ratings are important, because they assign different levels of conservation importance, associated with different requirements for the protection, rehabilitation and/or or management of aquatic resources within these sub-catchments.

FEPA ratings include the following categories:

- River FEPA and associated sub-quaternary catchment (FEPA): River FEPAs achieve biodiversity targets for river ecosystems and threatened fish species, and were identified in rivers that are currently in a good condition (A or B ecological category). Their FEPA status indicates that they should remain in a good condition in order to contribute to national biodiversity goals and support sustainable use of water resources;

- Fish sanctuary and associated sub-quaternary catchment (FishFEPA): Fish sanctuaries are rivers that are essential for protecting threatened indigenous freshwater fish. They comprise rivers in a good condition (A or B ecological category) and their whole associated sub-quaternary catchment;

- Fish Support Area and associated sub-quaternary catchment (FishFSA): Fish sanctuaries in lower than an A or B ecological condition are rated as Fish Support Areas – they include sub-quaternary catchments that are important for the migration of threatened fish species;

- Upstream Management Areas: These are sub-quaternary catchments in which human activities need to be managed to prevent degradation of downstream river FEPAs and Fish Support Areas;

- Phase 2 FEPA: Phase 2 FEPAs are rivers that should not be degraded further, as they may in future be considered for rehabilitation once FEPAs in good condition (A or B ecological category) have been fully rehabilitated and are well managed;

- Free-flowing river: Free-flowing rivers are rivers without dams.

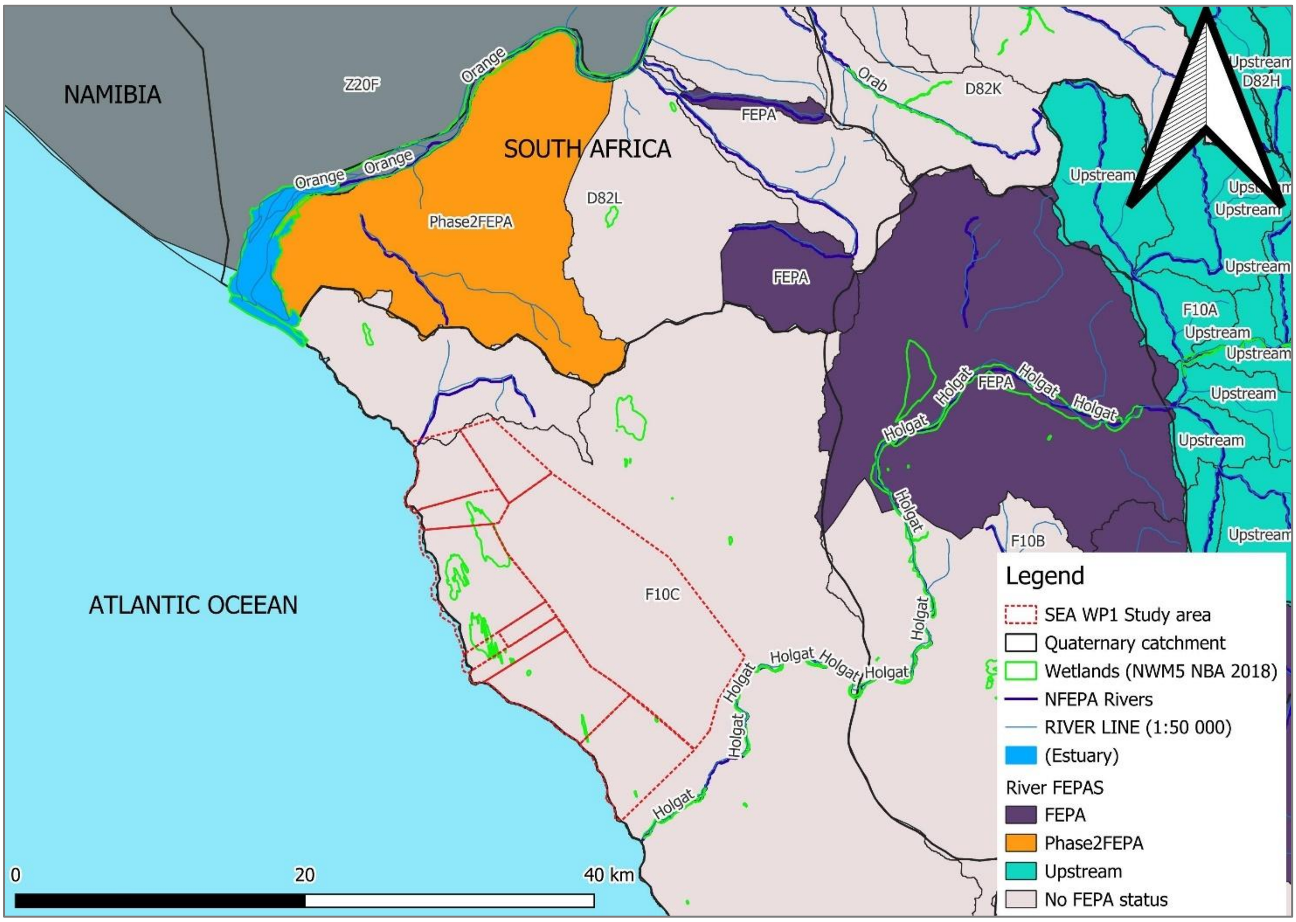

Figure 2.7
Study area in the context of rated FEPA sub-catchments (Driver et al. 2011).

Figure 2.7 shows the present study area in the context of river FEPAs. The figure indicates that:

- The entire site lies outside of any river FEPAs. This is not surprising, since the site drains towards the west, and there are no watercourses within the site that enter the sea – hence there is no downstream connectivity;

- A Phase 2 FEPA has been assigned to the sub-quaternary north of the study area, associated with and draining into the Orange River. The Orange River estuary has been accorded Ramsar wetland status, indicative of a wetland with extremely high conservation importance, at an international level.

2.9.2 Regional conservation planning data (Northern Cape Biodiversity Planning data)

Regional conservation planning data from the (draft) Northern Cape Biodiversity Planning dataset (Northern Cape Department of Environment and Nature Conservation 2018) were accessed for this assessment, and overlain as GIS data over the study area and surrounds. These data do not differentiate between aquatic and terrestrial ecosystems, as shown in **Figure 2.8**. However, the overlays of rivers and NBA (2018) wetlands do show where aquatic ecosystems may contribute to high conservation status in some areas.

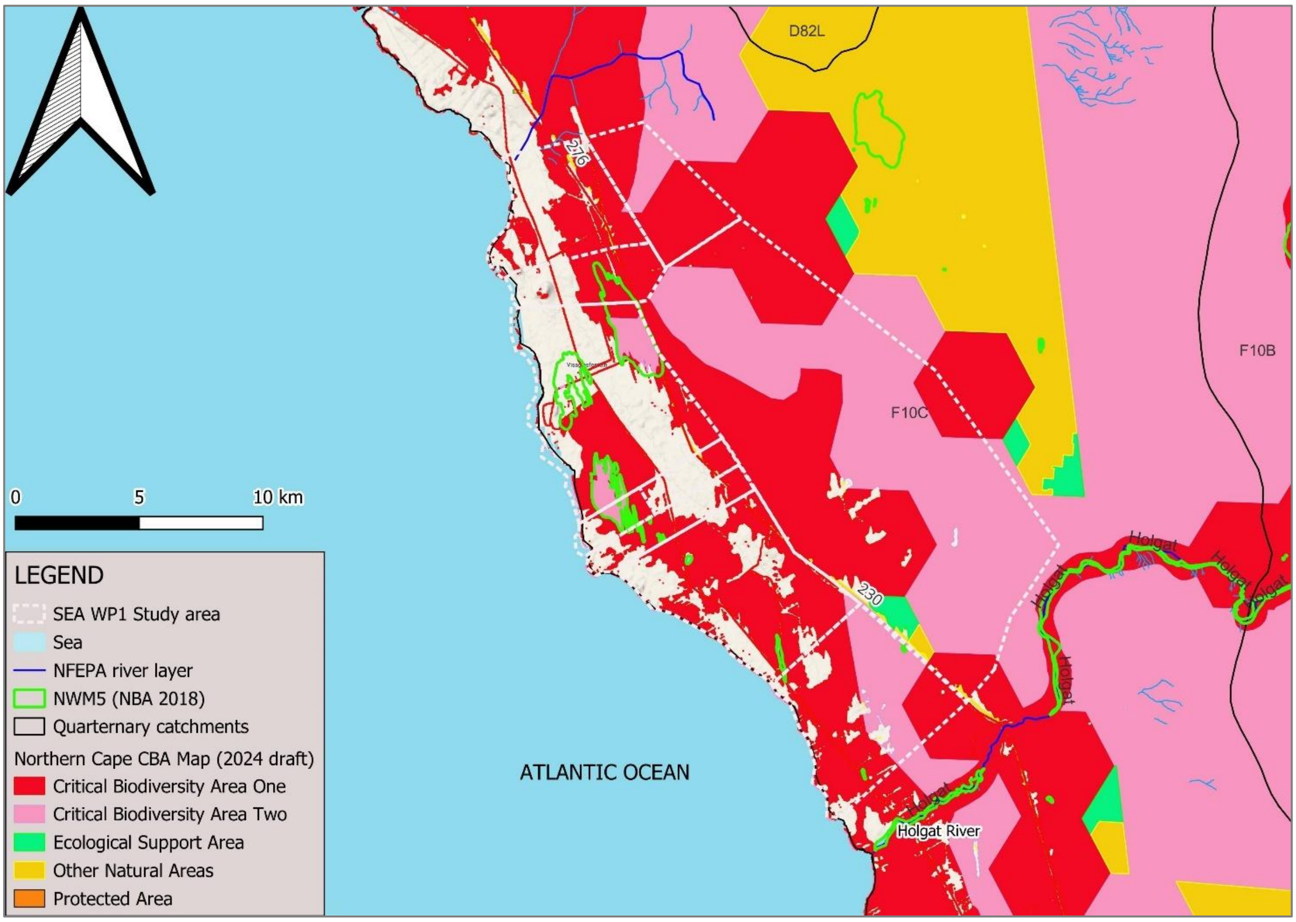

Figure 2.8
Study area in the context of Northern Cape Biodiversity Planning Data
(Northern Cape Department of Environment and Nature Conservation (2018).
Terrestrial and aquatic ecosystem data undifferentiated in dataset.

The data in **Figure 2.8** indicate that:

- Most of the study area lies in assigned CBA 1 and CBA 2 areas;
- Parts of the western portion of the study area, particularly along the coastal area in the north, has not been included among conservation priorities, presumably due to extensive mining in these areas;
- The mapped wetlands / pans within the study area that are indicated in the figure are all located within CBA 1 or CBA 2 areas, with the exception of the most north-westerly of the wetlands shown in the figure, the northern extent of which has been mapped outside of any conservation areas. This portion of the wetland lies outside of the mapped extant area of Critically Endangered Richtersveld Coastal Duneveld shown in **Figure 2.4** and is assumed to have been disturbed by mining. Its natural vegetation type is however still Richtersveld Coastal Duneveld;
- The Holgat River (outside of the study area) lies within a CBA 1 corridor – note that the river itself has been mapped as associated with wetlands in the reaches shown in the figure – ground-truthing indicates that this is not the case and the river lies within a deeply incised rocky gorge;
- The Orange River mouth and associated estuary and estuarine wetlands have all been mapped as CBA 1 areas.

2.10 Aquatic bioregions

Data from the National Biodiversity Assessment (NBA) of aquatic ecosystems (Van Deventer et al. 2018) show that aquatic ecosystems within the study area all fall within the **Namaqualand Sandveld Bioregion.**

All of the inland aquatic ecosystems mapped have been classified as wetland **depressions** in the dataset, as per the Level 4A hierarchical classification of Olllis et al. (2013) and are thus referred to **Namaqualand Sandveld Bioregion depressions**. Within the Namaqualand Sandveld Bioregion, depressions (including pans) have been rated as **Critically Endangered** with a protection status of **Not Protected**.

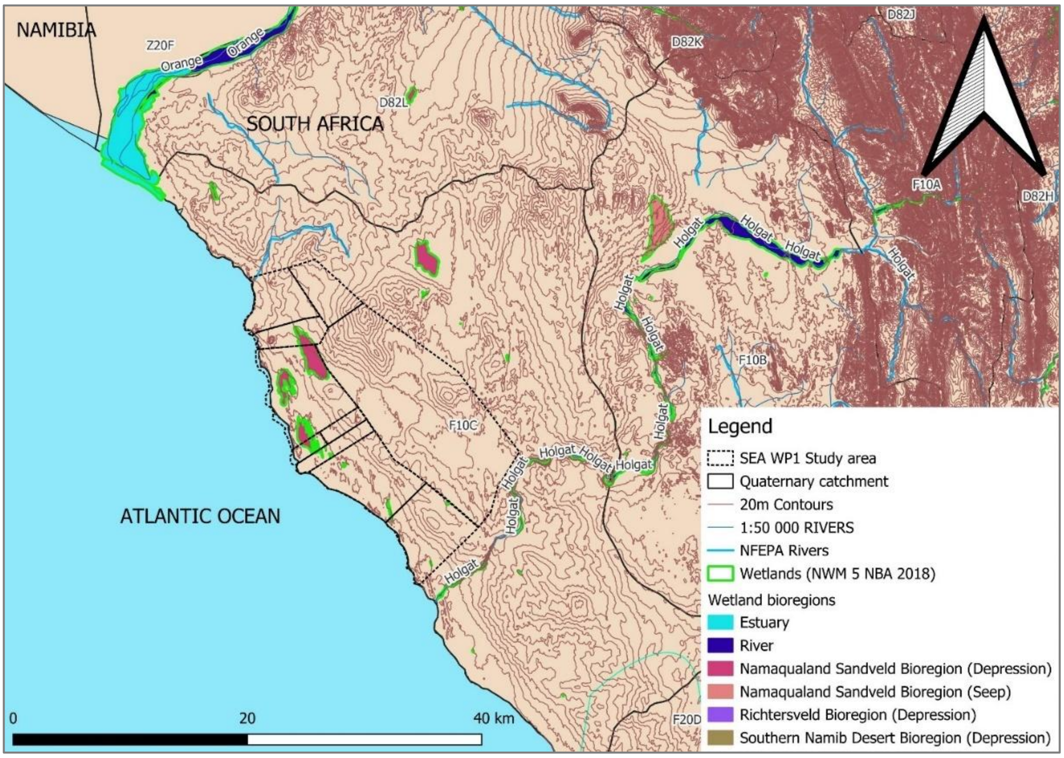

Figure 2.9
Study area in the context of the National Wetland Map (Version 5) (NWM Ver 5) (NBA 2018). All wetlands within the study area fall within the Namaqualand Sandveld Bioregion. Wetland types as classified in the NWM to Level 4A of the National Aquatic Ecosystem Classification system of Ollis et al. (2013).

2.11 Inland aquatic ecosystems on the site

2.11.1 Overview

The study area was visited in December 2024. This was in early summer, when seasonally inundated pans and other watercourses would not be expected to be inundated. The purpose of the site visit was primarily to ground-truth the presence, rough extent and type of wetlands indicated in the 2018 NBA data (NWM Ver 5) (Van Deventer et al. 2018). This wetland layer, shown in **Figure 2.10**, indicates three large wetland depressions in the north western quadrant of the study area, as well as a number of smaller depressions, all on the coastal side of the R382.

In total, 16 inland aquatic habitats have been mapped in **Figure 2.10**, using the NWM Ver 5 data as the basis for wetland extent, with ground-truthing eliminating a few of these mapped wetlands and adding one new wetland (BB5). Ground-truthing suggested that mapped wetland extent presented in the NWM may over-estimate wetland extent in some areas – in the absence of a detailed study including assessment of cyclic wet-period inundation in these ephemeral areas, the NWM data have however been assumed to represent a generally conservative mapping output in the study area. Of the 16 mapped wetlands, BB8 was not ground-truthed in December 2024. Three new watercourses were added to the dataset, based on site ground-truthing, and comprised BB5 (artificial), BB11 (artificial) and BB9 (assumed to be natural).

2.11.2 Pans and wetlands

Ground-truthing confirmed the presence of indicators of seasonal to permanent wetland conditions including obligate wetland plants (e.g. *Phragmites australis*); standing water and saturated soils with black organic material in the top layers, indicative of poor decomposition under saturated anaerobic conditions; and the presence in at least parts of all of these mapped systems of indicators of periodic inundation, if not prolonged saturation, across more extensive areas (e.g. thin crusts on pan surfaces and, in some areas, muck layers indicative of shallow past inundation, and cracking – these abiotic indicators are listed in Day et al. (2010) among those suitable for the identification of ephemeral systems in dry-season conditions).

The mapped NWM wetlands are numbered in **Figure 2.10** and most are illustrated photographically in **Table 2.1**. Of the three largest mapped pans, the wettest (referred to as [2]Visagiespan in Desmet (1996)) was the most northerly (BB-1 in **Figure 2.10**), with trickle flow out of a small reed-edged pool, even in early summer, suggesting that this part of the system at least is fed by a perennial water source (mapped as BB-1A within BB-1). The presence of small [3]fish in the deepest parts of the wetland added weight to the suggestion that this part of the wetland is perennial, while the presence of *Juncus kraussii* plants (indicative of seasonally moist to saturated conditions) on the gentle southern dune slopes leading down to the wetland suggested possible “wet season” percolation through the dune sands, with rainwater that has infiltrated dune areas being exposed to reduced evaporative loss than surface water (Desmet 1996). Once-off water quality data for the inundated waterbody suggested a fresh to brackish water supply, offset by evapoconcentration in the wetland, with water electrical conductivity (EC) measured at 2 057 mS/m (and within the range for [4]saline wetlands). Spoor of small antelope around the pool suggested that, despite its high salinity at least in summer, it remains a source of water and /or grazing for local fauna.

The wetland was edged by dense stands of perennial *Phragmites australis* reeds and clusters of *Juncus kraussii*, both wetland indicators. *Sarcocornia cf. pillansii* occurred on the salt-encrusted drier margins of the permanent pooled habitat. Water in the pool in December 2024 was rich in orthophosphate phosphorus (above hypertrophic thresholds), suggesting a productive system (see data in Appendix A), while relatively low concentrations of total ammoniacal nitrogen relative to total oxidised nitrogen (TON) suggested adequate dissolved oxygen in the water to support chemical and biological oxygen demand, while the wetland soils were black and anoxic.

The other two large pans shown in **Figure 2.10** are Rietfontein and Rietfonteinpan (BB-2 and BB-3 respectively) (as labelled in Desmet 1996), both of which comprise a series of wide, roughly north-east to south-west running low-lying areas between low dunes. Rietfontein was similar in vegetation and aquatic habitat to Visagiespan, being dominated by *Phragmites australis* and *Juncus kraussii,* with *Sarcocornia cf. pillansii* on adjacent damp flats. It was however drier than the latter in December 2024, with hypersaline water (24 150 mS/m) overlying black anoxic soils. Water quality data (Appendix A) showed that water at that time was characterised by very high ammoniacal nitrogen and sulphate concentrations, suggestive of low dissolved oxygen compared with chemical and biological oxygen demand, and with high availability of phosphorus (almost entirely in its biologically available orthophosphate form), well above hypertrophic concentrations for aquatic ecosystems (DWAF 1996).

The Rietfonteinpan wetland was dry in December 2024, but areas of the flat, low-lying duneslacks were vegetated with *Sarcocornia cf. pillansii* and showed signs of shallow inundation (e.g. crusting, occasional organic muck) at least at times.

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[2] Also referenced as Visagiesfontein in some reports (e.g. Niemandt 2024)
[3] Fish were not identified as they were confined to the deep parts of the pool and the need for fish sampling equipment had not been anticipated for the December site visit to an arid area
[4] That is, > 1 500 mS/m (USEPA: https://www.epa.gov/sites/default/files/documents/02_Godsey_-_Source_Options_508.pdf)

Desmet (1996) suggests that the Rietfonteinpan and Rietfontein section of the study area may in fact be **coastal salinas**, which are vestigial lagoons that have their own natural supply of ground water, usually in the form of sea water seepage (or vestigial sea water lenses from past sea levels) rather than rain runoff, and usually have local encrustations of gypsum or common salt. They would have been formed originally at higher sea levels, and were then abandoned as sea levels fell (see **Figure 2.2**).

In addition to these major pan systems, likely only to be inundated along their full mapped extent, if ever, after major rainfall events, a number of smaller wetlands were also noted. These are also indicated in **Figure 2.10** and include artificial scrapes / depressions, often excavated down to the hardpan or calcrete lens. Water pools in these areas after rainfall and the systems were variously characterised by *Phragmites australis* (wetter systems) and patches of *Sarcocornia cf. perenne*, indicating drier, more saline conditions.

Smaller stands of dense *Phragmites australis* in the Rietfontein and Rietfonteinpan areas may be indicative of wetlands that have formed in infilled paleochannels (e.g. Desmet 1996).

2.11.3 Minor Drainage channels / ephemeral watercourses

The 1:50 000 rivers layer for the study area and surrounds shows five drainage lines / sections of drainage lines that cut into the site along the northern boundary of the study area. Ground-truthing of these areas did not however show any discernible low points or indicators of even episodic drainage along these lines and they are thus not considered inland aquatic systems. An ephemeral drainage line was however noted some 1.3 km south of the northern boundary, crossing the R382. Upstream of the road the drainage line was barely visible, although concentration of flows under the road meant that a more defined drainage line was visible, as shown in Photo Q (**Table 2.1**). This petered out a few hundred meters downslope (west) of the road, and it is assumed that concentrated flows from the road culvert generally dissipate quite quickly into the deep sands in this area. The drainage line was ill-defined and not associated with any vegetation suggestive of access to additional moisture, and is treated in this assessment as an artefact of stormwater management rather than an aquatic ecosystem or other watercourse type.

Outside of the extensive pans mapped in **Figure 2.10**, within which there is certainly at times surface flows of water between depressions within these mosaics, no other defined drainage lines were observed on site during the site visit, and none are indicated in available river / watercourse spatial data. Given the aridity of the area and its characterisation by deep sands, this is not a surprising outcome, as it is assumed that surface water dissipates into the ground before forming overland flows.

The exception to the above is runoff from steep, rocky areas, where rainfall is likely to run as multiple fast flows or trickles to the sand below, dissipating quickly into the sand via small runnels at the base of these formations. These areas have been mapped in this report as the entire rocky structure and the area immediately surrounding it, as far as visible runnels extend (generally < 20 m from the base in the case of the Boegoeberg Twins). Similar runoff is likely off other steep, rocky terrain, including the Visagiesfonteinkop area in the north east of the study area. As a broad indicator of where concentrated surface flows are most likely to occur in this case, the terrain associated with the steepest slopes and visible runnels was mapped, with low confidence.

2.11.4 Other inland aquatic ecosystem habitat types within the study area

No other aquatic ecosystems were observed on the site, although it was noted that rocky outcrops in places on the site, including prominent features such as the Boegoeberg Twins, the high rocky outcrops north of Rietfontein and Visagiesfonteinkop, are likely to include hollows and depressions that would collect and retain water from rainfall events, and are thus assumed to play an important role in supporting plant and animal communities in these areas, at least at times. This aspect is discussed in more detail in Section 2.12.3.

2.11.5 The Holgat River

The Holgat River flows just south of the study area, within a deep, steep-sided rocky gorge or canyon. Harrison (1998) describes this system as having a catchment area of 1 635 km^2 and a river length of

102.4 km. Although mapped in the NWM Ver 5 as flowing through wetland areas in its reaches past the present study area, there are no wetlands associated with the river, although there is a narrow riparian fringe along the channel, at the bottom of the incised valley. NFEPA data (Driver et al. 2011) rate the river in these reaches as with a Present Ecological State (PES) Category B – "Largely natural". On the basis of the cursory site inspection, this rating is concurred with. The ephemeral nature of the river, coupled with its likely brackish to saline water quality in this arid region, as well as its isolation from major human settlements, mean that the river is largely undisturbed. Alien vegetation and limited tourism (e.g. 4x4 trails through the river in its lower reaches) may impose some impacts to this system under present landuse.

The features and aspects described in the above sections are illustrated in the photographs (December 2023) shown in **Table 2.1**.

Table 2.1
Photographic illustrations of key inland aquatic ecosystem habitats in the study area (December 2024)

Photo A
Defined high-lying ephemeral seep into BB1 (Visagiespan), with obligate wetland species *Juncus kraussii* suggesting broad mapped extent of BB1 is relatively accurate.

Photo B
Ephemerally inundated lower pan margins in BB1 (Visagiespan), on drier margins of mapped spring area (BB1A).

Photo C
Permanent deepwater pools at Visagiespan (BB1A), providing habitat to fish.

Photo D
Saltmarsh vegetation on saline drier pan margins (BB1A) with *Phragmites australis* dominating wetter, fresher areas along with *Juncus kraussii.*

Photo E
Bird tracks highlight local importance of Visagiespan for fauna in the study area.

Photo F
Crystalizing salt on the drier margins of Visagiespan (BB1A).

Photo G
Phragmites australis reedbed along wetter, fresher zones in the Rietfontein pan (BB2).

Photo H
Pooled hypersaline water in Rietfontein pan (BB2).

Photo I
Small antelope prints along the edge of BB2 (Rietfontein) indicate the value of even this hypersaline

Photo J
Hypersaline conditions in Rietfontein (BB2).

pan for local fauna (probably for grazing).

Photo K
Disturbed, possibly excavated and in part infilled depression within the broader mapped Rietfontein mosaic pan area (BB2), with *Phragmites australis* dominance suggesting fresher conditions than in other pans dominated by saltmarsh species.

Photo L
Ephemeral pans in BB3 (Rietfonteinpan)

Photos M
Duneslack pans between low rolling sand dunes characterise BB3 (Rietfonteinpan).

Photo N
Ephemeral pan (rarely inundated) (BB6).

Photo O
Excavated pan at BB7.

Ephemeral pan (BB9), dried out and with salt encrustantions in December 2024.

Excavated pan (BB4) with *Phragmites australis* reedbed.

Photo P
Holgat River at R382 crossing immediately south of the study area.

Photo Q
Barely discernible drainage line, downslope of R382, with concentrated flows dissipating quickly into the sands. Boegoeberg Twins visible in background.

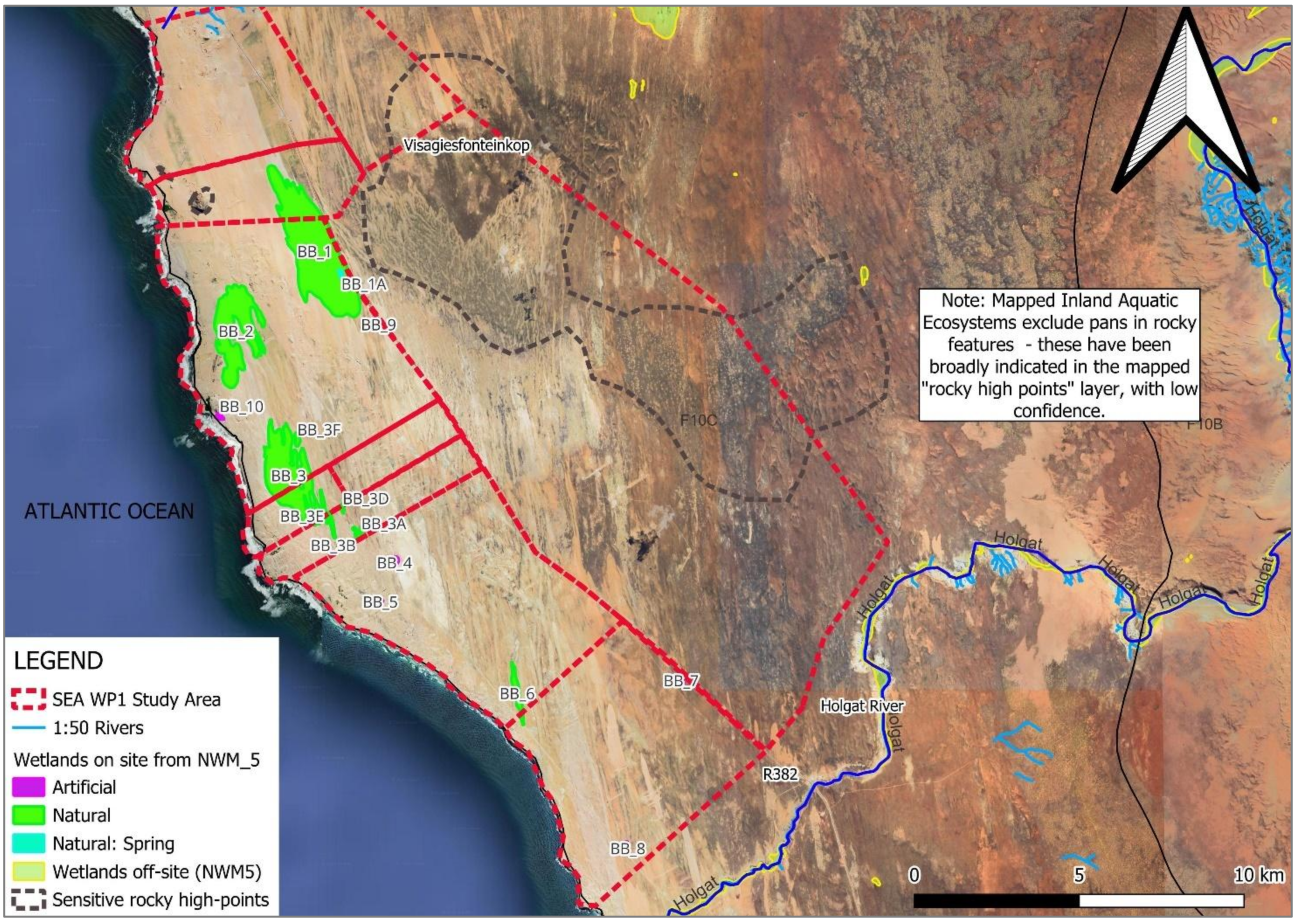

Figure 2.10
Coded, mostly ground-truthed inland watercourses in the study area, with extent based on that indicated in NWM VER 5. See text for names of major wetlands (e.g. BB1 = Visagiespan). Rocky high points mapped at desktop level with low confidence – faunal specialist sensitivity layer should be prioritised for these areas.

2.12 Inland aquatic fauna

2.12.1 Fish

At least one species of fish is supported in the (presumed permanent and, at least in summer, saline and eutrophic) waters of Visagiespan. The species is currently unconfirmed, as the fish could not be identified or photographed at distance and depth. Section 2.14.3 notes however the introduction of mullet (*Chelon richardsonii*) into excavated channels in the Holgat Estuary, and it is possible that these fish might also have been introduced into the spring environment. None of the other pans considered are likely to support fish as they all dry out in summer, with even Rietfontein, which still had some hypersaline hypertrophic pools in December 2024, being likely to dry out completely over summer.

2.12.2 Amphibians

Faunal biodiversity on the study area has been assessed in Niemandt (2025), who noted that, as a result of the scarcity of fresh water in the area, only four amphibian species are likely to occur there, namely:

- *Cacosternum namaquense* (Namaqua Caco);
- *Vandijkophrynus gariepensis* (Karoo Toad)

- *Vandijkophrynus robinsoni* (Paradise Toad)
- *Breviceps macrops* (Desert Rain Frog).

Of the above, only *C. namaquense* requires surface water for breeding and egg / tadpole habitat, as do the two *Vandijkophrynus* species, while *B. macrops* are largely independent of water, breeding in cavities that they excavate underground (du Preez and Carruthers 2009).

Rietfontein and Visagiespan are both likely to provide suitable habitat for these amphibians, although the high summer salinities and (at Rietfontein) drought mean that they are most likely to be suitable for amphibians during early wet season inundation only.

2.12.3 Aquatic invertebrates

Ephemeral pans and pools in the study area, including pans such as Visagiespan, Rietfontein, Rietfonteinpan; the various artificial scrapes noted in Section 2.11.2; and the temporary pools in rocky areas (Section 2.11.3) could all potentially support communities of invertebrate fauna that are adapted to life in transient aquatic conditions. Such fauna could include branchiopod crustaceans, with taxa from four orders all associated with temporary freshwater habitats (Conchostraca (clam shrimps); Cladocera (water fleas – e.g. *Daphnia*); Notostraca (tadpole shrimps of the genus *Triops* (Rayner and Bowland 19895)); and Anostraca (fairy shrimps)). Species richness in temporary waterbodies relates to the size and habitat diversity of the water body and to habitat duration (Ebert and Balko (1987); Hamer and Rayner (1996); and Mabidi et al. (2016)).

While no investigations into amphibians or aquatic invertebrate fauna in the current study area have informed this report, the above information highlights the potential importance of any aquatic habitat, from permanent to ephemeral, and ranging from natural water collectors such as pans and rock depressions to artificial roadside scrapes, borrow pits and reservoirs or dams.

2.13 Inland aquatic ecosystem drivers

Drivers of the inland aquatic ecosystems described above were poorly understood at the time of this report, at a level that could usefully inform development layout decision-making. However, at a conceptual level, the following main inland aquatic ecosystem drivers are likely to comprise:

- Climate (i.e. temperature, rainfall and evaporation rates) – by implication, climate change is also recognised as a significant driver of these ecosystems going forwards;
- In addition:
  - Links to palaeochannels – the exact mechanisms for the development of wetlands (e.g. *Phragmites australis* wetlands) in these areas is poorly understood;
  - Links to groundwater – some springs (e.g. Visagiespan spring) may link to groundwater and/or to vestigial perched ancient seawater lenses – Hattingh (2016) comments that groundwater daylights at Rietfontein, with the springs "probably fed by the secondary aquifer, but accommodated by the primary aquifer" – it is unclear whether this report includes the Visagiespan spring among the general "Rietfontein springs";
  - Links to primary aquifers in sand dunes (some pans may be fed by shallow subsurface flows from dune areas, with dunes acting as local infiltration zones);
  - Links to localised surface water flows, in perched (including artificial) pans, where inflowing water is trapped above impervious surfaces such as rock and/or calcrete; as well as where surface flows are artificially concentrated into channels (often downstream of roads).

2.14 Estuaries in the vicinity of the site

2.14.1 General

There are no estuaries in the present study area. Nevertheless, two estuarine systems lie in close proximity to the study area, and could potentially be affected by impacts associated with the proposed development. These estuaries comprise the Orange River Estuary (a Ramsar wetland site) to the north of the study area and the Holgat Estuary, immediately to the south.

2.14.2 The Orange River Estuary

The Orange River Estuary flows into the sea between the coastal towns of Alexander Bay (South Africa) and Oranjemund (Namibia). The estuary covers an area of about 2 700 ha, and comprises an (almost) permanently open river mouth; a 2 to 3 m deep tidal basin; a braided channel system (located between sand banks covered with pioneer vegetation) and a severely degraded saltmarsh on the south bank of the river mouth (DWS 2017a). It is a rare and unusual wetland type on the arid and semi-arid coastline of southern Africa, deriving its flows from a large catchment that begins in the Lesotho Highlands in Lesotho, some 2 432 km upstream of Alexander Bay. The estuary itself extends approximately 11 km upstream from the river mouth.

Figure 2.11
Section of the lower Orange River Estuary, December 2024.

Turpie et al. (2002) ranked the Orange as the seventh most important system in South Africa in terms of conservation importance. The prioritisation study calculated conservation importance on the basis of size, habitat diversity, zonal type rarity and biodiversity importance. Estuary importance is an expression of the value of a specific estuary to maintaining ecological diversity and functioning of estuarine systems on local and wider scales. The biodiversity importance score is in turn based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices.

Reflecting the above importance, the Orange River Estuary was designated a Ramsar Site (i.e. a wetland of international importance) in 1991 on the South African side and, following Namibia's ratification of the Ramsar Convention in 1995, on the Namibian side too. The on-line Ramsar description for this site (https://rsis.ramsar.org/RISapp/files/119/documents/ZA526lit.pdf?language=en) notes that the site is seasonally important for locally migrant water birds, including *Pelecanus onocrotalus, Phoenicopterus ruber roseus, P. minor, Recurvirostra avosetta* and *Charadrius pallidus*. Resident species include

Phalacrocorax carbo, P. capensis, P. africanus, Anhinga melanogaster, Ardea cinerea, Egretta garzetta, Alopochen aegyptiacus, Tadorna cana, Anas capensis, Oxyura maccoa, Charadrius marginatus, Vanellus armatus, Larus dominicanus, L. hartlaubii and *Sterna bergii.* Staging water birds include *Calidris minuta, C. ferruginea, Philomachus pugnax, Sterna hirundo* and *S. sandvicensis*

Unfortunately, by 1995, the South African Orange River Estuary Ramsar site had been placed on the Montreux Record (a list of Ramsar Sites around the world that are in a degraded state) as a result of severe degradation of saltmarsh on the south bank of the estuary (DWS 2017b).

The estuary is subject to numerous factors that impact on its present condition, assessed as Present Ecological State (PES) Category D by Van Niekerk et al. (2013a, b), reflecting its assessment as a largely modified system. This was attributed to the following key factors, summarised in DWS (2017a) as:

- Significant freshwater flow modification – both loss of floods and increased base-flows, (damming and regulation of flows in catchment): water resource development in the Orange-Senqu River basin has reduced runoff to the Orange Estuary by more than 50%;
- Lack of estuary mouth closure and with this a reduction in associated (desirable) resulting back-flooding of salt marshes with fresher water;
- Road infrastructure such as the old causeway crossing the saltmarshes and old bridge supports;
- Nutrient input from the catchment;
- Gill netting of indigenous fish species and considerable fishing effort at the mouth on both sides of the estuary;
- Riparian infrastructure, with levees preventing back-flooding;
- Grazing and hunting;
- Mining activities; and
- Wastewater disposal (including previous sewage and mining return flows).

DWS (2017a) notes that while non-flow impacts play a significant role in the degradation of the Orange Estuary, modification of flows (both floods and base flows) remains the main cause of its degradation.

Despite its levels of degradation, the Orange River Estuary forms part of the core set of estuaries in need of formal protection to achieve biodiversity targets in the region (Van Niekerk and Turpie, 2012) and is one of only two estuaries on the Namibian coast (Orange and Kunene Rivers) (DWS 201b). On these and other bases, including its Ramsar status, the estuary is rated as 'highly important'. However, its best attainable state (Recommended Ecological Condition (REC)) has been estimated as only a Category C, based on reasonably reversible or mitigable pressures (DWS 2017a).

Measures recommended by specialists engaged in the Determination of Ecological Water Requirements for surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA (DWS 2017a) recommended the following measures to improve estuarine condition to its REC, namely:

- Flow related requirements:
    - To reduce present winter base flows sufficiently to allow for mouth closure and related back-flooding of the saltmarshes with brackish water to reduce soil salinities, but not to the point where the estuary mouth remains closed for longer than 2 to 4 times in 10 years by decreasing river inflow to less than 5 m^3/s;
    - To elevate base flows above 10 m^3/s from December onwards, to address habitat degradation from long periods of low flows;

- Non-flow related measures:
  - To control the fishing effort on both the South African and Namibian side through increased compliance and law enforcement;
  - To enhance nursery function for estuarine dependant fish species;
  - To remove the remnant causeway that still transects the saltmarshes to improve circulation during high flow and floods events and assist with increasing the water circulation into the lower marsh areas;
  - To decrease nutrient input from the catchment downstream of Vioolsdrift, through improved agricultural practices;
  - To control windblown dust and wastewater from mining activities; and
  - To reduce/remove grazing and hunting pressures.

The above issues are all of high relevance in the light of the proposed Boegoebaai Part and SEZ, in the close vicinity of the Orange River Estuary.

2.14.3 The Holgat Estuary

The Holgat River estuary enters the Atlantic Ocean immediately south of the present study area. The estuary was assessed by Harrison (1998), who noted that:

- The Holgat River flows only very occasionally (i.e. is ephemeral (the Harison (1997) report noted that the riverbed at that time had been virtually dry for some years, with the last record of it flowing being in 1925;
- The lower estuary has been artificially manipulated, with Bickerton (1981) describing an "L" shaped water trench (100 m x 70 m x 10 m wide), used for the maintenance of roads and the processing of diamond gravel at the mouth of the system – Google Earth imagery shows that the mouth now opens into a wide deep rectangular pool, filled with seawater, just above the beach;
- Bickerton (1981) also describes the past introduction of mullet into the seawater trenches – it is possible that the fish observed in the Viagiespan spring were also mullet;
- The Holgat Estuary is classified as a micro-outlet using the revised classification system for estuaries of Van Niekerk et al. (2020), signifying its small and highly ephemeral character.

3. PROPOSED DEVELOPMENT AND ASSOCIATED ACTIVITIES

Figure 3.1 shows the proposed development layout considered in this work package of the SEA. Inland aquatic ecosystems (as per **Figure 2.10**) have been overlaid on the figure, for context.

Drawing from information supplied in Schreiner *et al*. (2024), the overall development would comprise:

- **Boegoebaai Port**, of which the most relevant aspects to the present assessment (as in relating to areas that could affect inland or estuarine aquatic ecosystems) comprise:
  - Dust suppression (presumably using water);
  - Stormwater management, allowing for the separation of clean and dirty water, with clean water diverted around the site. The drainage system would separate clean and dirty water, with clean water runoff diverted around the site. High-risk dirty runoff water would flow into concrete-lined channels, and low-risk dirty runoff water would into block and vegetated channels. Pollution control ponds would be lined with HDPE, attenuated to the 1:50 year pre-development condition and discharged to the receiving natural environment, such as the ocean;
  - Fuel storage;
  - Internal and external roads;
- The **Boegoebaai SEZ area**, encompassing approximately 31 300 ha, would be developed in phases and is envisaged to consist of eight subzones (see **Figure 3.1**):
  - Conservancy area – 1 170 ha;
  - SASOL area (Green ammonia facility), including a desalination plant, with brines and lye solution being discharged to the sea – 4 508 ha;
  - SEZ Industrial Park, for mixed uses including manufacturing, logistics, offices and warehousing; a desalination plant:
    - Phase 1 – 499 ha
    - Phase 2 – 411 ha
    - Phase 3 – 833 ha
  - Future green hydrogen facility – 3 713 ha
  - Future green hydrogen expansion 01 – 3 408 ha
  - Future green hydrogen expansion 02 – 15 067 ha
  - Future tank farm – 1 704 ha.

Of the above, areas identified in Section 2 of this report as supporting pans and wetlands (all rated as Critically Endangered in the 2018 NBA (Van Deventer et al. 2018)) lie in the following SEZ zones:

- The Conservancy area
- The SASOL area
- Phases 1, 2 and 3 of the SEZ industrial Park
- The Future Green Hydrogen Facility
- The Future Green Hydrogen Expansion area – 01.

The Visagiesfonteinkop high-lying rocky areas have also been rated as important support areas for temporary pools and pans in this assessment, and this area lies in the area flagged for Future Green Hydrogen Expansion (02).

In addition to the above, it is assumed that indirect aspects of the proposed development would include:

- Expansion of settlements in the Alexander Bay area, to accommodate workers;
- Increased associated demand for water and sanitation in the area;
- Increased use of roads and possible expansion of existing roads.

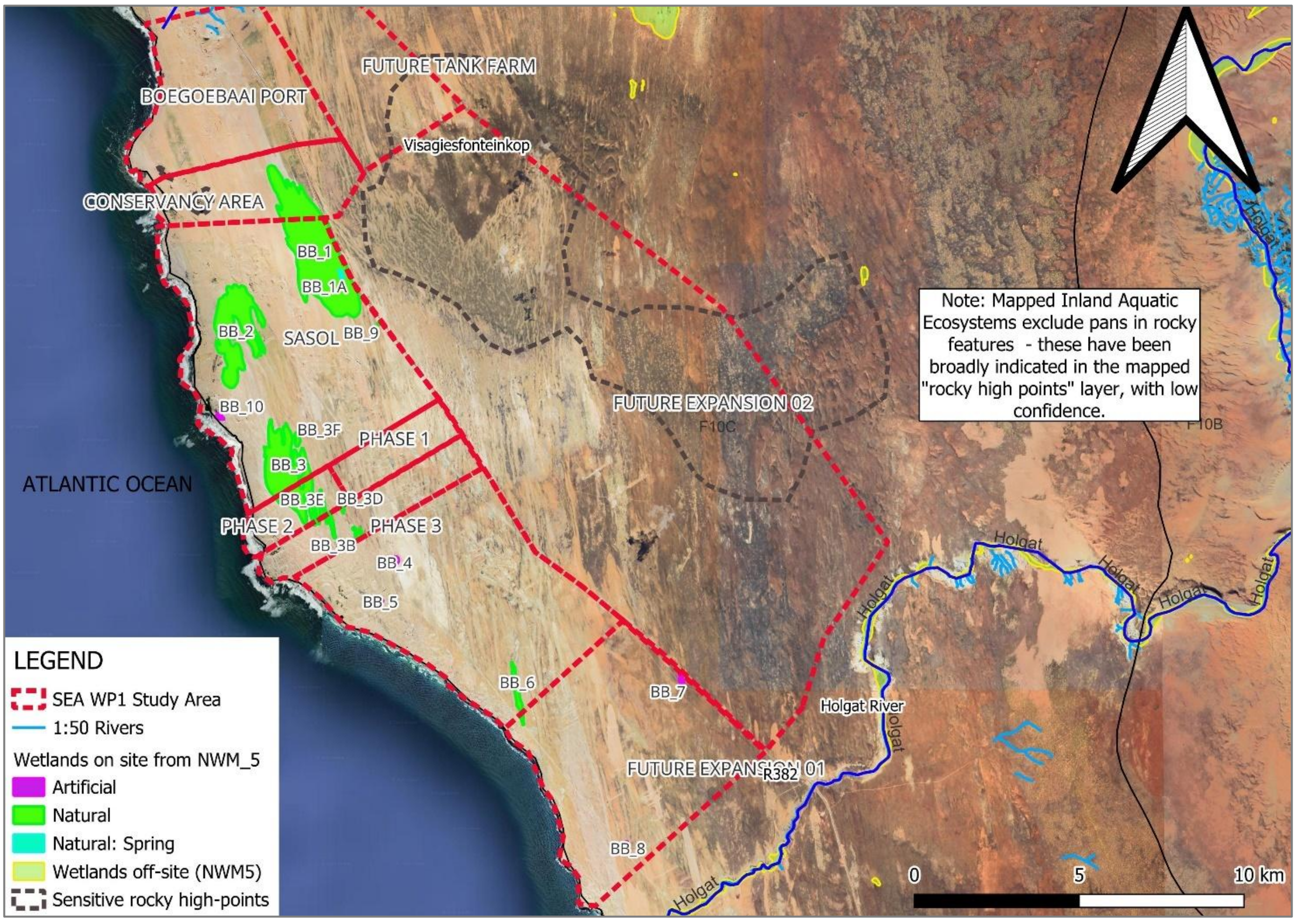

Figure 3.1
Proposed layout of Booegoebaai Port and SEZ for Work Phase 1 assessment, with overlay of inland aquatic ecosystems described in Section 2.

4. AQUATIC ECOSYSTEM SENSITIVITY RATINGS

4.1 Sensitivity defined

This section considers inland aquatic and estuarine ecosystems in the context of their likely sensitivity to the various activities associated with the proposed development, where aquatic sensitivity is defined as the capacity of an aquatic ecosystem (inland or estuarine) to tolerate disturbance. Sensitivity in this definition includes an element of ecological importance. That is, although some aquatic ecosystems may be "sensitive" (i.e. respond directly) to certain impacts, if they are of low ecological value, their sensitivity rating would not correspond to their actual response rating. Thus in this assessment, the term "sensitivity" includes elements of both the **ecological importance** and the **sensitivity** of the impacted system.

4.2 Issues likely to impact on aquatic ecosystems within the study area and its environs

4.2.1 Inland aquatic ecosystems

Section 2 identified a number of ephemeral pans, some of which include wetland habitat, comprising permanently to seasonally saturated areas, which support obligate wetland species such as *Phragmites australis* and *Sarcocornia cf. perenne*, and at least one of which includes a spring, fed by dune seepage, groundwater and/or relic lenses from past marine inundation. Some of the identified pans and wetlands comprise artificial systems, created by excavation during mining and, possibly, road construction, down to hardpan or calcrete lenses, on which water pools and provides ephemeral to seasonal aquatic habitat. All of the natural aquatic ecosystems in the study area have been categorised as Namaqualand Sandveld Bioregion depressions (including pans) and have been rated as Critically Endangered with a protection status of Not Protected.

These systems are considered highly sensitive to the following key issues, namely:

- Changes in hydroperiod:
    - Increases in hydroperiod (i.e. increased duration and frequency of inundation of the above systems could result in significant changes to habitat type and the biota that they support, potentially (and subject to water quality) increasing dominance by *Phragmites australis* reedbed, at the expense of biota including temporary pan zooplankton assemblages, adapted to life in ephemeral systems. In the absence of any data regarding the presence of such communities in these pans, a conservative approach has been taken, and it is assumed for the present that they occur in the study area;
    - Decreases in hydroperiod (i.e. interruption to the present sources of water into the pans and wetlands on the site would potentially also alter existing established aquatic ecosystems, potentially drying out existing sources of relatively fresh water on the site and the plants that they sustain, and thus impacting on food and/or water sources for terrestrial and aquatic fauna (see terrestrial ecosystem report for comments on the former) – disruption of existing water sources could stem from surface hardening (particularly of sand dunes that act as local aquifers) and diversion of stormwater systems past pans and wetlands usually linked to upstream seepage and flows;
- Changes in water quality:
    - "Freshening" of inflows into pans and wetlands (i.e. decreasing salinities) would potentially impact on natural / existing plant and animal communities that have adaptations to ecosystems that are characterised by brackish to saline conditions, increasing in some systems (e.g. BB2) to hypersaline periods. Freshening would be likely

to favour increasing dominance by freshwater-adapted species such as *Phragmites australis* at the expense of existing communities, particularly along the margins of permanent and seasonally inundated systems that currently support euryhaline and brackish plant species. Freshening could be associated with managed stormwater flows into pans and wetlands, if stormwater is piped or channelled such that it does not collect salts and minerals *en route* to receiving aquatic ecosystems;

- Nutrient enrichment: With the exception of aquatic ecosystems in pools and pans in rocky habitats, the identified pans and wetlands within the study area are probably least sensitive to nutrient enrichment, given that the permanent to seasonal systems (BB1 and BB2) were already in hypertrophic states in summer 2024, suggesting that these systems act as nutrient sinks, with nutrients contributing to the long-term build-up of organic layers in places that probably play a role in sustaining surface waters above these layers. However, all aquatic ecosystems would be assumed to have high sensitivity to pronounced and sustained nutrient enrichment, particularly in the forms of phosphorus and ammoniacal nitrogen, potentially associated with receipt of seepage or runoff from septic tanks, soakaways and treated sewage effluent;

- Physical disturbance:

  - The natural pans, wetlands and springs that occur in the study area all have high sensitivity to physical disturbance, which could disrupt subtle differences in topography, affecting inundation regime and also potentially exposing accumulations of organic material in seasonal wetland / spring areas, affecting rates of decomposition, nutrient cycling and aquatic ecosystem interactions. In the arid study area, physical disturbance (e.g. the creation of ruts and churning of surface sediments by machinery) would be unlikely to be re-set by natural processes such as flooding, and could result in permanent changes. In rocky outcrops, activities such as blasting or rock harvesting could destroy locally or regionally important ephemeral aquatic habitats and their biota;

  - Given their creation through excavation, artificial pans and depressions are assumed to have lower sensitivity to physical disturbance, although even artificial systems may support important biota - Bird (2012) for example found rare invertebrate fauna typical of ephemeral wetland habitat even in artificial roadside borrow pits in the region (e.g. notostracans of the genus *Triops*);

- Changes in surface runoff patterns:

  - All pans and other watercourses would be sensitive to changes in surface runoff velocities, potentially stemming from stormwater management systems for hardened surfaces including roads. Increased velocities would potentially lead to localised erosion, more importantly resulting in topographical changes in pans that alter inundation regime throughout the pan environment. Even subtle topographical change in these ephemeral systems could have significant ecological impacts;

- Fragmentation from other watercourses and supporting terrestrial areas:

  - Hydrological fragmentation: The wetland-associated pans (BB1, BB2, BB3 BB6 and spring area BB1-A) are most vulnerable to impacts of hydrological fragmentation, where this interrupts inflows into the systems or seepage from them. Such hydrological fragmentation could result from surface hardening of aquifer recharge areas, particularly in dune sands surrounding these pans and the spring area in particular, as well as from artificial diversion of stormwater flows past pans, wetlands and springs;

  - Physical (surface) fragmentation: The inland aquatic ecosystems identified in this study, particularly the larger pans BB1, BB2 and BB3 lie in relative proximity to each other and support birds, mammals, amphibian and invertebrate fauna and plants that rely on these areas at least at times. Isolation of these aquatic ecosystems from surrounding terrestrial areas and disruption of ecological corridors / links between pans could potentially significantly disrupt broader ecosystem function (assessed in the terrestrial faunal report) and affect the critical contribution of local aquatic ecosystems to broader terrestrial biodiversity.

4.2.2 Estuarine aquatic ecosystems

4.2.2.1 Orange River Estuary

Section 2.14.2 highlighted the current major challenges to effecting the required rehabilitation of the estuary to its REC of Category C. Drawing on these, at a local level, the estuary would be highly sensitive to activities / impacts that resulted in:

- Changes in freshwater flows (as a result of increased demand for fresh water, with water demand in Alexander Bay being met at least in part by flows from the Orange River upstream of the estuary (Hattingh 2016) - such demand could increase with an increased population in Alexander Bay, as a result of actual and perceived increases in local employment opportunities;

- Increased road infrastructure across the estuary, affecting flows into the estuarine saltmarshes (such impacts seem unlikely);

- Increased nutrient input – this could be associated with increased treated sewage effluent discharge from the Alexander Bay Waste Water Treatment Works (WWTW), as a result of local population increases;

- Increased fishing, as a result of a locally increased population, leading to increases in gill netting of indigenous fish species and fishing effort in the estuary;

- Increased grazing and hunting activities, particularly linked with a likely influx of population into the Alexander Bay area as a result of perceived or real employment opportunities;

- Increase in physical disturbance as a result of vehicle and other traffic into the estuary for bird viewing and other recreational activities – if such activities resulted in increased traffic across saltmarsh areas and increased localised dumping of solid waste (already visible along the estuarine margins in December 2024), in a seemingly largely unpoliced area, then significant estuarine degradation could accrue.

4.2.2.2 Holgat River Estuary

The Holgat Estuary is classified as a micro-outlet (see Section 2.14.3). Although its catchment has been rated as near-natural, the estuary itself has been highly altered by mining-associated activities and this, coupled with its highly ephemeral character, means that it has little estuarine function. The estuary has been rated as of Medium sensitivity to impacts associated with the proposed development, although both the Holgat River and its estuary lie outside of the study area and in fact are unlikely to be directly impacted by the proposed development.

4.3 Additive impacts of climate change

Any development in the study area would take place against a backdrop of climate change, potentially increasing water scarcity, temperature and evapo-concentration rates, as well as being associated with increased sea level and storm-surge heights (see Section 2.2.4). This report has already noted uncertainty with regard to surface/groundwater interactions in the study area (Section 2.11.2) and this adds to the uncertainty of predicting whether and how sea level rise might impact on inland aquatic ecosystem water quality (e.g. groundwater-linked wetlands) and thus on habitat quality. Sea level rise is, however, more likely to affect estuarine water quality and existing estuarine saltmarsh habitat. The Orange River Estuary, already impacted by reduced freshwater flows, would be particularly vulnerable to such changes. Increased surge heights could also result in increased vulnerability to erosion along the lower Orange River Estuary and its mouth. These kinds of impacts would be likely to affect aquatic ecosystem resilience, making them more sensitive to additional impacts associated with further development, and potentially increasing the magnitude of their response to these.

4.4 Sensitivity mapping

4.4.1 Approach

Drawing on the above sections, **Table 4.1** provides a structured approach to the rating of different aquatic ecosystems, from Very High to Low Sensitivity.

Table 4.1
Sensitivity rating categories for inland aquatic ecosystems

Sensitivity	Sensitivity Feature	Motivation
Very High	• Critically Endangered (CR) and Endangered (EN) wetland types from the NBA (Van Deventer et al. 2018) (i.e. depressions / pans) • Watercourses within CBA1 and CBA2 areas	These are highly threatened aquatic ecosystem types at both a regional and a national level These watercourses form part of the over-arching habitats that are required to ensure biodiversity conservation. [Note that with the exception of most of the Rietfontein wetlands (BB2), all of the present study area is included in CBA1 and CBA2 areas, and are rated as Critically Endangered watercourse types].
High	• FEPA sub-catchments • Upstream sub-catchments as identified in the NFEPA programme • All watercourses as mapped in 1:50 000 rivers layer and NFEPA river layer	These sub-catchments, including watercourses, need to be kept in good condition for the maintenance of important downstream river reaches Watercourses convey runoff into downstream reaches and therefore directly affect the condition of important downstream systems. They are also important corridors through the landscape and provide temporally rare and important habitat during wet periods. [In this assessment, artificial pans are rated as High sensitivity]
Medium	• All watercourse buffers / development setback areas	These areas are intended to provide protective space between the development edge (particularly hardened areas such as roads, buildings and solar panels) in which dissipation of stormwater and other impacts can take place. [In the absence of clear knowledge about surface/groundwater links between the larger pans (BB1, BB2 and BB3), 500m hydrological buffers have been allocated to accommodate recharge areas. 50 m setbacks have been allocated to all mapped wetlands, to accommodate low confidence in mapped extent and to provide protection from planned development activities].
Low	• Rest of site – i.e. non aquatic areas <u>outside of recommended aquatic ecosystem buffer zones</u>	Activities within these areas should have no impact on aquatic ecosystems and their dependent biota.

4.4.2 Assignment of sensitivity ratings

Drawing on the discussion in the previous section and **Table 4.1** in particular, inland and estuarine aquatic ecosystem sensitivity has been mapped, with specific regard to the proposed Boegoebaai Port and SEZ development. The results of this exercise are shown in **Figure 4.1**. In essence:

- Natural pans, associated wetlands and springs have been mapped as of Very High sensitivity;
- Artificial pans / excavations have been mapped as of High sensitivity;
- The Orange River Estuary has been mapped as of Very High sensitivity;
- The Holgat River Estuary (a micro-outlet) has been assessed as of Medium sensitivity – it is unlikely to be targeted as a water resource and lies outside of the proposed development;

- Pan / pool habitat assumed to be included in parts of rocky outcrops such as the Visagiesfonteinkop has been mapped as of High sensitivity – the mapped area corresponds to the mapped "sensitive rocky high points" data included in **Figure 2.10**;

- Buffer areas (50 m width outside of all mapped aquatic ecosystems have been included as protective setback areas that would help to ensure that mapped inland and estuarine aquatic ecosystems are protected from physical developmental impacts – these have been mapped as of Medium sensitivity;

- In addition, hydrological buffers, intended to improve confidence that hydrological linkages required for ensured ecosystem function can be maintained, have also been included and mapped as medium sensitivity – these have been conservatively set at 500 m for this assessment. This takes cognisance of the low confidence in this assessment as to some of the drivers of aquatic ecosystems in the study area, particularly with regards to BB1, BB2 and BB3. <u>This conservative buffer area could be reduced, if there is future improved, data-driven understanding of surface/groundwater/interflow linages and processes in this area</u>. These buffer areas have also been mapped as of Medium sensitivity

Note that **not** included in the sensitivity mapping below are corridors to allow for aquatic-to-aquatic and aquatic-to-terrestrial and coastal ecosystems, to ensure sustained ecological connectivity between different habitat types. This issue would need to be developed further during detailed development design, if such development was sanctioned for further consideration.

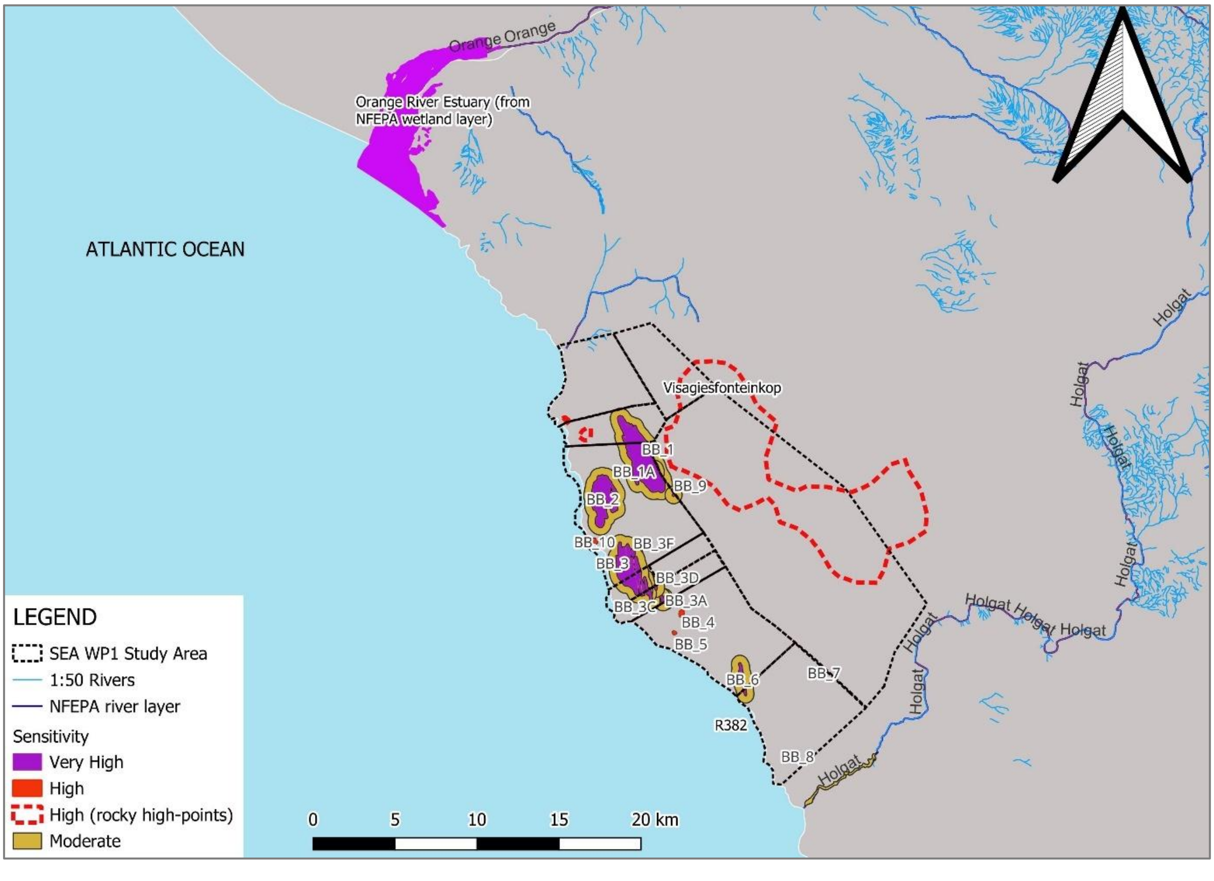

Figure 4.1
Inland and estuarine aquatic ecosystems sensitivity of the proposed Boegoebaai Port and SEZ study area (Work Package 1 of SEA assessment. Figure includes recommended buffer areas. Sensitivity applied only to the watercourses on and immediately abutting the site. Sensitivity layer assumes no mitigation measures.
<u>Grey areas on the site rated as of Low sensitivity to the present proposed project.</u>

5. ASPECTS AND IMPACTS REGISTER

This section draws on information and commentary provided in the previous sections, and uses these to compile an aspects and impacts register that highlights the key factors / issues likely to affect aquatic ecosystems as a result of the proposed developments, looking at the Work Package 1 development proposals only.

5.1 Aspects and impacts specific to inland and estuarine aquatic ecosystems

Impacts and aspects are outlined in **Table 5.1**, focusing only on those relevant to inland and estuarine aquatic ecosystems.

Table 5.1
Impacts and aspects register for inland and estuarine aquatic ecosystems

Development zone	Development aspect	Potential impact	Aquatic ecosystems of concern
Boegoebaai Port	Development footprint	Given low certainty about hydrological drivers for Visagiespan, Rietfontein and Rietfonteinpan wetlands and/or pans, the development footprint of the planned development would extend into the postulated recharge area of these important systems, and could potentially threaten their sustainability. This is a low-confidence impact, and detailed assessments could reduce uncertainty.	Extends (marginally) into potential recharge area for BB1 pan and springs; Also includes northern Boegoeberg Twin structure, which could potentially support inland aquatic biota typical of temporary / ephemeral pools
Conservancy area	This includes the northern portion of BB1 (Visagiespan)	Inclusion of the upper section of the mapped pan in the proposed conservancy area would be considered a positive aspect of the proposed development, albeit not compared to the *status quo*. Conservation of this area would potentially protect recharge areas for the pan and its wetlands and associated spring – however, improved confidence in understanding of pan, wetland and spring drivers is required.	BB1 (including BB1A)
SASOL area	This area would extend across the three largest pan / wetland / spring areas in the study area. Aspects of concern include: • Development footprint • Stormwater management • Roads (and associated culverts)	Impacts would include: • Destruction of wetlands that have been rated as Critically Endangered, are rare and interesting wetland systems, about which there is limited information, and which also are likely to play a critical role in supporting terrestrial fauna, at least at times • Degradation of any watercourses (wetlands, pans, springs) not lost to the development footprint, as a result of stormwater management systems that contain and divert stormwater, reducing recharge and increasing concentration of	This area includes the largest and most important pans, associated springs and wetlands within the study area.

Development zone	Development aspect	Potential impact	Aquatic ecosystems of concern
		flows, as well as potentially "freshening" flows into receiving pans / wetlands, as a result of bypassing sands and other substrate that would normally contribute dissolved salts to runoff; • Degradation from physical disturbance such as vehicle access.	
SEZ Industrial Park Phases 1, 2 and 3	This area would extend across the Rietfonteinpan (BB3) pan / wetland / spring area, and its hydrological buffer (assumed recharge area). Aspects of concern include: • Development footprint • Stormwater management • Roads • Treated sewage effluent disposal through septic tanks and use of infiltration systems	Impacts would include: • Destruction of pan and wetland habitat (BB3) that have been rated as Critically Endangered, are rare and interesting wetland systems, about which there is limited information; • Degradation of remaining pan and wetland areas as a result of physical disturbance such as vehicle access; • Potential increases in inflows of stormwater and treated sewage effluent into remnant wetlands / pans, likely to result in increased nutrient enrichment and possible changes in hydroperiod (increased water inflows). These would be likely to result in changes in vegetation (increased *Phragmites australis* dominance and loss of conditions that support (assumed) important ephemeral pan biotic assemblages.	Watercourse BB3 (ephemeral pan with wetland elements)
Future Green Hydrogen Facility	Aspects of concern include: • Development footprint • Stormwater management • Roads • Treated sewage effluent disposal through septic tanks and use of infiltration systems	Impacts in this area would include: • Destruction of presumed natural pan and wetland habitat (BB6) as well as artificial pans BB4 and BB5. • Potential increases in inflows of stormwater into remnant wetlands / pans, likely to result in changes in hydroperiod (increased water inflows). These would be likely to result in changes in vegetation (increased *Phragmites australis* dominance and loss of conditions that support (assumed) important ephemeral pan biotic assemblages, even in artificial systems; • Degradation from physical disturbance such as vehicle	This area includes artificial pans/wetlands, as well as an (un-ground-truthed) natural pan (BB6) and its potential recharge area).

Development zone	Development aspect	Potential impact	Aquatic ecosystems of concern
		access.	
Future Expansion 01	• Stormwater management • Roads • Treated sewage effluent disposal through septic tanks and use of infiltration systems	Impacts in this area would include: • Some destruction of the southern extreme of presumed natural pan and wetland habitat (BB6) as well as artificial pans BB7 and BB8. • Potential increases in inflows of stormwater into remnant wetlands / pans, likely to result in changes in hydroperiod (increased water inflows). These would be likely to result in changes in vegetation (increased *Phragmites australis* dominance and loss of conditions that support (assumed) important ephemeral pan biotic assemblages, even in artificial systems.	This area includes artificial pans/wetlands (BB7 and BB8) as well as the southern extent of the (un-ground-truthed) natural pan (BB6). Of these, BB6 is rated as Critically Endangered and the artificial systems also have probable high ecological importance
Future Expansion 02	Aspects of concern in this area would include blasting of rocks for construction; the development footprint; and treatment of stormwater from the site, potentially impacting on downstream systems including those within the SASOL site and Phases 1-3 of the propose SEZ Industrial Park.	Impacts in this area would include: • Destruction of presumed natural temporary pools/pan habitat; • Possible eutrophication of pan habitat as a result of inflows of polluted water – it is however assumed that most of these flows would occur downstream of important rocky pans / pools and that this impact would be unlikely; • Degradation of downstream ecosystems as a result of concentration of flows from upslope areas and/or increased rate of surface flows as a result of stormwater management interventions • Biodiversity impacts as a result of loss of physical connectivity between these high-lying areas and downstream areas – these impacts would however be primarily applicable to terrestrial biodiversity and have been assessed separately in the terrestrial faunal and floral biodiversity reports for this study.	This area includes the high-lying rocky outcrops of the Visagiesfonteinkop, which have been mapped with low confidence as including areas of ephemeral pans and pool of (undetermined) high biodiversity importance.

5.2 Indirect impacts

The proposed Boegoebaai Port and associated SEZ development, if implemented, could give rise to several indirect impacts to aquatic ecosystems (inland and estuarine), not highlighted in the aspects and impacts register presented in Table 5.1. These are outlined below.

5.2.1 Impacts to the Orange River Estuary

The Orange River Estuary lies outside of the Boegoebaai Port and SEZ areas. However, if development of these were to commence, there would potentially be highly significant impacts to the estuary, including its capacity to achieve its required REC. Degradation of the estuary is most likely to be associated with the following aspects, linked to increased human settlement (formal and informal) in the Alexander Bay area, resulting from real and/or perceived increased employment and other opportunities in the vicinity of the SEZ:

- Expansion of both formal and informal settlement within the town and its surroundings, with the increased population potentially associated with increased levels of solid waste accumulation, hunting and fishing – unmanaged hunting and fishing have both been identified as significant issues affecting estuarine condition;

- Increased demand for sewage reticulation and treatment which, if not met, would result in increased sources of pollution into the estuary;

- Increased water demand – it is assumed that this demand would be met by desalination projects within the SEZ and Boegoebaai Port areas – however, the availability of water in an arid area is likely to attract more people into the area, potentially encouraging urban sprawl and spill-over into adjacent saltpan margins on the edge of the existing town;

- Increased pressures on the estuary resulting from an expanding population, potentially including increased human and vehicle access to the estuary, perpetuating berms that currently provide vehicle access to the estuary mouth.

5.3 Other concerns

Not necessarily impacting on existing identified watercourses, but potentially contributing to landscape degradation over time, would be impacts resulting from stormwater management systems, across all proposed development zones. These would include management of runoff from roads and hardened areas. If stormwater design, particularly of culverts, do not take cognisance of the vulnerability of parts of the site to erode, during infrequent but major storm events (potentially at recurrences of 50 to 100 years only), then significant erosion dongas and associated degradation might develop in areas where watercourses are not currently in evidence, as a result of effective and rapid dissipation of stormwater flows into the landscape, without downslope channelling.

Near-coastal wetlands may potentially be additionally affected by sea level rise, if this affects groundwater quality potentially feeding these systems, leading to general loss of quality and resilience.

6. RECOMMENDED STRATEGIC MANAGEMENT ACTIONS

6.1 General

The study area is not rich in inland aquatic ecosystems. However, given the aridity of the area, those ecosystems that do occur are likely to be of very high importance from a terrestrial faunal perspective (see Niemandt 2025), and the ephemeral pans in this area are assumed to support interesting and rare aquatic invertebrate communities, including crustacean zooplankton fauna. The larger pans (Visagiespan, Rietfontein and Rietfonteinpan) in particular afford substantial wetland and pan habitat, with (unquantified) links to primary and/or secondary aquifers.

The study area also abuts two estuaries, with the Orange River Estuary being an important estuary at both a national and international level (Ramsar status and one of only two estuaries on the Namibian coast). The condition of the Orange River Estuary currently falls well short of its REC, requiring active interventions to improve estuarine condition. Developments that further threaten its condition, directly or indirectly, will have direct negative implications for meeting the estuarine Resource Quality Objectives.

6.2 Recommendations to reduce or avoid impacts

If the proposed Boegoebaai Port and associated SEZ project are pursued in the present study area, then, from the perspective of reducing impacts to important inland and estuarine aquatic ecosystems, the following measures should be implemented, to reduce otherwise significant impacts on inland and/or estuarine aquatic ecosystems:

- Avoidance:
    - Development of the SASOL block; and Phases 2 and 3 (western portion) of the SEZ Industrial Park; as well as the south-western portion of the Future GH2 Facility; and the northern corner of Future Expansion Area 01 (over the recharge / buffer area of BB6) would not be compatible with the required (from a biodiversity conservation perspective) conservation of the important pans and associated wetlands in these areas;
    - Development involving rock blasting, flattening of slopes and/or loss of rocky outcrops that include ephemeral pool and pan habitat (e.g. Visagiesfonteinkop area) would also potentially impact on important mosaic pan habitat and should also be avoided;
- Impact mitigation:
    - The no-development areas outlined above would need to be actively managed / policed to prevent vehicle passage across pans and wetlands outside of existing roads / tracks;
    - The no-development areas outlined above would need to be tied in to terrestrial corridors that allowed for faunal connectivity within and between terrestrial and aquatic habitats;
    - Developed areas would need to be designed such that they did not include hardening of surfaces or diversion of surface flows from the 500 m proposed recharge area for natural pans;
    - Stormwater management design would need to be such that it:
        - Would not result in concentration of flows through the landscape, leading to the creation of erosion gulleys and resultant changes in the flow of water across and through the site – multiple smaller culverts would as a general rule result in less impact than single large culverts in these terrains, although they might require more maintenance;

        - Takes cognisance of the need for dissipation of stormwater flows into the substrate, rather than its rapid conveyance to the coast;
        - Does not bypass inland aquatic ecosystems or their buffer areas;
    - Waste water treatment and management from developments within the study area would need to ensure that waste streams from these activities do not pass, by way of seepage or flows, into pans, wetlands or their buffer area, unless treated to levels that would have negligible impact on aquatic habitat, as determined by an aquatic ecologist;

- Impact management:
    - Development in this area would need to allow (specifically) for increased resources at the Orange River Estuary, to control and police fishing, hunting and vehicle access and movement within the estuary, including its important saltmarshes;
    - Any provision of fresh water from desalination plants to the Alexander Bay or other communities / urban areas must be matched by an equal increase in infrastructure and human resources to treat the additional resultant waste water that would be generated from these areas, to a level that would not impact negatively on any receiving watercourse, and the Orange River Estuary in particular. This might mean far more stringent water quality treatment standards than those imposed by the General and Special Effluent Limits currently applicable to most WWTWs;
    - Provision would also need to be made for the management of solid waste in expanding urban settlements associated directly or indirectly with the proposed development, and in Alexander Bay in particular, where the greatest levels of urban expansion would be anticipated;
    - Upgrading of existing or new external roads to the study areas would need to be designed with particular attention paid to the design of bridges and culverts, such that they do not result in the concentration of flows into downstream areas, or alternatively block off flood flows in episodic flood conditions.

6.3 Information gaps

In the event that this project is considered further, and enters the required Environmental Impact Assessment (EIA) process and/or application phases for consideration for water use authorisation or registration, the following additional information would be needed to inform the necessary specialist aquatic ecosystem assessments:

- High-confidence investigation of surface / groundwater linkages in the Visagiespan, Rietfontein and Rietfonteinpan systems, potentially by way of a hydropedological study and/or geohydrological assessment;
- Identification and mapping of key temporary pan habitat in rocky outcrops;
- Wet-season assessment of ephemeral wetland invertebrate faunal communities;
- Detailed stormwater management plans;
- Details regarding the approach to dealing with the impact avoidance, mitigation and management measures outlined in Section 6.2.

7. CONCLUSIONS

This report has provided an overview of inland and estuarine aquatic ecosystems on and in the vicinity of the proposed Boegoebaai Port and SEZ areas, highlighting their importance and sensitivity to various development-related aspects. Overall, the assessment showed that the study area is not rich in inland aquatic ecosystems. However, given the aridity of the area, those ecosystems that do occur are likely to be of very high importance from a terrestrial faunal perspective (see Niemandt 2025), and the ephemeral pans in this area are assumed to support interesting and rare aquatic invertebrate communities, including crustacean zooplankton fauna. The larger pans (Visagiespan, Rietfontein and Rietfonteinpan) in particular afford substantial wetland and pan habitat, with (unquantified) links to primary and/or secondary aquifers, which form springs in at least Visagiespan, creating permanent standing water pools which are clearly utilised by terrestrial fauna, either directly as a (brackish to saline water source) or indirectly, for grazing of wetland plants that are supported by perennial water supply in places. Other inland aquatic ecosystems of assumed high biodiversity importance include ephemeral pans located in rocky outcrops across the site, some of which are likely to support communities of invertebrates adapted to ephemeral conditions and with high conservation importance. These systems have been mapped in this study with low confidence.

The proposed development would, in the conceptual layout presented for assessment in this study, result in potential loss of all of the inland aquatic ecosystems identified in the study area. Of these, natural pans and depression wetlands have been rated as Critically Endangered systems in the 2018 NBA (Van Deventer et al. 2018). The report recommends major changes in development layout that avoid these systems, and furthermore include ecological corridors that link between ecologically important terrestrial, coastal and (inland) aquatic areas across the site. Mitigation measures include addressing potential impacts associated with concentrated stormwater flows through areas characterised by increasingly hardened surfaces, which could bypass dependent aquatic ecosystems.

The study area also abuts two estuaries, namely the ephemeral Holgat River estuary, classified as a micro-outlet, and the Orange River Estuary. The latter is an important estuary at both a national and international level, having been accorded Ramsar Wetland status and being one of only two estuaries on the Namibian coast. The condition of the Orange River Estuary does however fall well short of its Recommended Ecological Category, requiring active interventions to improve estuarine condition. This is important, because new developments, such as that proposed, that further threaten its condition, directly or indirectly, would have direct negative implications for meeting the estuary's Resource Quality Objectives.

The report notes that development of the Boegoebaai Port and SEZ, if approved, would need to allow (specifically) for increased resources at the Orange River Estuary, to control and police fishing, hunting and vehicle access and movement within the estuary, including its important saltmarshes. In addition, it would need to match any provision of fresh water from desalination plants to the Alexander Bay or other communities / urban areas with an equal increase in infrastructure and human resources capacity to treat the additional resultant waste water that would be generated from these areas, to a level that would not impact negatively on any receiving watercourse, and the Orange River Estuary in particular. This might mean far more stringent water quality treatment requirements. Other required measures to address indirect impacts associated with expansion of urban areas as a result of the proposed development include the need for upgrading of solid waste management and attention to the design of new and/or upgraded external access roads, such that they do not result in downstream erosion or blockages of flows in flood conditions.

Finally, the report highlighted a number of information gaps that would need to be addressed if the proposed project is considered further and taken into Environmental Impact Assessment and/or Water Use License Application phases. These include detailed studies to unpack surface / groundwater interactions at the major pan / spring/ wetland areas (BB1, BB2 and BB3); wet-season assessment of ephemeral wetland invertebrate faunal communities; development of detailed stormwater management plans that take cognisance of the sensitivity of inland and estuarine aquatic ecosystems on and near the site; and details as to measures that can address the impact avoidance, mitigation and management measures outlined in the report.

It is further noted that there are no positive impacts to inland or estuarine aquatic ecosystems that would be associated with the proposed Boegoebaai Port and SEZ development, and substantial negative impacts could accrue, unless stringently addressed in development layout (avoidance), design and management.

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