Volwaterbaai Desalination Plant and Associated Infrastructure, Northern Cape

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Appendix 4A Terrestrial and Aquatic Ecology Impact Assessment

TERRESTRIAL AND FRESHWATER ECOLOGICAL ASSESSMENT AS PART OF THE ENVIRONMENTAL ASSESSMENT AND AUTHORISATION PROCESS FOR THE PROPOSED CONSTRUCTION OF A SEAWATER DESALINATION PLANT, INCLUDING ASSOCIATED INFRASTRUCTURE AND SERVICES AT VOLWATERBAAI, NEAR ABRAHAMS VILLIERS BAY IN THE NORTHERN CAPE PROVINCE.

Prepared for

SRK Consulting.

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Declaration

This report has been prepared according to the requirements of Section 32 (3b) of the Environmental Impact Assessments EIA Regulations, 2010 (GNR 543). We (the undersigned) declare the findings of this report free from influence or prejudice.

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EXECUTIVE SUMMARY

Scientific Aquatic Services (SAS) was appointed to conduct a terrestrial and freshwater ecological assessment as part of the environmental assessment and authorisation process for the proposed construction of a seawater desalination plant producing 8M m^3/annum of fresh/potable water, including associated infrastructure and services at Volwaterbaai, on the farm Strandfontein 559 in the Northern Cape Province, to supply water via a transfer pipe (approximately 42km, distance may vary slightly between route alternatives) to the proposed Zandkopsdrift Mine by Sedex Minerals (Pty) Ltd (Sedex Minerals)(EIA ref : NC/EIA/NAM/KAM/ZAN/2012).

Access roads need to be provided from the desalination plant to the Zandkopsdrift Mine as well as to all pipelines, power lines, reservoirs and any other associated infrastructure. Initailly ten possible routes linking the proposed Volwaterbaai desalination plant and Zandkopsdrift mine were investigated. After the initial screening study only two route alternatives were assessed for the main access road and associated infrastructure from the desalination plant to Zandkopsdrift Mine. Both route alternatives follow existing gravel public roads (P2936, OG155, OG299 and OG153) and private 4x4 tracks for the majority of their lengths and will therefore only require the widening and upgrading of portions of existing gravel roads as well as the development of linear infrastructure adjacent to existing roads. The two alternatives assessed in the EIA will be referred to as the Kotzesrus Route and the Amended Bypass Route (Bypassing the town of Kotzesrus). Furthermore, five alternative positions for the desalination plant were identified on the farm Strandfontein 559 and will be referred to as sites A-E. The locations of each of the alternative routes and each of the desalination site alternatives are depicted in Figures 1 and 2 below. It should be noted that the larger area that includes the route alternatives, desalination site alternatives as well as immediate surroundings will be referred to as the “study area” in this report.

<u>The following general conclusions were drawn on completion of the assessment.</u>

DESKTOP ASSESSMENT

- According to the National Land Cover database (2009), the majority of the study area is indicated to be natural land, however, small portions along each of the route alternatives have been transformed for cultivation purposes and urban development;
- According to the National List of Threatened Terrestrial Ecosystems the study area does not fall within a threatened terrestrial ecosystem;
- According to the National Biodiversity Assessment (NBA, 2011) the study area is not located within either a formal or informal protected area; and
- According to the Namakwa District Biodiversity Sector Plan (2008) both route alternatives traverse similar areas of terrestrial Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs). However, the Kotzesrus Route traverses an aquatic ESA and CBA which is avoided by the Amended Bypass Route.

FLORAL ASSESSMENT

- Five floral habitat units were identified within the study area. These habitat units include:
    - The succulent karoo habitat unit which could be further divided into:
        - The strandveld habitat unit;
        - The hardeveld habitat unit; and
        - The coastal habitat unit.
    - The sand fynbos habitat unit;
    - The wetland/riparian habitat unit;
    - The rocky outcrop habitat unit; and
    - The transformed habitat unit.
- The Vegetation Index Score (VIS) for each of the habitat units was calculated and is listed below:
    - Vegetation characteristics varied between the sub-habitat units within the succulent karoo habitat unit, however, the overall PES of the different habitat units was similar and could therefore be considered in a single assessment. The succulent karoo habitat unit (including the strandveld, hardeveld and coastal habitat units) calculated a high score which falls within Class B – Largely natural with few modifications;
    - The sand fynbos habitat unit calculated a very high score which falls within Class A – Natural, unmodified;

- The wetland/riparian habitat unit calculated a high score which falls within Class B – Largely natural with few modifications;
- The rocky outcrop habitat unit calculated a high score which falls within Class B – Largely natural with few modifications; and
- The transformed habitat unit calculated a low score which falls within Class E- Loss of natural habitat is extensive.

➢ An assessment considering the presence of any floral Species of Conservation Concern (SCC) and protected plant species was undertaken:
  - Floral SCC identified within the study area at the time of the assessment include *Leucospermum rodolentum* (Vulnerable), *Babiana hirsuta* (Near threatened), *Bulbine bruynsii* (Vulnerable) and *Aloe arenicola* (Near Threatened);
    - *Leucospermum rodolentum* was identified scattered throughout sand fynbos occurring approximately 4km to the west of Kotzesrus;
    - *Babiana hirsuta* was identified scattered throughout the sand fynbos, strandveld and coastal habitat units to the west of Kotzesrus*;*
    - *Bulbine bruynsii* was restricted to quartz patches to the east of Kotzesrus; and
    - *Aloe arenicola* was identified within the strandveld habitat unit occurring approximately 8km to the west of Kotzesrus; and
  - There is also a moderate possibility that further undetected SCC including *Babiana rubella* (Declining), *Lampranthus procumbens* (Vulnerable)*, Leucoptera nodosa* (Vulnerable), *Muraltia obovata* (Vulnerable), *Helichrysum dunense* (Vulnerable), *Elegia* sp. nov. (not yet assessed) and *Oncosiphon schlechteri* (Endangered) may occur in the study area.

➢ In terms of vegetation sensitivity the study area can be divided into very high sensitivity vegetation, high sensitivity vegetation, moderate sensitivity vegetation and low sensitivity vegetation:
  - Very high sensitivity vegetation includes the wetland habitat unit, the rocky outcrop habitat unit and quartz and clay exposures within the hardeveld habitat unit;
  - High sensitivity vegetation includes the sand fynbos and coastal habitat units;
  - Moderate sensitivity vegetation includes the strandveld habitat unit and the hardeveld habitat unit (excluding quartz and clay exposure areas); and
  - Low sensitivity vegetation includes the transformed habitat unit.

FAUNAL ASSESSMENT

➢ Four faunal habitat units occur within the study area. These include terrestrial (succulent karoo and sand fynbos), rocky outcrop, wetland/riparian and transformed habitat units:
  - Faunal species are not likely to permanently inhabit terrestrial areas in the immediate vicinity of gravel roads as a result of the edge effects and noise associated with the movement of vehicles through the area, however, faunal species may move through these terrestrial habitats when migrating or foraging;
  - Rocky outcrop and wetland/riparian habitat units provide niche habitats for faunal species within the area and are likely to provide important foraging and breeding habitat. Furthermore, wetland/riparian habitat may provide important migratory corridors through the otherwise arid environment; and
  - Transformed habitat units are not likely to provide suitable habitat to support a large diversity of faunal species, however, faunal species may move through these areas when migrating or foraging;

➢ Three Red Data List (RDL) faunal species, *Sagittarius serpentarius* (Secretary Bird), *Gerrhosaurus typicus* (Namaqua Plated Lizard) and *Homopus signatus* (Padloper Tortoise), were identified during the site survey and a total of nine RDL faunal species were found to have a 60% or greater probability of occurrence within the study area;

➢ The Red Data Sensitivity Index Score (RDSIS) assessment of the study area resulted in a score of 53%, indicating a moderate importance in terms of RDL faunal species conservation within the region and specifically the study area. Habitat units located along each of the route alternatives are considered suitable to support RDL faunal species within the study area;

➢ In terms of faunal sensitivity the study area can be divided into very high sensitivity faunal habitat, moderate sensitivity faunal habitat and low sensitivity faunal habitat:
  - Very high sensitivity faunal habitat includes those habitat units which provide niche habitat for specialist faunal species and those habitats which are restricted and limited within the region. Very high sensitivity faunal habitats include rocky outcrop areas and wetland areas;
  - Moderate sensitivity faunal habitats include all terrestrial areas; and
  - Low sensitivity faunal habitats include transformed areas.

FRESHWATER ECOLOGY ASSESSMENT

- Wetland/Riparian habitat associated with the route alternatives could be divided into the following wetland groups:
  - The Brak River;
  - Tributaries of the Groen River;
  - Ephemeral pans; and
  - Artificial depressions.
- Numerous ephemeral drainage features were also identified intercepting the route alternatives. These drainage lines are likely to convey water during and immediately after rainfall events. However, the drainage lines do not retain water long enough for the formation of hydromorphic soils that would support facultative floral species. As a result these systems cannot be defined as wetlands;
- The function and service provision was calculated for each of the wetland groups associated with the route alternatives. From the results of the assessment, it is evident that none of the features encountered within the study area are regarded as being of exceptional importance in terms of function and service provision. The Brak River and tributaries of the Groen River are considered to provide a moderately low level of ecological function and service provision and natural ephemeral pans and artificial depression features are considered to provide a low level of ecological function and service provision;
- The PES of all wetland features was determined using the WET-health methodology:
  - The Brak River, tributaries of the Groen River and ephemeral pans can be considered largely intact wetland habitat and were therefore calculated to fall within PES Category A (unmodified, natural);
  - Artificial depressions are artificial features and were therefore calculated to fall within PES Category F (critically modified);
  - In terms of anticipated trajectory, should the development of linear infrastructure associated with route alternatives not take place, it is considered to be highly likely that the PES of all wetland features assessed would remain the same. However, should the development of the route alternatives occur, the health of wetland features would most likely decrease;
- The Ecological Importance and Sensitivity (EIS) was calculated for each wetland group:
  - The Brak River and tributaries of the Groen River were calculated to have an EIS falling within Category A (very high sensitivity);
  - The EIS score of the ephemeral pans was calculated to fall within Category B (high sensitivity);
  - The EIS score of the artificial depressions was calculated to fall within Category D (low sensitivity).
- The Recommended Ecological Category (REC) deemed appropriate to enhance and maintain current ecology as well as functionality within the Brak River, tributaries of the Groen River and ephemeral pans is Category A (Unmodified) and the REC deemed appropriate to maintain the current ecology as well as functionality within artificial depressions is Category D (largely modified);
- Both route alternatives are located within 32m of watercourses/wetlands and will therefore trigger activities as listed by the National Environmental Management Act (NEMA, Act 107 of 1998); and
- The linear nature of the proposed route alternatives means that it will be necessary for route alternatives to cross wetland areas and ephemeral drainage features within the study area. Although the majority of wetland and ephemeral drainage feature crossings occur on existing gravel roads and tracks, where roads need to be widened wetland habitat will be impacted. Furthermore, support structures of pipelines and power lines will fall within the road reserve and could therefore also have an impact on wetland features. Any activities occurring within the wetland boundary or within 32m of wetland features must be authorised by the Department of Water Affairs (DWA) in terms of Section 21 (c) & (i) of the NWA (Act 36 of 1998).

IMPACT ASSESSMENT

Impacts associated with the floral, faunal and freshwater ecology of the study area have been assessed separately for the Kotzesrus Route and the Amended Bypass Route. Desalination plant alternatives were divided into two groups with similar associated impacts. Sites A, C and D are all located within the strandveld habitat unit and will result in the removal of a similar extent of this moderate sensitivity vegetation. Sites B and E are located within high sensitivity coastal vegetation and will result in the removal of a similar extent of this vegetation. Impacts associated with sites A, C and D are therefore considered similar and impacts associated with sites B and E are considered similar. These two groups of alternatives were therefore assessed separately. Impacts have also been assessed separately for both the construction and operational phase of the development.

Table A below summarises the findings of the impact assessment, indicating the significance of each impact before management takes place and the likely significance of the impacts if management and mitigation takes place.

Table A: Summary of impact assessment results.

Impact	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
IMPACT 1: LOSS OF FLORAL HABITAT, BIODIVERSITY AND SCC (EXCLUDING QUARTZ AND CLAY EXPOSURE AREAS)					
KOTZESRUS ROUTE					
Construction Phase					
Without Mitigation	High	Definite	**HIGH**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
AMENDED BYPASS ROUTE					
Construction Phase					
Without Mitigation	Medium	Definite	**MEDIUM**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
DESALINATION PLANT ALTERNATIVES A, C AND D					
Construction Phase					
Without Mitigation	Medium	Definite	**MEDIUM**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
DESALINATION PLANT ALTERNATIVES B AND E					
Construction Phase					
Without Mitigation	Medium	Definite	**MEDIUM**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
IMPACT 2: LOSS OF FLORAL HABITAT, BIODIVERSITY AND SCC ASSOCIATED WITH QUARTZ AND CLAY EXPOSURE AREAS					
KOTZESRUS ROUTE AND AMENDED BYPASS ROUTE					
Construction Phase					
Without Mitigation	Very High	Definite	**VERY HIGH**	–ve	High
With Mitigation	LOW	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High

IMPACT 3: IMPACT ON FAUNAL HABITAT, DIVERSITY AND RDL/PROTECTED SPECIES					
KOTZESRUS ROUTE					
Construction Phase					
Without Mitigation	High	Definite	**HIGH**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Probable	**LOW**	–ve	High
With Mitigation	Low	Possible	**VERY LOW**	–ve	High
AMENDED BYPASS ROUTE					
Construction Phase					
Without Mitigation	Low	Definite	**LOW**	–ve	High
With Mitigation	Low	Definite	**VERY LOW**[1]	–ve	High
Operational Phase					
Without Mitigation	Low	Probable	**LOW**	–ve	High
With Mitigation	Low	Possible	**VERY LOW**	–ve	High
DESALINATION PLANT ALTERNATIVES A, C AND D					
Construction Phase					
Without Mitigation	Low	Definite	**LOW**	–ve	High
With Mitigation	Low	Definite	**VERY LOW**[2]	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
DESALINATION PLANT ALTERNATIVES B AND E					
Construction Phase					
Without Mitigation	Medium	Definite	**MEDIUM**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
IMPACT 4: DISRUPTION OF FAUNAL MIGRATORY CORRIDORS					
KOTZESRUS ROUTE AND AMENDED BYPASS ROUTE					
Construction and Operational Phase					
Without Mitigation	Low	Probable	**LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High
IMPACT 5: LOSS OF WETLAND HABITAT AND ECOLOGICAL STRUCTURE					
KOTZESRUS ROUTE					
Construction Phase					
Without Mitigation	High	Definite	**HIGH**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High

[1] Although the impact rating methodology provided by SRK resulted in a low significance rating after the implementation of mitigation measures, it is the opinion of the ecological specialist, based on professional judgment and experience, that the mitigation measures, if strictly adhered to, are deemed sufficient to reduce the overall impact to a very low level.

[2] Although the impact rating methodology provided by SRK resulted in a low significance rating after the implementation of mitigation measures, it is the opinion of the ecological specialist, based on professional judgment and experience, that the mitigation measures, if strictly adhered to, are deemed sufficient to reduce the overall impact to a very low level.

AMENDED BYPASS ROUTE					
Construction Phase					
Without Mitigation	Medium	Definite	**MEDIUM**	–ve	High
With Mitigation	Low	Definite	**LOW**	–ve	High
Operational Phase					
Without Mitigation	Low	Possible	**VERY LOW**	–ve	High
With Mitigation	Very Low	Improbable	**INSIGNIFICANT**	–ve	High

CONCLUSION

The Kotzesrus Route and the Amended Bypass Route follow the same route for the majority of their lengths. The only variation in the route is where the Kotzesrus Route follows a gravel road running through the town of Kotzesrus and the Amended Bypass Route diverts around the town of Kotzesrus before re-joining the Kotzesrus Route to the west of Kotzesrus.

The Kotzesrus Route traverses the Brak River both to the east of Kotzesrus and to the west of Kotzesrus. To the east of Kotzesrus the route traverses the Brak River on a well-developed provincial gravel road. However, to the west of Kotzesrus it traverses the Brak River on a smaller, poorly developed gravel road. The Brak River is considered to be of very high sensitivity and very high sensitivity rocky outcrop habitat is also associated with the portion of the river to the west of Kotzesrus. The development of the Kotzesrus Route through this portion of river may require the widening of the existing road and the loss of wetland and rocky outcrop habitat, and the development of pipelines and power lines through the river will also result in the disturbance and loss of habitat.

The majority of the portion of the Amended Bypass Route which diverts around Kotzesrus follows existing gravel roads and 4x4 tracks. The route followed by the Amended Bypass route runs through moderate sensitivity strandveld vegetation which is perceived to have been disturbed as a result of small livestock grazing, and *Acacia cyclops* encroachment was also noted along the majority of the route. By diverting around the town of Kotzesrus the Amended Bypass Route avoids crossing the very high sensitivity Brak River and avoids the disturbance of very high sensitivity rocky outcrop areas associated with the river. The route does traverse an ephemeral drainage line which augments the Brak River. However it traverses the drainage feature at a 90 degree angle which will limit disturbance to the feature, and if all mitigation measures are implemented, hydrological connectivity will not be lost as a result of the crossing. Both the Kotzesrus Route and the Amended Bypass Route traverse a similar distance through terrestrial CBAs and ESAs. However, by diverting around the town of Kotzesrus the Amended Bypass Route avoids crossing the aquatic CBA associated with the Brak River.

Both route alternatives were found to traverse very high sensitivity quartz and clay exposure areas which provide the habitat to support the rare and vulnerable SCC *Bulbine bruynsii*. This species was originally though to consist of one population of approximately 300 plants (Helme and von Staden, 2012). However, a recent survey of the area (Helme, 2014) revealed that *Bulbine bruynsii* is in fact much more widely distributed than was previously thought, although it is still a rare and localised species in global terms. If mitigation measures as listed within this report are implemented it is unlikely that more than 20 plants of *Bulbine bruynsii* would be lost as a result of the development of either route alternative. This is likely to be less than 1% (possibly as little as 0.3%) of the total population, and would therefore constitute a low negative impact on the species. The proposed mitigation should also ensure that overall habitat damage is minimised and kept within acceptable limits (Helme, 2014).

When considering the above, the overall impact that will be created as a result of the development of the Kotzesrus Route is deemed to be higher than that created as a result of the development of the Amended Bypass Route due to the fact that the Kotzesrus Route will traverse the Brak River and associated rocky outcrop areas. Therefore, although the development of both route alternatives is considered acceptable, it is the opinion of the ecologist that the Amended Bypass Route be chosen as the preferred alternative. If the Amended Bypass Route is chosen as the preferred alternative the very high sensitivity Brak River and rocky outcrop areas can be avoided.

Desalination plant alternatives A, C and D are located a greater distance from the coastal environment and very high sensitivity coastal rocky outcrop areas when compared to desalination plant alternatives B and E. The development of sites A, C and D will therefore result in the removal of moderate sensitivity strandveld vegetation rather than high sensitivity coastal vegetation and is less likely to impact on coastal rocky outcrop areas when compared to sites B and E. Therefore, although the development of all sites is considered acceptable, it is the opinion of the ecologist that the development of site A, C or D would be preferable to the development of site B or E. However, site C is located in close proximity to gravel roads which lead to areas in the vicinity of seawater intake and discharge sites. The development of pipelines within these disturbed road or road reserve areas will reduce the impact on surrounding natural areas. Site C will require the shortest distance of pipeline to be constructed along existing gravel roads and is therefore the preferred site for the development of the desalination plant from an ecological view point, followed by site A and D.

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GLOSSARY OF TERMS

Alien Invasive vegetation	Alien invaders are plants that are of exotic origin and are invading previously pristine areas or ecological niches
nov.	New species
Rare	Organisms with small populations at present.
Red Data Listed species	Organisms that fall into the Extinct in the Wild, Critically Endangered, Endangered, Vulnerable categories of ecological status as listed by the IUCN.
Species of Conservation Concern	Floral species that have a high conservation importance in terms of preserving South Africa's high floristic diversity and include not only threatened species, but also those classified in the categories Extinct in the Wild, Regionally Extinct, Near Threatened, Critically Rare, Rare, Declining and Data Deficient - Insufficient Information.
Threatened species	Species that are facing a high risk of extinction. Any species classified in the IUCN categories Critically Endangered, Endangered or Vulnerable is a threatened species.

ACRONYMS

ARC	Agricultural Research Council
BGIS	Biodiversity Geographic Information Systems
DEA	Department of Environmental Affairs
EAP	Environmental Assessment Practitioner
EIS	Ecological Importance and Sensitivity
CARA	Conservation of Agricultural Resources Act
CBA	Critical Biodiversity Area
DWA	Department of Water Affairs
ECO	Environmental Control Officer
ESA	Ecological Support Area
GIS	Geographic Information System
IUCN	International Union for Conservation of Nature and Natural Resources
m	Metres
mm	Millimetres
Mm^3/a	1000 cubic meters per year
NBA	National Biodiversity Assessment
NCNCA	Northern Cape Nature Conservation Act
NEMA	National Environmental Management Act
NEMBA	National Environmental Management Biodiversity Act
NFEPA	National Freshwater Ecosystem Priority Areas
NT	Near Threatened
NWA	National Water Act
NYBA	Not Yet Been Assessed

PES	Present Ecological State
pg	Page
POC	Probability of occurrence
PRECIS	Pretoria Computer Information Systems
PSDF	Provincial Spatial Development Framework
QDS	Quarter degree square (1:50,000 topographical mapping references)
RDL	Red Data listed
RDSIS	Red Data Sensitivity Index Score
REC	Recommended Ecological Category
SANBI	South African National Biodiversity Institute
SAS	Scientific Aquatic Services
SCC	Species of Conservation Concern
Sp.	Species

1 INTRODUCTION

1.1 Background

Scientific Aquatic Services (SAS) was appointed to conduct a terrestrial and freshwater ecological assessment as part of the environmental assessment and authorisation process for the proposed construction of a seawater desalination plant producing 8M m^3/annum of fresh/potable water, including associated infrastructure and services at Volwaterbaai, on the farm Strandfontein 559 in the Northern Cape Province, to supply mineralised water via a transfer pipe (approximately 42km, distance may vary slightly between route alternatives) to the proposed Zandkopsdrift Mine by Sedex Minerals (Pty) Ltd (Sedex Minerals)(EIA ref : NC/EIA/NAM/KAM/ZAN/2012).

Access roads need to be provided from the desalination plant to the Zandkopsdrift Mine as well as to all pipelines, power lines, reservoirs and any other associated infrastructure. Initailly ten possible routes linking the proposed Volwaterbaai desalination plant and Zandkopsdrift mine were investigated. After the initial screening study only two route alternatives were assessed for the main access road and associated infrastructure from the desalination plant to Zandkopsdrift Mine. Both route alternatives follow existing gravel public roads (P2936, OG155, OG299 and OG153) and private 4x4 tracks for the majority of their lengths and will therefore only require the widening and upgrading of portions of existing gravel roads as well as the development of linear infrastructure adjacent to existing roads. The two alternatives assessed in the EIA will be referred to as the Kotzesrus Route and the Amended Bypass Route (Bypassing the town of Kotzesrus). Furthermore, five alternative positions for the desalination plant were identified on the farm Strandfontein 559 and will be referred to as sites A-E. The locations of each of the alternative routes and each of the desalination site alternatives are depicted in Figures 1 and 2 below. It should be noted that the larger area that includes the route alternatives, desalination site alternatives as well as immediate surroundings will be referred to as the “study area” in this report.

This report, after consideration and description of the Present Ecological State (PES) as well as the ecological importance and sensitivity (EIS) of the study area, aims to guide the proponent (Sedex Desalination (Pty) Ltd., Environmental Assessment Practitioner (EAP), and authorities, by means of recommendations, as to viability of each of the alternatives from an environmental perspective, with a specific focus on terrestrial and freshwater ecology.

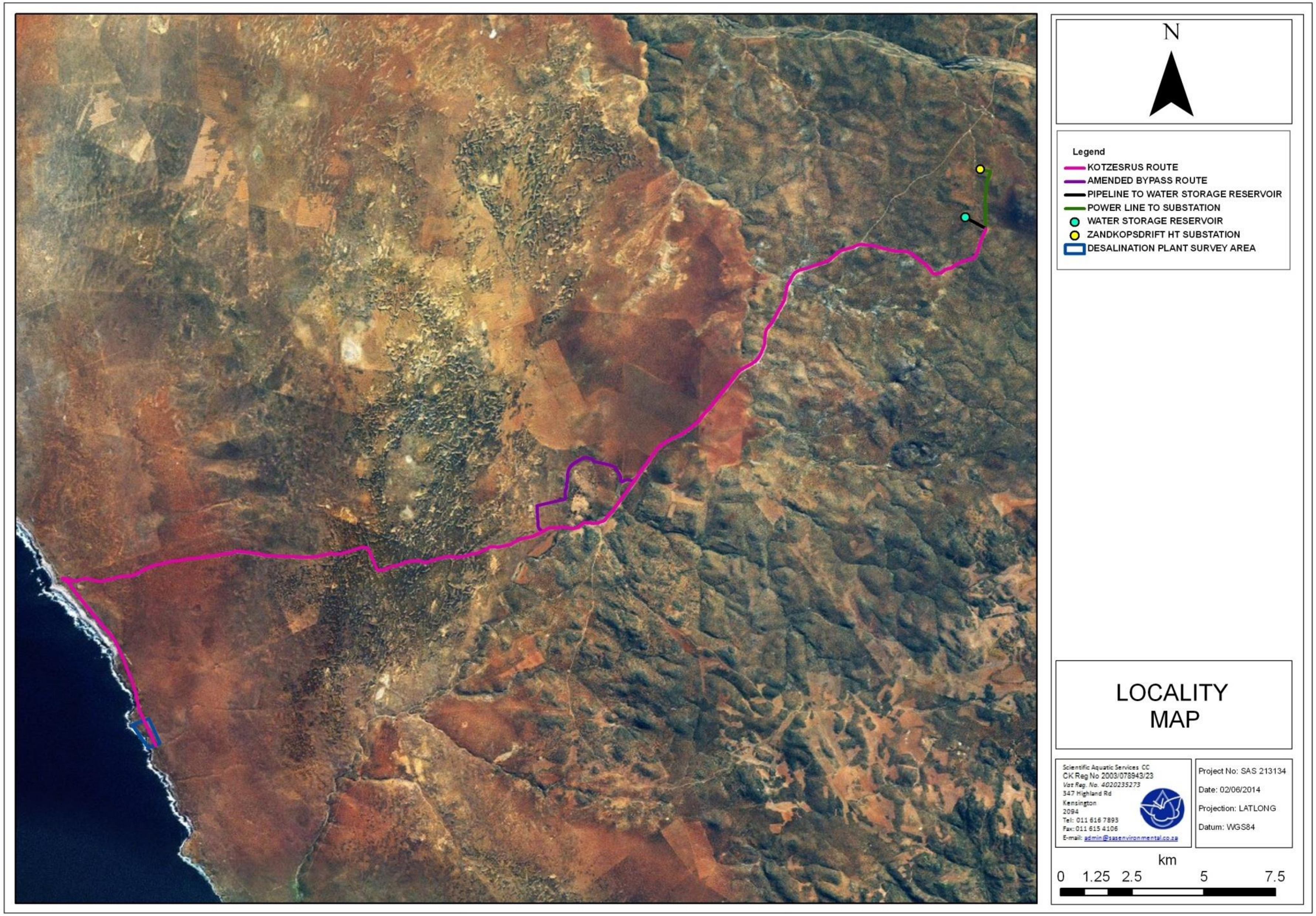

Figure 1: Digital satellite image depicting the locations of each of the alternative routes in relation to surrounding areas.

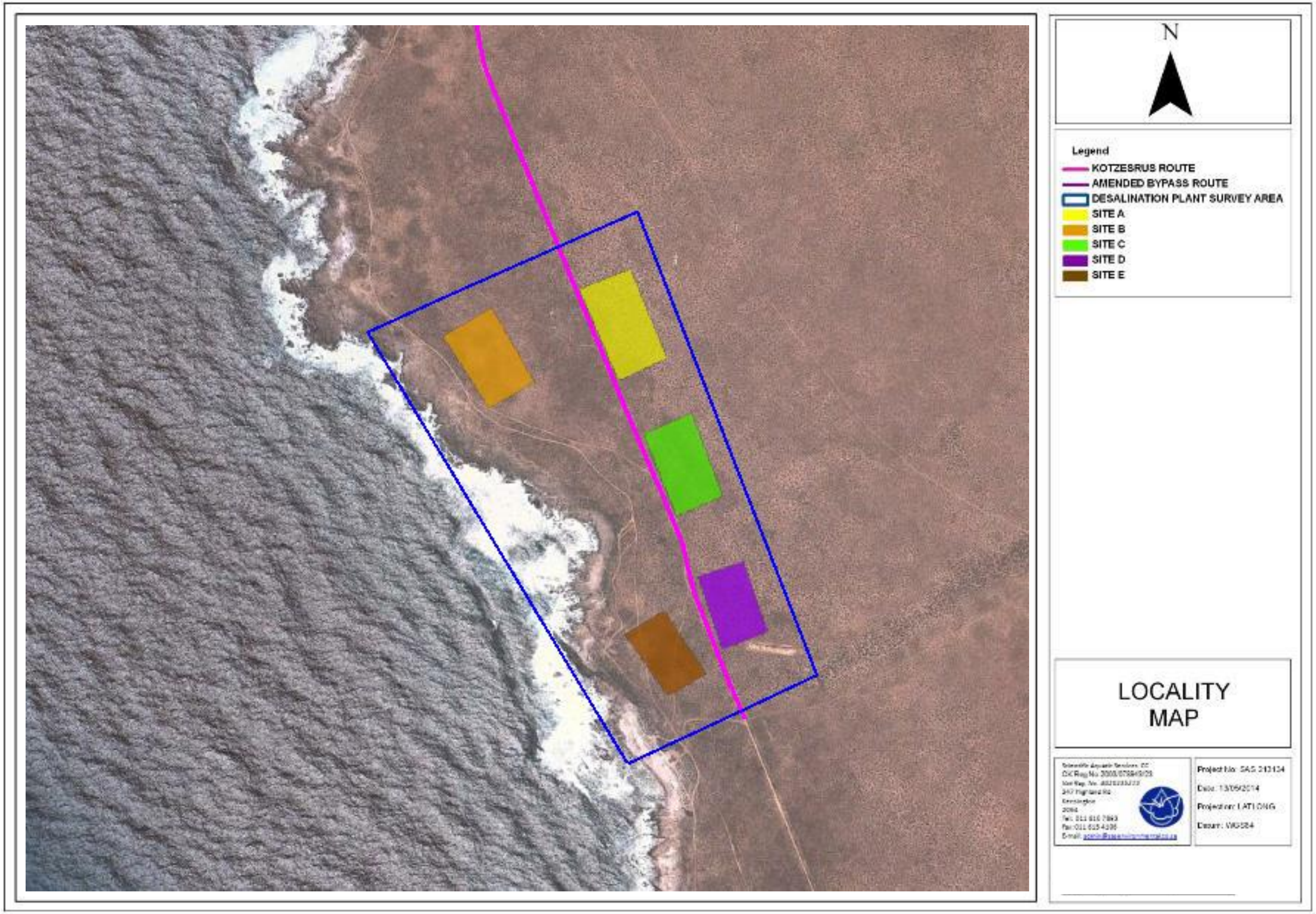

Figure 2: Digital satellite image depicting the locations of each of the desalination site alternatives in relation to surrounding areas.

1.2 Scope

The following Terms of Reference (ToR) are proposed for the study:

- Undertake an ecological investigation based on desktop research as well as seasonal field assessments focusing on the faunal and floral integrity of the area as well as floral Species of Conservation Concern[3] (SCC) and faunal Red Data List[4] (RDL) species in the area;
- Undertake a field investigation of the wetlands, rivers and other aquatic features within the study area;
- Describe the baseline terrestrial and freshwater ecology of the area, making specific reference to SCC occurring in the area as well as the conservation value of the areas proposed for development;
- Identify and assess the impacts of the proposed development on the terrestrial and freshwater ecology of the study area during the construction and operational phases of the project, using SRK's standard impact assessment methodology;
- Summarise, categorise and rank all identified impacts on terrestrial and freshwater ecology in appropriate Impact Assessment tables, to be incorporated in the overall Environmental Impact Assessment (EIA);
- Recommend practicable management measures to avoid and mitigate and/or optimise impacts;
- Compile a monitoring plan to monitor impacts, if required;
- Assist the EIA team in responding to any comments received from stakeholders as they relate to terrestrial and freshwater ecological impacts; and
- Provide technical input required for the submission of applications to the Department of Water Affairs (DWA) in terms of the National Water Act (NWA, Act 36 of 1998).

1.3 Assumptions and Limitations

The following assumptions and limitations are applicable to this report:

- The vegetation and freshwater ecology assessments were confined to areas occurring within 15m to either side of the existing gravel road centre line and to the alternative desalination sites. The vegetation and freshwater ecology assessments did not include a field assessment of adjacent areas and neighbouring properties, however, these areas were considered as part of the desktop assessment;
- Sampling by its nature, means that not all individuals are assessed and identified. Some species and taxa within the study area may therefore have been missed during the assessment;
- Site surveys were undertaken in February and August 2013. August is considered the peak spring flowering season for the Namaqualand region. However, during the assessment of the site it was found that a number of geophytes were not yet in flower. This limited the identification of geophytes and may have resulted in SCC being missed. However, where possible geophytes were identified to genus level;
- The pipeline to the water storage reservoir in the mine area and the power line to the Zandkopsdrift HT substation were added to the study area after the site assessment had been undertaken. A field assessment of the area to be disturbed by this infrastructure was therefore not undertaken. However, the area has been assessed as part of previous ecological studies (Henning, 2014 and Helme 2012). The findings of previous assessments could therefore be incorporated into the current assessment results;

[3] SCC are floral species that have a high conservation importance in terms of preserving South Africa's high floristic diversity and include not only threatened species, but also those classified in the categories Extinct in the Wild (EW) Regionally Extinct (RE), Near Threatened (NT), Critically Rare, Rare, Declining and Data Deficient - Insufficient Information (DDD)

[4] Organisms that fall into the Extinct in the Wild, Critically Endangered, Endangered, Vulnerable categories of ecological status as listed by the IUCN.

- Due to the nature and habits of most faunal taxa it is unlikely that all species would have been observed during a site assessment of limited duration. Therefore, site observations are compared with literature studies where necessary;
- The identification of faunal species was limited due to rainy and overcast conditions at the time of the assessment;
- Due to the majority of wetland features being ephemeral within the region where the study area is located, very few areas were encountered that displayed more than one wetland characteristic as defined by the DWA (2005) method. As a result, identification of outer temporary zones proved difficult in some areas. The wetland delineation as presented in this report is therefore regarded as a best estimate of the wetland boundary based on the site conditions present at the time of assessment, and are considered adequate for the assessment of impacts and identification of mitigation and management requirements; and
- Wetlands and terrestrial areas form transitional areas where an ecotone is formed as vegetation species change from terrestrial species to facultative[5] and obligate[6] wetland species. Within this transition zone some variation of opinion on the wetland boundary may occur, however if the DWA (2005) method is followed, all assessors should get largely similar results;
- With ecology being dynamic and complex, some aspects (some of which may be important) may have been overlooked. However, the level of detail to which the study was undertaken is considered sufficient to ensure that the results of this assessment accurately define the EIS and the PES of the study area and to provide the relevant planners and decision makers with sufficient information to formulate an opinion on the viability of the proposed route alternatives and desalination plant site alternatives from an ecological conservation viewpoint.

1.4 Indemnity and Terms of Use of this Report

The findings, results, observations, conclusions and recommendations given in this report are based on the author's best scientific and professional knowledge as well as available information. The report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken and SAS CC and its staff reserve the right to modify aspects of the report including the recommendations if and when new information may become available from ongoing research or further work in this field, or pertaining to this investigation.

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1.5 Legislative Requirements

National Environmental Management Act, (NEMA, Act 107 of 1998)

[5] Species usually found in wetlands (67% to 99% of occurrence) but occasionally found in non-wetland areas (DWAF, 2005)
[6] Species almost always found in wetlands (greater than 99% of occurrence) (DWAF, 2005)

The guiding principles of NEMA (Act 107 of 1998) refer specifically to biodiversity management in the following Clause:

(4) (a) Sustainable development requires the consideration of all relevant factors including the following:
(i) That the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimised and remedied.

- NEMA as amended and the associated Regulations (Listing No R. 544, No R. 545 and R. 546), states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment process or the EIA process depending on the nature of the activity and scale of the impact.

National Environmental Management Biodiversity Act (NEMBA, Act 10 of 2004)

The objectives of this act are (within the framework of the National Environmental Management Act) to provide for:

- the management and conservation of biological diversity within the Republic of South Africa and of the components of such diversity;
- the use of indigenous biological resources in a sustainable manner;
- the fair and equitable sharing among stakeholders of benefits arising from bio prospecting involving indigenous biological resources;
- to give effect to‘ ratified international agreements relating to biodiversity which are binding to the Republic;
- to provide for co-operative governance in biodiversity management and conservation; and
- to provide for a South African National Biodiversity Institute to assist in achieving the objectives of this Act.

This act alludes to the fact that management of biodiversity must take place to ensure that the biodiversity of surrounding areas are not negatively impacted upon, by any activity being undertaken, in order to ensure the fair and equitable sharing among stakeholders of benefits arising from indigenous biological resources.

Furthermore a person may not carry out a restricted activity involving either:

a) a specimen of a listed threatened or protected species
b) specimen of an alien species; or
c) a specimen of a listed invasive species without a permit.

Permits for the above may only be issued after an assessment of risks and potential impacts on biodiversity is carried out. Before issuing a permit, the issuing authority may in writing require the applicant to furnish it, at the applicant’s expense, with such independent risk assessment or expert evidence as the issuing authority may determine. The Minister may also prohibit the carrying out of any activity which may negatively impact on the survival of a listed threatened or protected species or prohibit the carrying out of such activity without a permit. Provision is made for appeals against the decision to issue/refuse/cancel a permit or conditions thereof.

Conservation of Agricultural Resources Act (CARA, Act 43 of 1983)

Removal of the alien and weed species encountered on the project footprint must take place in order to comply with existing legislation (amendments to the regulations under the CARA, 1983 and Section 28 of the NEMA, 1998). Removal of species should take place throughout the construction and operational phases.

The Northern Cape Nature Conservation Act (Act 9 of 2009)

Restricted activities involving specially protected plants:

49(1) No person may, without a permit –

(a) Pick;
(b) Import;
(c) Export;
(d) Transport;
(e) Possess;
(f) Cultivate; or
(g) Trade in,

a specimen of a specially protected plant.

<u>Restricted activities involving protected plants</u>

50 (1) Subject to the provision of section 52, no person may, without a permit –

(a) Pick;
(b) Import;
(c) Export;
(d) Transport;
(e) Cultivate; or
(f) Trade in,

a specimen of a protected plant.

<u>Restricted activates involving indigenous plants</u>

51 (1) No person may, without a permit, pick an indigenous plant in such manner that it constitutes large scale harvesting or for commercial purposes.

National Water Act (NWA, Act 36 of 1998)

- The NWA (Act 36 of 1998) recognises that the entire ecosystem and not just the water itself in any given water resource constitutes the resource and as such needs to be conserved;
- No activity may therefore take place within a watercourse unless it is authorised by DWA; and
- Any area within a wetland or riparian zone is therefore excluded from development unless authorisation is obtained from DWA in terms of Section 21.

General Notice 1199 as published in the Government Gazette 32805 of 2009 as it relates to the NWA

- Wetlands are extremely sensitive environments and as such, the Section 21 (c) and (i) water uses cannot be authorised through General Authorisation where these water uses occur within a distance of 500 meters upstream or downstream from the boundary of any wetland or estuary.

2 METHOD OF ASSESSMENT

2.1 Terrestrial Ecology

Two site visits were undertaken during February and August 2013 (peak spring flowering period) in order to determine the EIS of the study area. A thorough 'drive through' of the area was undertaken to determine the general habitat types found throughout the study area. Special emphasis was placed on areas that may potentially support floral SCC as listed by the South African National Biodiversity Institute (SANBI) PRECIS (National Herbarium Pretoria (PRE) Computerised Information System) database and RDL faunal species. Portions of the study area were investigated on foot in order to identify the occurrence of the dominant floral and faunal communities, species and habitat diversities. The presence of any faunal inhabitants of the study area was also assessed through direct visual observation or identifying species through calls, tracks, scats and burrows.

The Terrestrial Ecology Assessment aimed at determining the PES of the study area was undertaken making use of the terrestrial assessment methodology provided in Appendix A.

2.2 Freshwater Ecology

The Freshwater Ecology Assessment included a literature review, followed by site assessments undertaken in February and August 2013. All wetland features within the study area were identified and a wetland classification assessment was undertaken according to the *Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland systems* (Ollis *et al*., 2013). In addition, the WET-Health (Macfarlane *et al.,* 2009), wetland ecological and socio-economic service provision (Kotze *et al.* 2008) and EIS of wetlands was determined. The method used for the EIS determination was adapted from the method as provided by DWA (1999) for floodplains. The method takes into consideration PES scores obtained for WET-Health as well as function and service provision to enable the assessor to determine the most representative EIS Category for the wetland feature or group being assessed.

Delineation of the wetland zones took place according to "*DWA, 2005: A Practical Guideline Procedure for the Identification and Delineation of Wetlands and Riparian Zones*". Aspects such as soil morphological characteristics, vegetation types and wetness were used to delineate the temporary zones of the wetlands according to the guidelines. The buffer zones were then delineated around the temporary zone.

The Freshwater Ecology Assessment aimed at determining the EIS of wetland features associated with the study area was undertaken making use of the freshwater assessment methodology provided in Appendix A.

3 DESCRIPTION OF THE AFFECTED ENVIRONMENT: VEGETATION

3.1 Regional Context

The study area is located within the Kamiesberg Municipality which is located within the Namakwa District Municipality within the arid Namaqualand Region. The study area covers both the Fynbos and the Succulent Karoo biomes and is situated within the *North West Fynbos, Namaqualand Hardeveld* and *Namaqualand Sandveld bioregions.* The Succulent Karoo Biome is one of only three existing semi-arid biodiversity hotspots in the world and exhibits the highest plant diversity of any arid ecosystem (Namakwa District Biodiversity Sector Plan, 2008). Namaqualand contains about 3500 plant species with about 25% of this flora endemic to the region. It is also home to an exceptionally high level of invertebrate and reptile endemism, with new species still being discovered. Vegetation types associated with the study area include *Namaqualand Strandveld, Namaqualand Sand Fynbos, Namaqualand Heuweltjieveld, Namaqualand Coastal Duneveld, Namaqualand Inland Duneveld* and *Namaqualand Seashore* Vegetation Types (Figure 3). None of these vegetation types are considered to be of conservation concern. However, all of the vegetation types are under conserved and are under increased threat as a result of habitat loss to mining activities in the region as well as to agricultural activities, road development, water extraction and anthropogenic activities.

3.2 Importance according to the Northern Cape Provincial Spatial Development Framework (PSDF, 2012)

According to the PSDF (2012) the study area is located within the Succulent Karoo Region of Endemism in the Northern Cape Province and is located within an area of high vulnerability with regards to biodiversity sensitivity.

3.3 National Land Cover (2009)

Land cover and land use changes often indicate major impacts on biodiversity, especially if those changes show the loss of natural habitat due to urban sprawl, cultivation, etc. The majority of the study area is indicated to be natural land; however, small portions along each of the alternative routes have been transformed for cultivation purposes and urban development.

3.4 National List of Threatened Terrestrial Ecosystems for South Africa (2011)

The NEMBA provides for listing of threatened or protected ecosystems, in one of four categories: Critically Endangered, Endangered, Vulnerable or Protected. Threatened ecosystems are listed in order to reduce the rate of ecosystem and species extinction by preventing further degradation and loss of structure, function and composition of threatened ecosystems. The purpose of listing protected ecosystems is primarily to conserve sites of exceptionally high conservation value (SANBI Biodiversity Geographic Information Systems (BGIS)).

The study area does not fall within the original extent of a threatened terrestrial ecosystem.

3.5 National Biodiversity Assessment (NBA), 2011

The NBA (2011) provides an assessment of South Africa's biodiversity and ecosystems, including headline indicators such as ecosystem threat status and ecosystem protection level, and national maps for the terrestrial, freshwater, estuarine and marine environments. The NBA (2011) includes a summary of spatial biodiversity priority areas that have been identified through systematic biodiversity plans at national, provincial and local levels.

According to the NBA (2011) the study area is not located within either a formal or informal protected area and is listed as a least threatened ecosystem. Furthermore, portions of the study area are listed as poorly protected, hardly protected and not protected.

3.6 Importance according to the Namakwa District Biodiversity Sector Plan (2008)

According to the Namakwa District Biodiversity Sector Plan (2008) the study area contains areas of conservation importance in the form of terrestrial and aquatic Critical Biodiversity Areas (CBAs), and terrestrial and aquatic Ecological Support Areas (ESAs).

CBA's are terrestrial and aquatic features in the landscape that are critical for retaining biodiversity and supporting continued ecosystem functioning and services (SANBI 2007). ESA's are areas that are not essential for meeting biodiversity representation targets/thresholds but which nevertheless play an important role in supporting the ecological functioning of CBAs and/or in delivering ecosystem services that support socio-economic development, such as water provision, flood mitigation or carbon sequestration. The degree of restriction on land use and resource use in these areas may be lower than that recommended for CBAs.

Both route alternatives extend through terrestrial and aquatic CBAs (Type 2), and terrestrial and aquatic ESAs (Figure 4). Type 2 terrestrial and aquatic CBAs are listed as important areas known to be of high biodiversity value and should be maintained as near-natural landscapes with no or limited loss of biodiversity pattern and limited loss of ecosystem processes. Terrestrial and aquatic ESAs are listed as areas that support key biodiversity resources (e.g. water) or ecological processes (e.g. movement corridors) in the landscape and should be maintained as near-natural landscapes with some loss of biodiversity pattern and limited loss of ecosystem processes permissible.

Both route alternatives traverse similar areas of terrestrial CBAs and ESAs, however the Kotzesrus Route traverses an additional aquatic ESA and CBA (Brak River).

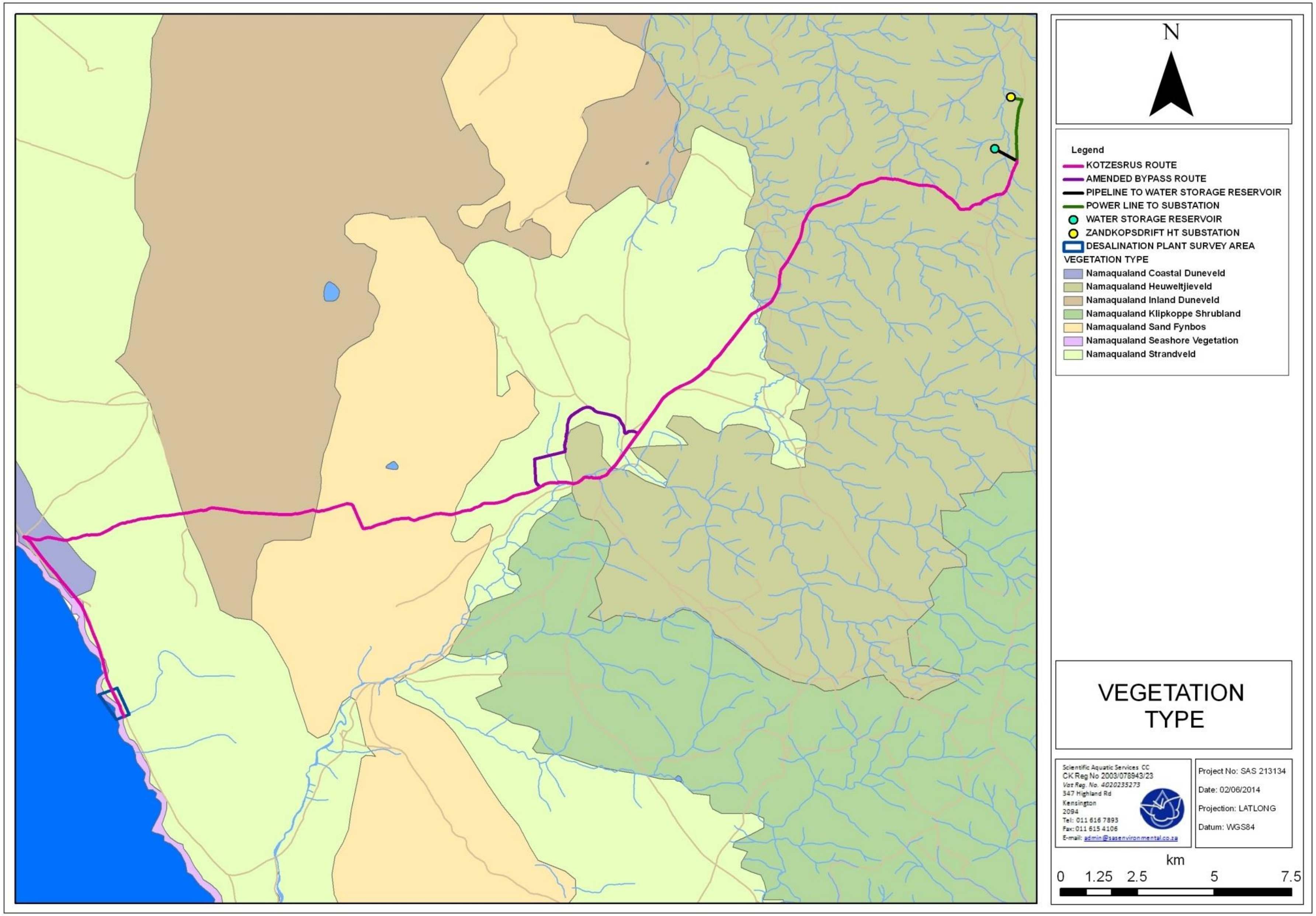

Figure 3: Vegetation types associated with the study area (Mucina & Rutherford, 2006).

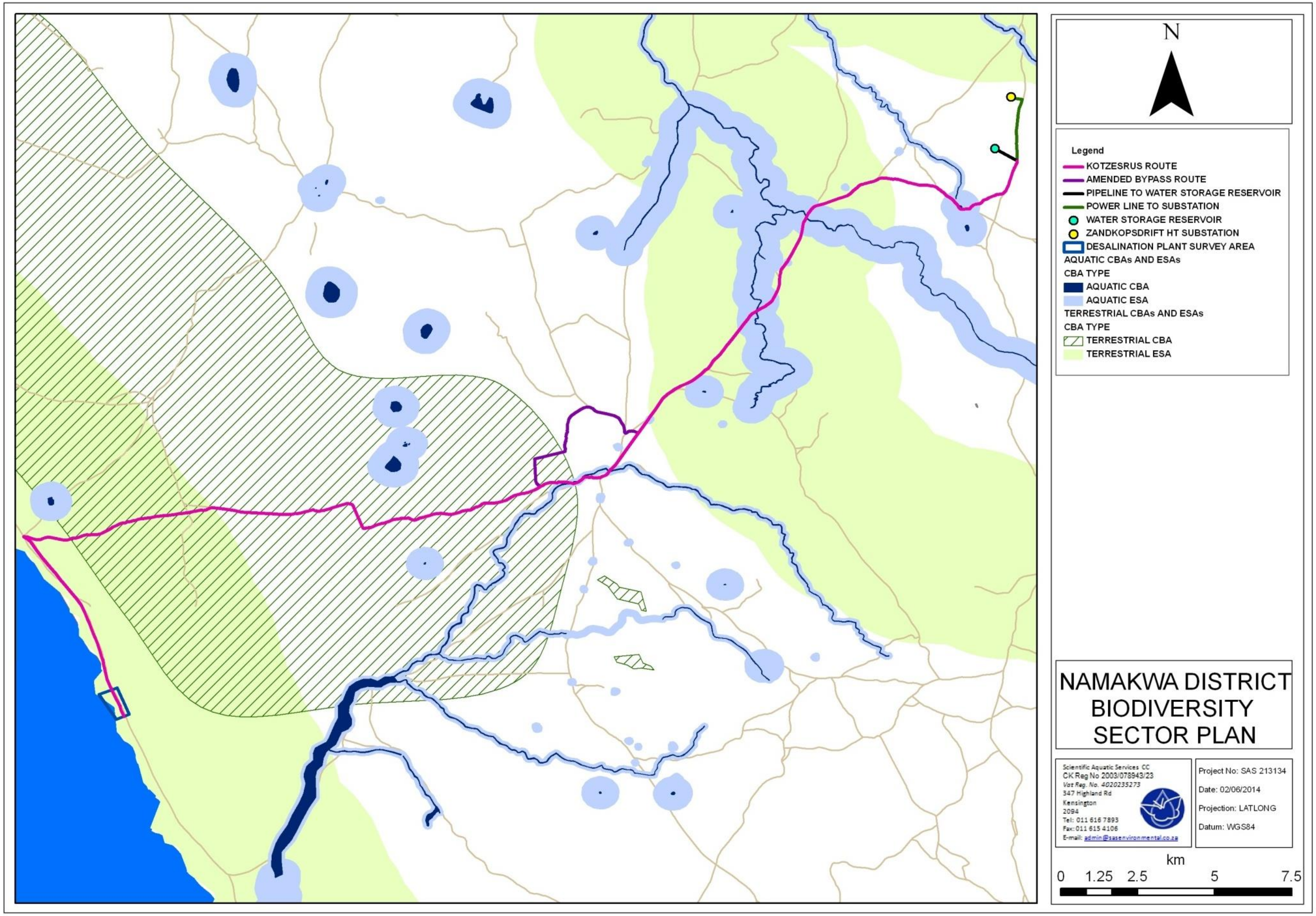

Figure 4: Terrestrial and Aquatic CBAs and ESAs of the study area (Namakwa District Biodiversity Sector Plan, 2008))

3.7 Vegetation Habitat Unit Descriptions

Vegetatation within the area in which the route alternatives and desalination plant alternatives are to be located has remained largely intact, with isolated areas which have been transformed as a result of anthropogenic activities. Five vegetation habitat units were identified within the study area. These habitat units include:

- The succulent karoo habitat unit which could be further divided into:
  - The strandveld habitat unit (includes the Namaqualand strandveld vegetation type and the Namaqualand inland duneveld vegetation type);
  - The hardeveld habitat unit (includes the Namaqualand heuweltjieveld vegetation type); and
  - The coastal habitat unit (includes the Namaqualand coastal duneveld and Namaqualand seashore vegetation types);
- The sand fynbos habitat unit (incudes the Namaqualand sand fynbos vegetation type);
- The wetland/riparian habitat units;
- The rocky outcrop habitat unit; and
- The transformed habitat unit.

The vegetation habitat units applicable to various portions of the route alternatives and to the desalination plant survey area are indicated in Figure 5 and will be discussed in further detail in the paragraphs to follow. The Kotzesrtus Route is indicated by the path A-B-C-D-E-F and the Amended Bypass Route is indicated by path A-B-D-E-F. Detailed vegetation habitat unit maps for the eastern, central and western portions of route alternatives are available in Appendix E (Figures A, B and C).

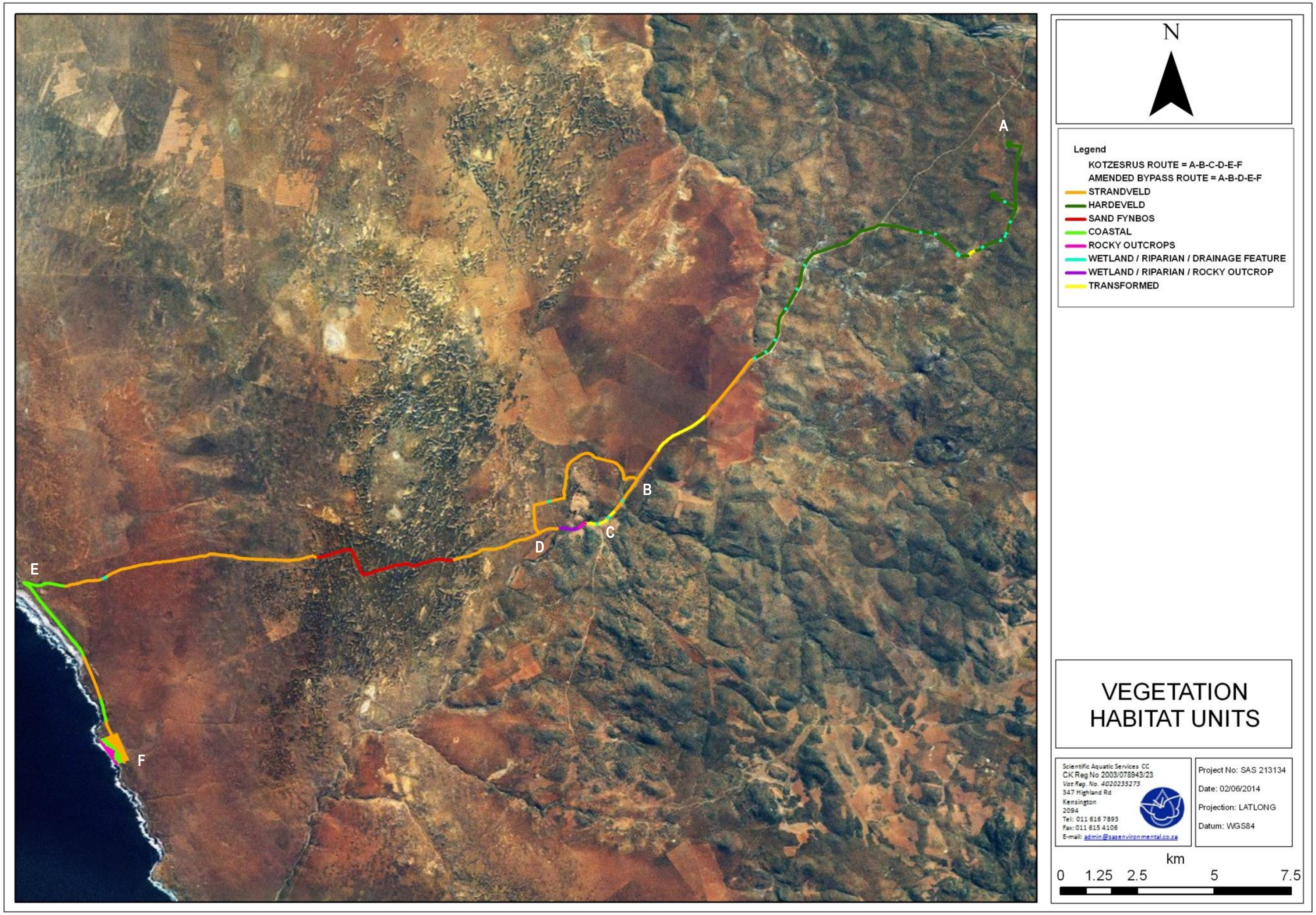

Figure 5: Vegetation habitat units associated with the study area (A-B-C-D-E-F = Kotzesrus Route and A-B-D-E-F = Amended Bypass Route).

3.7.1 Succulent Karoo Habitat Unit

Due to the diversity of habitats associated with the succulent karoo habitat unit, the unit was further subdivided into the strandveld habitat unit, the hardeveld habitat unit and the coastal habitat unit.

3.7.1.1 The Strandveld Habitat Unit

The strandveld habitat unit is traversed by both route alternatives and contains the desalination plant alternatives A, C and D. The strandveld habitat unit consists of low to medium-high, succulent rich vegetation which occurs on deep red-brown sands.

The Namaqualand strandveld and Namaqualand inland duneveld vegetation types which constitute the strandveld habitat unit are not listed as a threatened vegetation types (National List of Threatened Terrestrial Ecosystems, 2011). According to Mucina and Rutherford (2006) approximately 90% of Namaqualand strandveld vegetation type remains intact and no obvious transformation of the Namaqualand inland duneveld vegetation has taken place. However, in recent years Namaqualand strandveld has been under increased threat as a result of habitat loss to mining activities in the region as well as to agricultural activities, road development, water extraction and anthropogenic activities. The poor conservation of the vegetation type (less than 1% of the target of 26%) may result in further transformation in the future.

Floral species dominating the strandveld habitat unit include *Didelta carnosa*, *Tripteris oppositifolia, Othonna cylindrical, Galenia africana, Zygophyllum cordifolia, Zygophyllum morgsana, Tetragonia fruticosa, Stoeberia utilis, Eriocephalus racemosa, Euphorbia mauritanica, Pteronia glomerata, Pteronia onobromoides* and *Salvia lanceolata*. A complete list of dominant floral species encountered within the strandveld habitat unit is presented in Appendix B (Table B).

Two SCC, *Babiana hirsuta* and *Aloe arenicola* were identified within the strandveld habitat unit. SCC will be discussed in greater detail in the SCC and protected species assessment to follow (Section 3.9).


Figure 6: The strandveld habitat unit.

3.7.1.2 The Hardeveld Habitat Unit

The hardeveld habitat unit occurs on shallow gravelly soils and loamy sands. This habitat unit consists of low growing, succulent rich vegetation and is characterised by the presence of numerous quartz and clay exposure areas. The hardeveld habitat unit will be traversed by the northern portions of both route alternatives as well as by the pipeline which extends to the water storage reservoir on the mine and by the power line which extends to the Zandkopsdrift substation.

The Namaqualand heuweltjieveld vegetation type which constitutes the hardeveld habitat is not listed as a threatened vegetation type (National List of Threatened Terrestrial Ecosystems, 2011) and is not considered to be under immediate threat. However, the Namaqualand heuweltjieveld is listed as a vegetation type which is near endemic to the Namakwa District Municipality and is considered under conserved with only 11% of the national target of 28% currently conserved in the Namaqua National Park.

Species dominating the hardeveld habitat unit include *Didelta carnosa*, *Zygophyllum cordifolium, Mesembryanthemum guerichianum, Cephalophyllum pillansii, Cephalophyllum sp, Drosanthemum hispidum, Atriplex lindleyi, Galenia sarcophylla, Jordaaniella* sp., *Chrysochoma ciliata, Conicosia elongata and Ruschia* spp*.* A complete list of dominant floral species encountered within the hardeveld habitat unit is presented in Appendix B (Table C).

Sensitive clay and quartz exposure areas associated with the hardeveld habitat unit are known to provide the habitat to support SCC. The presence of these quartz and clay exposure areas within the hardeveld vegetation unit therefore increases the sensitivity and ecological importance of the vegetation unit. SCC occurring within the hardeveld habitat unit include *Bulbine bruynsii*. SCC will be discussed in further detail in the SCC and protected species assessment to follow (Section 3.9).

Figure 7: The hardeveld habitat unit illustrating quartz and clay exposure areas in the landscape.

3.7.1.3 The Coastal Habitat Unit

The coastal habitat unit includes both the Namaqualand coastal duneveld and the Namaqualand seashore vegetation types. This vegetation unit is restricted to coastal areas and occurs on coastal dune areas and on coastal rocky formations. The desalination plant alternatives B and E will be located within the coastal habitat unit and the far western portions of both route alternatives will traverse the coastal habitat unit.

Neither the Namaqualand coastal duneveld nor the Namaqualand seashore vegetation types are listed as a threatened by the National List of Threatened Terrestrial Ecosystems. However, less than 1% of each of these vegetation types is statutorily conserved (national target is 26%) and the vegetation is under current and future threat as a result of mining activities for heavy mineral sands as well as road development.

Species dominating the coastal habitat unit include *Arctotis decurrens, Didelta carnosa, Drosathemum hispidum, Amphibolia sp, Senecio elegans, Jordaaniella spongiosa, Othonna cylindrica, Tripteris oppositifolia, Zygophyllum morgsana, Zygophyllum cordifolium, Pteronia divaricata, Salvia lanceolata, Senecio sarcoides, Tetragonia fruticosa, Galenia sarcophylla, Pharnaceum croceum, Hypertelis angrae-pequenae, Babiana hirsuta* and *Sporobolus virginicus.* A complete list of dominant floral species encountered within the coastal habitat unit is presented in Appendix B (Table D).

One SCC, *Babiana hirsuta*, was identified within the Coastal habitat unit. SCC will be discussed in greater detail in the SCC and protected species assessment to follow (Section 3.9).

Figure 8: The coastal habitat unit

3.7.2 Sand Fynbos Habitat Unit

The Sand Fynbos habitat unit occurs primarily on slightly acidic, sandy, inland dune areas and is traversed by the central portion of both route alternatives.

Namaqualand Sand Fynbos is not listed as a threatened vegetation type, however, conservation of the vegetation type is poor with only 1% conserved in the Namaqua National Park (the conservation target for the vegetation type is 29%). Mining activities, agricultural activities, road development, water extraction and anthropogenic activities in recent years have resulted in a cumulative loss of the vegetation type from the region. Furthermore, the dune areas constituting the sand fynbos habitat may form part of a dune plume system which extends from the Groen River to the Brak River. This dune plume most likely acts as an ecological corridor and is therefore considered of increased sensitivity. Both route alternatives traverse this portion of sand fynbos.

Species diversity within the sand fynbos habitat unit is considered high. Species dominating the sand fynbos habitat unit include *Thamnochortus bachmanii, Willdenowia incurvata, Stoebe nervigera, Asparagus capensis, Lebeckia sericea, Wiborgia obcordata, Mesembryanthemum guerichianum, Anthospermum aethiopicum, Leucospermum rodolentum, Eriocephalus racemosus, Elytropappus rhinocerotis, Ehrharta calycina* and *Aspalathus spinescens*. A complete list of dominant floral species encountered within the sand fynbos habitat unit is presented in Appendix B (Table E).

SCC identified within the sand fynbos habitat unit include *Leucospermum rodolentum* and *Babiana hirsuta*. SCC will be discussed in further detail in the SCC and protected species assessment to follow (Section 3.9).

Figure 9: Sand Fynbos habitat unit.

3.7.3 Wetland/ Riparian Habitat Unit

The Brak River system, tributaries of the Groen River, natural ephemeral pans, artificial depressions and ephemeral drainage features are associated with both route alternatives and constitute the wetland/riparian habitat. The wetland habitat unit is discussed in further detail in Section 5.

Figure 10: Brak River (a), Tributary of the Groen River (b), natural ephemeral pan feature (c) and an artificial depression (d).

3.7.4 Rocky Outcrop Habitat Unit

The majority of rocky outcrop areas along the alternative routes are restricted to riparian/wetland areas and therefore share vegetation characteristic of wetland areas. Additional rocky outcrop areas were also associated with the coastal habitat unit.

Figure 11: Rocky outcrops occurring within riparian areas (a) and in coastal areas (b).

3.7.5 Transformed Habitat Unit

Some areas of vegetation associated with both route alternatives have been transformed as a result of construction of infrastructure associated with the town of Kotzesrus and with the Zandkopsdrift Mine. Furthermore, historical clearing of vegetation for agricultural purposes has occurred along the gravel road between Kotzesrus and the mine. During the time of the assessment areas historically cultivated were identified by an increase in the occurrence of the grass species *Stipagrostis zeyheri* and by a decrease in indigenous species diversity.

Due to degree of transformation no SCC were identified within the transformed habitat unit.

Figure 12: Transformation associated with route alternatives.

3.8 Vegetation Index Score

The information gathered during the assessment of the alternative routes was used to determine the Vegetation Index Score (VIS) which was designed to determine the ecological state of each habitat unit defined within an assessment site – see Appendix C for VIS calculations.

Vegetation characteristics varies between the sub-habitat units within the succulent karoo habitat unit, however, the overall PES of the different habitat units is similar and can therefore be considered in a single assessment. The succulent karoo habitat unit, including the strandveld, hardeveld and coastal habitat units, calculated a high score which falls within *Class B – Largely natural with few modifications*. Although portions of the succulent karoo habitat unit have undergone disturbance as a result of gravel road construction and grazing activities in the area, the majority of the unit is considered to be in a good ecological condition. Encroachment of alien invasive species is limited, with significant numbers of *Acacia cyclops* restricted to the portion of the Amended Bypass Route that diverts around Kotzesrus.

The sand fynbos habitat unit calculated a very high score which falls within *Class A – Natural, unmodified*. Although a track runs through the habitat unit to the west of Kotzesrus the impact of this track on the vegetation of the area is considered limited.

The wetland/riparian habitat unit calculated a high score which falls within *Class B – Largely natural with few modifications*. The majority of wetland features associated with the route alternatives are either traversed by existing gravel roads or are in close proximity to existing gravel roads. Impact on wetland vegetation as a result of the disturbance created by these gravel roads is therefore evident. However, disturbance of the features is largely restricted to the immediate vicinity of the gravel roads and the remainder of the vegetation associated with the wetland features is considered in a good condition.

The rocky outcrop habitat unit calculated a high score which falls within *Class B – Largely natural with few modifications*. Rocky outcrop areas are largely restricted to riparian areas and have been slightly disturbed as a result of a gravel road construction. Further rocky outcrop areas are associated with the coastal habitat unit. These areas are in a good condition with limited disturbance as a result of gravel road construction.

The transformed habitat unit calculated a low score which falls within *Class E- Loss of natural habitat is extensive*. The transformed habitat unit includes areas which have undergone transformation as a result of historic cultivation, and as a result of the construction of the town of Kotzesrus and the infrastructure associated with the Zandkopsdrift Mine. Cultivated areas are characterised by a decrease in indigenous species diversity and an increase in invasive grass species and vegetation associated with the town of Kotzesrus has been almost completely transformed.

3.9 SCC and Protected Species Status Assessments

An assessment considering the presence of any floral SCC and protected plant species was undertaken. The complete Pretoria Computerised Information System (PRECIS) SCC lists for the applicable Quarter Degree Square (QDS) (3017DD, 3017DC, 3117BA and 3117BB) were obtained from SANBI. A significant number of floral species are indicated to be of concern in the applicable QDS (see Appendix B, Table A). Floral SCC identified within the study area at the time of the assessment include *Leucospermum rodolentum* (Vulnerable), *Babiana hirsuta* (Near threatened), *Bulbine bruynsii* (Vulnerable) and *Aloe arenicola* (Near Threatened). Although not identified at the time, there is a moderate possibility that further undetected SCC including *Babiana rubella* (Declining), *Lampranthus procumbens* (Vulnerable), *Leucoptera nodosa* (Vulnerable), *Muraltia obovata* (Vulnerable), *Helichrysum dunense* (Vulnerable), *Elegia* sp. nov. (not yet assessed) and *Oncosiphon schlechteri* (Endangered) may occur in the study area.

Leucospermum rodolentum is threatened by pollution, natural disasters, invasive alien species (direct effects), habitat loss and habitat degradation (Rebelo *et al*, 2005). The species has suffered a population reduction of at least 30% estimated based on a 34% reduction in range size and 43% habitat loss due to agriculture and groundwater extraction in the past 60 years. Furthermore, subpopulations are severely fragmented and susceptible to drought-related mortality (SANBI Red List of South African Plants). The development of linear infrastructure along either of the route alternatives through sand fynbos habitat occurring approximately 4km to the west of Kotzesrus may require the removal of individuals of this species.

Babiana hirsuta is threatened by diamond mining activities in the northern part of its range and by grazing and development in the southern part (Raimando and Helme, 2008). A new threat to the southern populations is the planned mining for heavy minerals in the Groen River area (Raimando and Helme, 2008). The development of linear infrastructure along either of the route alternatives through the strandveld, coastal and sand fynbos habitat units may require the removal of numerous individuals of this species.

Bulbine bruynsii is a rare, localized habitat specialist which is restricted to quartz exposure areas within the region of the study area. This species was originally thought to consist of a single population, of approximately 300 plants (Helme and von Staden, 2012). However, during a recent suvey undertaken by Nick Helme (2014) (please refer to Appendix G for a copy of the report), twelve subpopulations were recorded and it is estimated that there could be as many as twenty, using a habitat based approach. Within the twelve sub-populations it was estimated that 2100 plants may be present, and thus by extrapolation, the total population in all twenty sub-populations may be in the vicinity of 3500 plants. It should however be noted that there is a large degree of uncertainty associated with this estimation, and it could in fact range from 2500 – 7000. However, even using these upper estimates it is clear that the species has a small global population, even though it may be locally common. The Red List assessment of Vulnerable is therefore accurate (Helme, 2014). The sub-population identified during the site assessment undertaken in August 2013 is the original population as was previously identified in the area in 2012. This subpopulation is restricted to quartz and clay exposure areas which occur along approximately 950m of the existing gravel road leading from Kotzesrus to the mine (i.e to the east of Kotzesrus). The development of the pipeline and power line through quartz patches located to the east of Kotzesrus is likely to result in the significant disturbance of individuals of the population and their associated habitat (the locality of quartz and clay exposure areas is indicated in Figure Q within Appendix E).

Aloe arenicola is threatened by mining activities and by overgrazing which has resulted in a continuing decline in habitat, subpopulations, locations and mature individuals of the species (Victor and Smith, 2004). The development of linear infrastructure along either of the route alternatives through strandveld occurring approximately 8km to the west of Kotzesrus is likely to result in the loss of individuals of this species.

Species listed as protected by the NCNCA (Act 9 of 2009) were also identified within the study area (refer to Appendix B for a list of protected species). Should any protected or specially protected species as listed by Schedule 1 and 2 of the Northern Cape Nature Conservation Act (Act 9 of 2009) be removed or destroyed, a permit will be required from the Northern Cape Department of Environment and Nature Conservation.

Figure 13: *Leucospermum rodolentum* (a), *Babiana hirsuta* (b), *Bulbine bruynsii* (c) and *Aloe arenicola* (d)

3.10 Exotic and Invader Species

The study area is located within a region outside of the urban edge (National Land Cover, 2009) in which little disturbance and transformation has occurred. Due to low levels of disturbance a low diversity of alien invasive species were encountered. Dominant alien invasive species identified within the study area include *Acacia cyclops* (Category 2), *Atriplex lindleyi* (Category 3), *Salsola kali* (Category not declared) and *Opuntia ficus-indica* (Category 1).

Alien and weed species encountered within the development footprint are to be removed in order to comply with existing legislation (amendments to the regulations under the CARA, 1983 and Section 28 of the NEMA, 1998). Removal and control of invasive plant species should take place throughout the pre-construction, construction and operational phases.

3.11 Medicinal Plants

The table below presents a list of plant species with traditional medicinal value, plant parts traditionally used and their main applications, which were identified during the field assessment. The majority of these species are considered common in the region, however, *Crassula muscosa, Gethylis spirallis* and *Haemanthus coccineus* are listed as protected species by the NCNCA (Act 9 of 2009). *Crassula muscosa* was encountered within the strandveld and hardeveld habitat units, *Gethylis spirallis* was encountered within the hardeveld habitat unit and *Haemanthus coccineus* was encountered within the strandveld, hardeveld and coastal habitat units.

Table 1: Dominant medicinal plants identified during the field assessment. Medicinal applications and application methods are also presented.

Dominant Species	Name	Plant parts used	Medicinal uses
Asparagus capensis	Wild asparagus	Rhizomes and fleshy roots	Asparagus species are traditionally used in southern Africa as a treatment for tuberculosis, kidney ailments and rheumatism.
Ballota africana	Kattekruid	Leaves	Leaves used to treat fever and measles. Infusions or brandy tinctures are popular in the Western Cape for the treatment of colds and influenza, asthma, bronchitis, hoarseness, heart trouble, hysteria, insomnia, typhoid fever, headaches, liver problems, piles and as a footbath for arthritis.
Chrysocoma ciliata	Bitterbos	Entire plant	A decoction is used for the washing of wounds and sores, also as an external treatment for syphilis. This decoction is also claimed to be a remedy for gout and rheumatism, for jaundice, gastric fever, appendicitis and constipation.
Crassula muscosa	Lizards tail bush	Entire plant	Infusions of the whole plant are made and are used sparingly.
Diospyros lycioides	Bloubos	Roots and twigs	The roots are used as chewing sticks which will impart a yellow colour to the teeth. It has been shown that the roots contain antibacterial substances. The roots and twigs are also used as toothbrushes.
Elytropappus rhinocerotis	Renosterbos	Young tips of the branches	Infusions of the young branches in brandy or wine are a traditional Cape medicine for indigestion, dyspepsia, ulcers and stomach cancer. It may also be taken as a tonic to improve a lack of appetite and as a stomache bitter. The medicine is regarded as a diaphoretic as it stimulates perspiration. Tinctures were used to treat gravel.
Eriocephalus racemosus	Kapokbos	Leaves and twigs	Traditionally used as diaphoretics and diuretics.
Euphorbia mauritanica	Geelmelkbos	Milky latex	The white latex exuding from this plant is applied to warts and corns.

Dominant Species	Name	Plant parts used	Medicinal uses
Galenia africana	Kraalbos	Leaves	The plant is chewed to relieve toothache however if too much is chewed it will blister the mucose membrane of the mouth. A leaf infusion can be used in the morning and evening as a mouth rinse for toothache. A mixture consisting of Kraalbos and Dassiepis (Hyraeum) is used to treat impotence and to push up the sperm count but it has to be used for at least three weeks.
Gethyllis spiralis	Koekemakranka	Ripe fleshy fruits	Koekemakranke brandy is one of the early Cape remedies for colic and indigestion. The edible fruit was highly valued to perfume rooms and linen.
Haemanthus coccineus	April fool	Leaves and bulb	A fresh leaf is applied as a dressing to sores and septic ulcers, and also to the pustules of anthrax. The sliced bulb boiled in vinegar mixed with honey was used as a diuretic and for asthma.
Hermannia cuneifolia	Agtdae-geneesbossie	Entire plant	An infusion of the plant was used as a wash for open wounds and as a poultice to treat the wound. The same infusion was used as a lotion applied to the skin for rashes, acne, sores and boils. It is claimed that this treatment will heal a wound or a sore within 8 days.
Oncosiphon suffruticosum	Stinkkruid	Leaves	Used to sweat out a fever and is also used a diuretic. Infusions of the plant treat asthma and pneumonia. A few drops of leaf juice can be added to milk as a gripe water for babies with winds and cramps.
Zygophyllum morgsana	Lion bush	Seeds and roots	The dry seeds are powdered and used in the form of an infusion, to treat convulsions, stroke and paralysis. A decoction of the roots is used to ease backache and to treat kidney problems.

Source: (van Wyk, Oudtshoorn, Gerick, 2009, Mintsa Mi Nzui, 2009 and de Jager, 2010).

3.12 Vegetation Sensitivity

In terms of vegetation sensitivity the study area can be divided into very high sensitivity vegetation, high sensitivity vegetation, moderate sensitivity vegetation and low sensitivity vegetation. Sensitivities were determined based on the irreplaceability of the habitat unit, on observations of the abundance and diversity of floral species present at the time of the assessment, on the presence of SCC within the habitat units, on the presence of CBAs and ESAs and on the degree of disturbance encountered as a result of historical activities. The varying vegetation sensitivities are discussed below and are illustrated in Figure 14 below. Detailed vegetation habitat unit maps for the eastern, central and western portions of route alternatives are available in Appendix E (Figures D, E and F).

Very High Sensitivity
Very high sensitivity vegetation includes the wetland habitat unit, the rocky outcrop habitat unit and quartz and clay exposures within the hardeveld habitat unit.

Wetland/riparian areas are considered of increased importance in terms of the occurrence of ecologically important vegetation, the likely occurrence of SCC and are associated with aquatic CBAs and ESAs. Wetland and riparian features are also considered to be scarce in the arid Namaqualand region and are critical for retaining biodiversity and supporting continued ecosystem functioning and services.

The rocky outcrop habitat unit is likely to provide niche habitat that could support a wide range of unique floral species. Rocky outcrop areas are therefore considered to be of increased importance in terms of the likely occurrence of floral SCC and are also considered to be of increased importance due to their location within a terrestrial CBA or ESA.

Quartz and clay exposure areas are known to provide the habitat to support SCC and rare floral species. The SCC *Bulbine bruynsii* occurs within this habitat and is considered a rare species with a limited distribution range. Furthermore, the majority of quartz and clay exposure areas associated with the route alternatives are located within an ESA.

High Sensitivity

High sensitivity habitat units include the sand fynbos and coastal habitat units.

The sand fynbos habitat unit comprises of the Namaqualand sand fynbos vegetation type. This vegetation type is not listed as threatened, however, species diversity within the vegetation is considered to be high, and populations of the SCC *Leucospermum rodolentum* and *Babiana hirsuta* were encountered. Although not identified at the time of the assessment, there is also the probability that the sand fynbos habitat may support the SCC *Babiana rubella*, *Lampranthus procumbens* and *Muraltia obovata*. Furthermore, the dunes which constitute the sand fynbos habitat may form part of a dune plume system which extends from the Groen River to the Brak River. This dune plume most likely acts as a migratory corridor and is therefore considered of high sensitivity. Namaqualand sand fynbos is considered of increased importance in terms of the occurrence of natural vegetation, the occurrence of SCC, the provision of migratory corridors and the presence of a CBA, however, sand fynbos is relatively common in the area.

Coastal habitat is restricted to coastal areas and occurs on coastal dunes and on coastal rocky formations. Coastal vegetation is adapted to the specific set of conditions prevailing at the coastal edge and is under direct influence of the sea through the deposition of salt spray and fine air-borne sediments of sea origin (Mucina and Rutherford, 2006). Coastal habitats are sensitive environments which can easily be damaged or disrupted. The coastal environment is also indicated as a terrestrial ESA.

Moderate sensitivity

Moderate sensitivity vegetation includes the strandveld habitat unit and the hardeveld habitat unit (excluding quartz and clay exposure areas).

Although strandveld vegetation within the immediate vicinity of the well-developed gravel road to the north east of Kotzesrus has been disturbed by the effects of historic road construction activity and current road use, the vegetation is located within a terrestrial ESA (Type 2) and is therefore still considered to be of moderate sensitivity. Furthermore, strandveld vegetation to the west of Kotzesrus occurs along a 4x4 track in a CBA in which there has been little disturbance. Therefore, strandveld vegetation is considered of increased sensitivity in terms of the occurrence of natural vegetation. However, the strandveld vegetation unit is widespread and relatively untransformed in the region and the loss of this vegetation type within the construction footprint area will therefore result in the loss of a very small percentage of the total extent of the vegetation in the region.

Hardeveld vegetation consists of low growing, succulent rich vegetation. Although the hardeveld vegetation unit falls within a terrestrial ESA and covers a portion of an aquatic CBA and ESA, the vegetation unit is relatively common in the region and its loss from the construction footprint is deemed to be of a moderate sensitivity.

Low sensitivity

Low sensitivity areas include transformed areas characterised by the historical clearing of vegetation for agricultural purposes and by the construction of the infrastructure and roads associated with the town of Kotzesrus and the Zandkopsdrift Mine. Although portions of the transformed habitat unit to the east of Kotzesrus occur within a terrestrial ESA, these areas have been significantly transformed due to past agricultural activities and are not deemed to be of a high importance in terms of the provision of habitat. No SCC were identified within the transformed habitat unit at the time of the assessment and it is deemed highly unlikely that SCC will occur. The transformed habitat unit is therefore considered to be of a low sensitivity.

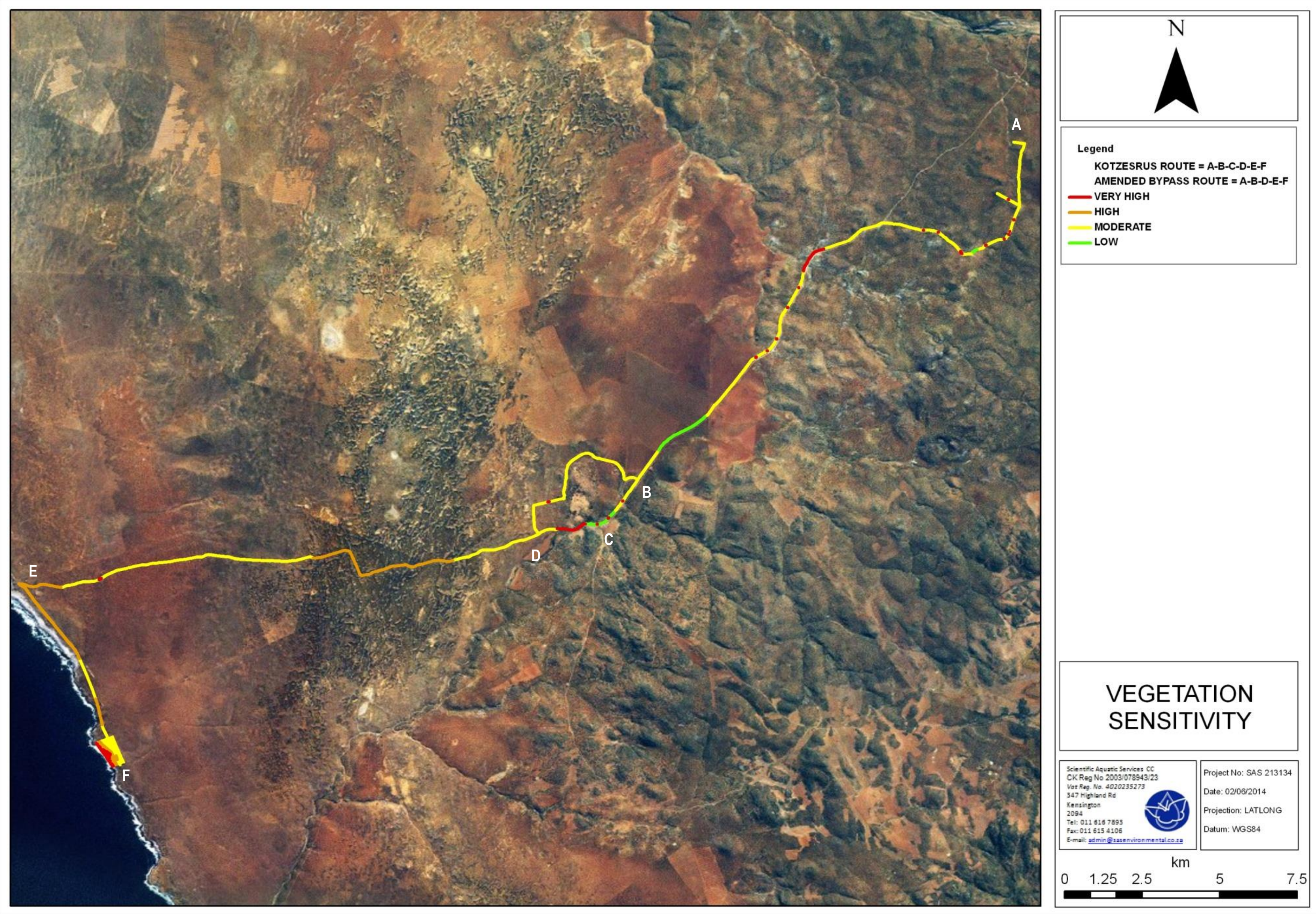

Figure 14: Sensitivity of the vegetation associated with the route and desalination plant alternatives (A-B-C-D-E-F = Kotzesrus Route and A-B-D-E-F = Amended Bypass Route)

4 DESCRIPTION OF THE AFFECTED ENVIRONMENT: FAUNA

4.1 Faunal Habitat Units

Four faunal habitat units occur within the study area (Figure 15). These include terrestrial (succulent karoo and sand fynbos), rocky outcrop, wetland/riparian and transformed habitat units. Faunal species are not likely to permanently inhabit terrestrial areas in the immediate vicinity of gravel roads as a result of the disturbance associated with the movement of vehicles through the area, however, more common faunal species such as *Suricata suricatta* (Suricate) may inhabit less disturbed areas within the road reserve and additional faunal species may move through terrestrial habitat units when migrating or foraging.

Rocky outcrop and wetland/riparian habitat units provide niche habitats for faunal species within the area and are likely to provide important foraging and breeding habitat. The study area is located within a water stressed region (Namaqua District Biodiversity Sector Plan, 2008) and as a result available wetland and riparian habitat is considered to be of increased conservation importance in terms of wetland dependent floral and faunal species. Furthermore, wetland/riparian habitat may provide important migratory corridors through the otherwise arid environment.

Faunal habitat within the area in which the route alternatives and desalination plant alternatives are to be located has remained largely intact, with isolated areas which have been transformed as a result of anthropogenic activities. Transformed habitat units include those areas disturbed as a result of historic agricultural activities, road construction activities and as a result of the construction of infrastructure associated with the town of Kotzesrus and with the Zandkopsdrift Mine. These areas are not likely to provide suitable habitat to support a large diversity of faunal species, however, faunal species may move through these areas when migrating or foraging. Detailed faunal habitat unit maps for the eastern, central and western portions of route alternatives are available in Appendix E (Figures G, H and I).

4.2 Threatened faunal species of the Northern Cape

A regional list of protected faunal species for the Northern Cape Province is included in the NCNCA (Act No. 9 of 2009). However, no Red Data List (RDL) status has been included in this report and thus the National publication of RDL faunal species list, which was published in 2004 and amended in 2007, will be used. Therefore, all faunal species observed and which are deemed likely to occur in the vicinity of the proposed route alternatives have been cross referenced with the NEMBA (Act No. 10 of 2004) threatened species list and with the IUCN (2013) RDL status ratings.

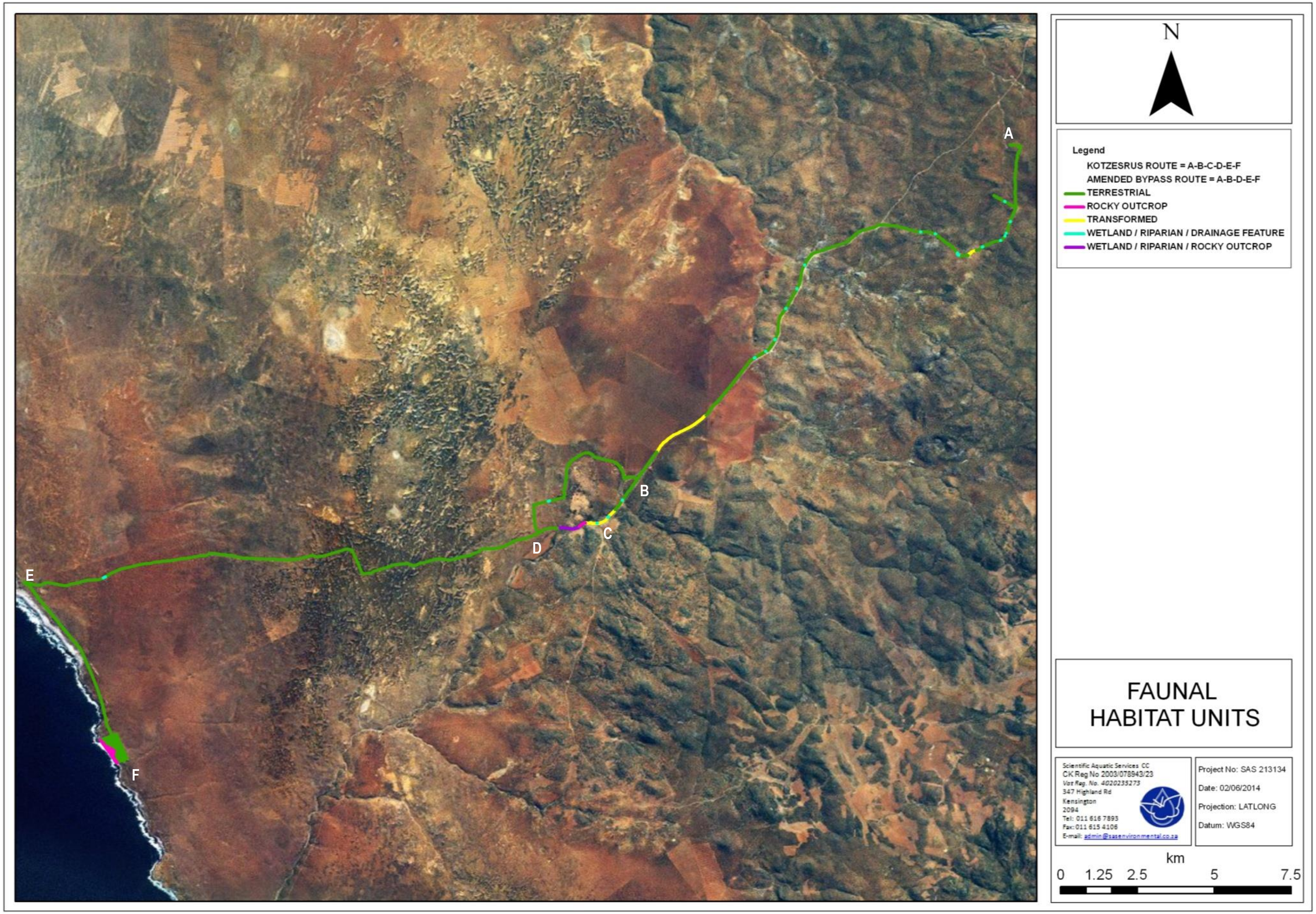

Figure 15: Faunal habitat units associated with the study area (A-B-C-D-E-F = Kotzesrus Route and A-B-D-E-F = Amended Bypass Route).

4.3 Mammals

The Southern African bio climate zones, or biotic zones, for mammals are identified in *Mammals of Southern Africa, A Field Guide* based on which the study area falls within the Cape macchia of fynbos biotic zone for mammal species (Smithers, 2000). This zone occurs along the coast spanning from Port Elizabeth to St Helena Bay. It supports a high diversity of floral species but has rather poor habitat for mammal species.

Sixteen mammal species were identified within the study area through direct visual observation or with the use of tracks, scats and burrows. A list of mammal species identified within the study area is presented in Table A within Appendix D. The mammal species identified along the proposed route alternatives and within the study area during the site assessment were all common species for the region and are listed as non-threatened species by the IUCN (2013). However, the majority of mammal species identified within the study area are listed as protected species by the NCNCA (Act 9 of 2009) and three mammal species identified at the time of the assessment are listed as protected by NEMBA (Act 4 of 2004) (Table A, Appendix D).

The current movement of vehicles along existing roads is likely to discourage mammal species from permanently inhabiting the road reserve in which construction related activities will take place. Mammal species are therefore more likely to be passing through the area and it is highly likely that species will move out of construction footprint areas prior to the commencement of construction related activities.

Figure 16: *Raphicerus campestris* spoor (Steenbok) (a), *Felis silvestris lybica* (African Wildcat) (b), *Ocycteropus afer* spoor (Bat-eared fox) (c) *Cynictis penicillata* spoor (Yellow mongoose) (d).

4.4 Avifauna

The study area lies within the karoo habitat area which comprises of semi-arid west-central stony plains, either flat or undulating and sparsely covered with succulents, shrubs, small trees with rocky, scrub covered flat topped hills. Avifaunal life in this habitat primarily comprises of korhaans, larks, warblers and canaries including raptors such as Black and Martial eagles and kestrels (Sinclair *et al*, 2002).

Fifty bird species were visually observed or confirmed by vocal identification during the winter 2013 site surveys within the study area and adjacent land (Table B, Appendix D). One RDL species, *Sagittarius serpentarius* (Secretary bird) has been identified within the study area (Pers. comm. – Peter Schroeder, 2013), and is listed as Vulnerable by the IUCN (2013). *Sagittarius serpentarius* was not identified in close proximity to the route alternative areas, however, this species may move into construction footprint areas during foraging activities.

A number of raptor species were also identified within the study area. Although listed as species of Least Concern, raptor species, particularly *Falco biarmicus* (Lanner Falcon), *Aquila verreauxii* (Verreauxs Eagle), *Circaetus pectoralis* (Black-chested Snake Eagle) and the *Elanus caeruleus* (Black-winged Kite) are under severe threat as a result of persecution by small stock farmers. This threat along with loss of foraging habitat puts severe pressure on these avifaunal species. The majority of the above listed raptor species are not likely to inhabit the construction footprint area but may rather move through the area when foraging. However, at the time of the assessment an *Aquila verreauxii* (Verreauxs Eagle) breeding pair was identified nesting within a tree in close proximity to the Kotzesrus Route where it traverses the Brak River.

Additional threatened avifaunal species which may move through the study area during foraging activities include; *Neotis ludwigii* (Ludwig's Bustard), *Phalacrocorax neglectus* (Bank Cormorant), *Circus maurus* (Black Harrier), *Polemaetus bellicosus* (Martial Eagle) and *Phalacrocorax neglectus* (Bank Cormorant). However, these species do not permanently inhabit the construction footprint area.

The remaining avifaunal species identified within the study area are listed as species of Least Concern (IUCN, 2013) and are common species for the region. However, the majority of the species identified are listed as protected species by the NCNCA (Act 9 of 2009) and two species are listed as protected by NEMBA (Act 4 of 2004) (Table B, Appendix D).

Figure 17: *Aquila verreauxii* (*Verreaux's Eagle*) (a), *Recurvirostra avosetta* (Pied Avocet) (b), *Afrotis afra* (Southern Black Korhaan) eggs (c) and *Melierax canorus* (Pale Chanting-goshawk) (d).

4.5 Reptiles

The reptile ecoregion for the study area falls within the succulent karoo ecoregion. Limited to the western parts of southern Africa, this ecoregion is characterized by species of arid adapted succulent leaf scrubs where rainfall is low and droughts common. Reptile species richness is relatively high and a high proportion of species are endemic and many species are rupicolous which means they predominantly inhabit rocky areas (Alexander and Marais, 2008).

Nine reptile species in total were observed during the summer and winter site surveys and indicated a good representation of reptile species for the region.

The majority of reptiles identified at the time of the assessment were associated with rocky outcrop areas with special mention of rocky areas occurring at the coast. However, snake and tortoise species were also identified within more sandy areas of the study area.

One near threatened reptile species (IUCN, 2013), *Gerrhosaurus typicus* (Namaqua Plated Lizard), was identified during the summer survey and an additional near threatened species *Homopus signatus* (Padloper tortoise) has been previously identified within the study area (Pers. comm. – Peter Schroeder, 2013). Furthermore, three species identified at the time of the assessment, *Cordylus polyzonus* (Karoo girdled lizard), *Cordylus niger* (Black girdled lizard) and *Homopus signatus* (Padloper Tortoise) are listed as protected species by the NCNCA (Act 9 of 2009).

The remaining reptile species identified at the time of the assessment are listed as Not Yet Been Assessed (IUCN) and are commonly occurring species in the region. A list of all reptile species identified within the study are is included in Table C within Appendix D

Figure 18: *Chersina angulata* (Angulate Tortoise) and *Cordylus niger* (Black girdled lizard)

4.6 Amphibians

There are nine principal biomes in Southern Africa for amphibian habitats. The study area falls within the karoo (semi-desert) amphibian habitat (du Preez and Carruthers, 2009). This habitat comprises of arid stony areas with low, flat topped koppies and sparse scrub vegetation in the south central and west central areas (du Preez and Carruthers, 2009).

No amphibians were encountered during the summer or winter survey of the study area. However, non-perennial wetland habitat which provide surface water for limited times of the year could potentially allow for breeding of amphibian species. The study area is located within the distribution range of three amphibian species, *Breviceps namaquensis* (Namaqua Rain Frog), *Cacosternum namaquense* (Namaqua Caco) and *Amietia fuscigula* (Cape River Frog).

Breviceps namaquensis (Namaqua Rain Frog) occurs along the Namaquland coast and is a burrowing species which is not dependent on water for survival. In previous studies of the Zandkopsdrift mining area (Helme, 2012) calls of *Cacosternum namaquensis* (Namaqua Caco) were heard. This species aestivate (hibernates in summer) in rock crevices and rocky outcrop areas are therefore considered of increased importance with regards to the conservation of this species. *Amietia fusciguta* (Cape River Frog)

Additional species which may occur within wetland areas and seasonal drainage lines (Helme, 2012) include *Tomopterna delelandii* (Cape sand frog), *Bufo robinsoni* (Paradise Toad) and *Strongylopus springbokesis* (Namaqua Stream Frog). All of these species are listed as Least Concern by the IUCN (2013). *Strongylopus springbokesis* (Namaqua Stream Frog) was listed as Vulnerable in 2004 (Minter *et. al*., 2004), however, the species has been found in a larger area between what were previously considered to be fragmented subpopulations (IUCN, 2013) and it is now listed as Least Concern in view of its wide extent of occurrence and stable population (IUCN, 2013).
All species of frogs and toads are listed as protected by the NCNCA (Act 9 of 2009).

4.7 Invertebrates, Arachnids and Scorpions

Invertebrate vegetation habitat types in Southern Africa are divided into five major types. The study area falls within the karoo vegetation distribution area and specifically the succulent (Namaqualand) karoo area. There is a unique assemblage of insects in this area with an above average representation of beetles, grasshoppers, flies, wasps and lacewings, many emerging for brief periods in late spring (Picker *et al,* 2004).

The invertebrate assessment conducted was a general assessment with the purpose of identifying common species and taxa in the study area. As such, the invertebrate assessment will not be an indication of the complete invertebrate diversity potential of the study area. A representation of commonly encountered families in the Insecta class that were observed during the assessment is listed in Table E within Appendix D. It should be noted that invertebrate species have been identified to family level, and where possible, invertebrates have been identified to genus and species level.

During the field survey, 24 invertebrate species were collected or observed, none of which are listed to be of conservation significance. All insect species observed are considered widespread within the region and are classified as being not threatened at a regional level (NCNCA, 2009). One interesting burrowing Zodariidae spider from the genus *Capheris* (personal communication – Dr Ansie Dipenaar-Schoeman, 2013) was however identified within the coastal habitat unit. This species of burrowing Zodariidae spider is a possible new species (personal communication – Dr Ansie Dipenaar-Schoeman, 2013) and no information is therefore available regarding its threat status.

After completion of the general invertebrate field survey conducted within the study area the likelihood of finding any RDL invertebrate, scorpion or spider species is considered low.

Figure 19: A burrowing Zodariidae spider from the genus *Capheris* (personal communication – Dr Ansie Dipenaar-Schoeman) (a), *Phymateus morbillosus* (Common Milkweed Locust) (b), *Psammotermes allocerus* (Desert termite) (c) and *Acanthoplus discoidalis* (Corn cricket) (d).

4.8 Red Data Sensitivity Index Score (RDSIS)

Three RDL faunal species, *Sagittarius serpentarius* (Secretary Bird), *Gerrhosaurus typicus* (Namaqua Plated Lizard) and *Homopus signatus* (Padloper Tortoise), were identified during the site survey. Furthermore, a total of nine RDL threatened faunal species were found to have a 60% or greater probability of occurrence on the study area and are presented in Table 2 below.

Table 2: Threatened faunal species with a 60% or greater Probability of Occurrence (POC) in the study area

Scientific name	Common Name	RDSIS POC%	2013 IUCN
	Lizard		
Gerrhosaurus typicus	Namaqua Plated Lizard	100	NT
Cordylus cataphractus	Armadillo Lizard	62	VU
	Tortoise		
Homopus signatus	Padloper Tortoise	100	NT
	Snake		
Bitis schneideri	Namaqua dwarf adder	65	VU
	Avifauna		
Phalacrocorax neglectus	Bank Cormorant	85	EN
Sagittarius serpentarius	Secretarybird	100	VU
Circus maurus	Black Harrier	75	VU
Neotis ludwigii	Ludwig's Bustard	70	EN
Polemaetus bellicosus	Martial Eagle	75	NT

(CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened, NE – Near Extinct; T = Threatened)

The species presented in the table above were then used to calculate the RDSIS for the site, the results of which are presented in Table 3 below.

Table 3: Red Data Sensitivity Index Score calculated for the study area.

Red Data Sensitivity Index Score	
Average Total Species Score	**91**
Average Threatened Taxa Score	**91**
Average (Ave TSS + Ave TT/2)	**54**
% Species greater than 60% POC	**14%**
RDSIS of Site	**53%**

The RDSIS assessment of the study area resulted in a score of 53%, indicating a moderate importance in terms of RDL faunal species conservation within the region and specifically the study area.

Habitat units located along each of the route alternatives are considered suitable to support RDL species within the study area. Wetland and rocky outcrop habitat units are considered of increased importance in terms of the conservation of RDL species. These habitat units are restricted within the region and may provide niche habitat and vital resources which are necessary to support RDL species. The Kotzesrus Route traverses the greatest distance of both wetland and rocky outcrop habitat and is therefore likely to have the greatest impact on RDL species within the study area.

4.9 Faunal Sensitivity

In terms of faunal sensitivity the study area can be divided into very high sensitivity faunal habitat, moderate sensitivity faunal habitat and low sensitivity faunal habitat. The varying faunal habitat sensitivities are discussed below and are illustrated in Figure 20 below. Detailed vegetation habitat unit maps for the eastern, central and western portions of route alternatives are available in Appendix E (Figures J, K and L).

Very High Sensitivity

Very high sensitivity faunal habitat includes those habitat units which provide niche habitat for specialist faunal species and those habitats which are limited within the region. Very high sensitivity faunal habitats include rocky outcrop areas and wetland areas. Rocky outcrops provide the habitat to support a large variety of reptile species which are adapted to living within rocky areas. The wetland habitat is considered to be of a very high importance in the water scarce Namaqua region. Although all wetland features within the study area are ephemeral, they provide important breeding and foraging habitat for faunal species during the wet season and are therefore considered to be of increased importance. Furthermore, wetland/riparian areas may be of increased importance in terms of the provision of a migratory corridor in an otherwise arid region. The Kotzesrus Route traverses a greater distance of very high sensitivity faunal habitat than the Amended Bypass Route, and desalination sites B and E are located in close proximity to coastal rocky outcrop areas.

Moderate Sensitivity

Moderate sensitivity faunal habitats include all terrestrial areas (succulent karoo habitat unit and the sand fynbos habitat unit). The development of linear infrastructure along either of the route alternatives will result in the removal of terrestrial faunal habitat from the study area. However, terrestrial fauna habitat within the study area is abundant and faunal species will be able to migrate from the construction footprint area into surrounding terrestrial areas. Moderate sensitivity faunal habitat is associated with both route alternatives; however, the Amended Bypass Route traverses a slightly greater distance of the terrestrial habitat unit than the Kotzesrus Route.

Low Sensitivity

Low sensitivity faunal habitats include transformed areas associated with the town of Kotzesrus, the Zandkopsdrift Mine and with historically cultivated fields. Faunal habitat provision within transformed areas is deemed limited. Low sensitivity faunal habitat is associated with both route alternatives, however, the Kotzesrus Route traverses the town of Kotzesrus and therefore covers a greater distance of the Low sensitivity faunal habitat than the Amended Bypass Route.

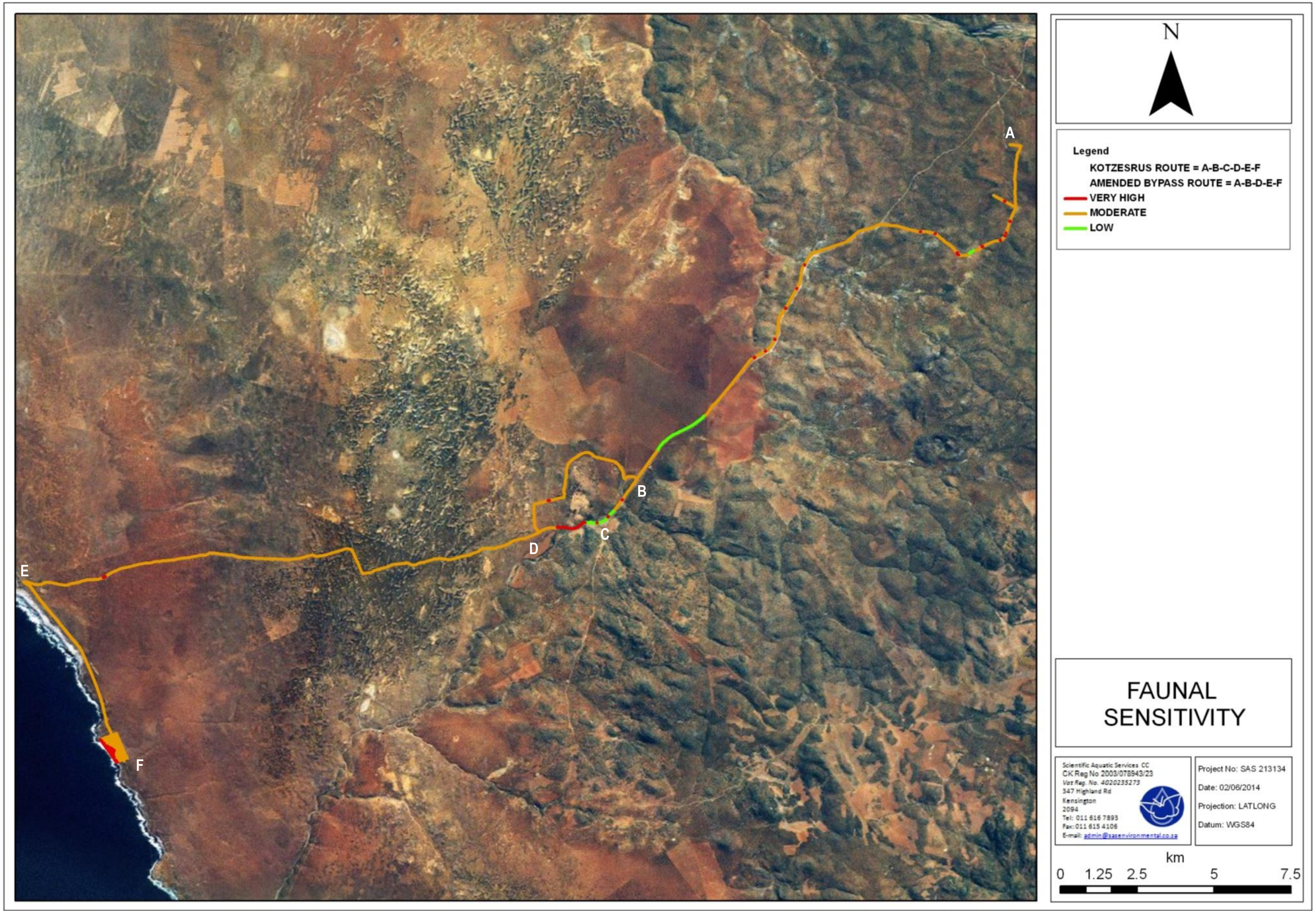

Figure 20: Sensitivity of the faunal habitats associated with the route and desalination plant alternatives (A-B-C-D-E-F = Kotzesrus Route and A-B-D-E-F = Amended Bypass Route).

5 DESCRIPTION OF THE AFFECTED ENVIRONMENT: FRESHWATER

5.1 Regional Context

The study area is located within a water stressed region (Namakwa District Biodiversity Sector Plan, 2008) and as a result available freshwater habitat is considered to be of increased conservation importance. Wetlands in the arid, lowland coastal areas of the Kamiesberg Muicipality in which the study area is located occupy only 5% or less of the area (Namakwa District Biodiversity Sector Plan, 2008). Some of the main pressures affecting freshwater ecosystems in the study area include agriculture, road crossings, overgrazing and trampling, inappropriate fire regimes and drainage, dams or abstraction.

Freshwater features within the study area are limited to ephemeral river systems such as the Brak River which will be traversed by the Kotzesrus Route as well as tributaries of the Groen River which will be traversed by both route alternatives. A small number of ephemeral pans also occur within the study area. Four ephemeral pans are likely to impacted as a result of the development of linear infrastructure associated with both route alternatives.

5.2 National Freshwater Ecosystem Priority Areas

According to the NFEPA database (2011), both route alternative traverse valley floor wetland features, these features include wetlands associated with the Brak River and tributaries of the Groen River. The Brak River is indicated as a channelled valley bottom wetland feature which is in a good condition (Class AB) and tributaries of the Groen River are indicated as floodplain wetland features in a good condition. The Brak River is traversed by the Kotzesrus Route to the east and to the west of Kotzesrus, and tributaries of the Groen River are traversed by both route alternatives to the north east of Kotzesrus.

One natural flat wetland considered to be in a good condition as well as two artificial unchannelled valley bottom wetlands and one artificial flat wetland considered to be in a critically modified condition also occur in close proximity to the route alternatives to the north east of Kotzesrus. None of these features are indicated as FEPA wetlands, and, on further inspection, it was found that the artificial valley flat wetland lacked wetland indicators. This feature has been created as a result of borrow pit construction in the area and was therefore not classified as a wetland feature.

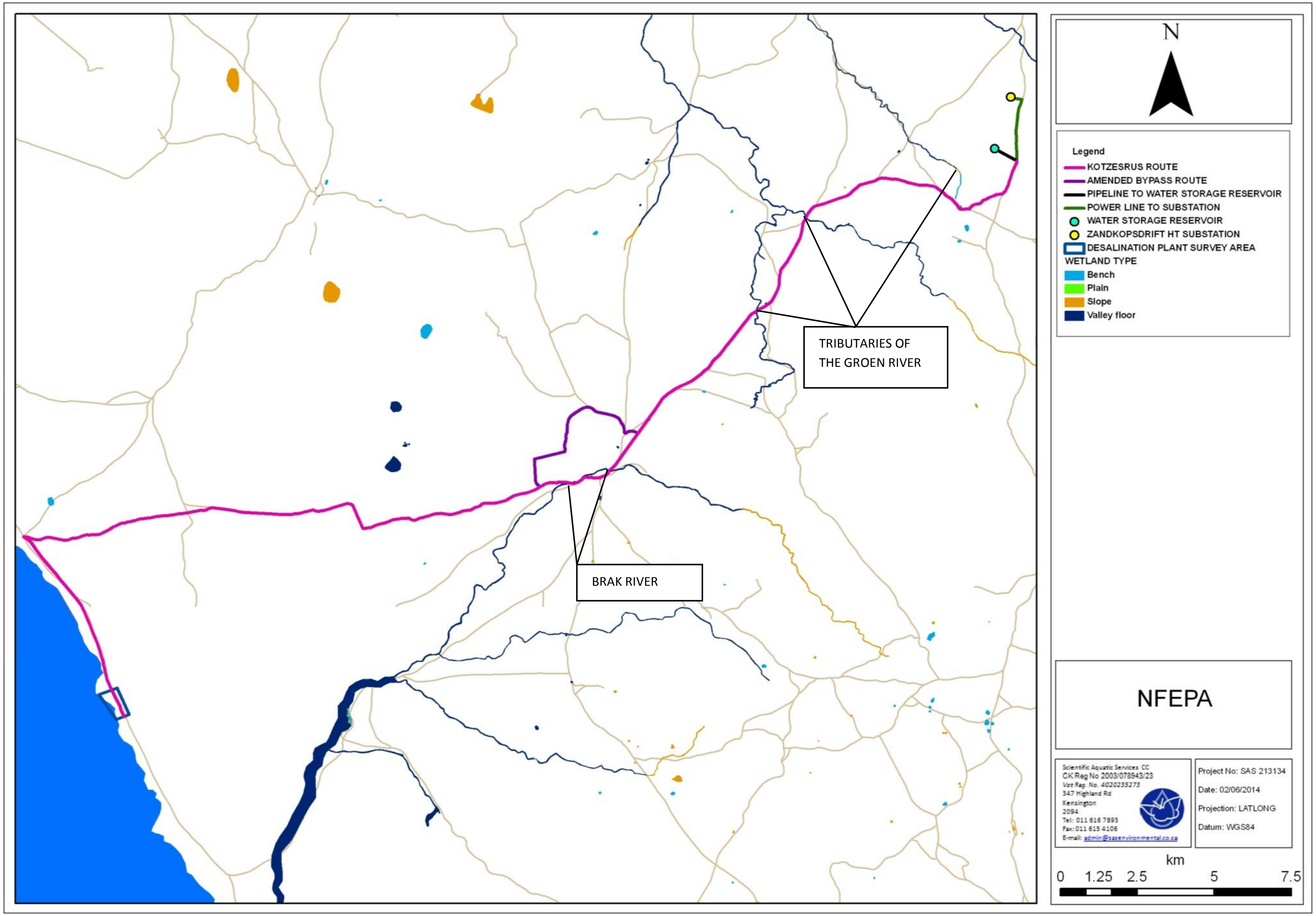

Figure 21: NFEPA wetland types within the study area.

5.3 *Freshwater Features in the Study Area*

5.3.1 The Brak River

The Brak River is a non-perennial system which contains flowing surface water for very limited periods every few years, directly after isolated cloud bursts. This feature is indicated as a channeled valley bottom wetland by the NFEPA database (2011), however, upon assessment of the feature it was determined that the Brak River portion which is associated with the route alternatives is more representative of an unchannelled valley bottom wetland. The Brak River System is characterised by alluvial soils and the presence of vegetation species such as *Sarcocornia natalensis* which is an indicator of saline conditions, as well as *Salsola aphylla, Crassula natans* and *Lycium cinereum*. The Kotzesrus route follows an existing gravel road which traverses the Brak River at two points, one to the east and one to the west of the town of Kotzesrus. The sensitivity of the portion of the Brak River to the west of Kotzesrus is increased by the presence of numerous rocky outcrop and bed rock areas and by a higher floral species diversity. Where the gravel road to be followed by the Kotzesrus route traverses the Brak River signs of erosion were evident.


Figure 22: Brak River

5.3.2 Tributaries of the Groen River

Both route alternatives follow an existing provincial gravel road to the north east of the town of Kotzesrus which traverses two non-perennial tributaries of the Groen River which are indicated as floodplain wetlands by the NFEPA database (2011). Similarly to the Brak River, these tributaries only contain flowing surface water for very limited periods directly after isolated cloud burst every few years. Tributaries of the Groen River are characterised by alluvial soils and the presence of species such as *Sarcocornia natalensis, Salsola aphylla, Crassula natans, Cotula coronopifolia* and *Moraea miniata.* The development of the existing gravel road through these features has resulted in erosion of the features and inadequate culvert design has resulted in the disruption of hydrological connectivity within the features.


Figure 23: Tributaries of the Groen River

5.3.3 Natural Ephemeral Pan Features

One natural ephemeral pan feature as indicated by the NFEPA database (2011) was identified to the north east of Kotzesrus in close proximity to the provincial gravel road leading from Kotzesrus to the mine (P2936), and three further ephemeral pan features which have not been indicated by any regional or provincial wetland databases were identified adjacent to tracks associated with both route alternatives leading from Kotzesrus to the coast (OG299) (included in wetland delineation, Figure 35).

Ephemeral pan features are found where the underlying clays are located in close proximity to the soil surface which consequently enables the depressions to contain water for a short period of time during the wet winter months and during spring. During this period they may serve as a source of water for a variety of wetland as well as terrestrial faunal species. Furthermore, ephemeral pans may serve as breeding areas for invertebrate and amphibian species which in turn provide foraging habitat for avifaunal species.

Figure 24: Ephemeral pans.

5.3.4 Ephemeral Drainage Features and Artificial Depressions

Numerous ephemeral drainage features were identified intercepting the route alternatives. These drainage features are likely to convey water during and immediately after rainfall events. However, the drainage features do not retain water long enough for the formation of hydromorphic soils that would support facultative floral species. As a result these systems cannot be defined as wetlands (DWA, 2005). Although not considered wetland features, ephemeral drainage features are likely to play an important role in the augmentation of larger wetland features downstream and are therefore considered of increased importance in terms of stream flow regulation.

It should also be noted that two artificial impoundments were encountered within the drainage features most likely due to farmers trying to retain water for as long as possible (indicated as artificial unchannelled valley bottom wetlands by NFEPA, 2011). These artificial impoundments contain surface water during the rainy season and have remained inundated for long enough for the formation of hydromorphic soils and are therefore considered to be wetland habitat.

Figure 25: Ephemeral drainage feature and artificial depression.

Earthworks associated with borrowing activities for the construction of the existing roads in the area have led to localised alterations to drainage patterns. These changes have led to localized ponding of water within the disused borrow pits with evidence of standing water occurring from time to time noted. The presence of standing water however does not occur for sufficient periods of time for soils to develop signs of hydromorphy (gleying and mottling). Based on these observations, the features cannot be defined as wetlands as defined by the NWA (Act 36 of 1998).

Figure 26: Borrow pit areas.

5.4 Wetland Characterisation

Features within the study area were categorised with the use of the *Classification System for Wetlands and other Aquatic Ecosystems in South Africa* (Ollis *et al*., 2013). After the field assessment it can be concluded that four main wetland groups are present within the study area, namely rivers and river tributaries (Brak River and tributaries of the Groen River) and natural and artificial depressions. These features are situated in both valley floor and plain landscape settings and can be classified as unchannelled valley bottom, floodplain and depression Hydrogeomrphic (HGM) units on the basis of hydrology and geomorphology (refer to freshwater ecology methodology in Appendix A for description of landscape settings and HGM Types). The results are illustrated in the table below (Please refer to Appendix E, Figures R, S and T for an indication of the localities of the various wetland groups).

Table 4: Classification for the Brak River, tributaries of the Groen River, natural ephemeral pans and artificial depressions (SANBI 2013).

	Level 3: Landscape unit	**Wetland Groups (HGM Type)**
Brak River	Valley floor	Unchannelled valley bottom wetland
Tributaries of the Groen River	Valley floor	Floodplain wetland
Natural Ephemeral Pans	Plain	Depression - natural
Artificial Depressions	Plain	Depression - artificial

5.5 Wetland Function Assessment

The function and service provision of the Brak River, tributaries of the Groen River, natural ephemeral pan features and artificial depressions was assessed based on Kotze *et. al*, 2008. The ecosystem services provided by the wetland features were scored and an average score for all the ecosystem services provided by the features is presented in Table 5 below. Scores for the various ecosystem services are graphically presented in the radar plot in Figure 27.

Table 5: Wetland functions and service provision.

Ecosystem service	Brak River	Tributaries of the Groen River	Natural ephemeral pans	Artificial depressions
Flood attenuation	1.5	1.2	0	0
Streamflow regulation	1.2	1.2	0	0
Sediment trapping	2.8	2.2	0.25	0.5
Phosphate assimilation	1.7	1.5	0.7	0.8
Nitrate assimilation	1.2	1.2	0.5	0.5
Toxicant assimilation	1.6	1.4	0.7	0.9
Erosion control	1.6	1.6	1	0.8
Biodiversity maintenance	2.8	2.4	1.3	1.3
Carbon Storage	0.3	0.3	0.3	0.3
Water Supply	0.5	0.3	0	0.6
Harvestable resources	0.6	0.2	0	0
Cultural value	0	0	0	0
Cultivated foods	0	0	0	0
Tourism and recreation	1	1.2	0.4	0.3
Education and resource	0.5	0.25	0.2	0.2
SUM	**17.3**	**15.0**	**5.4**	**6.2**
Average score	**1.2**	**1.0**	**0.4**	**0.4**
Class	**Moderately low**	**Moderately low**	**Low**	**Low**

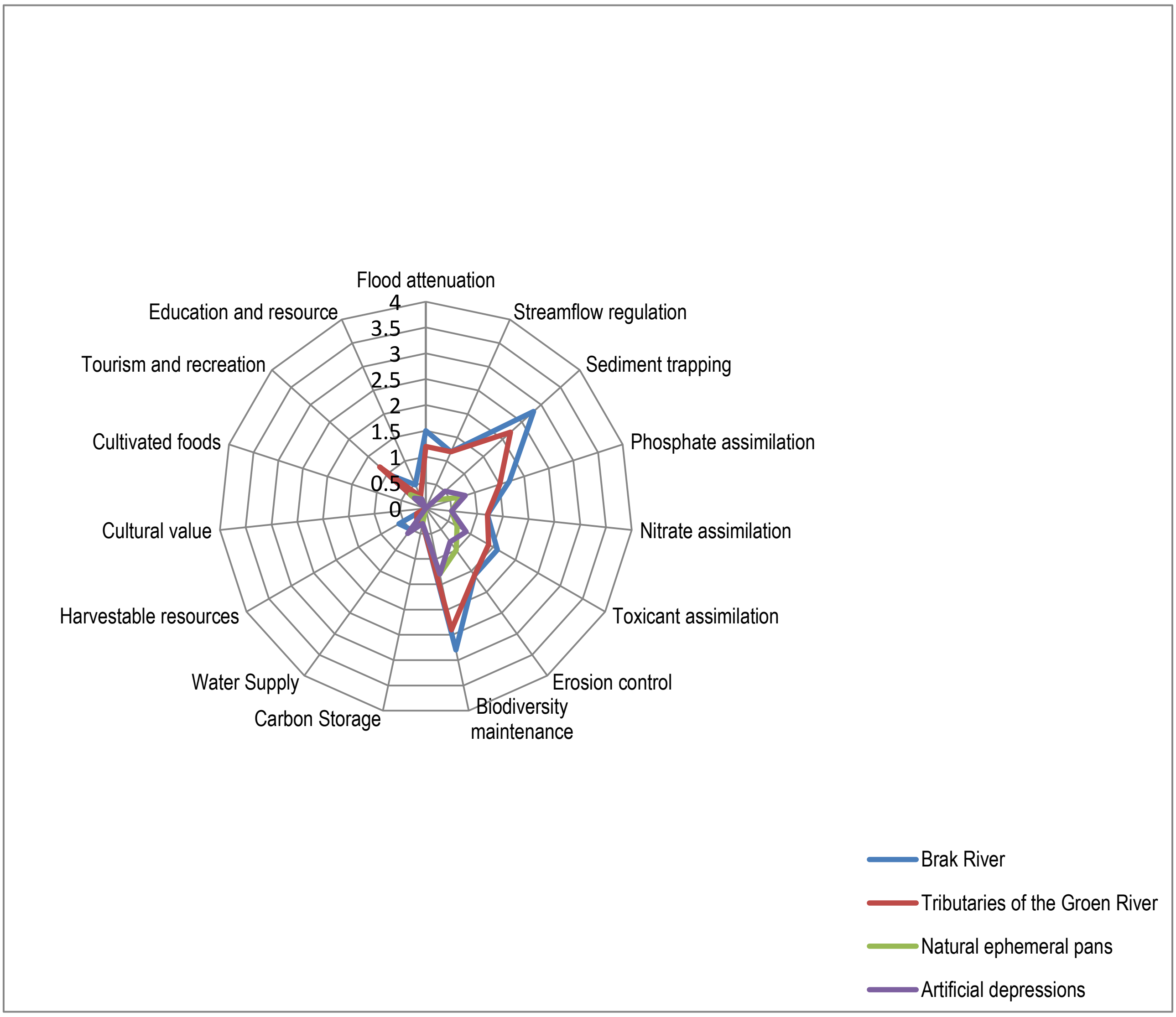

Figure 27: Radar plot of wetland services.

From the results of the assessment, it is evident that the Brak River and tributaries of the Groen River, have a moderately low level of ecological function and service provision and that the natural ephemeral pans and artificial depression features have a low level of ecological function and service provision (average scores – Table 5). The lack of flowing water within the Brak River and tributaries of the Groen River for extended periods decreases the importance of the features in terms of stream flow regulation, flood attenuation and water supply. However, the features are considered important in terms of sediment trapping due to the sandy nature of soil in the region with erosion evident within the features. The maintenance of biodiversity within the features is also considered to be of increased importance due to the presence of indigenous vegetation, rocky outcrop areas and due to the connectivity of the features to other natural areas. The importance of the features in terms of the assimilation of phosphates, nitrates and toxicants is considered to be of a moderate to moderately low level. Although features support facultative wetland species which may potentially assimilate these substances, the study area is located in a rural area and the land use activities are not associated with the release of a high level of phosphates, nitrates and toxicants. Furthermore, the importance of the features in terms of harvestable resources, cultural value and cultivated foods is considered low and further decreases the overall importance in terms of service provision of the features.

Natural ephemeral pan features and artificial depressions associated with the route alternatives are endorheic features and the importance calculated for flood attenuation and stream flow regulation is therefore considered to be very low. Furthermore, the importance of natural ephemeral pan features and artificial depression features in terms of water supply, provision of harvestable resources and cultivated food, cultural significance, tourism and recreation as well as education is considered very low and decreases the overall score of the features.

5.6 Wetland Health

A level 2 WET-health assessment was undertaken to determine the health of the wetland features associated with the study area. Wetland features were split into hydrogeomorphic (HGM) units which have been defined based on geomorphic setting, water source and pattern of water flow through the wetland. Indicators based on hydrology, geomorphology and vegetation were then used to assess the health of different HGM units as follows:

- For the assessment of the study area the Brak River was classified as an unchannelled valley bottom wetland and was assessed as a single HGM unit;
- Both tributaries of the Groen River were classified as floodplain wetlands and were therefore considered to fall within the same HGM unit and as a result were assessed together; and
- Although natural ephemeral pans and artificial depression wetlands are both considered to fall within the depression HGM unit, aspects of the hydrology and vegetation differed slightly and so they were assessed separately. Furthermore, although artificial depression wetland features are located within ephemeral drainage features, these drainage features cannot be considered true wetlands and so artificial depression wetlands were assessed separately from their drainage features.

Table 6: Summary of the Hydrological, Geomorphological and Vegetation PES of the wetland features based on impact score and change score should the development proceed.

Feature Type	Hydrology		Geomorphology		Vegetation	
	PES	Change Score	PES	Change Score	PES	Change Score
Brak River	A	↓	A	↓	A	↓
Tributaries of the Groen River	A	↓	A	↓	A	↓
Ephemeral Pan Features	A	↓	N/A	N/A	A	↓
Artificial Depressions	F	↓	N/A	N/A	D	↓

*Change score: ↓ = condition is likely to deteriorate slightly.

The present hydrological state of the Brak River, tributaries of the Groen River and natural ephemeral pans calculated scores that fall within Category A (unmodified, natural). These features are non-perennial systems which contain water for limited periods of the year. Furthermore, the features are located in a rural area with minimal hardening of land surfaces and the land use activities in the catchment of these features are not likely to result in the significant reduction or increase of inflows into the features. The wetland features have not been canalised and no stream modification has taken place. Although the Brak River and tributaries of the Groen River are traversed by gravel roads, and although ephemeral pans are located in close proximity to gravel roads, the impacts as a result of these roads on the natural hydrological regime is considered negligible.

The present hydrological state of the artificial depression wetlands calculated a score which falls within Category F (critically modified). The poor score calculated for the hydrological state of the features is a result of the artificial nature of the features.

The present geomorphological state of wetland features can only be assessed for wetland features which are connected to the drainage network in some way (Macfarlane *et. al* 2009). The ephemeral pans and artificial depressions associated with the study area are endorheic features and the geomorphological health of these features was therefore not assessed. The present geomorphological state of the remaining HGM units calculated scores that fall within Category A (unmodified, natural). The portion of the Brak River to the west of Kotzesrus has been affected by erosion and deposition as a result of the construction of gravel roads through the feature, however, the aridity of the area together with the low runoff potential of the catchment decreases the significance of the impact.

The geomorphology of tributaries of the Groen River has not been impacted as a result of dams in the system and the features have not been straightened. Although gravel roads traversing the features impede the subsurface flow through features to some degree, the impact of gravel roads on the geomorphological health of the features is limited.

The present vegetation state of the Brak River, tributaries of the Groen River and natural ephemeral pans calculated scores that fall within Category A (unmodified, natural), and artificial depressions calculated scores which fall within Category D (Largely modified). All wetland features associated with the study area are located within a rural area in which disturbance and transformation is limited. Historically cultivated land, gravel roads and infrastructure associated with the town of Kotzesrus are located within the study area, however the majority of these disturbed areas are limited to areas falling outside of the wetland features with exception of a few areas in which gravel roads which will be followed by route alternatives traverse wetland features or run in close proximity to wetland features with special mention of areas in which gravel roads associated with both route alternatives traverse tributaries of the Groen River and where a gravel road followed by the Kotzesrus Route traverses the Brak River. The low level of disturbance of the wetland features as a result of existing impacts has resulted in a low impact associated with the encroachment of alien invasive species into the features. Alien invasive species present within the Brak River are limited to a few scattered individuals of *Acacia cyclops*. Artificial depression features calculated a lower vegetation health score due to an increase in vegetation disturbance as a result of historical excavation activities associated with the creation of the impoundments.

The overall score for all wetland features which aggregates the scores for the three modules, namely hydrology, geomorphology and vegetation, was calculated using the formula as provided by the Wet-Health methodology. The Brak River, tributaries of the Groen River and natural ephemeral pans calculated an overall score falling within the PES Category A (unmodified, natural) and artificial depressions calculated an overall score falling within the PES Category F (Critically modified). The PES was then used during the determination of an appropriate category for the EIS of the wetland features (section 5.7 below).

In terms of anticipated trajectory[7] (change score), should the development of the linear infrastructure associated with route alternatives not take place, it is considered to be highly likely that the PES of all wetland features assessed would remain the same. However, should the development of the linear infrastructure associated with route alternatives occur, the health of wetland features would most likely decrease slightly.

[7] Anticipated change over the next 5 years.

5.7 EIS Determination

The method used for the EIS determination was adapted from the method as provided by DWA (1999) for floodplains. The method takes into consideration PES scores obtained for WET-Health as well as function and service provision to enable the assessor to determine the most representative EIS Category for the wetland feature or group being assessed.

A series of determinants for EIS are assessed on a scale of 0 to 4, where 0 indicates no importance and 4 indicates very high importance. The median of the determinants is used to assign the EIS Category as listed in Table 7 below. A confidence score is also provided on a scale of 0 to 4, where 0 indicates low confidence and 4 indicates high confidence.

Table 7: EIS determination.

Determinant	Brak River		Tributaries of the Groen River		Ephemeral Pans		Artificial depressions	
	Score	Conf	Score	Conf	Score	Conf	Score	Conf
PRIMARY DETERMINANTS								
1. Rare & Endangered Species	3	2	3	2	2	2	0	4
2. Populations of Unique Species	3	2	3	2	2	2	0	4
3. Species/taxon Richness	3	3	3	3	3	3	1	4
4. Diversity of Habitat Types or Features	2	4	2	4	2	4	1	4
5 Migration route/breeding and feeding site for wetland species	3	4	3	4	2	4	2	4
6. PES as determined by WET-Health assessment	4	4	4	4	4	4	0	4
7. Importance in terms of function and service provision	2	4	2	4	0	4	0	4
MODIFYING DETERMINANTS								
8. Protected Status according to NFEPA Wetveg/ Aquatic CBA or ESA	3	4	4	4	3	4	0	4
9. Ecological Integrity	4	3	3	3	3	3	1	4
TOTAL	27		27		21		5	
MEDIAN	3		3		2.3		0.5	
OVERALL EIS	**A**		**A**		**B**		**C**	

Based on the findings of the study it is evident that the Brak River and tributaries of the Groen River have an EIS falling within Category A (very high sensitivity). The EIS calculated was based on the following factors:

- Although rare and endangered species were not identified within the wetlands at the time of the assessment there is a high probability of occurrence of SCC in these features;
- Floral species diversity within the features was considered to be high;
- Both features are deemed to be of a high importance in terms of the provision of breeding and feeding sites for faunal species and in terms of faunal migratory routes;
- The PES calculated for the features was high; and
- The ecological integrity of the features is considered to be largely intact.

The EIS score of the ephemeral pans was calculated to fall within Category B (high sensitivity). The EIS calculated was based on the following factors:

- Floral species diversity within the features was considered to be high;
- Ephemeral pans are deemed to be of a moderate importance in terms of the provision of breeding and foraging sites for faunal species;
- The PES calculated for the features was high; and
- The ecological integrity of the features is considered to be largely intact.

The EIS score of the artificial depressions was calculated to fall within Category C (moderately sensitive). The EIS calculated was based on the following factors:

- Floral species diversity within the features was not as high as within natural features;
- Artificial depressions are deemed to be of a moderate importance in terms of the provision of breeding and foraging sites for faunal species;
- The PES calculated for the features was very low; and
- The ecological integrity of the features is considered to be lower than that of other natural features.

A map of the EIS of all wetland features associated with the study area is presented below. Detailed EIS maps for the eastern, central and western portions of route alternatives are available in Appendix E (Figures N, O and P).

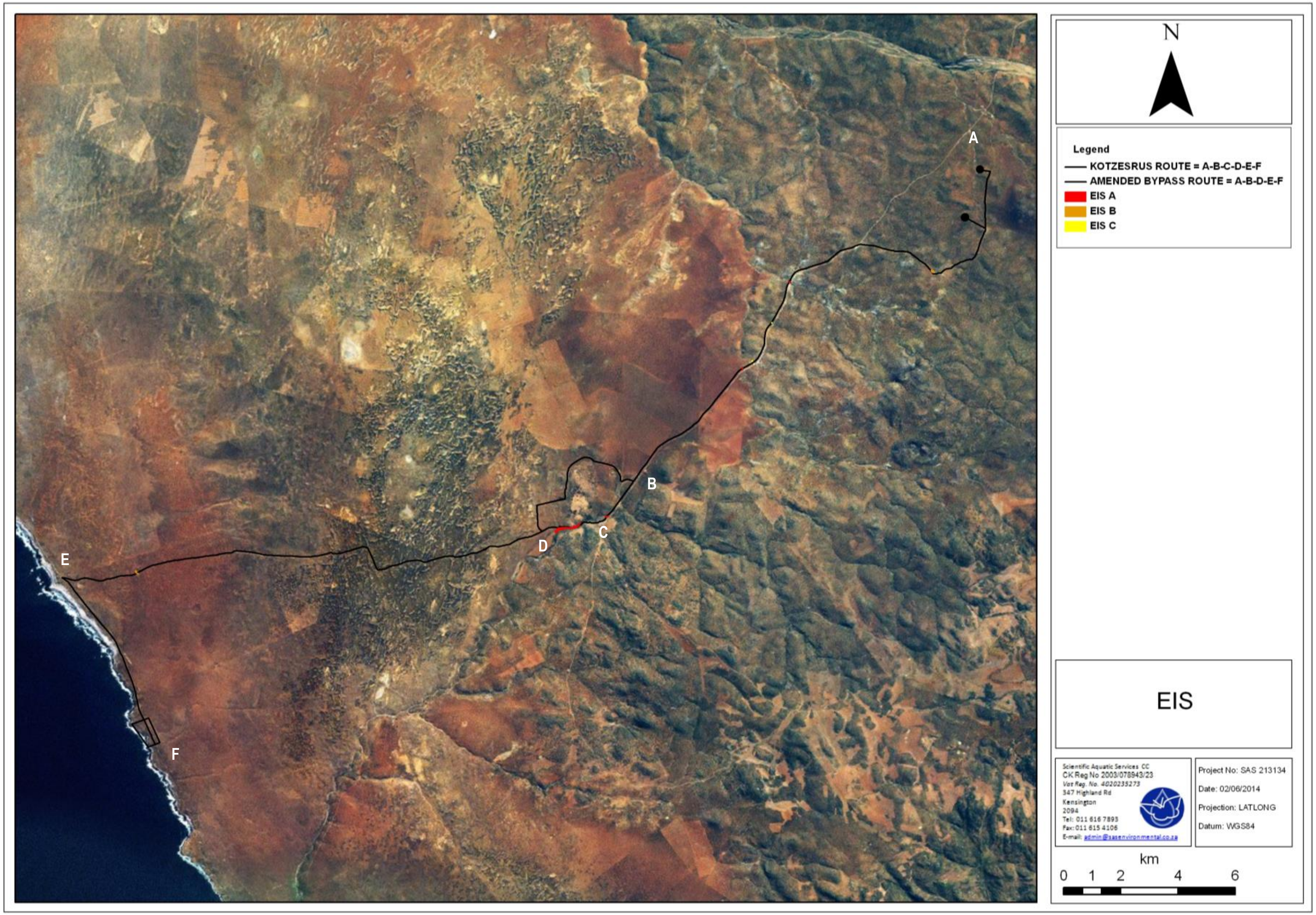

Figure 28: Ecological Importance and Sensitivity (A-B-C-D-E-F = Kotzesrus Route and A-B-D-E-F = Amended Bypass Route) (detailed EIS maps for the eastern, central and western portions of route alternatives are available in Appendix E).

5.8 Recommended Ecological Category

The Brak River, tributaries of the Groen River and ephemeral pans were calculated to fall within PES Category A (unmodified, natural). The REC deemed appropriate to maintain the current ecology as well as functionality within these features is therefore a Category A (Unmodified).

Artificial depressions were calculated to fall within PES Category F (critically modified). Due to the significance of impacts already present within the features and due to the disturbance of the surrounding catchment area as a result of excavation activities, it is doubtful that the PES of the features can be significantly increased. However, if possible the PES of artificial depressions should be increased to Category D features.

5.9 Wetland Delineation

The objective of the delineation procedure is to identify the outer edge of the wetland temporary zone (refer to the freshwater ecology methodology in Appendix A for an explanation of wetland zonation). This outer edge marks the boundary between the wetland and adjacent terrestrial areas (DWA, 2005). Wetlands are delineated in order to spatialy define these hydrologically sensitivite areas. Temporary zones of all wetland features were delineated according to the guidelines advocated by DWA (2005) taking into consideration wetland soil characteristics as defined by Job (2009). It should be noted that the identification of the temporary zone proved difficult in some areas as a result of the lack of wetland vegetation. However, the delineation as presented in this report is regarded as a best estimate of the wetland boundary based on the site conditions present at the time of assessment.

During the assessment, the following temporary zone indicators were used:

Brak River

- The obligate wetland species *Sarcocornia natalensis* dominated the portion of the Brak River to the east of Kotzesrus and surface water was present. Therefore, wetland vegetation could be used as the primary indicator of the temporary zone of this portion of the river and surface water could be used as a secondary indicator of the temporary zone;
- The obligate wetland species *Sarcocornia natalensis* was scattered within the portion of the Brak River to the west of Kotzesrus and surface water was restricted to the small isolated pools. Therefore, terrain units could be used as the primary indicator of the temporary zone of the wetland and surface water as well as wetland vegetation could be used as secondary indicators; and
- For the soil form indicator, the presence of gleyed soils (most of the iron has been leached out of the soil leading to a low chroma greyish/greenish/bluish colour) and mottling (created by a fluctuating water table) were investigated. Gleying of the soil was noted however no mottling was present.

Figure 29: Temporary zone of the western portion of the Brak River dominated by *Sarcocornia natalensis*.

Tributaries of the Groen River

- The obligate wetland species *Sarcocornia natalensis* as well as facultative wetland species including *Cotula coronopifolia*, *Moraea miniata* and *Crassula natans* could be used as primary indicators of the wetland temporary zone;
- The presence of surface water could be used as a secondary indicator of the temporary zone; and
- For the soil form indicator, the presence of gleyed soils (most of the iron has been leached out of the soil leading to a low chroma greyish/greenish/bluish colour) and mottling (created by a fluctuating water table) were investigated. Gleying of the soil was noted however no mottling was present.


Figure 30: Temporary zone dominated by wetland vegetation; and gleyed wetland soils.

Ephemeral pans

- No obligate or facultative wetland species were identified within ephemeral pans to the west of Kotzesrus, however, a distinct change in vegetation composition was noted between pan temporary zones and surrounding terrestrial areas with special mention of an increase in the occurrence of the weed species *Oncosiphon suffruticosum*. This distinct change in vegetation composition could then be used as a primary indicator when determining the temporary wetland boundary of the ephemeral pans;
- A definite change in vegetation was noted within the ephemeral pan to the north east of Kotzesrus. Shrubs were restricted to the outer boundary of the feature and the temporary zone was devoid of vegetation. This is as a result of hard underlying clays close to the surface which prevent vegetation from setting root and which form an impermeable layer preventing water from seeping away from the surface. Lack of vegetation could therefore be used as an indicator of the wetland temporary zone; and
- Facultative wetland species including *Spiloxene aquatic* and *Crassula natans* were also present in the outer boundary of the temporary zone of the ephemeral pan to the north east of Kotzesrus and was also used to inform the delineation.

Figure 31: Temporary zone of an ephemeral pan dominated by *Oncosiphon suffruticosum*.

Artificial depressions

- Terrain units and the presence of surface water could be used as primary indicators during the determination of artificial depression boundaries; and
- For the soil form indicator, the presence of gleyed soils (most of the iron has been leached out of the soil leading to a low chroma greyish/greenish/bluish colour) and mottling (created by a fluctuating water table) were investigated. Gleyed, clay soils were noted within the temporary zones of artificial depressions.

Figure 32: Surface water and gleyed clay soils.

5.10 Buffer Allocation

The implementation of a 32 m buffer to wetland features and watercourses is considered industry best practice complying with the requirements of NEMA. All wetland features that are located adjacent to or within the construction footprint and their associated 32 m buffer areas are presented in the figures to follow (Refer to Figures 33-35).

As they are currently proposed, construction activities associated with both route alternatives will fall within 32m of wetlands/watercourses. It should be noted that any activity occurring within the wetland features or within the buffers of wetland features, will require authorisation in terms of Section 21 (c) and (i) of the NWA and any development within 32m of the wetland boundary will require authorisation in terms of NEMA (Act 107 of 1998).

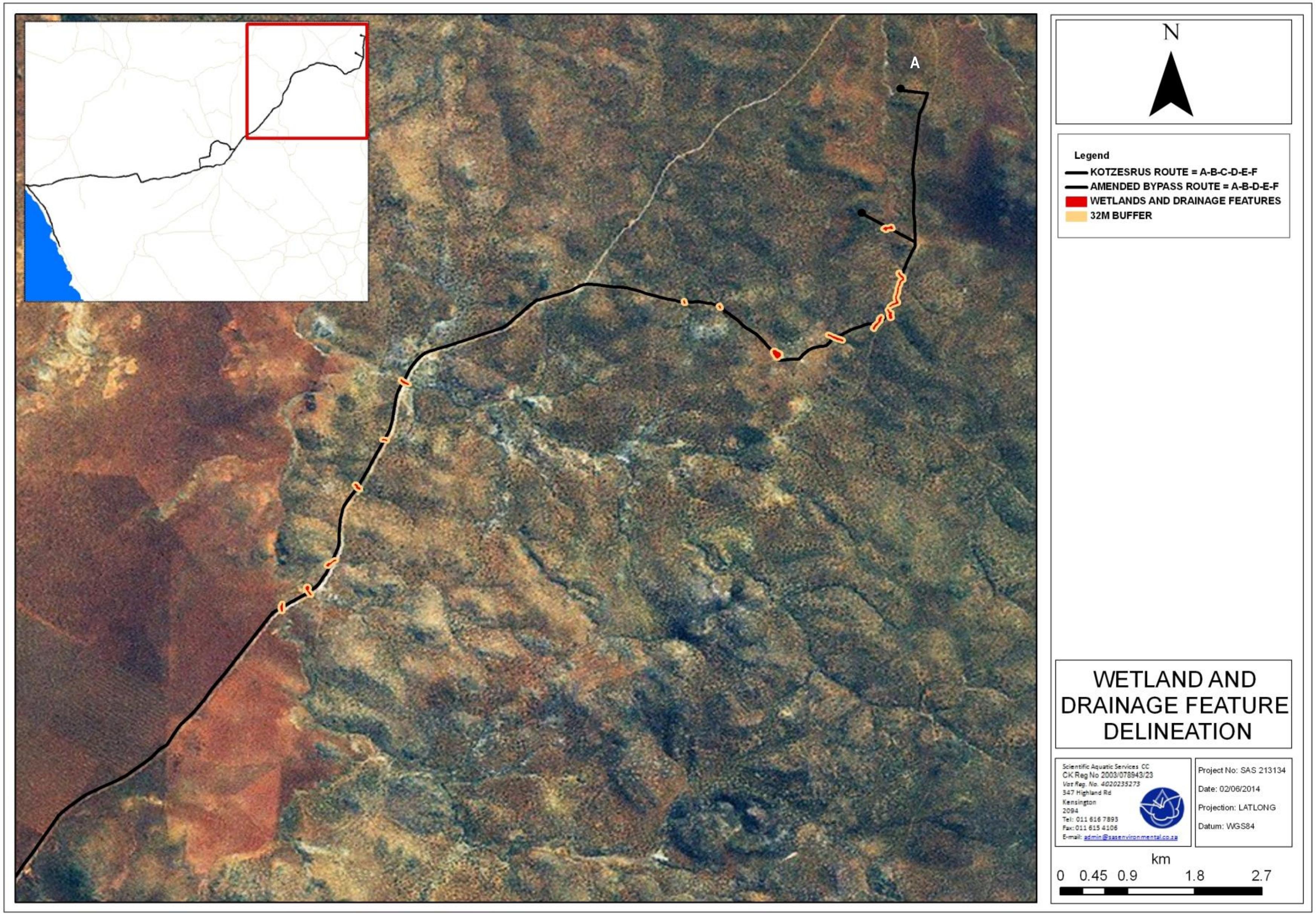

Figure 33: Wetlands and drainage features with associated buffers (east).

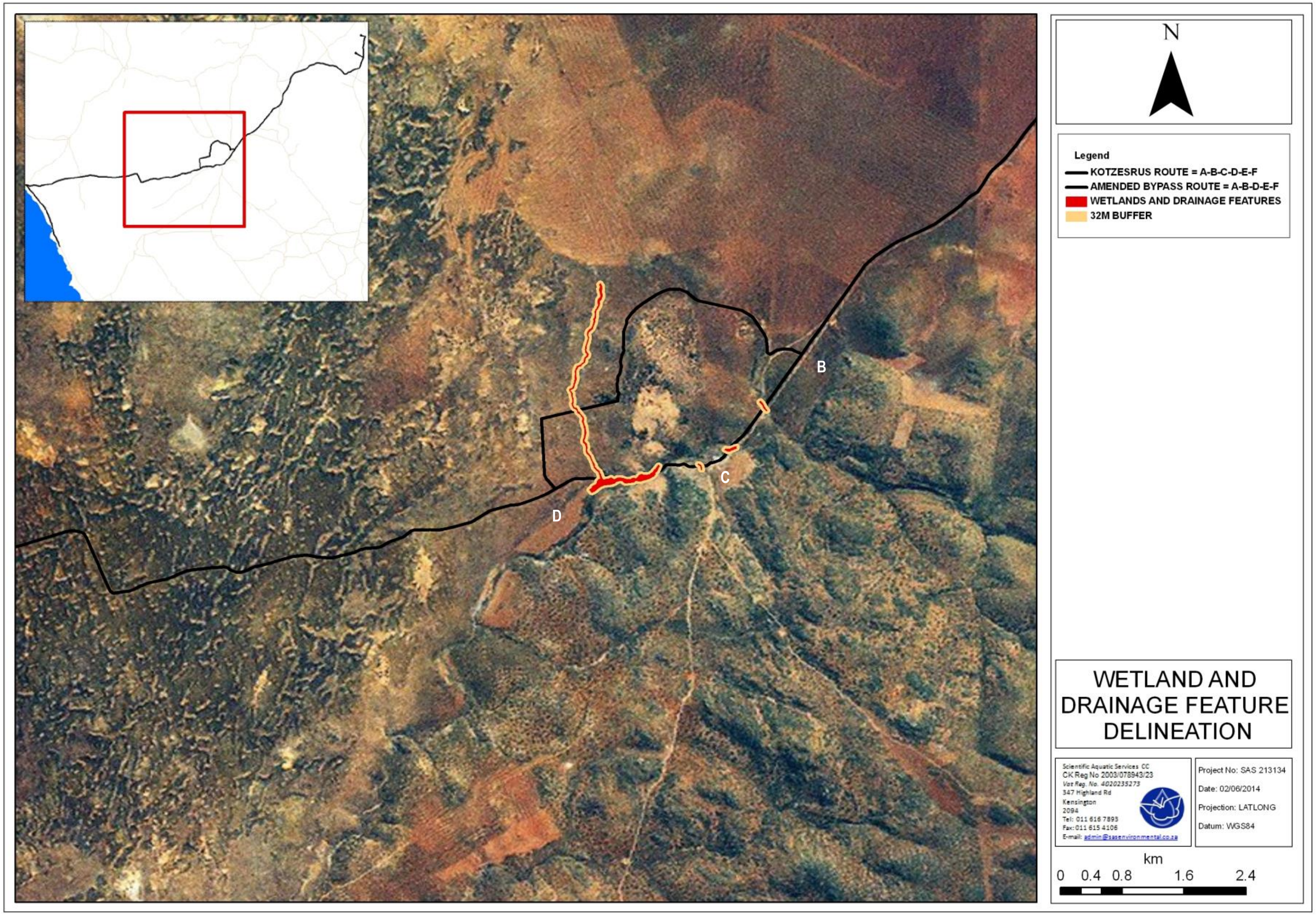

Figure 34: Wetlands and drainage features with associated buffers (centre).

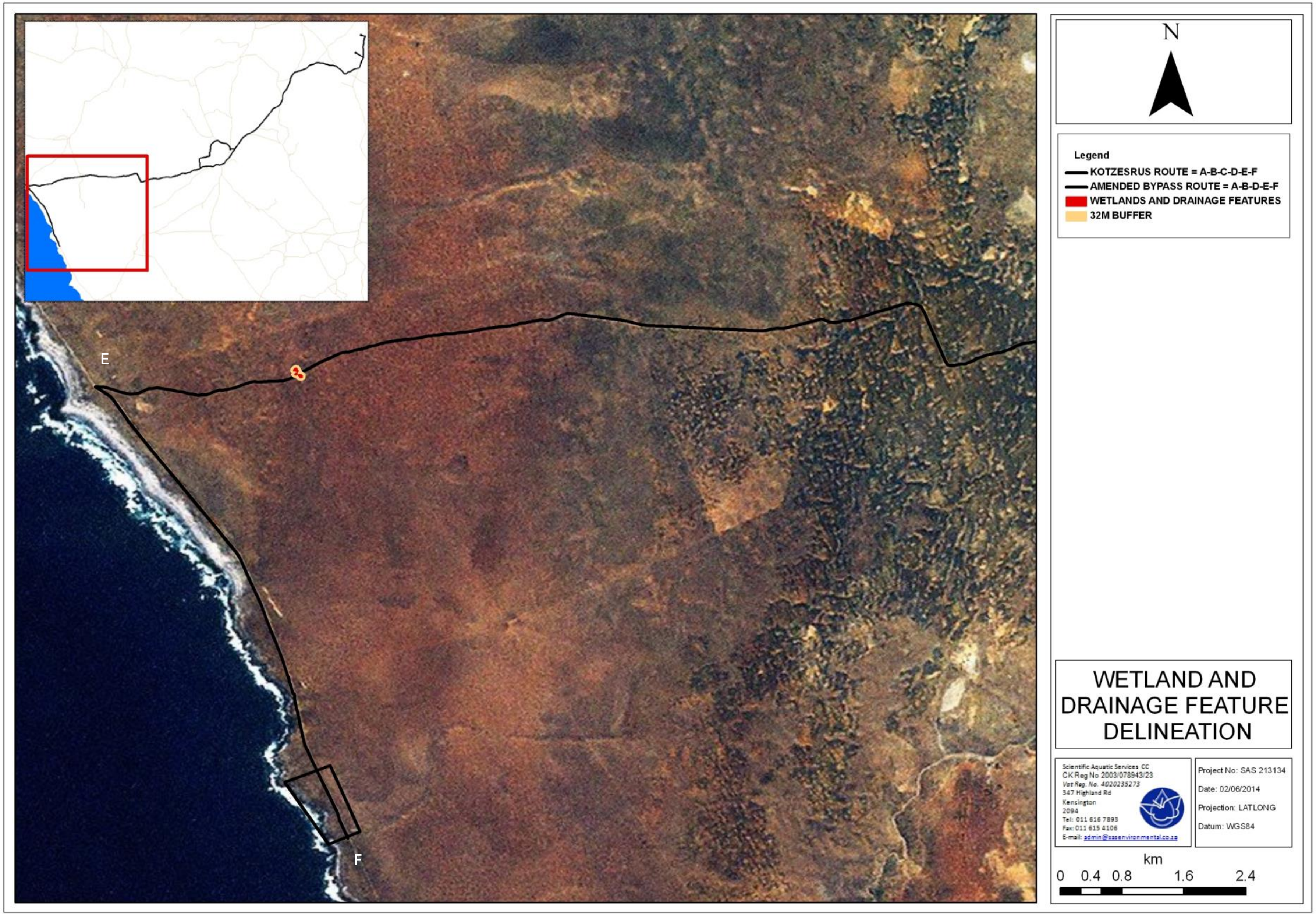

Figure 35: Wetlands and drainage features with associated buffers (west).

6 IMPACT ASSESSMENT

The tables below serve to summarise the significance of potential impacts on the terrestrial and freshwater ecology of the study area. Impacts associated with the floral, faunal and freshwater ecology of the study area have been assessed separately for the two route alternatives: Kotzesrus Route and the Amended Bypass Route. Desalination plant alternatives were divided into two groups with similar associated impacts. Sites A, C and D are all located within the strandveld habitat unit and will result in the removal of a similar extent of this moderate sensitivity vegetation. Sites B and E are located within high sensitivity coastal vegetation and will result in the removal of a similar extent of this vegetation. Impacts associated with sites A, C and D are therefore considered similar and impacts associated with sites B and E are considered similar. These two groups of alternatives were therefore assessed separately. Impacts have also been assessed separately for both the construction and operational phase of the development. The sections below present the impact assessment according to the method prescribed by SRK. In addition, it also indicates the required mitigatory and management measures needed to minimise potential ecological impacts and presents an assessment of the significance of the impacts assuming the available mitigatory measures are fully implemented. In the assessment of impacts prior to the implementation of mitigation measures the assumption has been made that all general good housekeeping measures and general construction principles as listed in Appendix F will be strictly adhered to throughout all phases of the development.

6.1 Vegetation Impact Assessment

Due to the sensitivity of the quarts and clay exposure areas, which support SCC, the impacts on these areas have been assessed separately form the remainder of the habitat types, in which impacts are similar.

IMPACT 1: LOSS OF FLORAL HABITAT, BIODIVERSITY AND SCC (EXCLUDING QUARTZ AND CLAY EXPOSURE AREAS)

KOTZESRUS ROUTE

<u>Construction phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of vegetation;
- Disturbance of soils; and
- Dust generation.

The majority of the route followed by the Kotzesrus Route will traverse habitat considered to be of low to moderate sensitivity (strandveld - approximately 70%), however, smaller areas of high sensitivity (sand fynbos and coastal - approximately 26%) and very high sensitivity (rocky outcrops - approximately 2%) will also be traversed as well as areas indicated as CBAs and ESAs. The existing tracks followed by the Kotzesrus Route to the west of Kotzesrus (OG155, OG153 and OG299) will need to be widened to approximately 4m width in order to accommodate large construction vehicles, and vegetation to either side of the widened road will have to be cleared to make way for pipelines and power line support structures. This will result in the loss of predominantly moderate sensitivity strandveld vegetation, however it may also result in the loss of very high sensitivity rocky outcrop areas associated with the Brak River crossing and will result in the loss of high sensitivity sand fynbos and coastal vegetation. Although the gravel road to the east of Kotzesrus will not be widened, pipelines and power lines will still need to be constructed within areas adjacent to the road which will result in the disturbance and loss of areas of moderate and low sensitivity vegetation. The development of the

Kotzesrus Route and the associated removal of vegetation is also likely to result in the loss of floral SCC and protected species such as *Leucospermum rodolentum, Babiana hirsuta* and *Aloe arenicola*.

The impact associated with the loss of floral habitat, diversity and SCC is restricted to the local area and is therefore considered to be local in extent. However, vegetation will need to be removed permanently in order to make way for the development of new infrastructure and so the duration of the impact is considered long term. Although the majority of the habitat which will be disturbed or lost is considered to be of a low to moderate sensitivity the development of the linear infrastructure through the Brak River will result in the loss of very high sensitivity rocky outcrop areas and the impact associated with the loss is considered to be of a high intensity. The overall impact is therefore considered to be of a high significance prior to the implementation of mitigation measures.

The implementation of mitigation measures will not prevent the permanent removal of floral habitat from the development footprint and the duration of the impact therefore remains long term. However, with the implemtation of mitigation measures such as the minimisation of the development footprint, the rescue and relocation of SCC and the avoidance of rocky outcrop areas, the intensity of the impact may be reduced and the overall impact significance may be reduced to a low level.

Without Mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	High	Long-term	**High**	Definite	**HIGH**	**– ve**	High
	1	3	3	7				

Essential mitigation measures during the construction phase:

- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise environmental damage;
- Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
- Limit the removal of vegetation from the road reserve and servitude to that which is essential;
- Pipelines and power lines must be built on support structures above the ground;
- The pipeline should ideally be constructed within the road reserve, or alternatively as close as possible to the road / road reserve edge (Helme, 2014);
- Ensure that as far as possible all infrastructure is placed outside of rocky outcrop areas;
- A detailed rescue and relocation plan must be compiled and an attempt must be made to rescue and relocate SCC to a suitable habitat outside of the construction footprint area;
- Appoint a suitably experienced person to oversee the removal and rescue and relocation of all SCC;
- Obtain special authorisation for SCC, protected and indigenous species to be cut, disturbed, damaged or destroyed. Applications for such activities must be made to the Northern Cape Department of Environment and Nature Conservation;
- Remove alien and weed species encountered within the study area in order to comply with existing legislation (amendments to the regulations under the Conservation of Agricultural Resources Act, 1983 and Section 28 of the National Environmental Management Act, 1998). Species specific and area specific eradication recommendations:
    - Take care with the choice of herbicide to ensure that no additional impact and loss of indigenous plant species occurs due to the herbicide used, with special mention of areas in close proximity to SCC;
    - Keep footprint areas as small as possible when removing alien plant species;
    - Dispose of removed alien plant material at a registered waste disposal site.

Recommended mitigation measures during the construction phase:

- In order to minimise damage in more sensitive habitat units such as rocky outcrops, sand fynbos and coastal areas, clearing for construction should be restricted to the dry dormancy period within the region (November to April) as far as possible; and
- Enforce a speed limit for construction vehicles of 40km/h along route alternatives occurring to the west of Kotzesrus in order to curb dust generation.

With Mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	Low	Long-term	**Low**	Definite	**LOW**	**– ve**	High
	1	1	3	**5**				

<u>Operational Phase</u>

Activities leading to impact:

- Maintenance activities;
- Alien and invasive vegetation proliferation in disturbed areas; and
- Dust generation

The impact associated with the operational phase will be limited to an increase in the movement of maintenance vehicles along the road and the associated dust generation. However this increase will be limited to approximately six light and six heavy vehicle trips per day. Vegetation may also be disturbed as a result of possible maintenance activities. Furthermore, disturbance created as a result of maintenance activities may result in the encroachment of alien invasive species into the area. If left unmitigated alien and invasive species could proliferate and would remain within the area permanently. The impact associated with the operational phase is therefore considered of a local extent, of a low intensity and of a long term duration. However, the probability of the impact is only considered to be possible as the limited maintenance activities associated with the project (repairing leaks in pipelines and grading of gravel roads) will not necessarily result in the proliferation of alien and invasive species and the long term loss of habitat. The overall impact is therefore considered to be of a very low significance prior to the implementation of mitigation measures. However with the implementation of mitigation measures the duration of the impact may be reduced to short term as any alien vegetation proliferation that does occur will be controlled and any natural vegetation that is disturbed will be able to recover. The overall impact may therefore be reduced to an insignificant level.

Without mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**– ve**	High
	1	1	3	5				

Essential mitigation measures during the operational phase:

- Remove alien and weed species encountered within the study area in order to comply with existing legislation (amendments to the regulations under the Conservation of Agricultural Resources Act, 1983 and Section 28 of the National Environmental Management Act,
- If maintenance activities within very high sensitivity habitats are unavoidable, the activities must be undertaken by hand;
- Do not permit heavy machinery into very high sensitivity habitat units;
- Restrict the number of personnel entering into very high sensitivity habitats during maintenance activities;
- Ensure that maintenance activities are restricted to the road reserve and do not encroach into surrounding open veld areas and that these open veld areas are strictly off-limits to maintenance vehicles and personnel;
- Strictly prohibit maintenance personnel from collecting plant material from surrounding natural areas;
- Monitor water pipelines for leaks (specifically in very high sensitivity habitats where a change in water availability may alter habitat characteristics) and any leaks which are detected must be repaired immediately.

Recommended mitigation measures during the operational phase:

- Enforce a speed limit for operational and maintenance vehicles of 40km/h along route alternatives occurring to the west of Kotzesrus in order to curb dust generation.

With mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Local	Low	Short-term	**Very Low**	Improbable	**INSIGNIFICANT**	**– ve**	High
	1	1	1	**3**				

AMENDED BYPASS ROUTE

<u>Construction phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of vegetation;

- Disturbance of soils; and
- Dust generation.

The route followed by the Amended Bypass Route is identical to that of the Kotzesrus Route with exception of a small portion which diverts around Kotzesrus before re-joining the Kotzesrus Route to the west of Kotzesrus. By diverting around the town of Kotzesrus the Amended Bypass Route avoids the disturbance of very high sensitivity rocky outcrop areas.

The impact associated with the loss of floral habitat, diversity and SCC is restricted to the local area and is therefore considered to be local in extent. However, vegetation will need to be removed permanently in order to make way for the development of new infrastructure and so the duration of the impact is considered long term. By diverting around Kotzesrus, the route will avoid the disturbance of very high sensitivity rocky outcrop areas associated with the Brak River and the intensity of the impact will therefore be reduced to medium. The overall impact is therefore considered to be of a medium significance prior to the implementation of mitigation measures.

The implementation of mitigation measures will not prevent the permanent removal of floral habitat from the development footprint and the duration of the impact therefore remains long term. However, with the implemtation of mitigation measures such as the minimisation of the development footprint and the rescue and relocation of SCC, the intensity of the impact may be reduced and the overall impact significance may be reduced to a low level.

Without Mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Amended Bypass Route	Local	Medium	Long-term	**Medium**	Definite	**MEDIUM**	**– ve**	High
	1	2	3	6				
Essential mitigation measures during the construction phase: • Refer to construction phase mitigation measures as listed for the Kotzesrus Route (pg 56). **Recommended mitigation measures during the construction phase:** • Refer to construction phase mitigation measures as listed for the Kotzesrus Route (pg 56)								
With Mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Amended Bypass Route	Local	Low	Long-term	**Low**	Definite	**LOW**	**– ve**	High
	1	1	3	**5**				

Operational Phase

Activities leading to impact:
- Maintenance activities;
- Alien and invasive vegetation proliferation in disturbed areas;
- Dust generation

The operational phase impact associated with the Amended Bypass Route will be the same as that associated with the Kotzesrus Route (refer to operational phase discussion and table for the Kotzesrus Route on pages 56 and 57 above).

DESALINATION PLANT ALTERNATIVES A, C AND D

Construction phase

Activities leading to impact
- Clearing of the construction footprint and the removal of vegetation;

- ➢ Disturbance of soils; and
- ➢ Dust generation.

The development of sites A, C and D will require the removal and disturbanceof approximately 15 000 m^2 of moderate sensitivity strandveld vegetation and associated SCC.

The impact associated with the development of the desalination plant at site alternatives A, C or D will be local in extent and will be of a permanent duration. However, the impact intensity associated with the removal of the moderate sensitivity vegetation is considered medium. The overall impact significance is therefore considered medium prior to the implementation of mitigation measures.

The implementation of mitigation measures may reduce the intensity of the impact associated with the development of desalination plant alternatives as alien vegetation proliferation will be controlled. However, the duration of the impact will remain permanent and the overall impact will therefore only be reduced to a low significance.

<table>
<tr><th>Unmanaged</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives A, C and D</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Definite</td><td rowspan="2">MEDIUM</td><td rowspan="2">-ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase:
• Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
• If it is unavoidable that SCC such as Babiana hirsuta will be disturbed, a detailed rescue and relocation plan must be compiled and an attempt must be made to rescue and relocate SCC to a suitable habitat outside of the construction footprint area;
• Appoint a suitably experienced person to oversee the removal and rescue and relocation of all SCC;
• Obtain special authorisation for SCC, protected and indigenous species to be cut, disturbed, damaged or destroyed. Applications for such activities must be made to the Northern Cape Department of Environment and Nature Conservation;
• Remove alien and weed species encountered within the study area in order to comply with existing legislation (amendments to the regulations under the Conservation of Agricultural Resources Act, 1983 and Section 28 of the National Environmental Management Act, 1998). Species specific and area specific eradication recommendations:
o Take care with the choice of herbicide to ensure that no additional impact and loss of indigenous plant species occurs due to the herbicide used, with special mention of areas in close proximity to SCC;
o Keep footprint areas as small as possible when removing alien plant species;
o Dispose of removed alien plant material at a registered waste disposal site;

Recommended mitigation measures during the construction phase:
• In order to minimise environmental damage, clearing for construction should be restricted to the dry dormancy period within the region (November to April) as far as possible.</td></tr>
<tr><th>Managed</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives A, C and D</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

Operational Phase

Activities leading to impact:

- ➢ Maintenance activities;
- ➢ Alien and invasive vegetation proliferation in disturbed areas;
- ➢ Dust generation

Maintenance activities within the operational phase and an increase in anthropogenic activity and disturbance within natural areas surrounding the desalination plant (for any of the alternatives) may result in the loss of natural vegetation and the proliferation of alien and invasive species which will remain permanently if left uncontrolled. However, natural areas surrounding the desalination plant will not necessarily be disturbed by maintenance personnel (since a relatively low number of personnel will be required on site) and alien vegetation was not common on site and so will not necessarily proliferate with the limited level of disturbance associated with the operational phase. The probability of the impact is therefore considered to be possible. Furthermore, the intensity of the impact associated with any disturbance is likely to be low and the overall impact significance will therefore be very low prior to the implementation of mitigation measures. With the implementation of mitigation measures the impact intensity may be reduced and the duration of the impact may be decreased to short term as any alien vegetation encountered will be controlled and any disturbed areas are likely to recover. The overall impact significance may therefore be reduced to an insignificant level.

Without mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination alternatives A, C and D	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**-ve**	High
	1	1	3	5				
Essential mitigation measures during the operational phase: • Remove alien and weed species encountered within the study area in order to comply with existing legislation (amendments to the regulations under the Conservation of Agricultural Resources Act, 1983 and Section 28 of the National Environmental Management Act, • Ensure that maintenance activities do not encroach into surrounding open veld areas and that these open veld areas are strictly off-limits to maintenance vehicles and personnel; • Strictly prohibit maintenance personnel from collecting plant material from surrounding natural areas; • Monitor sea water pipelines for leaks and any leaks which are detected must be repaired immediately.								
With mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination alternatives A, C and D	Local	Low	Short-term	**Very Low**	Improbable	**INSIGNIFICANT**	**– ve**	High
	1	1	1	**3**				

DESALINATION PLANT ALTERNATIVES B AND E

<u>Construction phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of vegetation;
- Disturbance of soils; and
- Dust generation.

The development of sites B and E will require the removal and disturbance of approximately 15 000 m^2 of high sensitivity coastal vegetation and associated SCC. Furthermore, the edge effects of construction activity may have a negative impact on coastal rocky outcrop areas which lie in close proximity to the construction footprint.

The impact associated with the development of the desalination plant at site alternatives B or E will be local in extent and will be of a permanent duration. Although the coastal habitat unit is considered to be of a high sensitivity the disturbance area associated with the proposed desalination site is limited when considering the total extent of the coastal habitat present and the intensity of the loss of habitat is therefore considered to be medium. The overall impact significance is therefore considered medium prior to the implementation of mitigation measures.

The implementation of mitigation measures may reduce the intensity of the impact associated with the development of desalination plant as alien vegetation proliferation will be controlled and maintenance personnel will be restricted to the project footprint. However, the duration of the impact will remain permanent and the overall impact will therefore only be reduced to a low significance.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives B and E</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Definite</td><td rowspan="2">MEDIUM</td><td rowspan="2">-ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase:
• Refer to construction phase mitigation measures as listed for desalination plant alternatives A, C and D (pg 58 and 59); and
• Ensure that the edge effects of construction related activities do not impact upon coastal rocky outcrop areas.

Recommended mitigation measures during the construction phase:
• In order to minimise environmental damage, clearing for construction should be restricted to the dry dormancy period within the region (November to April) as far as possible.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives B and E</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

<u>Operational Phase</u>

Activities leading to impact:

- Maintenance activities;
- Alien and invasive vegetation proliferation in disturbed areas;
- Dust generation

The operational phase impact associated with sites B and E will be similar to that associated with sites A, C and D (refer to operational phase discussion and table associated with desalination plant alternatives A, C and D on pages 59 and 60 above).

IMPACT 2: LOSS OF FLORAL HABITAT, BIODIVERSITY AND SCC ASSOCIATED WITH QUARTZ AND CLAY EXPOSURE AREAS

KOTZESRUS AND AMENDED BYPASS ROUTE

<u>Construction phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of vegetation;
- Disturbance of soils; and
- Dust generation.

Although the majority of the habitat to be removed or disturbed as a result of development of both alternatives is considered to be of a low to moderate sensitivity (assessed as part of Impact 1), the development of both routes will require the removal and disturbance of very high sensitivity habitat associated with quartz and clay exposure areas which are located within the road reserve/servitude (approximately 4% of total route length). Although the route traverses these areas on an existing gravel road which will not need to be widened, this sensitive habitat (estimated 900m along the road between the mine and Kotzezrus) will still be disturbed as a result of pipeline and power line construction within the road reserve or servitude. The movement of construction vehicles and personnel within the road reserve and servitude will result in the disruption of the quartz layer which will cause the permanent alteration of the habitat and the potential loss of SCC individuals such as the rare dwarf succulent *Bulbine bruynsii*.

Recent surveys of the area resulted in the discovery of additional sub-populations of *Bulbine bruynsii* (Helme, 2014), however, although locally common this species is still considered to be rare within the region and the loss of individuals of the species together with their associated habitat is therefore considered of a regional significance. Furthermore, without the implementation of suitable mitigation measures such as the demarcation of the construction footprint, the construction of the pipeline and power line as close to the road or road reserve boundary as possible and the development of the pipeline above ground, a larger area of the highly sensitive quartz exposure habitat associated with the species may be significantly impacted by construction activities, earth moving activities and the movement of construction vehicles and personnel through the habitat. The impact intensity is therefore considered to be high and the overall impact significance is considered to be very high prior to the implementation of mitigation measures.

With the implementation of mitigation measures the intensity of the impact may be reduced to low, however, vegetation will be permanently removed to make way for pipeline and power line support structures and areas in the immediate surroundings of these structures are likely to be disturbed. The restoration of disturbed quartz and clay areas is likely to take many years and certain species may not return as a result of the compaction of soils and the changes to soil structure. Therefore, although the intensity of the impact can be significantly reduced, the duration of the impact will remain long term. However, with the implementation of mitigation measures, the disturbance footprint within quartz and clay exposure areas will be reduced and any individuals of *Bulbine bruynsii* to be disturbed by construction will be rescued and relocated to suitable habitat thereby preventing their loss. The extent of the impact may therefore be reduced to local and the overall impact significance may be reduced to a low level after the implementation of mitigation measures.

Without Mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Regional	High	Long-term	**Very High**	Definite	**VERY HIGH**	**– ve**	High
	2	3	3	8				

Essential mitigation measures specifically applicable to very high sensitivity quartz and clay exposure areas (refer to Appendix E Figure Q for an indication of the approximate locality of quartz and clay exposure areas):

- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise environmental damage;
- Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
- The final route chosen should be demarcated for the construction period by stringing coloured rope between fence droppers hammered into the ground. No disturbance may take place outside the demarcated area, and access should be from the existing road (Helme, 2014);
- Restrict power lines and pipelines in close proximity to quartz and clay exposure areas to the west of the existing gravel road (Helme, 2014);
- The pipeline should ideally be constructed within the road reserve or alternatively as close as possible to the road / road reserve edge ((Helme, 2014);
- Pipelines and power lines must be built on support structures above the ground. These support structures (plinths) must have as small a footprint as possible (Helme, 2014);
- When the pipe is placed onto the plinths this should ideally be done by crane from the road edge, in order to minimise disturbance (trampling, temporary storage of pipe, etc.) to sensitive areas between the plinths (Helme, 2014);
- Individuals of *Bulbine bruynsii* within the construction footprint must be demarcated and cordoned off with a 2m buffer around each individual or group of individuals. Support structures for pipelines and power lines (and associated construction disturbance areas) may not encroach on any such cordoned off areas. Note: this may require that support structures are unevenly spaced in these areas;
- If it is unavoidable that individuals of *Bulbine bruynsii* will be disturbed, the plants must be dug up (roots are usually only 2-3cm deep) and translocated immediately to a suitable area outside the development footprint. The plants are only evident above ground from about June – September. Thus ideally the plinth positions should be identified in this area during this period, and someone who is capable of identifying *Bulbine bruynsii* plants should check for them in these areas, and undertake the translocation, if necessary (Helme, 2014);
- If individuals are to be translocated special authorisation must be obtained from the Northern Cape Department of Environment and Nature Conservation (*Bulbine bruynsii* falls within the family Asphodelaceae which is protected under the Northern Cape Nature Conservation Act, 2009);
- Where possible, dig excavations for power line and pipeline support structures traversing quartz and clay exposure areas by hand;
- Where pipelines traverse quartz and clay exposure areas the number of construction personnel allowed into the sensitive habitat areas must be restricted;
- A suitably qualified ecologist should review the method statements for all construction activities in quartz and clay exposure areas and

- an ECO should be present on site throughout the construction period, and must be responsible for ensuring compliance with all mitigation requirements (Helme, 2014);
- Restrict material and equipment storage areas to areas falling outside of sensitive quartz and clay exposure areas;
- Do not store material removed during the construction of pits for power line and pipeline support structures within the road reserve adjacent to quartz and clay exposure areas. Temporarily remove construction related material to a designated area offsite and permanently remove construction related waste and refuse from site;
- Before the commencement of development activity a comprehensive EMP, including ecological mitigation measures, must be developed for all phases of development.

Recommended mitigation measures during the construction phase:

- In order to minimise damage, clearing for construction within quartz and clay exposue areas should be restricted to the dry dormancy period within the region (November to April) as far as possible; and
- Enforce a speed limit for construction vehicles of 40km/h through areas associated with quartz and clay exposure to curb dust generation.

With Mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Local	Low	Long-term	**Low**	Definite	**LOW**	**– ve**	High
	1	1	3	**5**				

Operational Phase

Activities leading to impact:

- ➢ Maintenance activities;
- ➢ Alien and invasive vegetation proliferation in disturbed areas; and
- ➢ Dust generation

The impact associated with the operational phase will be limited to an increase in the movement of maintenance vehicles along the road and the associated dust generation. However this increase will be limited to approximately three light and three heavy vehicle trips to and from the desalination plant per day. Vegetation may also be disturbed as a result of possible maintenance activities. Furthermore, disturbance created as a result of maintenance activities may result in the encroachment of alien invasive species into the area. If left unmitigated alien and invasive species could proliferate and would remain within the area permanently. The impact associated with the operational phase is therefore considered of a local extent, of a low intensity and of a long term duration. However, the probability of the impact is only considered to be possible as the limited maintenance activities associated with the project (repairing leaks in pipelines and grading of gravel roads) will not necessarily result in the proliferation of alien and invasive species and the long term loss of habitat. The overall impact is therefore considered to be of a very low significance prior to the implementation of mitigation measures. However with the implementation of mitigation measures the duration of the impact may be reduced to short term as any alien vegetation proliferation that does occur will be controlled and disturbance to the habitat will be restricted. The overall impact may therefore be reduced to an insignificant level.

Without mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**– ve**	High
	1	1	3	5				

Essential mitigation measures during the operational phase:

- If maintenance activities within very high sensitivity quartz and clay exposure areas are unavoidable, the activities must be undertaken by hand;
- Do not permit heavy machinery into very high sensitivity quartz and clay exposure areas;
- Restrict the number of personnel entering into quartz and clay exposure areas during maintenance activities;
- Ensure that maintenance activities are restricted to the development footprint and do not encroach into surrounding open veld areas and that these open veld areas are strictly off-limits to maintenance vehicles and personnel;
- Strictly prohibit maintenance personnel from collecting plant material from quartz and clay exposure areas;
- Monitor water pipelines for leaks (specifically in very high sensitivity habitats where a change in water availability may alter habitat characteristics) and any leaks which are detected must be repaired immediately.

With mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Kotzesrus Route	Local	Low	Short-term	**Very Low**	Improbable	**INSIGNIFICANT**	**– ve**	High
	1	1	1	**3**				

6.2 Faunal Impact Assessment

IMPACT 3: IMPACT ON FAUNAL HABITAT, DIVERSITY AND RDL/PROTECTED SPECIES

KOTZESRUS ROUTE

Construction Phase

Activities leading to impact

- Clearing of the construction footprint and the removal of faunal habitat;
- Collision of fauna with construction vehicles; and
- Illegal hunting and poaching.

The development of the Kotzesrus Route will require the permanent removal of vegetation and associated faunal habitat from the road reserve. However, the current movement of vehicles along existing gravel roads is likely to discourage faunal species from permanently inhabiting the road reserve, particularly in areas of moderate and low faunal sensitivity. Faunal species are therefore more likely to be passing through the area and it is highly likely that species will move out of construction footprint areas into similar habitat in the surroundings prior to the commencement of major construction related activities. However, the construction of the Kotzesrus route through very high sensitivity rocky outcrops is likely to result in the loss of important reptile and amphibian niche habitat. The upgrading of roads and the development of pipelines and power lines through terrestrial rocky outcrops may result in the permanent alteration of these habitats and faunal species inhabiting these areas would not necessarily be able to migrate to similar habitat elsewhere. RDL reptile species such as *Gerrhosaurus typicus* (Namaqua Plated Lizard) and protected reptile species such as *Cordylus polyzonus* (Karoo girdled lizard) and *Cordylus niger* (Black girdled lizard) were encountered within the study area and may therefore be permanently lost from these areas. The protected amphibian species *Cacosternum namaquensis* (Namaqua Caco) is also known to aestivate within rocky areas and may therefore also be lost. Furthermore, an *Aquila verreauxii* (Verreauxs Eagle) breeding pair listed as protected by the NCNCA (Act 9 of 2009) was identified nesting within a tree in close proximity to the very high sensitivity rocky outcrop habitat associated with the Brak River. Construction related activities taking place in close proximity to the nesting habitat of the *Aquila verreauxii* (Verreauxs Eagle) breeding pair is likely to disturb the pair and may cause the pair to migrate from their nest. There is therefore the risk that juveniles in the nest at the time of construction may be abandoned.

Faunal species may be negatively impacted as a result of collisions with construction vehicles, and the increased number of construction personnel within the area may result in an increase in the trapping and poaching of faunal species.

The impact associated with the loss of faunal habitat, diversity, RDL and protected species is considered of a local extent and the development of the linear infrastructure along the Kotzesrus Route alternative will result in the permanent removal of sensitive faunal habitat in some areas. Furthermore, the Kotzesrus Route traverses very high sensitivity rocky outcrop areas which will be permanently altered as a result of construction related activities and species inhabiting this niche habitat will not necessarily be able to move out of the area before construction commences. The impact associated with the Kotzesrus Route is therefore considered to be of a high intensity. The overall impact is therefore considered to be of a high significance prior to the implementation of mitigation measures.

The implementation of mitigation measures will not prevent the permanent removal of faunal habitat from the construction footprint and the duration and probability of the impact will therefore remain long term and definite. However, the intensity of the impact can be reduced to low as the implementation of mitigation measures will ensure that the removal of faunal habitat is limited to that which is essential and will reduce the number of faunal species lost as a result of collision with construction vehicles and as a result of poaching and hunting. The overall impact significance can therefore be decreased to a medium level.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>High</td><td>Long-term</td><td>High</td><td rowspan="2">Definite</td><td rowspan="2">HIGH</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>3</td><td>3</td><td>7</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase
• Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
• Limit the removal of vegetation and associated faunal habitat from the road reserve to that which is essential;
• Ensure that as far as possible all infrastructure is placed outside rocky outcrop areas;
• Reduce noise levels in areas in close proximity to the Brak River crossing in order to avoid the disturbance of the Aquila verreauxii (Verreauxs Eagle) breeding pair;
• Rescue and relocate fauna encountered within the construction footprint with special mention of slower moving species such as tortoises;
• Strictly prohibit the trapping and hunting of fauna by construction personnel; and
• Enforce a speed limit for construction vehicles of 40km/h along route alternatives occurring to the west of Kotzesrus in order to reduce collision of construction vehicles with fauna.

Recommended mitigation measures
• Inform staff about dominant faunal species, associated habitat and importance of their conservation in the region.</td></tr>
<tr><th>Managed</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

Operational Phase

Activities leading to impact:

- Maintenance activities;
- Collision of fauna with maintenance vehicles;
- Collision of fauna with power lines; and
- Illegal hunting and poaching.

The impact associated with the operational phase includes an increase in the movement of maintenance vehicles along the road and the associated collision of vehicles with fauna. However this increase in the movement of vehicles will be limited to approximately six light and six heavy vehicle trips per day which is likely to redice the intensity of the impact. Furthermore, avifaunal species including the RDL species *Sagittarius serpentarius* (Secretary Bird) may be lost as a result of collision with power lines. An increase in maintenance personnel within the area may also result in an increase in hunting and poaching, however, a relatively low number of personnel will be required which also reduces the intensity of the impact.

The impact associated with the operational phase is considered of a local extent and of a low intensity, however, the collision of fauna with maintenance vehicles and power lines will possibly occur throughout the operational phase and the impact will therefore be of a long term duration. The overall impact is therefore considered to be of a very low significance prior to the implementation of mitigation measures. With the implementation of mitigation measures the possibility of the impact occurring can be decreased, however, the impact will remain of a long term duration as even with the implementation of mitigation measures there is still the possibility that faunal species may be killed as a result of collision with maintenance vehicles. The overall impact significance will therefore remain at a very low level.

Without mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**– ve**	High
	1	1	3	5				
Essential mitigation measures during the operational phase • Ensure that maintenance activities are restricted to the road reserve and do not encroach into surrounding open veld areas and that these open veld areas are strictly off-limits to maintenance vehicles and personnel; • Strictly prohibit the trapping and hunting of fauna by maintenance personnel; • Enforce a speed limit for operational and maintenance vehicles of 40km/h along route alternative occurring to the west of Kotzesrus in order to reduce collision of maintenance vehicles with fauna; and • Rescue and relocate any faunal species encountered within the road with special mention of slower moving species such as tortoises.								
Managed	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	Low	Long-term	**Low**	Improbable	**VERY LOW**	**– ve**	High
	1	1	3	5				

AMENDED BYPASS ROUTE

<u>Construction Phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of faunal habitat;
- Collision of fauna with construction vehicles; and
- Illegal hunting and poaching.

The impact associated with the Amended Bypass Route will be similar to that associated with the Kotzesrus Route (refer to discussion for the Kotzesrus Route on pages 64 and 65 above). However, this route does not pass through very high sensitivity rocky outcrop areas and although the route will result in the permanent removal of moderate and low sensitivity habitat, this habitat is common in the region and faunal species will be able to move into surrounding similar habitat.

The impact associated with development of the Amended Bypass Route is therefore considered to be of a local extent, of a low intensity and of a permanent duration, and the overall impact is considered to be of a low significance prior to the implementation of mitigation measures.

With the implementation of mitigation measures the intensity of the impact will decrease as the number of faunal species lost will be reduced, however, faunal habitat will be permanently removed and the impact therefore remains of a permanent duration. Although the impact associated with the Amended Bypass Route remains low according to the impact assessment methodology as provided by SRK, it is the opinion of the specialist, based on professional judgement and experience, that the overall impact significance associated with the Amended Bypass Route can be decreased to a very low level after the implementation of mitigation measures.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase
• Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
• Limit the removal of vegetation and associated faunal habitat from the road reserve to that which is essential;
• Rescue and relocate fauna occurring within the construction footprint with special mention of slower moving species such as tortoises;
• Strictly prohibit the trapping and hunting of fauna by construction personnel; and
• Enforce a speed limit of 40km/h along route alternative occurring to the west of Kotzesrus in order to reduce collision of construction vehicles with fauna.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">VERY LOW[8]</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

<u>Operational Phase</u>

Activities leading to impact:

- Maintenance activities;
- Collision of fauna with maintenance vehicles;
- Collision of fauna with power lines; and
- Illegal hunting and poaching.

The operational phase impact associated with the Amended Bypass Route will be similar to that associated with the Kotzesrus Route (refer to operational phase discussion and table for the Kotzesrus Route on pages 65 and 66 above).

DESALINATION PLANT ALTERNATIVES A, C AND D

<u>Construction Phase</u>

Activities leading to impact

- Clearing of the construction footprint and the removal of faunal habitat;
- Collision of fauna with construction vehicles; and
- Illegal hunting and poaching.

The development of sites A, C and D will result in the permanent removal of moderate sensitivity faunal habitat. However, faunal species will be able to move from the construction footprint into similar surrounding habitat prior to construction. The impact will therefore be of a local extent, of a permanent duration and of a low intensity, and the overall impact significance will be low.

[8] Although the impact rating methodology provided by SRK resulted in a low significance rating after the implementation of mitigation measures, it is the opinion of the ecological specialist, based on professional judgment and experience, that the mitigation measures, if strictly adhered to, are deemed sufficient to reduce the overall impact to a very low level.

The implementation of mitigation measures will not prevent the permanent removal of fauna habitat from the construction footprint. However, mitigation measures are likely to reduce the intensity of the impact associated with the loss of faunal species to poaching, hunting and collision with construction vehicles. Therefore, although the impact rating methodology provided by SRK resulted in a low significance rating after the implementation of mitigation measures, it is the opinion of the ecological specialist, based on professional judgement and experience, that the mitigation measures listed below, if strictly adhered to, are deemed sufficient to reduce the overall impact significance to a very low level.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives A, C and D</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">-ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase
• Strictly control edge effects of construction activities such as erosion and alien vegetation proliferation;
• Limit the removal of vegetation and associated faunal habitat from the construction footprint to that which is essential;
• Where possible, develop seawater intake and discharge pipelines within existing gravel road reserves in order to reduce impact on surrounding natural habitat;
• Rescue and relocate fauna occurring within the construction footprint with special mention of slower moving species such as tortoises; and
• Strictly prohibit the trapping and hunting of fauna by construction personnel.

Recommended mitigation measures
• Inform staff about dominant faunal species, associated habitat and importance of their conservation in the region.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Desalination alternatives A, C and D</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">VERY LOW[9]</td><td rowspan="2">-ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

Operational phase

Activities leading to impact:

- Maintenance activities;
- Illegal hunting and poaching.

Maintenance activities within the operational phase and the increase in anthropogenic activity and disturbance within natural areas surrounding desalination plant alternatives may result in an impact on faunal habitat and may disturb faunal communities in the area. Furthermore, there is a possibility that an increase in maintenance personnel in the area may result in an increase in hunting and poaching of faunal species. Although the impact is likely to occur throughout the operational phase of the development and will therefore be of a long term duration, the probability of the impact is only possible as surrounding natural areas will not necessarily be disturbed and maintenance personnel will not necessarily trap and poach fauna. The extent of the impact is also likely to be local and the intensity low. The overall impact is therefore likely to be of a very low significance prior to the implementation of mitigation measures. With the implementation of mitigation measures the duration of the impact may be reduced to short term as disturbance will be restricted to the construction footprint and poaching and hunting will be strictly prohibited. The probability of the impact may therefore be reduced and the overall impact significance may be decreased to an insignificant level.

[9] Although the impact rating methodology provided by SRK resulted in a low significance rating after the implementation of mitigation measures, it is the opinion of the ecological specialist, based on professional judgment and experience, that the mitigation measures, if strictly adhered to, are deemed sufficient to reduce the overall impact to a very low level.

Without mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination alternatives A, C and D	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**-ve**	High
	1	1	3	5				

Essential mitigation measures during the operational phase
- Ensure that maintenance activities do not encroach into surrounding open veld areas and that these open veld areas are strictly off-limits to maintenance vehicles and personnel; and
- Strictly prohibit the trapping and hunting of fauna by maintenance personnel.

With mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination alternatives A, C and D	Local	Low	Short-term	**Very Low**	Improbable	**INSIGNIFICANT**	**-ve**	High
	1	1	1	3				

DESALINATION PLANT ALTERNATIVES B and E

<u>Construction Phase</u>

Activities leading to impact
- Clearing of the construction footprint and the removal of faunal habitat;
- Collision of fauna with construction vehicles; and
- Illegal hunting and poaching.

The impact associated with the development of sites B and E will be similar to that associated with the development of sites A, C and D (refer to the construction phase discussion for sites A, C and D on page 67 and 68 above). However, alternative B and E are located in closer proximity to coastal rocky outcrop areas that provide niche habitat to faunal species than sites A, C and D and the risk that these very high sensitivity faunal habitat areas may be impacted as a result of the edge effects of construction activities is therefore higher. The impact will therefore be of a local extent, of a permanent duration and of a medium intensity, and the overall impact significance will be medium prior to the implementation of mitigation measures.

The implementation of mitigation measures will not prevent the permanent removal of fauna habitat from the construction footprint. However, mitigation measures are likely to reduce the intensity of the impact associated with the loss of faunal species to poaching, hunting and collision with construction vehicles, and disturbance of coastal rocky outcrop areas will be avoided. The overall impact significance may therefore be reduced to a low level.

Without mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination Alternatives B and E	Local	Medium	Long-term	**Medium**	Definite	**MEDIUM**	**– ve**	High
	1	2	3	6				

Essential mitigation measures during the construction phase
- Refer to construction related mitigation measures as listed for desalination plant alternatives A, C and D (pg 67 and 68); and
- Ensure that the edge effects of construction related activities do not impact on very high sensitivity coastal rocky outcrop areas.

Recommended mitigation measures
- Inform staff about dominant faunal species, associated habitat and importance of their conservation in the region.

With mitigation	*Extent*	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Desalination Alternatives B and E	Local	Low	Long-term	**Low**	Definite	**LOW**	**– ve**	High
	1	1	3	5				

Operational phase

Activities leading to impact:

- Maintenance activities; and
- Illegal hunting and poaching.

The operational phase impact associated with sites B and E will be the same as that associated with sites A, C and D (refer to operational phase discussion for desalination plant alternatives A, C and D above).

Without mitigation	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Desalination Alternatives B and E	Local	Low	Long-term	**Low**	Possible	**VERY LOW**	**– ve**	High
	1	1	3	5				
Essential mitigation measures during the operational phase • Refer to operational related mitigation measures as listed for desalination plant alternatives A, C and D (pg 68); and • Ensure that the edge effects of maintenance activities do not impact on very high sensitivity coastal rocky outcrop areas. **Recommended mitigation measures** • Inform staff about dominant faunal species, associated habitat and importance of their conservation in the region.								
With mitigation	**Extent**	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**	**Status**	**Confidence**
Desalination Alternatives B and E	Local	Low	Short-term	**Very Low**	Improbable	**INSIGNIFICANT**	**– ve**	High
	1	1	1	5				

IMPACT 4: DISRUPTION OF FAUNAL MIGRATORY CORRIDORS

The impact associated with the disruption of faunal migratory corridors is similar for both the construction and operational phases of development. Pipelines and power lines will be present during both phases of the development and the impact associated with both phases was therefore assessed in a single impact assessment. The development of both the Kotzesrus Route and the Amended Bypass Route will have a similar impact on faunal migration corridors and were therefore also considered in a single impact assessment. Furthermore, desalination plant alternatives are not likely to create any significant barriers to migration through the area and their impact on faunal migration was therefore not assessed.

Construction and operational phase

The development of pipelines and power lines may result in the disruption of faunal migration through the study area. If pipelines are developed 15cm above ground some faunal species will not be able to move below them. Individuals of *Raphicerus campestris* (Steenbok) are approximately 45-60cm tall and individuals of *Sylvicapra grimmia* (Common duiker) are approximately 30-40cm tall (Smithers, 2000). These species would need to move below or jump over the pipelines and smaller reptile species such as tortoises will need to move below the pipelines. Porcupines and jackals will be able to dig down in order for them to pass under the pipeline, however, this may result in the potential issue of tortoises becoming stuck in the excavated areas if they roll over whilst trying to navigate under the pipe. If the pipeline is constructed too close to the ground it may also form a predatory trap, as animals may get trapped up against the pipe and become easy pickings for local predators.

A portion of the infrastructure route (approximately 6.5 km) will run parallel to the coast line (along the existing gravel road within 500m of the coast) and may prevent the migration of faunal species to and from coastal areas. In addition, the migration of faunal species from areas to the north of the study area to the Brak River located to the south of route alternatives may be disrupted and the creation of a steep lip to either side of the gravel road during construction is likely to have a negative impact on smaller faunal taxa which may struggle to cross the road safely.

The impact associated with the disruption of faunal migratory corridors is considered of a local extent and will be of a long term duration. Although faunal migration through the area has already been disrupted as a result of numerous boundary fences, the development of pipelines which are too close to the ground will further disrupt the movement of medium sized faunal species and the additional impact created as a result of the construction of pipelines is therefore likely to be of a medium intensity. The overall impact significance is therefore considered medium for both route alternatives prior to the implementation of mitigation measures. If pipelines are buried below the ground the restriction to faunal migration through the area will be reduced. However, burying pipelines below ground is likely to create a higher level of disturbance to faunal habitat during construction and is therefore not recommended. It has been recommended that pipelines be constructed 30-45cm above ground with a minimum of 30cm above ground in order to allow the passage of faunal species below or over pipelines. However, in the assessment of impacts it has been assumed that pipelines will be constructed 15cm above ground. The impacts associated with the disruption of faunal migratory corridors will therefore remain the same before and after the implementation of mitigation measures.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Probable</td><td rowspan="2">MEDIUM</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Probable</td><td rowspan="2">MEDIUM</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction and operational phase
• Access roads should allow for the movement of faunal species, in this regard special mention is made of tortoises that struggle to cross gravel roads with continuous heaps of sand on either side. Design gravel roads in such a way to allow for either a gradual curb or regular ‘exits’ from the road in order to allow faunal species such as tortoises to safely cross. This would necessitate the regular inspection of gravel roads.

Recommended mitigation measures during the construction and operational phase
• Construct pipelines a minimum of 30cm above ground.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Probable</td><td rowspan="2">MEDIUM</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Probable</td><td rowspan="2">MEDIUM</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
</table>

6.3 Freshwater Impact Assessment[10]

IMPACT 5: LOSS OF WETLAND HABITAT AND ECOLOGICAL STRUCTURE ASSOCIATED WITH THE KOTZESRUS ROUTE

Construction Phase

Activities leading to impact

[10] Freshwater habitat does not occur within any of the proposed desalination plant alternatives. The impact on wetland habitat was therefore only assessed for the development of the Kotzesrus Route and the Amended Bypass Route

- Construction of infrastructure within wetland areas;
- Site clearing and the disturbance of soils and removal of vegetation;
- Increased stormwater runoff from cleared areas; and
- Dust generation by general driving and earth moving activities.

The development of the Kotzesrus Route will require the disturbance and removal of wetland vegetation and soils, which will result in the permanent loss of wetland habitat within the construction footprint. The Kotzesrus Route traverses two tributaries of the Groen River and numerous ephemeral drainage features to the north east of Kotzesrus. However, where the route alternative traverses these features it does so on an existing provincial gravel road. Impacts associated with the construction of the route through these features will therefore be restricted to the upgrading of gravel roads and the development of pipelines and power lines through the features. A single ephemeral drainage feature will also be disturbed as a result of the development of the pipeline which extends to the water storage reservoir within the Zandkopsdrift mining area.

One natural ephemeral pan and two artificial depression wetlands also occur in close proximity to the provincial gravel road to the west of Kotzesrus. The upgrading of gravel roads and the development of pipelines and power lines are however only likely to occur within the 32m buffer of these features and is not likely to take place within the features. In addition, three natural ephemeral pans are located to the west of the route alternative. These features are located in close proximity to the gravel road and the widening of the existing gravel road and the potential development of pipelines and power lines through these features may therefore result in an impact on this wetland habitat.

Both the Kotzesrus Route and the Amended Bypass Route follow the same path for the majority of their lengths, however, the Kotzesrus Route passes through Kotzesrus and crosses the Brak River whereas the Amended Bypass Route diverts around Kotzesrus and therefore avoids crossing the Brak River. The development of the Kotzesrus Route to the west of Kotzesrus will require the widening of the existing gravel road which runs through a sensitive well vegetated portion of the Brak River, and will require the development of pipelines and power lines through the river system. The development of the Kotzesrus Route through the Brak River may therefore have significant negative impacts on wetland habitat. Furthermore, the Brak River is listed as an aquatic CBA (Namakwa District Biodiversity Sector Plan, 2008) and the development of the Kotzesrus Route will therefore result in disturbance within this CBA.

In addition to impacts on wetland habitat, the development of the Kotzesrus Route may have significant impacts on wetland hydrological function. During construction, site clearing and the removal of vegetation may result in an increase in runoff from disturbed areas and an increase in the erosion and incision of wetland areas. In addition, sediment deposition as a result of the disturbance of soils and increased sediment runoff during the construction phase may result in a change in the sediment balance of the features and may affect the movement of water through the features.

Due to the limited disturbance footprint associated with the development of the Kotzesrus Route and the arid nature of the study area (freshwater features are ephemeral and contain surface water for very limited periods), it is unlikely that impacts associated with the construction of the route will affect the downstream hydrology and habitat of freshwater features and the loss of wetland habitat associated with the development of the Kotzesrus Route will be a localised impact. However, the widening of gravel roads and the development of pipelines and power lines through wetland features is likely to result in the permanent removal of wetland habitat and construction related activities such as the indiscriminate movement of construction vehicles and personnel through wetland features is likely to result in a high intensity impact which will cause the long term disturbance of wetland habitat. The overall impact associated with the development of the Kotzesrus Route is therefore considered to be of a high significance prior to the implementation of mitigation measures. However, with the implementation of mitigation measures the intensity of the impact may be reduced and the overall impact significance will therefore be reduced to a low level.

Although the upgrading of the current wetland crossing areas associated with the provincial gravel road to the east of Kotzesrus (crossings associated with tributaries of the Groen River and ephemeral drainage features) and the rehabilitation of impacted wetland areas may result in a positive impact, the disturbance associated with the development of pipelines and power lines through wetland areas and the loss of wetland habitat associated with the development of the Kotzesrus Route through the Brak River will result in an overall negative impact.

Without mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	High	Long-term	**High**	Definite	**HIGH**	**– ve**	High
	1	3	3	7				

Essential mitigation measures during the construction phase

- Demarcate and keep all sensitive wetland zones outside of the construction area off limits;
- Where pipelines and power lines need to cross wetlands and drainage features they must do so at as close to a 90 degree angle to the features as possible in order to limit the area of disturbance within the features and, where possible, pipelines and power lines must span over the wetland/drainage feature with associated buffer zone;
- If the construction of pipeline and power line support structures within wetland habitat is unavoidable then permit only essential construction personnel within the wetland habitat and dig excavations for support structures by hand;
- Obtain the relevant approvals from DWA for any activities within wetland areas and their associated buffers particularly in terms of Section 21 c and i of the NWA (Act 36 of 1998);
- Prevent run-off from work areas entering wetland habitats;
- Incorporate adequate erosion and stormwater management measures in order to prevent erosion and the associated sedimentation of wetland areas. Management measures may include berms, silt fences, hessian curtains, stormwater diversion away from areas susceptible to erosion and stormwater attenuation. Care should however be taken so as to avoid additional disturbance during the implementation of these measures;
- Upgrade inadequate bridges and culverts which do not comply with the points listed below:
  - Bridges and culverts must span the entire width of wetland and drainage features;
  - Bridge structures must not alter seasonal stream flow patterns;
  - Habitat connectivity must be maintained beneath bridge structures and culverts. In this regard special mention is made of constructing underpasses so that they are sufficiently high to allow for the movement of local fauna, including small antelope, and (where possible) sufficiently wide to include a buffer along the margins of the wetland habitat;
  - Bridges and culverts must not result in the incision and canalisation of the wetland and drainage areas. Bridgess and culverts must allow for sufficient dispersion of water through wetland and drainage areas to prevent the concentration of flow which could lead to scouring and incision of the system.
- Rehabilitate all wetland areas impacted by construction related activities in order to ensure that wetland functions are re-instated after construction.

Recommended mitigation measures

- Restrict clearing & earthworks for construction through wetland and drainage areas to the drier summer months, if possible, to avoid erosion of exposed soils and sedimentation of wetland habitats associated with the route alternative.

With mitigation	***Extent***	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Kotzesrus Route	Local	Low	Long-term	**Low**	Definite	**LOW**	**– ve**	High
	1	1	3	**5**				

<u>Operational Phase</u>

Activities leading to impact:

- Maintenance activities within wetland areas;
- Increased stormwater runoff from hardened surfaces; and
- Ineffective stormwater drainage.

Impacts associated with the operational phase will be limited to the maintenance of infrastructure that is located within the various wetland features and the possible erosion and sedimentation of wetland features as a result of an increase in runoff velocities from hardened surfaces and ineffective stormwater management. The disturbance associated with maintenance activities may result in the loss of some wetland habitat and could possibly result in the erosion of the features, however, wetlands cover a very limited extent of the Kotzesrus Route and the probability that maintenance activities will need to be undertaken within wetland features is therefore considered possible and not definite. Furthermore, the limited maintenance activities that would need to be undertaken (repairing leaks in pipelines and grading of gravel roads) will not necessarily result in the long term loss of wetland habitat. In addition, the impact associated with ineffective stormwater drainage and increased runoff velocities from hardened surfaces will only increase slightly when compared to the current situation and when taking into consideration the existing hardened surfaces associated with existing gravel roads.

The impact associated with the operational phase will be local in extent, of a low intensity and if left unmitigated may remain permanent. The overall impact is therefore considered to be of a very low intensity prior to the implementation of mitigation measures. However, with the implementation of mitigation measures the intensity of the impact may be reduced and the duration of the impact will be short term as disturbance to the wetland habitat will be limited and any disturbed areas are likely to recover. The overall impact may therefore be reduced to an insignificant level after the implementation of mitigation measures.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Possible</td><td rowspan="2">VERY LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
<tr><td colspan="9">Essential mitigation measures during the operational phase
• If maintenance activities within wetland areas are unavoidable permit only essential personnel within the wetland habitat;
• Do not permit heavy machinery or vehicles into wetland areas;
• Keep all demarcated sensitive wetland zones outside of the maintenance areas off limits;
• Prevent run-off from work areas entering wetland habitats;
• Incorporate adequate erosion and stormwater management measures in order to prevent erosion and the associated sedimentation of wetland areas. Management measures may include berms, silt fences, hessian curtains, stormwater diversion away from areas susceptible to erosion and stormwater attenuation. Care should however be taken so as to avoid additional disturbance during the implementation of these measures; and
• Monitor water pipelines for leaks and any leaks which are detected must be repaired immediately.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Kotzesrus Route</td><td>Local</td><td>Low</td><td>Short-term</td><td>Very Low</td><td rowspan="2">Improbable</td><td rowspan="2">INSIGNIFICANT</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>3</td></tr>
</table>

AMENDED BYPASS ROUTE

<u>Construction Phase</u>

Activities leading to impact

- Construction of infrastructure within wetland areas;
- Site clearing and the disturbance of soils and removal of vegetation;
- Earthworks within wetland features;
- Compaction of soils;
- Increased stormwater runoff from cleared areas;
- Dust generation by general driving and earth moving activities.

The Kotzesrus Route and the Amended Bypass Route follow the same path for the majority of their lengths. The impact associated with each of the routes will therefore be similar (refer to the construction phase discussion for the Kotzesrus Route on pages 71, 72 and 73 above). However, by diverting around the town of Kotzesrus, the Amended Bypass Route avoids crossing the Brak River which is listed as an aquatic CBA (Namakwa District Biodiversity Sector Plan, 2008) and instead traverses a small ephemeral drainage feature located to the north west of Kotzesrus. The avoidance of the highly sensitive Brak River decreases the intensity of the impact associated with the Amended Bypass Route substantially in comparison with the Kotzesrus Route.

The impact associated with the Amended Bypass Route will therefore be of a local extent, of a medium intensity and of long term duration and the overall impact significance will be medium prior to the implementation of mitigation measures. However, with the implementation of mitigation measures the intensity of the impact may be reduced to a low level and the overall impact significance may therefore be reduced to a low level.

Although the upgrading of the current wetland crossing areas associated with the provincial gravel road to the east of Kotzesrus (crossings associated with tributaries of the Groen River and ephemeral drainage features) and the rehabilitation of impacted wetland areas may result in a positive impact, the disturbance associated with the development of pipelines and power lines through wetland areas will result in an overall negative impact.

<table>
<tr><th>Without mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Medium</td><td>Long-term</td><td>Medium</td><td rowspan="2">Definite</td><td rowspan="2">MEDIUM</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td colspan="9">Essential mitigation measures during the construction phase
• Refer to the construction phase mitigation measures as listed for the Kotzesrus Route (pg 72 and 73).

Recommended mitigation measures
• Restrict clearing and earthworks for construction to the drier summer months, if possible, to avoid erosion of exposed soils and sedimentation of wetland habitats associated with the route alternative.</td></tr>
<tr><th>With mitigation</th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Amended Bypass Route</td><td>Local</td><td>Low</td><td>Long-term</td><td>Low</td><td rowspan="2">Definite</td><td rowspan="2">LOW</td><td rowspan="2">– ve</td><td rowspan="2">High</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>5</td></tr>
</table>

Operational Phase

Activities leading to impact:

- Maintenance activities within wetland areas; and
- Ineffective stormwater drainage.

The operational phase impact associated with the development of the Amended Bypass Route is the same as that associated with the development of the Kotzesrus Route (refer to operational phase discussion and table for the Kotzesrus Route on pages 73 and 74 above).

6.4 No Go Alternative

6.4.1 Terrestrial Habitat Units

The study area is located within an area mainly utilised for livestock grazing with isolated areas used for crop cultivation. Furthermore, farms tend to be relatively large within the region due to the lack of palatable floral species as well as marginal vegetation cover for grazing livestock, necessitating more ha per individual. As a result, impacts due to trampling and overgrazing typically associated with grazing as land use, were not considered significant; resulting in the larger extent of the study area comprising of intact floral and faunal habitat.

Due to the lack of urban development near the proposed route alternatives in combination with the present land use being small scale livestock farming, it is doubtful that any present impact due to anthropogenic activities would increase in either extent or intensity within the next 5 years. It is therefore expected that floral and faunal habitat and diversity would remain the same if the proposed development does not proceed.

6.4.2 Wetland/Riparian Habitat

The study area is located within a water stressed region (Namaqua District Biodiversity Sector Plan, 2008) and as a result available wetland and riparian habitat is considered to be of increased conservation importance in terms of wetland dependent floral and faunal species. Although most features are ephemeral and will contain water for limited periods of the year, these features will still be used as breeding and foraging habitat after sufficient rainfall events. Furthermore, both route alternatives are located within an area mainly utilised for livestock grazing with isolated areas used for crop cultivation. As a result, the majority of the wetland habitat within the areas assessed have not been impacted upon by anthropogenic activity and can still be considered representative of intact wetland and riparian habitat.

With the lack of urban development near the route alternatives in combination with the present land use being livestock farming, it is doubtful that any present impact such as alien vegetation encroachment, erosion and sedimentation would increase in either extent or intensity within the next 5 years. Therefore, no change is envisioned for the wetland habitat associated with the study area, should the proposed development of the linear infrastructure associated with route alternatives not proceed. Therefore the EIS of the wetland/riparian features associated with the route alternatives will remain the same.

6.5 Cumulative Impact Assessment

6.5.1 Terrestrial Habitat Units

The area in which the route alternatives and desalination plant alternatives are proposed has remained free from urban development with the exception of the small town of Kotzesrus. Lack of water within the region has also restricted activities that would have resulted in complete loss of floral and faunal habitat such as crop cultivation. As a result, floral and faunal habitat within the area in which the route alternatives and desalination plant alternatives are to be located has remained largely intact, with isolated areas impacted by farm infrastructure and road development. Therefore, the proposed development of the route alternatives and desalination plant alternatives is not expected to significantly contribute to cumulative floral and faunal habitat loss within the region, provided that mitigation measures as listed above are adhered too.

6.5.2 Wetland/Riparian Habitat

Due to the limited grazing value of the vegetation, farms tend to extend over large areas, with very little evidence of overgrazing or trampling evident near wetland and riparian resources. As a result, these features have remained largely intact. Presently, mining and agricultural activities are considered the main threat to wetland resources within the region. Therefore, the proposed development of the route alternatives and desalination plant alternatives is not expected to significantly contribute to cumulative wetland/riparian habitat loss within the region, provided that mitigation measures as listed above are adhered too.

6.6 Indirect Impacts

The upgrading of gravel roads may increase the number of tourists which are able to access the area. An increase in anthropogenic activities and associated disturbance within the area may have a detrimental effect on floral and faunal habitat. Furthermore, the upgrading of the gravel road may also require the excavation of borrow pits which if not located within an appropriate area may result in the loss of sensitive floral and faunal habitat.

7 CONCLUSION

SAS was appointed to conduct a terrestrial and freshwater ecological assessment as part of the environmental assessment and authorisation process for the proposed construction of a seawater desalination plant producing 8M m^3/annum of fresh/potable water, including associated infrastructure and services at Volwaterbaai, on the farm Strandfontein 559 in the Northern Cape Province, to supply water via a transfer pipe (approximately 42km, distance may vary slightly between route alternatives) to the proposed Zandkopsdrift Mine by Sedex Minerals (Pty) Ltd (Sedex Minerals)(EIA ref : NC/EIA/NAM/KAM/ZAN/2012).

Access roads need to be provided from the desalination plant to the Zandkopsdrift Mine as well as to all pipelines, power lines, reservoirs and any other associated infrastructure. Initailly ten possible routes linking the proposed Volwaterbaai desalination plant and Zandkopsdrift mine were investigated. After the initial screening study only two route alternatives (the Kotzesrus Route and the Amended Bypass Route) were assessed for the main access road and associated infrastructure from the desalination plant to Zandkopsdrift Mine. Both route alternatives follow existing gravel public roads (P2936, OG155, OG299 and OG153) and private 4x4 tracks for the majority of their lengths and will therefore only require the widening and upgrading of portions of existing gravel roads as well as the development of linear infrastructure adjacent to existing roads. Furthermore, five alternative positions for the desalination plant were identified on the farm Strandfontein 559 (Site A-E).

The Kotzesrus Route and the Amended Bypass Route follow the same route for the majority of their lengths. The only variation in the route is where the Kotzesrus Route follows a gravel road running through the town of Kotzesrus and the Amended Bypass Route diverts around the town of Kotzesrus before re-joining the Kotzesrus Route to the west of Kotzesrus.

The Kotzesrus Route traverses the Brak River both to the east of Kotzesrus and to the west of Kotzesrus. To the east of Kotzesrus the route traverses the Brak River on a well-developed provincial gravel road. However, to the west of Kotzesrus it traverses the Brak River on a smaller, poorly developed gravel road. The Brak River is considered to be of very high sensitivity and very high sensitivity rocky outcrop habitat is also associated with the portion of the river to the west of Kotzesrus. The development of the Kotzesrus Route through this portion of river may require the widening of the existing road and the loss of wetland and rocky outcrop habitat, and the development of pipelines and power lines through the river will also result in the disturbance and loss of habitat.

The majority of the portion of the Amended Bypass Route which diverts around Kotzesrus follows existing gravel roads and 4x4 tracks. The route followed by the Amended Bypass route runs through moderate sensitivity strandveld vegetation which is perceived to have been disturbed as a result of small livestock grazing, and *Acacia cyclops* encroachment was also noted along the majority of the route. By diverting around the town of Kotzesrus the Amended Bypass Route avoids crossing the very high sensitivity Brak River and avoids the disturbance of very high sensitivity rocky outcrop areas associated with the river. The route does traverse an ephemeral drainage line which augments the Brak River. However it traverses the drainage feature at a 90 degree angle which will limit disturbance to the feature, and if all mitigation measures are implemented, hydrological connectivity will not be lost as a result of the crossing. Both the Kotzesrus Route and the Amended Bypass Route traverse a similar distance through terrestrial CBAs and ESAs. However, by diverting around the town of Kotzesrus the Amended Bypass Route avoids crossing the aquatic CBA associated with the Brak River.

Both route alternatives were found to traverse very high sensitivity quartz and clay exposure areas which provide the habitat to support the rare and Vulnerable SCC *Bulbine bruynsii*. This species was originally though to consist of one population of approximately 300 plants (Helme and von Staden, 2012). However, a recent survey of the area (Helme, 2014) revealed that *Bulbine bruynsii* is in fact much more widely distributed than was previously thought, although it is still a rare and localised species in global terms. If mitigation measures as listed within this report are implemented it is unlikely that more than 20 plants of *Bulbine bruynsii* would be lost as a result of the development of both route alternatives. This is likely to be less than 1% (possibly as little as 0.3%) of the total population, and would therefore constitute a low negative impact on the species. The proposed mitigation should also ensure that overall habitat damage is minimised and kept within acceptable limits (Helme 2014).

When considering the above, the overall impact that will be created as a result of the development of the Kotzesrus Route is deemed to be higher than that created as a result of the development of the Amended Bypass Route due to the fact that the Kotzesrus Route will traverse the Brak River and associated rocky outcrop areas. Therefore, although the development of both route alternatives is considered acceptable, it is the opinion of the ecologist that the Amended Bypass Route be chosen as the preferred alternative. If the Amended Bypass Route is chosen as the preferred alternative the very high sensitivity Brak River and rocky outcrop areas can be avoided.

Desalination plant alternatives A, C and D are located a greater distance from the coastal environment and very high sensitivity coastal rocky outcrop areas when compared to desalination plant alternatives B and E. The development of sites A, C and D will therefore result in the removal of moderate sensitivity strandveld vegetation rather than high sensitivity coastal vegetation and is less likely to impact on coastal rocky outcrop areas when compared to sites B and E. Therefore, although the development of all sites is considered acceptable, it is the opinion of the ecologist that the development of site A, C or D would be preferable to the development of site B or E. However, site C is located in close proximity to gravel roads which lead to areas in the vicinity of seawater intake and discharge sites. The development of pipelines within these disturbed road or road reserve areas will reduce the impact on surrounding natural areas. Site C will require the shortest distance of pipeline to be constructed along existing gravel roads and is therefore the preferred site for the development of the desalination plant from an ecological view point, followed by site A and D.

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APPENDIX A

Method of Assessment

A- TERRESTRIAL METHOD OF ASSESSMENT

A-1 Desktop Study

- Maps, aerial photographs and digital satellite images were consulted prior to the field assessment in order to determine broad habitats, vegetation types and potentially sensitive sites. An initial visual on-site assessment of the study area was made in order to confirm the assumptions made during consultation of the maps;
- Literature review with respect to habitats, vegetation types and species distribution was conducted;
- Relevant data bases and reports considered during the assessment of the study area included:
  - The National Land Cover Dataset (2009);
  - The National Biodiversity Assessment (NBA, 2011);
  - The National List of Threatened Terrestrial Ecosystems (2011);
  - The Namaqua District Biodiversity Sector Plan (2008);
  - The South African National Biodiversity Institute (SANBI) Threatened species programme (TSP); and
  - Pretoria Computer Information Systems (PRECIS).

A-2 Vegetation Index Score

The Vegetation Index Score (VIS) was designed to determine the ecological state of each habitat unit defined within an assessment site. This enables an accurate and consistent description of the Present Ecological state (PES) concerning the study area in question. The information gathered during these assessments also significantly contributes to sensitivity mapping, leading to a more truthful representation of ecological value and sensitive habitats.

Each defined habitat unit is assessed using separate data sheets and all the information gathered then contributes to the final VIS score. The VIS is derived using the following formulas:

VIS = [(EVC) + (SI x PVC)+(RIS)]
Where:
1. **EVC** is extent of vegetation cover;
2. **SI** is structural intactness;
3. **PVC** is percentage cover of indigenous species; and
4. **RIS** is recruitment of indigenous species.

Each of these contributing factors is individually calculated as discussed below. All scores and tables indicated in blue are used in the final score calculation for each contributing factor.

1. ***EVC=[(EVC1+EVC2)/2]***

EVC 1 - Percentage natural vegetation cover:

Vegetation cover % Site score	0%	1-5%	6-25%	26-50%	51-75%	76-100%
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score Site score	0	Very Low	Low	Moderately	High	Very High
EVC 2 score	5	4	3	2	1	0

2. SI=(SI1+SI2+SI3+SI4)/4)

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous								
Clumped								
Scattered								
Sparse								

Present State (P/S) = currently applicable for each habitat unit
Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	**Continuous**	**Clumped**	**Scattered**	**Sparse**
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

3. PVC=[(EVC)-(exotic x 0.7) + (bare ground x 0.3)

Percentage vegetation cover (exotic):

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
PVC Score	0	1	2	3	4	5

4. RIS

Extent of indigenous species recruitment	**0**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
RIS	**0**	**1**	**2**	**3**	**4**	**5**

The final VIS

scores for each habitat unit is then categorised as follows:

Vegetation Index Score	Assessment Class	Description
25	A	Unmodified, natural
20 to 24	B	Largely natural with few modifications.
15 to 20	C	Moderately modified
10 to 15	D	Largely modified
5 to 10	E	The loss of natural habitat extensive
<5	F	Modified completely

A-3 Species of Conservation Concern Assessment

Prior to the field visit, a record of floral SCC as well as protected species and their habitat requirements were acquired from SANBI for the quarter degree square (QDS) associated with the study area. Throughout the vegetation assessment special attention was paid with the identification of any of these SCC as well as identification of suitable habitat that could potentially sustain these species.

A-4 Fauna and the Red Data Sensitivity Index

Given the restrictions of field assessments to identify all the faunal species that possibly occur on a particular property, the Red Data Sensitivity Index (RDSIS) has been developed to provide an indication of the potential Red Data List (RDL) faunal species that could reside in the area, while simultaneously providing a quantitative measure of the study areas value in terms of conserving faunal diversity. The RDSIS is based on the principles that when the knowledge of the specie's historical distribution is combined with a field assessment that identifies the degree to which the property supports a certain species habitat and food requirements, inferences can be made about the chances of that particular species residing on the property. Repeating this procedure for all the potential RDL faunal species of the area and collating this information then provides a sensitivity measure of the study area that has been investigated. The detailed methodology to determine the RDSIS of the study area is presented below:

Probability of Occurrence (POC): Known distribution range (D), habitat suitability of the site (H) and availability of food sources (F) on site were determined for each of the species. Each of these variables is expressed a percentage (where 100% is a perfect score). The average of these scores provided a Probability of Occurrence (POC) score for each species. The POC value was categorised as follows:

- **0-20% = Low;**
- **21-40% = Low to Medium;**
- **41-60% = Medium;**
- **61-80% = Medium to High and**
- **81-100% = High**

POC = (D+H+F)/3

Total Species Score (TSS): Species with a POC of more than 60% (High-medium) were considered when applying the RDSIS. A weighting factor was assigned to the different International Union for the Conservation of Nature (IUCN) categories providing species with a higher conservation status, a higher score. This weighting factor was then multiplied with the POC to calculate the total species score (TSS) for each species. The weighting as assigned to the various categories is as follows:

- **Data Deficient = 0.2;**
- **Rare = 0.5;**
- **Near Threatened = 0.7;**
- **Vulnerable = 1.2;**
- **Endangered = 1.7 and**
- **Critically Endangered = 2.0.**

TSS = (IUCN weighting*POC) where POC > 60%

Average Total Species Score (Ave TSS) and Threatened Taxa Score (Ave TT): The average of all TSS potentially occurring on the site is calculated. The average of all the Threatenedtaxa (TT) (*Near threatened*, *Vulnerable*, *Endangered* and *Critically Endangered)* TSS scores are also calculated. The average of these two scores (Ave TSS and Ave TT) was then calculated in order to add more weight to threatened taxa with POC higher than 60%.

Ave = Ave TSS [TSS/No of Spp] + Ave TT [TT TSS/No of Spp]/2

Red Data Sensitivity Index Score (RDSIS): The average score obtained above and the sum of the percentage of species with a POC of 60% or higher of the total number of Red Data Listed species listed for the area was then calculated. The average of these two scores, expressed as a percentage, gives the RDSIS for the area investigated.

RDSIS = Ave + [Spp with POC>60%/Total no Of Spp*100]/2

RDSIS interpretation:

Table A: RDSIS value interpretation with regards to RDL mammal importance within the study area.

RDSIS Score	RDL mammal importance
0-20%	Low
21-40%	Low-Medium
41-60%	Medium
60-80%	High-Medium
81-100%	High

B – FRESHWATER ECOLOGYMETHOD OF ASSESSMENT

B-1 Desktop Study

A desktop study was compiled with all relevant information as presented by the South African National Biodiversity Institutes (SANBI's) Biodiversity Geographic Information Systems (BGIS) website (http://bgis.sanbi.org). Wetland specific information resources taken into consideration during the desktop assessment of the project footprint included:

- National Freshwater Ecosystem Priority Areas (NFEPAs) (2011)
  - NFEPA water management area (WMA);
  - NFEPA wetlands/National wetlands map;
  - Wetland and estuary Fresh Water Ecosystem Priority Areas (FEPA);
  - FEPA (sub)WMA % area;
  - Sub water catchment area FEPAs;
  - Water management area FEPAs;
  - Fish sanctuaries;
  - Wetland ecosystem types;
- The Stellenbosch Municipality Fine Scale Plan
- Prioritisation of City Wetlands Map (2009)

Classification System for Wetlands and other Aquatic Ecosystems in South Africa

All wetland features encountered within the project footprint were assessed using the *Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland systems* (Ollis *et al*., 2013).

A summary of Levels 1 to 4 of the proposed Classification System for Inland Systems are presented in Tables B and C, below.

Table B: Proposed classification structure for Inland Systems, up to Level 3.

WETLAND / AQUATIC ECOSYSTEM CONTEXT		
LEVEL 1: SYSTEM	LEVEL 2: REGIONAL SETTING	LEVEL 3: LANDSCAPE UNIT
Inland Systems	DWA Level 1 Ecoregions OR NFEPA WetVeg Groups OR Other special framework	Valley Floor
		Slope
		Plain
		Bench (Hilltop / Saddle / Shelf)

Table C: Hydrogeomorphic (HGM) Units for the Inland System, showing the primary HGM Types at Level 4A and the subcategories at Level 4B to 4C.

FUNCTIONAL UNIT		
LEVEL 4: HYDROGEOMORPHIC (HGM) UNIT		
HGM type	Longitudinal zonation/ Landform / Outflow drainage	Landform / Inflow drainage
A	**B**	**C**
River	Mountain headwater stream	Active channel
		Riparian zone
	Mountain stream	Active channel
		Riparian zone
	Transitional	Active channel
		Riparian zone
	Upper foothills	Active channel
		Riparian zone
	Lower foothills	Active channel
		Riparian zone
	Lowland river	Active channel
		Riparian zone
	Rejuvenated bedrock fall	Active channel
		Riparian zone
	Rejuvenated foothills	Active channel
		Riparian zone
	Upland floodplain	Active channel
		Riparian zone
Channelled valley-bottom wetland	(not applicable)	(not applicable)
Unchannelled valley-bottom wetland	(not applicable)	(not applicable)
Floodplain wetland	Floodplain depression	(not applicable)
	Floodplain flat	(not applicable)
Depression	Exorheic	With channelled inflow
		Without channelled inflow
	Endorheic	With channelled inflow
		Without channelled inflow
	Dammed	With channelled inflow
		Without channelled inflow
Seep	With channelled outflow	(not applicable)
	Without channelled outflow	(not applicable)
Wetland flat	(not applicable)	(not applicable)

Level 1: Inland systems

For the proposed Classification System, Inland Systems are defined as ***an aquatic ecosystem that have no existing connection to the ocean***[11] (i.e. characterised by the complete absence of marine exchange and/or tidal influence) but ***which are inundated or saturated with water, either permanently or periodically.*** It is important to bear in mind, however, that certain Inland Systems may have had an historical connection to the ocean, which in some cases may have been relatively recent.

Level 2: Ecoregions

For Inland Systems, the regional spatial framework that has been included at Level 2 of the proposed Classification System is that of DWA's Level 1 Ecoregions for aquatic ecosystems (Kleynhans *et al.,* 2005). There are a total of 31 Ecoregions across South Africa, including Lesotho and Swaziland

[11] Most rivers are indirectly connected to the ocean via an estuary at the downstream end, but where marine exchange (i.e. the presence of seawater) or tidal fluctuations are detectable in a river channel that is permanently or periodically connected to the ocean, it is defined as part of the estuary.

(figure below). DWA Ecoregions have most commonly been used to categorise the regional setting for national and regional water resource management applications, especially in relation to rivers.

Level 2: NFEPA Wet Veg Groups

The Vegetation Map of South Africa, Swaziland and Lesotho (Mucina & Rutherford, 2006) groups vegetation types across the country according to Biomes, which are then divided into Bioregions. To categorise the regional setting for the wetland component of the NFEPA project, wetland vegetation groups (referred to as WetVeg Groups) were derived by further splitting Bioregions into smaller groups through expert input (Nel *et al*., 2011). There are currently 133 NFEPA WetVeg Groups. It is envisaged that these groups could be used as a special framework for the classification of wetlands in national- and regional-scale conservation planning and wetland management initiatives.

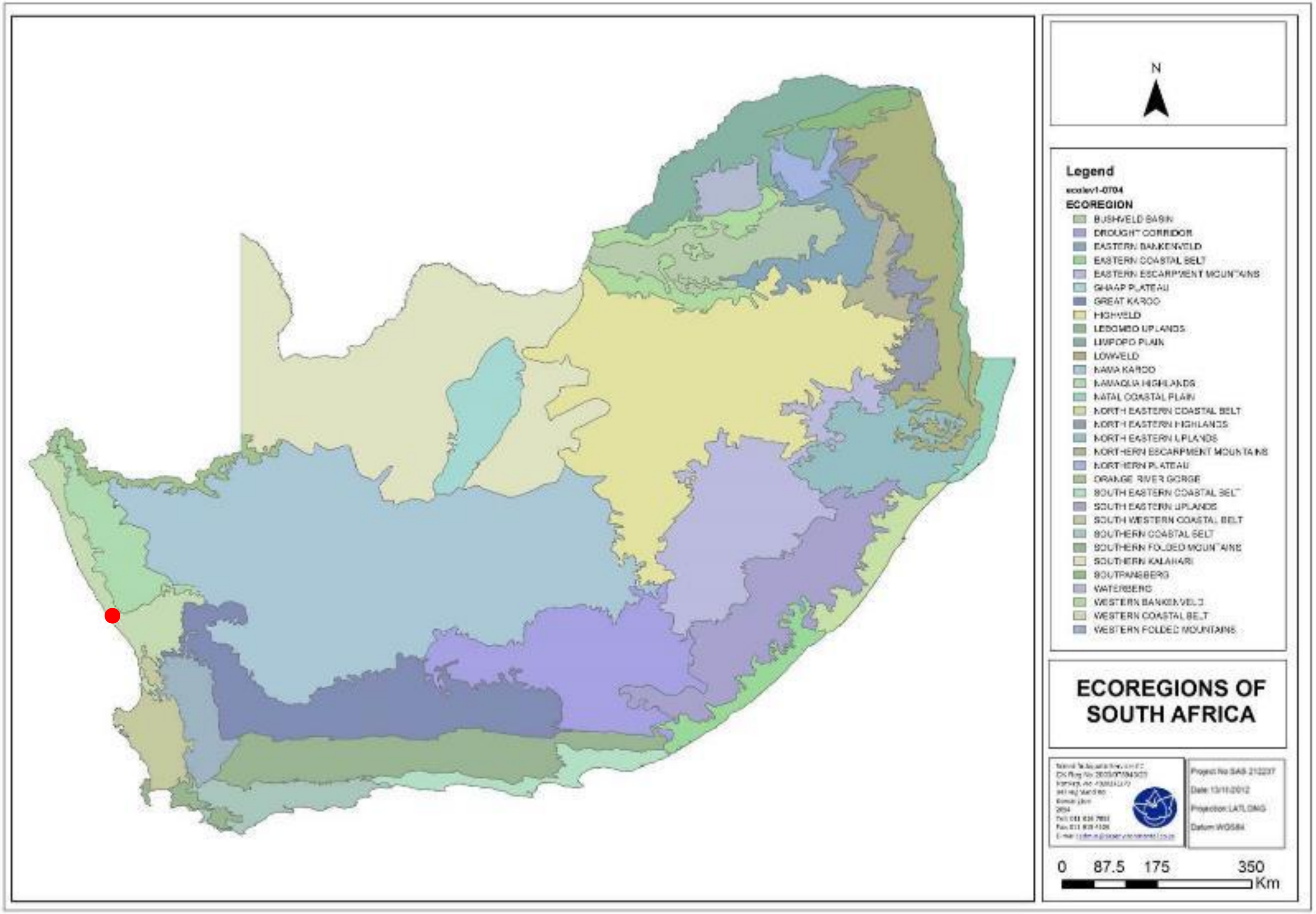

Figure A: Map of Level 1 Ecoregions of South Africa, with the approximate position of the project footprint indicated in red.

Level 3: Landscape Setting

At Level 3 of the proposed classification System, for Inland Systems, a distinction is made between four Landscape Units (Table 3) on the basis of the landscape setting (i.e. topographical position) within which an HGM Unit is situated, as follows (Ollis *et al.,* 2013):

- ***Slope*****:** an included stretch of ground that is not part of a valley floor, which is typically located on the side of a mountain, hill or valley.
- ***Valley floor:*** The base of a valley, situated between two distinct valley side-slopes.
- ***Plain:*** an extensive area of low relief characterised by relatively level, gently undulating or uniformly sloping land.
- ***Bench (hilltop/saddle/shelf):*** an area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops/crests (areas at the top of a mountain or hill flanked by down-slopes in all directions), saddles (relatively high-lying areas flanked by down-slopes on two sides in one direction and up-slopes on two sides in an approximately permendicular direction), and shelves/terraces/ledges (relatively high-lying, localised flat areas along a slope, representing a break in slope with an up-slope one side and a down-slope on the other side in the same direction).

Level 4: Hydrogeomorphic Units

Eight primary HGM Types are recognised for Inland Systems at Level 4A of the proposed National Wetland Classification Systems (NWCS) (Table 13), on the basis of hydrology and geomorphology (Ollis *et al*., 2013), namely:

- ***River:*** a linear landform with clearly discernible bed and banks, which permanently or periodically carries a concentrated flow of water.
- ***Channelled valley-bottom wetland:*** a valley-bottom wetland with a river channel running through it.
- ***Unchannelled valley-bottom wetland:*** a valley-bottom wetland without a river channel running through it.
- ***Floodplain wetland:*** the mostly flat or gently sloping land adjacent to and formed by an alluvial river channel, under its present climate and sediment load, which is subject to periodic inundation by over-topping of the channel bank.
- ***Depression:*** a landform with closed elevation contours that increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates.
- ***Wetland Flat:*** a level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. Closed elevation contours are not evident around the edge of a wetland flat
- ***Seep:*** a wetland area located on (gently to steeply) sloping land, which is dominated by the colluvial (i.e. gravity-driven), unidirectional movement of material down-slope. Seeps are often located on the side-slopes of a valley but they do not, typically, extend into a valley floor.

The above terms have been used for the primary HGM Units in the Classification System to try and ensure consistency with the wetland classification terms currently in common usage in South Africa. Similar terminology (but excluding categories for “channel”, “flat” and “valleyhead seep”) is used, for example, in the recently developed tools produced as part of the Wetland Management Series including WET-Health (Macfarlane *et al.,* 2009) and WET-EcoServices (Kotze *et al.,* 2008).

B-2 WET-Health

Healthy wetlands are known to provide important habitats for wildlife and to deliver a range of important goods and services to society. Management of these systems is therefore essential if these attributes are to be retained within an ever changing landscape. The primary purpose of this assessment[12] is to evaluate the ecophysical health of wetlands, and in so doing promote their conservation and wise management.

Level of Evaluation

Two levels of assessment are provided by WET-Health:

- Level 1: Desktop evaluation, with limited field verification. This is generally applicable to situations where a large number of wetlands need to be assessed at a very low resolution;
- Level 2: On-site evaluation. This involves structured sampling and data collection in a single wetland and its surrounding catchment; and

Framework for the Assessment

A set of three modules has been synthesised from the set of processes, interactions and interventions that take place in wetland systems and their catchments: hydrology (water inputs, distribution and retention, and outputs), geomorphology (sediment inputs, retention and outputs) and vegetation (transformation and presence of introduced alien species).

Units of Assessment

Central to WET-Health is the characterisation of hydrogeomorphic (HGM) units, which have been defined based on geomorphic setting (e.g. hillslope or valley-bottom; whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated) and pattern of water flow through the wetland unit (diffusely or channelled) as described under the *Classification System for Wetlands and other Aquatic Ecosystems* in Section B-1.

Quantification of Present State of a wetland

The overall approach is to quantify the impacts of human activity or clearly visible impacts on wetland health, and then to convert the impact scores to a Present State score. This takes the form of assessing the spatial *extent* of impact of individual activities and then separately assessing the *intensity* of impact of each activity in the affected area. The extent and intensity are then combined to determine an overall *magnitude* of impact. The impact scores and Present State categories are provided in Table D.

Table D: Impact scores and categories of present State used by WET-Health for describing the integrity of wetlands.

Impact category	Description	Impact score range	Present State category
None	Unmodified, natural	0-0.9	A
Small	Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	1-1.9	B
Moderate	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact.	2-3.9	C

[12] Kleynhans et al., 2007

Large	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	4-5.9	D
Serious	The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9	E
Critical	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10	F

Assessing the Anticipated Trajectory of Change

As is the case with the Present State, future threats to the state of the wetland may arise from activities in the catchment upstream of the unit or from within the wetland itself or from processes downstream of the wetland. In each of the individual sections for hydrology, geomorphology and vegetation, five potential situations exist depending upon the direction and likely extent of change (Table E).

Table E: Trajectory of Change classes and scores used to evaluate likely future changes to the present state of the wetland.

Change Class	Description	HGM change score	Symbol
Substantial improvement	State is likely to improve substantially over the next 5 years	2	↑↑
Slight improvement	State is likely to improve slightly over the next 5 years	1	↑
Remain stable	State is likely to remain stable over the next 5 years	0	→
Slight deterioration	State is likely to deteriorate slightly over the next 5 years	-1	↓
Substantial deterioration	State is expected to deteriorate substantially over the next 5 years	-2	↓↓

Overall health of the wetland

Once all HGM units have been assessed, a summary of health for the wetland as a whole needs to be calculated. This is achieved by calculating a combined score for each component by area-weighting the scores calculated for each HGM unit. Recording the health assessments for the hydrology, geomorphology and vegetation components provides a summary of impacts, Present State, Trajectory of Change and Health for individual HGM units and for the entire wetland.

B-3 Wetland function assessment

"The importance of a water resource, in ecological social or economic terms, acts as a modifying or motivating determinant in the selection of the management class".[13] The assessment of the ecosystem services supplied by the identified wetlands was conducted according to the guidelines as described by Kotze *et* al (2009). An assessment was undertaken that examines and rates the following services according to their degree of importance and the degree to which the service is provided:

[13] Department of Water Affairs and Forestry, South Africa *Version 1.0 of Resource Directed Measures for Protection of Water Resources, 1999*

- Flood attenuation
- Stream flow regulation
- Sediment trapping
- Phosphate trapping
- Nitrate removal
- Toxicant removal
- Erosion control
- Carbon storage
- Maintenance of biodiversity
- Water supply for human use
- Natural resources
- Cultivated foods
- Cultural significance
- Tourism and recreation
- Education and research

The characteristics were used to quantitatively determine the value, and by extension sensitivity, of the wetlands. Each characteristic was scored to give the likelihood that the service is being provided. The scores for each service were then averaged to give an overall score to the wetland.

Table F: Classes for determining the likely extent to which a benefit is being supplied.

Score	Rating of the likely extent to which the benefit is being supplied
<0.5	Low
0.6-1.2	Moderately low
1.3-2	Intermediate
2.1-3	Moderately high
>3	High

B-4 Defining Ecological Importance and Sensitivity

The method used for the Ecological Importance and Sensitivity (EIS) determination was adapted from the method as provided by DWA (1999) for floodplains. The method takes into consideration PES scores obtained for WET-Health as well as function and service provision to enable the assessor to determine the most representative EIS category for the wetland feature or group being assessed.

A series of determinants for EIS are assessed on a scale of 0 to 4, where 0 indicates no importance and 4 indicates very high importance. The median of the determinants is used to assign the EIS category.

Table G: EIS Category definitions

EIS Category	Range of Median	Recommended Ecological Management Class[14]
Very high Wetlands that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these wetlands is usually very	>3 and <=4	A

[14] Ed's note: Author to confirm exact wording for version 1.1

sensitive to flow and habitat modifications.		
High Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these wetlands may be sensitive to flow and habitat modifications.	>2 and <=3	B
Moderate Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications.	>1 and <=2	C
Low/marginal Wetlands that are not ecologically important and sensitive at any scale. The biodiversity of these wetlands is ubiquitous and not sensitive to flow and habitat modifications.	>0 and <=1	D

B-5 Recommended Ecological Category

"A high management class relates to the flow that will ensure a high degree of sustainability and a low risk of ecosystem failure. A low management class will ensure marginal maintenance of sustainability, but carries a higher risk of ecosystem failure." [15]

The REC was determined based on the results obtained from the PES, reference conditions and Ecological Importance and Sensitivity of the resource (sections above). Followed by realistic recommendations, mitigation, and rehabilitation measures to achieve the desired REC.

A wetland may receive the same class for the PES, as the REC if the wetland is deemed in good condition, and therefore must stay in good condition. Otherwise, an appropriate REC should be assigned in order to prevent any further degradation as well as to enhance the PES of the wetland feature.

Table H: Description of REC classes.

Class	Description
A	Unmodified, natural
B	Largely natural with few modifications
C	Moderately modified
D	Largely modified

B-6 Wetland Delineation

For the purposes of this investigation, a wetland habitat is defined in the NWA (1998) as including the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterized by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent areas.

The wetland zone delineation took place according to the method presented in the final draft of "A practical field procedure for identification and delineation of wetlands and riparian areas" published by the Department of Water Affairs and Forestry (DWAF) in February 2005. Attention was also paid to wetland soil guidelines as defined by Job (2009) for the Western Cape. The foundation of the method is based on the fact that wetlands have several distinguishing factors including the following:

- The presence of water at or near the ground surface;

[15] Department of Water Affairs and Forestry, South Africa *Version 1.0 of Resource Directed Measures for Protection of Water Resources 1999*

- Distinctive hydromorphic soils; and
- Vegetation adapted to saturated soils.

By observing the evidence of these features, in the form of indicators, wetlands and riparian zones can be delineated and identified. If the use of these indicators and the interpretation of the findings are applied correctly, then the resulting delineation can be considered accurate (DWAF 2005).

Riparian and wetland zones can be divided into three zones (DWAF 2005). The permanent zone of wetness is nearly always saturated. The seasonal zone is saturated for a significant part of the rainy season and the temporary zone surrounds the seasonal zone and is only saturated for a short period of the year, but is saturated for a sufficient period, under normal circumstances, to allow for the formation of hydromorphic soils and the growth of wetland vegetation. The object of this study was to identify the outer boundary of the temporary zone and then to identify a suitable buffer zone around the wetland area.

APPENDIX B

Floral Species lists

Table A: PRECIS SCC plant list for the QDS 3017DC, 3017DD, 3117BB and 3117BA (Raimondo *et al*., 2009; SANBI, www.sanbi.org).

Family	Species	Threat status	Growth froms
ASPHODELACEAE	*Bulbine louwii L.I.Hall*	Rare	Geophyte, herb, succulent
ASPHODELACEAE	*Bulbine wiesei L.I.Hall*	Rare	Geophyte, herb, succulent
ASTERACEAE	*Helichrysum marmarolepis S.Moore*	NT	Herb
ASTERACEAE	*Leucoptera oppositifolia B.Nord.*	Rare	Dwarf shrub
ASTERACEAE	*Cotula filifolia Thunb.*	CR	Herb, tenagophyte
ASTERACEAE	*Helichrysum dunense Hilliard*	VU	Herb
ASTERACEAE	*Helichrysum marmarolepis S.Moore*	NT	Herb
ASTERACEAE	*Oncosiphon schlechteri (Bolus)*	EN	Shrub
ASTERACEAE	*Amphiglossa celans Koekemoer*	Rare	Dwarf shrub, scrambler
ASTERACEAE	*Helichrysum tricostatum (Thunb.) Less.*	NT	Shrub
ASTERACEAE	*Ursinia pygmaea DC.*	Rare	Herb
ERIOSPERMACEAE	*Eriospermum arenosum P.L.Perry*	VU	Geophyte
FABACEAE	*Lebeckia plukenetiana E.Mey.*	EN	Herb
GERANIACEAE	*Pelargonium appendiculatum (L.f.) Willd.*	EN	Geophyte, succulent
IRIDACEAE	*Babiana brachystachys (Baker) G.J.Lewis*	Declining	Geophyte, herb
IRIDACEAE	*Babiana lewisiana B.Nord.*	VU	Geophyte, herb
IRIDACEAE	*Babiana rubella Goldblatt & J.C.Manning*	VU	Geophyte, herb
IRIDACEAE	*Moraea rivulicola Goldblatt & J.C.Manning*	Rare	Geophyte, herb
IRIDACEAE	*Babiana hirsuta (Lam.) Goldblatt & J.C.Manning*	NT	Geophyte, herb
IRIDACEAE	*Babiana confusa (G.J.Lewis) Goldblatt & J.C.Manning*	VU	Geophyte, herb
IRIDACEAE	*Ferraria foliosa G.J.Lewis*	NT	Geophyte, herb
MESEMBRYANTHEMACEAE	*Antimima komkansica (L.Bolus) H.E.K.Hartmann*	Threatened	Succulent
MESEMBRYANTHEMACEAE	*Lampranthus amoenus (Salm-Dyck ex DC.) N.E.Br.*	EN	Succulent
MESEMBRYANTHEMACEAE	*Leipoldtia klaverensis L.Bolus*	EN	Succulent
MESEMBRYANTHEMACEAE	*Lithops divergens L.Bolus*	NT	Succulent
MOLLUGINACEAE	*Adenogramma teretifolia (Thunb.) Adamson*	DDD	Dwarf shrub
OXALIDACEAE	*Oxalis dines Ornduff*	VU	Geophyte
OXALIDACEAE	*Oxalis virginea Jacq.*	Rare	Geophyte
POLYGALACEAE	*Muraltia obovata DC.*	VU	Dwarf shrub, shrub
PROTEACEAE	*Leucadendron linifolium (Jacq.) R.Br.*	VU	Shrub
PROTEACEAE	*Leucospermum rodolentum (Salisb. ex Knight) Rourke*	VU	Shrub
RHAMNACEAE	*Phylica greyii Pillans*	EN	Dwarf shrub
RHAMNACEAE	*Phylica hirta Pillans*	NT	Dwarf shrub
ROSACEAE	*Cliffortia acockii Weim.*	CR	Shrub
SCROPHULARIACEAE	*Manulea cinerea Hilliard*	VU	Dwarf shrub

Table B: Dominant floral species identified within the Strandveld Habitat Unit

Grass/sedge/reed species	Forbs, dwarf shrubs, succulents and geophytes	Trees and shrubs
Odyssea paucinervis	*Albuca canadensis*	*Acacia cyclops*
Ehrharta calycina	*Aloe arenicola*	*Ballota africana*
Stipagrostis zeyheri	*Aridaria noctiflora*	*Berkheya fruticosa*
Schismus barbatus	*Asparagus capensis*	*Didelta carnosa*
Willdenowia incurvata	*Atriplex lindleyi*	*Didelta spinosa*
	Atriplex vesicaria	*Diospyros lycioides*
	Babiana hirsuta	*Eriocephalus racemosus*
	Boophone haemanthoides	*Galenia africana*
	Brunsvigia bosmaniae	*Lebeckia sericea*
	Conicosia pugioniformis	*Manochlamys albicans*
	Chrysocoma ciliata	*Montinia caryophyllacea*
	Crassula expansa	*Opuntia ficus-indica*
	Crassula muscosa	*Othonna cylindrica*
	Euphorbia burmannii	*Pteronia glomerata*
	Euphorbia caput-medusae	*Pteronia onobromoides*
	Euphorbia mauritanica	*Salvia lanceolata*
	Haemanthus coccineus	*Searsia undulata*
	Hermannia althaeifolia	*Tripteris oppositifolia*
	Heliophila coronopifolia	*Tylecodon wallichii*
	Lachenalia unifolia	*Wiborgia obcordata*
	Mesembryanthemum crystallinum	*Zygophyllum morgsana*
	Mesembryanthemum guerichianum	
	Microloma sagittatum	
	Monsonia spinosa	
	Moraea fugax	
	Nemesia ligulata	
	Oncosiphon suffruticosum	
	Osteospermum pinnatum	
	Rhynchopsidium pumilum	
	Ruschia floribunda	
	Sarcocaulon flavescens	
	Senecio pubigerus	
	Senecio sarcoides	
	Stoeberia utilis	
	Tetragonia fruticosa	
	Trachyandra divaricata	
	Trachyandra falcata	
	Zaluzianskya villosa	
	Zygophyllum cordifolium	

Table C: Dominant floral species identified within the Hardeveld Habitat Unit. Species marked with an asterisk have been identified as part of previous studies of the Zandkopsdrift mine (Henning, 2014).

Grass/sedge/reed species	Forbs, dwarf shrubs, succulents and geophytes	Trees and shrubs
Odyssea paucinervis	*Adenogramma glomerata**	*Berkheya fruticosa*
Ehrharta calycina	*Albuca spiralis*	*Deverra denudate**
*Stipagrostis namaquensis**	*Antimima compacta**	*Galenia africana*
Stipagrostis zeyheri	*Aridaria noctiflora*	*Gymnosporia buxifolia**
Schismus barbatus	*Asparagus capensis**	*Lebeckia sericea*
	Atriplex lindleyi	*Lycium pilifolium**

	Brunsvigia bosmaniae	*Lycium cinereum**
	*Bulbine praemorsa**	*Pteronia divaricate**
	Caulipsolon rapaceum	*Tripteris oppositifolia*
	Cephalophyllum pillansii	
	*Cephalophyllum spp.**	
	Chrysochoma ciliata	
	Chlorophytum undulatum	
	Colchicum coloratum	
	Conicosia pugioniformis	
	Conophytum bilobum	
	Conophytum minutum	
	Cotula turbinata	
	Crassula columnaris	
	Crassula elegans	
	Crassula expansa	
	Crassula muscosa	
	Crotalaria humilis	
	Cyanella hyacinthoides	
	Didelta carnosa	
	*Dimorphotheca pinnata**	
	Drimia sp.	
	Drosanthemum hispidum	
	Drosanthemum pulverulentum	
	Euphorbia caput-medusae	
	Euphorbia hamata	
	Euphorbia mauritanica	
	Euphorbia burmannii	
	Felicia bergeriana	
	Galenia fruticosa	
	Galenia sarcophylla	
	Galenia secunda	
	Gethyllis spiralis	
	Gladiolus scullyi	
	Gladiolus orchidiflorus	
	Haemanthus coccineus	
	Haemanthus crispus	
	Heliophila coronopifolia	
	*Hermannia subdivaricata**	
	Hyobanche sanguinea	
	Hypertelis salsoloides	
	Jamesbrittenia racemosa	
	Jordaaniella cuprea	
	*Kedrostis psammophylla**	
	*Lachenalia undulata**	
	Lachenalia unifolia	
	Lampranthus otzenianus	
	*Lampranthus watermeyerii**	
	*Lessertia diffusa**	
	Leysera tenella	
	Manulea silenoides	
	Massonia depressa	
	Mesembryanthemum crystallinum	
	Mesembryanthemum guerichianum	
	*Microloma sagittatum**	
	Monilaria sp.	
	*Monsonia salmoniflora**	
	*Moraea schlechteri**	

	Moraea serpentina	
	Moraea miniata	
	Nemesia ligulata	
	Ornithoglossum viride	
	*Ornithogalum xanthochloricum**	
	Osteospermum pinnatum	
	*Oxalis clavifolia**	
	*Oxalis pulchella**	
	*Oxalis sonderiana**	
	*Oxalis flava**	
	*Oxalis pes-capre**	
	*Pelargonium carnosum**	
	Pharnaceum croceum	
	*Phyllobolus grossus**	
	Phyllobolus sp.	
	Rhynchopsidium pumilum	
	Ruschia floribunda	
	Ruschia leucosperma	
	Ruschia robusta	
	Salsola sp.*	
	Sarcocaulon flavescens	
	Stoeberia utilis	
	*Strumaria truncata**	
	Tetragonia fruticosa	
	Trachyandra falcata	
	Zaluzianskya villosa	
	Zygophyllum cordifolium	
	Zygophyllum sp.nov.*	

Table D: Dominant floral species identified within the Coastal Habitat Unit

Grass/sedge/reed species	Forbs, dwarf shrubs, succulents and geophytes	Trees and shrubs
Chaetobromus involucratus	*Adenogramma glomerata*	*Eriocephalus racemosus*
Cladoraphis cyperoides	*Albuca canadensis*	*Lebeckia sericea*
Ehrharta calycina	*Amphibolia sp.*	*Lycium tetrandrum*
Odyssea paucinervis	*Arctotis decurrens*	*Manochlamys albicans*
Schismus barbatus	*Asparagus capensis*	*Othonna cylindrica*
Sporobolus virginicus	*Babiana hirsuta*	*Pelargonium fulgidum*
	Boophane haemanthoides	*Pteronia divaricata*
	Bulbine praemorsa	*Salvia lanceolata*
	Didelta carnosa	*Tripteris oppositifolia*
	Dimorphotheca pluvialis	*Zygophyllum morgsana*
	Dimorphotheca sinuata	
	Drosanthemum floribundum	
	Drosanthemum hispidum	
	Euphorbia burmannii	
	Euphorbia caput-medusae	
	Galenia secunda	
	Galenia sarcophylla Grielum grandiflorum	
	Haemanthus coccineus	
	Heliophylla coronopifilia	
	Hypertelis angrae-pequenae	
	Jordaaniella spongiosa	
	Limeum africanum	
	Lyperia tristis	
	Manulea silenoides	
	Mesembryanthemum	

	crystallinum	
	Mesembryanthemum guerichianum	
	Microloma sagittatum	
	Monilaria sp	
	Nemesia ligulata	
	Oxalis ambigua	
	Pharnaceum croceum	
	Psilocaulon dinteri	
	Rhynchopsidium pumilum	
	Senecio arenarius	
	Senecio elegans	
	Senecio sarcoides	
	Spergularia bocconii	
	Stoeberia utilis	
	Tetragonia decumbens	
	Trachyandra divaricata	
	Trachyandra falcata	
	Tetragonia fruticosa	
	Tripteris sinuata	
	Zalusianskya villosa	
	Zygophyllum cordifolium	

Table E: Dominant floral species identified within the Sand Fynbos Habitat Unit

Grass/sedge/reed species	Forbs, dwarf shrubs, succulents and geophytes	Trees and shrubs
Chaetobromus involucratus	*Adenogramma glomerata*	*Aspalathus spinescens*
Ehrharta calycina	*Anthospermum aethiopicum*	*Diospyros lycioides*
Odyssea paucinervis	*Asparagus alopecurus*	*Elytropappus rhinocerotis*
Stipagrostis zeyheri	*Babiana ambigua*	*Euclea racemosa*
Schismus barbatus	*Babiana hirsuta*	*Lebeckia sericea*
Thamnochortus bachmanii	*Babiana spiralis*	*Leucospermum rodolentum*
Willdenowia incurvata	*Boophane haemanthoides*	*Lobostemon sp.*
	Brunsvigia bosmaniae	*Muraltia sp.*
	Chrysocoma ciliata	*Salvia lanceolata*
	Cleretum rourkei	*Searsia spinosa*
	Diascia capensis	*Searsia undulata*
	Drosanthemum hispidum	*Seriphium nervigera*
	Euphorbia ephedroides	*Seriphium plumosa*
	Felicia sp.	*Trichocephalus stipularis*
	Gladiolus sp.	*Trichogyne ambigua*
	Grielum grandiflorum	*Trichogyne repens*
	Gymnodiscus capillaris	*Wiborgia obcordata*
	Heliophila coronopifolia	*Euryops tenuissimus*
	Hermannia althaeifolia	*Zygophyllum spinosum*
	Hermannia cuneifolia	
	Hirpicium alienatum	
	Hyobanche sanguinea	
	Lachenalia hirta	
	Lachenalia mutabilis	
	Lapeirousia jacquinii	
	Lapeirousia silenoides	
	Leysera tenella	
	Limeum africanum	
	Lyperia tristis	
	Manulea altissima	
	Mesembryanthemum	

	guerichianum *Microloma sagittatum* *Monsonia spinosa* *Moraea fugax* *Ornithoglossum viride* *Pelargonium triste* *Thesium spinosum* *Zalusianskya villosa*

Table F: Floral species protected under the Northern Cape Nature Conservation Act (Act 9 of 2009)

Family/Genus	Species
Aizoaceae	*Amphibolia sp.* *Tetragonia decumbens* *Tetragonia fruticosa*
Amaryllidaceae	*Boophone haemanthoides* *Brunsvigia bosmaniae* *Gethyllis spiralis* *Haemanthus coccineus* *Haemanthus crispus* *Strumaria truncata*
Antheriaceae	*Chlorophytum undulatum*
Apocynaceae	*Microloma sagittatum*
Asphodelaceae	*Aloe arenicola* *Bulbine bruynsii* *Bulbine praemorsa* *Trachyandra divaricata* *Trachyandra falcata*
Crassulaceae	*Crassula columnaris* *Crassula elegans* *Crassula expansa* *Crassula muscosa* *Tylecodon wallichii*
Cyanella spp	*Cyanella hyacinthoides*
Diascia spp	*Diascia capensis*
Euphorbia spp	*Euphorbia burmannii* *Euphorbia caput-medusa* *Euphorbia ephedroides* *Euphorbia hamata* *Euphorbia mauritanica*
Iridaceae	*Babiana ambigua* *Babiana hirsuta* *Babiana spiralis* *Gladiolus orchidiflorus* *Gladiolus scullyi* *Lapeirousia jacquinii* *Lapeirousia silenoides* *Moraea fugax* *Moraea miniata* *Moraea schlechteri* *Moraea serpentina*
Jamesbrittenia spp	*Jamesbrittenia racemosa*
Lachenalia spp	*Lachenalia hirta* *Lachenalia mutabilis* *Lachenalia undulata* *Lachenalia unifolia*
Manulea spp	*Manulea altissima* *Manulea silenoides*
Mesembryanthemaceae	*Antimima compacta*

	Antimima sp. *Aridaria noctiflora* *Cleretum rourkei* *Cephalophyllum pillansii* *Conicosia elongata* *Conicosia pugioniformis* *Conophytum bilobum* *Conophytum minutum* *Drosanthemum floribundum* *Drosanthemum hispidum* *Drosanthemum pulverulentum* *Jordaaniella cuprea* *Jordaaniella spongiosa* *Lampranthus otzenianus* *Lampranthus watermeyerii* *Mesembryanthemum crystallinum* *Mesembryanthemum guerichianum* *Monilaria sp.* *Phyllobolus grossus* *Phyllobolus sp* *Ruschia floribunda* *Ruschia leucosperma* *Ruschia robusta*
Nemesia spp	*Nemesia ligulata*
Ornithogalum spp	*Ornithogalum suaveolens* *Ornithogalum xanthochloricum*
Oxalis spp	*Oxalis ambigua* *Oxalis clavifolia* *Oxalis flava* *Oxalis pes-capre* *Oxalis pulchella* *Oxalis sonderiana*
Pelargonium spp	*Pelargonium carnosum* *Pelargonium fulgidum* *Pelargonium triste*
Proteaceae	*Leucospermum rodolentum*
Restionaceae	*Elegia sp. nov* *Thamnochortus bachmanii* *Willdenowia incurvata*

APPENDIX C

VIS

Vegetation Index Score –Succulent Karoo Habitat Unit

EVC=[[(EVC1+EVC2)/2] = 4

EVC 1 - Percentage natural vegetation cover:

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Site score						X
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score	0	Very Low	Low	Moderately	High	Very High
Site score			X			
EVC 2 score	5	4	3	2	1	0

SI=(SI1+SI2+SI3+SI4)/4) = 3

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous			X	X				
Clumped					X	X		
Scattered								
Sparse	X	X					X	X

Present State (P/S) = Currently applicable for each habitat unit

Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	Continuous	Clumped	Scattered	Sparse
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

PVC=[(EVC)-((exotic x 0.7) + (bare ground x 0.3)) = 3

Percentage vegetation cover (exotic):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

RIS

Extent of indigenous species recruitment	**0**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
						X
RIS	**0**	**1**	**2**	**3**	**4**	**5**

VIS = [(EVC)+((SIxPVC)+(RIS))] = 18

The final VIS scores for each habitat unit are then categorised as follows:

Vegetation Index Score	Assessment Class	Description
22 to 25	**A**	Unmodified, natural
18 to 22	**B**	Largely natural with few modifications.
14 to 18	**C**	Moderately modified
10 to 14	**D**	Largely modified
5 to 10	**E**	The loss of natural habitat extensive
<5	**F**	Modified completely

Vegetation Index Score –Sand Fynbos Habitat Unit

EVC=[[(EVC1+EVC2)/2] = 4.5

EVC 1 - Percentage natural vegetation cover:

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Site score						X
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score	0	Very Low	Low	Moderately	High	Very High
Site score		X				
EVC 2 score	5	4	3	2	1	0

SI=(SI1+SI2+SI3+SI4)/4) = 3

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous							X	X
Clumped			X	X				
Scattered					X	X		
Sparse	X	X						

Present State (P/S) = Currently applicable for each habitat unit

Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	Continuous	Clumped	Scattered	Sparse
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

PVC=[(EVC)-((exotic x 0.7) + (bare ground x 0.3)) = 4.2

Percentage vegetation cover (exotic):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %	X					
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

RIS

Extent of indigenous species recruitment	0	Very Low	Low	Moderate	High	Very High
						X
RIS	**0**	**1**	**2**	**3**	**4**	**5**

VIS = [(EVC)+((SIxPVC)+(RIS))] = 22

The final VIS scores for each habitat unit are then categorised as follows:

Vegetation Index Score	Assessment Class	Description
22 to 25	**A**	Unmodified, natural
18 to 22	**B**	Largely natural with few modifications.
14 to 18	**C**	Moderately modified
10 to 14	**D**	Largely modified
5 to 10	**E**	The loss of natural habitat extensive
<5	**F**	Modified completely

Vegetation Index Score –Wetland/Riparian Habitat Unit

EVC=[[(EVC1+EVC2)/2] = 4

EVC 1 - Percentage natural vegetation cover:

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Site score						X
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score	0	Very Low	Low	Moderately	High	Very High
Site score				X		
EVC 2 score	5	4	3	2	1	0

SI=(SI1+SI2+SI3+SI4)/4) = 3

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous								
Clumped			X	X				
Scattered					X	X		
Sparse	X	X					X	X

Present State (P/S) = Currently applicable for each habitat unit

Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	Continuous	Clumped	Scattered	Sparse
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

PVC=[(EVC)-((exotic x 0.7) + (bare ground x 0.3)) = 2.7

Percentage vegetation cover (exotic):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %			X			
PVC Score	0	1	2	3	4	5

RIS

Extent of indigenous species recruitment	**0**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
						X
RIS	**0**	**1**	**2**	**3**	**4**	**5**

VIS = [(EVC)+((SIxPVC)+(RIS))] = 18.1

The final VIS scores for each habitat unit are then categorised as follows:

Vegetation Index Score	Assessment Class	Description
22 to 25	A	Unmodified, natural
18 to 22	B	Largely natural with few modifications.
14 to 18	C	Moderately modified
10 to 14	D	Largely modified
5 to 10	E	The loss of natural habitat extensive
<5	F	Modified completely

Vegetation Index Score – Rocky Outcrop Habitat Unit

EVC=[[(EVC1+EVC2)/2] = 4

EVC 1 - Percentage natural vegetation cover:

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Site score						X
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score	0	Very Low	Low	Moderately	High	Very High
Site score			X			
EVC 2 score	5	4	3	2	1	0

SI=(SI1+SI2+SI3+SI4)/4) = 3

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous								
Clumped			X	X				
Scattered					X	X		
Sparse	X	X					X	X

Present State (P/S) = Currently applicable for each habitat unit

Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	Continuous	Clumped	Scattered	Sparse
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

PVC=[(EVC)-((exotic x 0.7) + (bare ground x 0.3)) = 3.3

Percentage vegetation cover (exotic):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %	X					
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

RIS

Extent of indigenous species recruitment	**0**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
						X
RIS	**0**	**1**	**2**	**3**	**4**	**5**

VIS = [(EVC)+((SIxPVC)+(RIS))] = 18.9

The final VIS scores for each habitat unit are then categorised as follows:

Vegetation Index Score	Assessment Class	Description
22 to 25	A	Unmodified, natural
18 to 22	B	Largely natural with few modifications.
14 to 18	C	Moderately modified
10 to 14	D	Largely modified
5 to 10	E	The loss of natural habitat extensive
<5	F	Modified completely

Vegetation Index Score – Transformed Habitat Unit

EVC=[[(EVC1+EVC2)/2] = 2

EVC 1 - Percentage natural vegetation cover:

Vegetation cover %	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Site score				X		
EVC 1 score	0	1	2	3	4	5

EVC2 - Total site disturbance score:

Disturbance score	0	Very Low	Low	Moderately	High	Very High
Site score					X	
EVC 2 score	5	4	3	2	1	0

SI=(SI1+SI2+SI3+SI4)/4) = 2

	Trees (SI1)		Shrubs (SI2)		Forbs (SI3)		Grasses (SI4)	
Score:	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State	Present State	Perceived Reference State
Continuous			X					
Clumped				X	X			X
Scattered						X		
Sparse	X	X					X	

Present State (P/S) = Currently applicable for each habitat unit

Perceived Reference State (PRS) = If in pristine condition

Each SI score is determined with reference to the following scoring table of vegetation distribution for present state versus perceived reference state.

	Present state (P/S)			
Perceived Reference state (PRS)	Continuous	Clumped	Scattered	Sparse
Continuous	3	2	1	0
Clumped	2	3	2	1
Scattered	1	2	3	2
Sparse	0	1	2	3

PVC=[(EVC)-((exotic x 0.7) + (bare ground x 0.3)) = 0.7

Percentage vegetation cover (exotic):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %		X				
PVC Score	0	1	2	3	4	5

Percentage vegetation cover (bare ground):

	0%	1-5%	6-25%	26-50%	51-75%	76-100%
Vegetation cover %			X			
PVC Score	0	1	2	3	4	5

RIS

Extent of indigenous species recruitment	**0**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
				X		
RIS	**0**	**1**	**2**	**3**	**4**	**5**

VIS = [(EVC)+((SIxPVC)+(RIS))] = 6.4

The final VIS scores for each habitat unit are then categorised as follows:

Vegetation Index Score	Assessment Class	Description
22 to 25	**A**	Unmodified, natural
18 to 22	**B**	Largely natural with few modifications.
14 to 18	**C**	Moderately modified
10 to 14	**D**	Largely modified
5 to 10	**E**	The loss of natural habitat extensive
<5	**F**	Modified completely

APPENDIX D

Faunal species lists

Table A: Mammal species identified through sighting or other evidence within the study area with 2013 IUCN status. Species protected under the NCNCA (2009) and NEMBA (2004) are indicated with an X. Additional mammal species identified by Helme (2012) which may occur in the study area are indicated with an asterisk.

Scientific name	Common name	2013 IUCN Status	NCNCA (2009)	NEMBA (2004)
Cynictis penicillata	Yellow mongoose	LC	X	
Atilax paludinosus	Water mongoose	LC	X	
Procavia capensis	Rock hyrax	LC	X	
Felis silvestris cafra	Southern African Wild Cat	LC	X	
Rhabdomys pumilio	Striped Field Mouse	LC	X	
Cryptomys hottentotus	African mole rat	LC	X	
Otocyon megalotis	Bat eared fox	LC	X	X
Arctocephalus pusillus pusillus	Cape Fur Seal	LC	X	X
Sylvicapra grimmia	Common Duiker	LC	X	
Ocycteropus afer	Aardvark	LC	X	X
Tatera afra	Cape gerbil	LC	X	
Suricata suricatta	Suricate	LC	X	
Hystrix africaeaustralis	Cape porcupine	LC	X	
Raphicerus campestris	Steenbok	LC	X	
Lepus saxatilis	Scrub hare	LC	X	
Acomys subspinosus	Cape Spiny Mouse	LC	X	
*Gerbillurus paeba**	Hairy-footed Gerbil	LC	X	
*Vulpes chama**	Cape Fox	LC	X	X
*Canis mesomelas**	Blackbacked Jackal	LC		
*Genetta genetta**	Small Spotted Genet	LC	X	
*Ictonyx striatus**	Striped Polecat	LC	X	

LC = Least Concern. NYBA = Not yet been assessed for the IUCN Red List.

Table B: Avifauna species identified through sighting or call identification within the study area with 2013 IUCN status. Species protected under the NCNCA (2009) and NEMBA (2004) are indicated with an X.

Scientific name	Common name	2013 IUCN Status	NCNCA (2009)	NEMBA (2004)
Falco biarmicus	Lanner Falcon	LC	X	
Aquila verreauxii	Verreauxs Eagle	LC	X	
Elanus caeruleus	Black-winged Kite	LC	X	
Corvus albus	Pied crow	LC		
Lanius collaris	Common fiscal	LC	X	
Afrotis afra	Southern black korhaan	LC	X	
Sagittarius serpentarius	Secretary bird	VU	X	
Ploceus velatus	Southern masked weaver	LC		
Circaetus pectoralis	Black-chested snake eagle	LC	X	
Passer melanurus	Cape sparrow	LC		
Streptopelia capicola	Cape turtle dove	LC	X	
Serinus flaviventris	Yellow canary	LC		
Eupodotis vigorsii	Karoo Korhaan	LC	X	
Buteo rufofuscus	Jackal Buzzard	LC	X	

Scientific name	Common name	2013 IUCN Status	NCNCA (2009)	NEMBA (2004)
Nectarinia chalybea	Southern Double collared Sunbird	LC	X	
Melierax canorus	Pale chanting goshawk	LC	X	
Falco naumanni	Lesser Kestrel	LC	X	
Afrotis afra	Southern Black Korhaan	LC	X	
Certhilauda curvirostris	*Cape Long-billed Lark*	LC	X	
Recurvirostra avosetta	*Pied Avocet*	LC	X	
Circaetus pectoralis	*Black-chested Snake Eagle*	LC	X	
Elanus caeruleus	*Black-winged Kite*	LC	X	
Struthio camelus	Ostrich	LC	X	
Parus afer	Grey tit	LC	X	
Certhilauda albescens	Karoo lark	LC	X	
Myrmecocichla formicivora	Southern Ant-eating Chat	LC	X	
Oenanthe pileata	Capped Wheatear	LC	X	
Eremopterix australis	Black eared sparrow lark	LC	X	
Serinus albogularis	White-throated Canary	LC	X	
Sigelus silens	Fiscal flycatcher	LC	X	
Batis capensis	Cape batis	LC	X	
Saxicola torquatus	African stone chat	LC	X	
Bubo capensis	Cape Eagle Owl	LC	X	
Cisticola subruficapilla	Grey Backed Cisticola	LC	X	
Cercotrichas coryphaeus	Karoo Scrub Robin	LC	X	
Emberiza impetuani	Lark like Bunting	LC	X	
Actitis hypoleucos	Common Sandpiper	LC	X	
Sterna bergii	Swift Tern	LC	X	X
Larus hartlaubii	Hartlaubs Gull	LC	X	X
Larus vetula	Cape Gull	LC		
Sterna hirundo	Common Tern	LC	X	
Mirafra apiata	Cape Clapper Lark	LC	X	
Telophorus zeylonus	Bokmakierie Bush Shrike	LC	X	
Numida meleagris	Helmeted Guineafowl	LC	X	
UpUpa africana	African Hoopoe	LC	X	
Cinnyris fuscus	Dusky Sunbird	LC	X	
Bostrychia hagedash	Hadeda Ibis	LC	X	
Prinia maculosa	Karoo Prinia	LC	X	
Malcorus pectoralis	Rufous-eared Warbler	LC	X	
Motacilla capensis	Cape wagtail	LC	X	

LC = Least Concern. NYBA = Not yet been assessed for the IUCN Red List.

Table C: Reptile species list within the study area for the summer and winter surveys with 2013 IUCN status. Species protected under the NCNCA (2009) and NEMBA (2004) are indicated with an X.

Scientific name	Common name	2013 IUCN Status	NCNCA (2009)	NEMBA (2004)
Chersina angulata	Angulate tortoise	NYBA		
Agama atra	Southern rock agama	NYBA		
Cordylus polyzonus	Karoo girdled lizard	NYBA	X	
Cordylus niger	Black girdled lizard	NYBA	X	
Naja nivea	*Cape Cobra*	NYBA		
Bitis arietans	*Puff Adder*	NYBA		
Gerrhosaurus typicus	*Namaqua Plated Lizard*	NT		
Causus rhombeatus	*Night Adder*	NYBA		
Homopus signatus.	*Padloper Tortoise*	NT	X	X

VU = Vulnerable, EN = Endangered, NT = Near threatened. NYBA = not yet been assessed according to the IUCN Red List, 2013.

Table D: Invertebrate, scorpion and spider species identified through sighting or other evidence within the study area during 2013 survey periods with 2013 IUCN status.

Scientific name	Common name	2013 IUCN Status
	Invertebrates	
Apis mellifera capensis	Cape Honeybee	NYBA
Psammodes bertolonii	Toktokkie	NYBA
Microhodotermes viator	Southern harvester termites	NYBA
Fucellia capensis	Kelp flies	NYBA
Systoechus sp	Bee fly	NYBA
Messor capensis	Harvester ants	NYBA
Meloe angulatus	Oil beetle	NYBA
Scarabaeus rugosus	Green grooved dung beetle	NYBA
Hoplolopha sp	Saw backed locust	NYBA
Lepisiota capensis	Small Black Sugar Ants	NYBA
Tachypompilus ignites	Spider hunting wasp	NYBA
Synhoria hottentotta	Carpenter bee blister beetle	NYBA
Camponotus fulvopilosus	Balbyter Ant	NYBA
Acanthoplus discoidalis	Corn cricket	NYBA
Psammotermes allocerus	Desert termite	NYBA
Stenocara dentata	Long legged Darkling beetle	NYBA
Archispirostreptus gigas	African millipede	NYBA
Theba pisana	Mediterranean coastal snail	NYBA
Scantius forstrei	Red Bug	NYBA
Phymateus morbillosus	Common Milkweed Locust	NYBA
Hoplocorypha macra	Light build mantids	NYBA
	Scorpions and Spiders	
Stegodyphus sp	Community nest spiders	NYBA
Angelena sp	Funnel web spiders	NYBA
Capheris sp	Burrowing spider	NYBA

LC = Least Concern. NYBA = Not yet been assessed for the IUCN Red List.

APPENDIX E

Maps

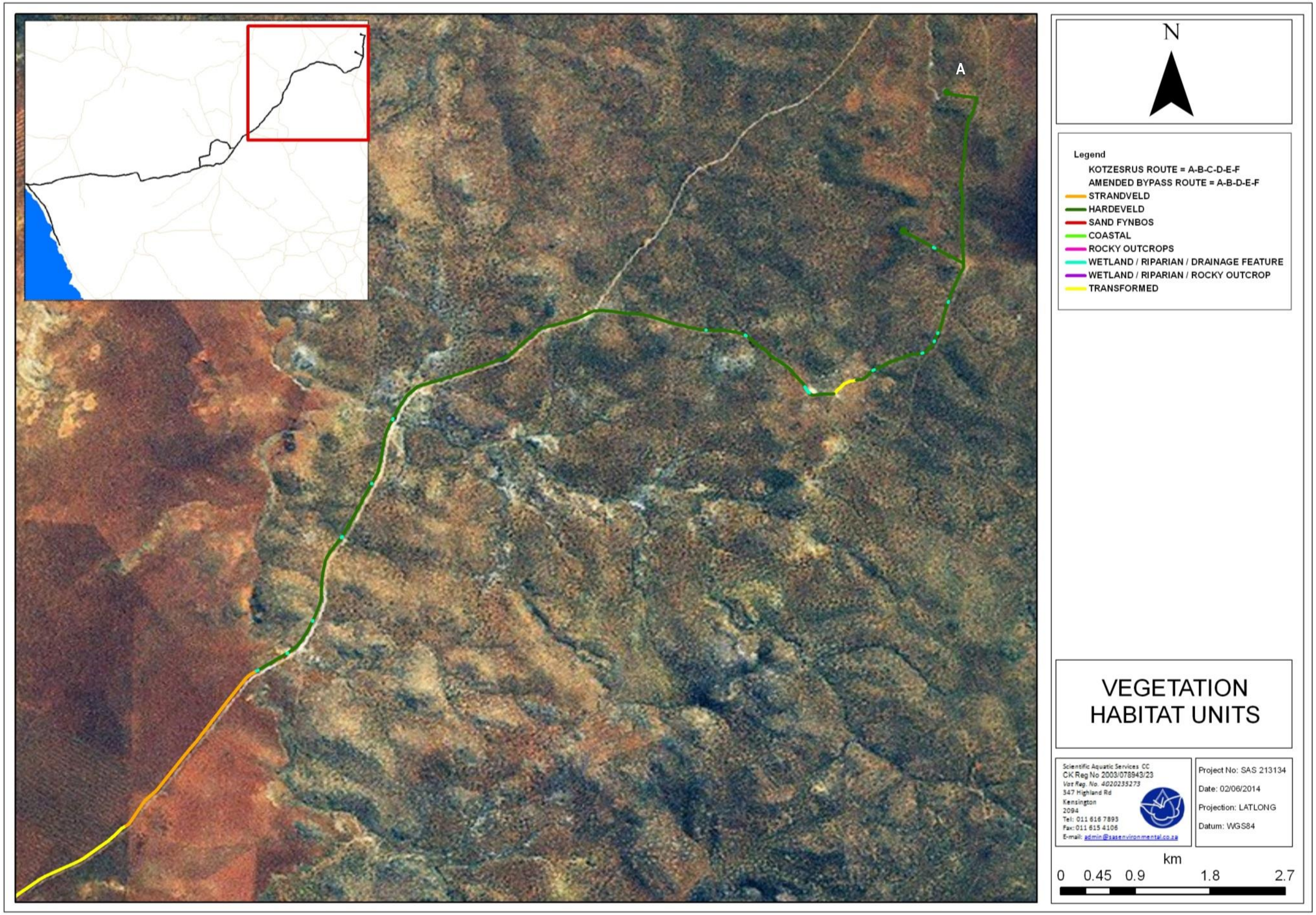

Figure A: Vegetation habitat units associated with the study area (east)

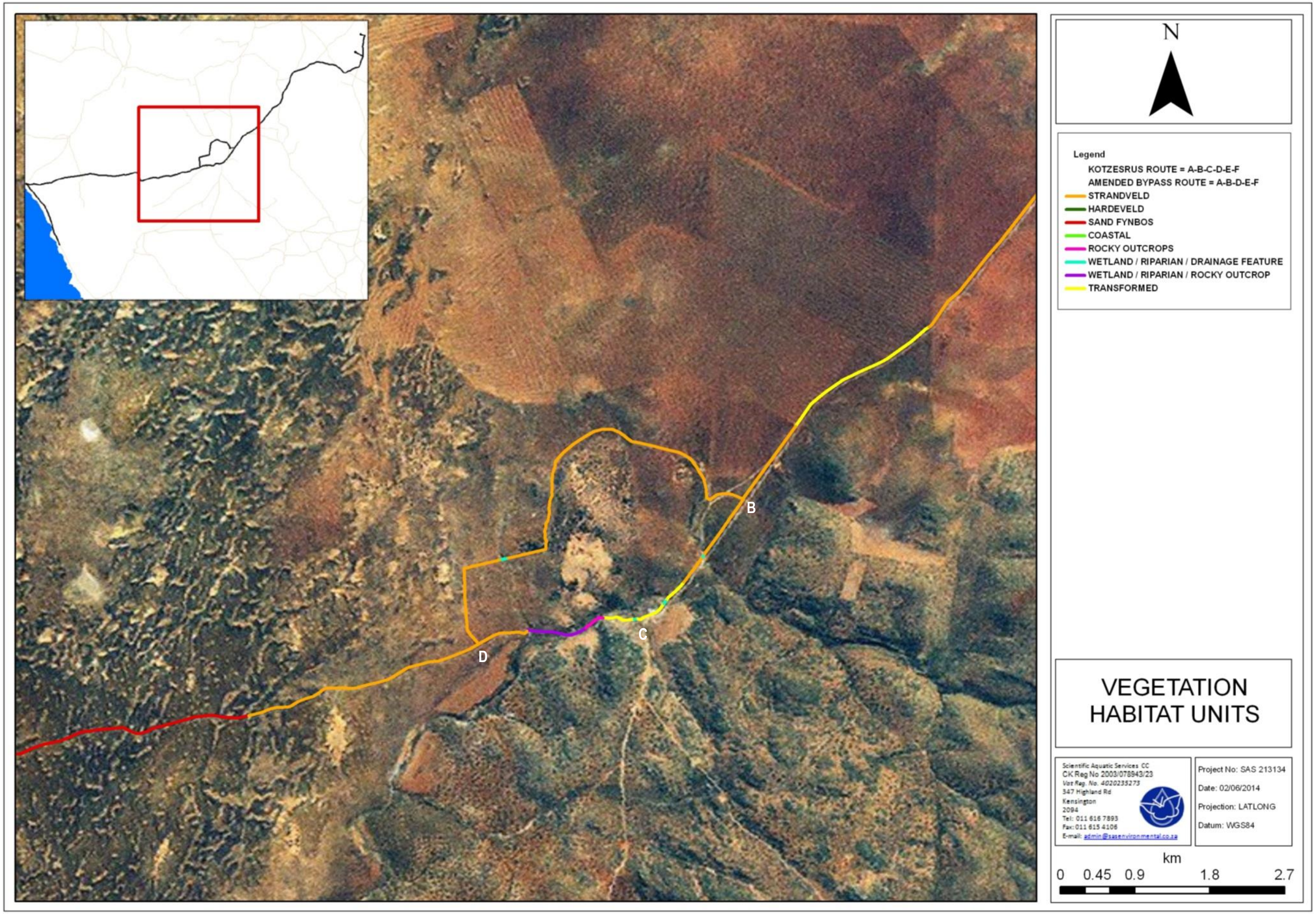

Figure B: Vegetation habitat units associated with the study area (centre)

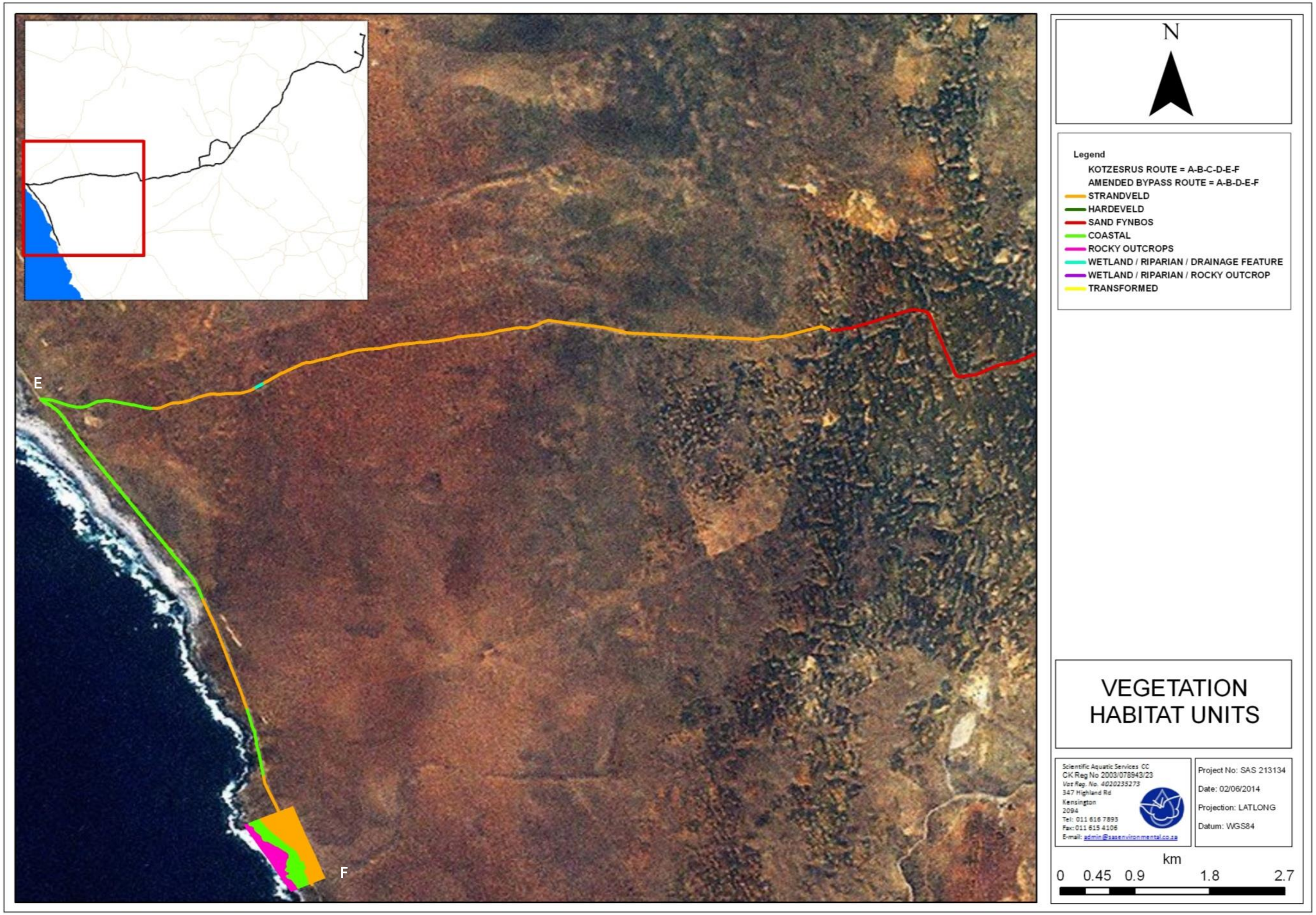

Figure C: Vegetation habitat units associated with the study area (west)

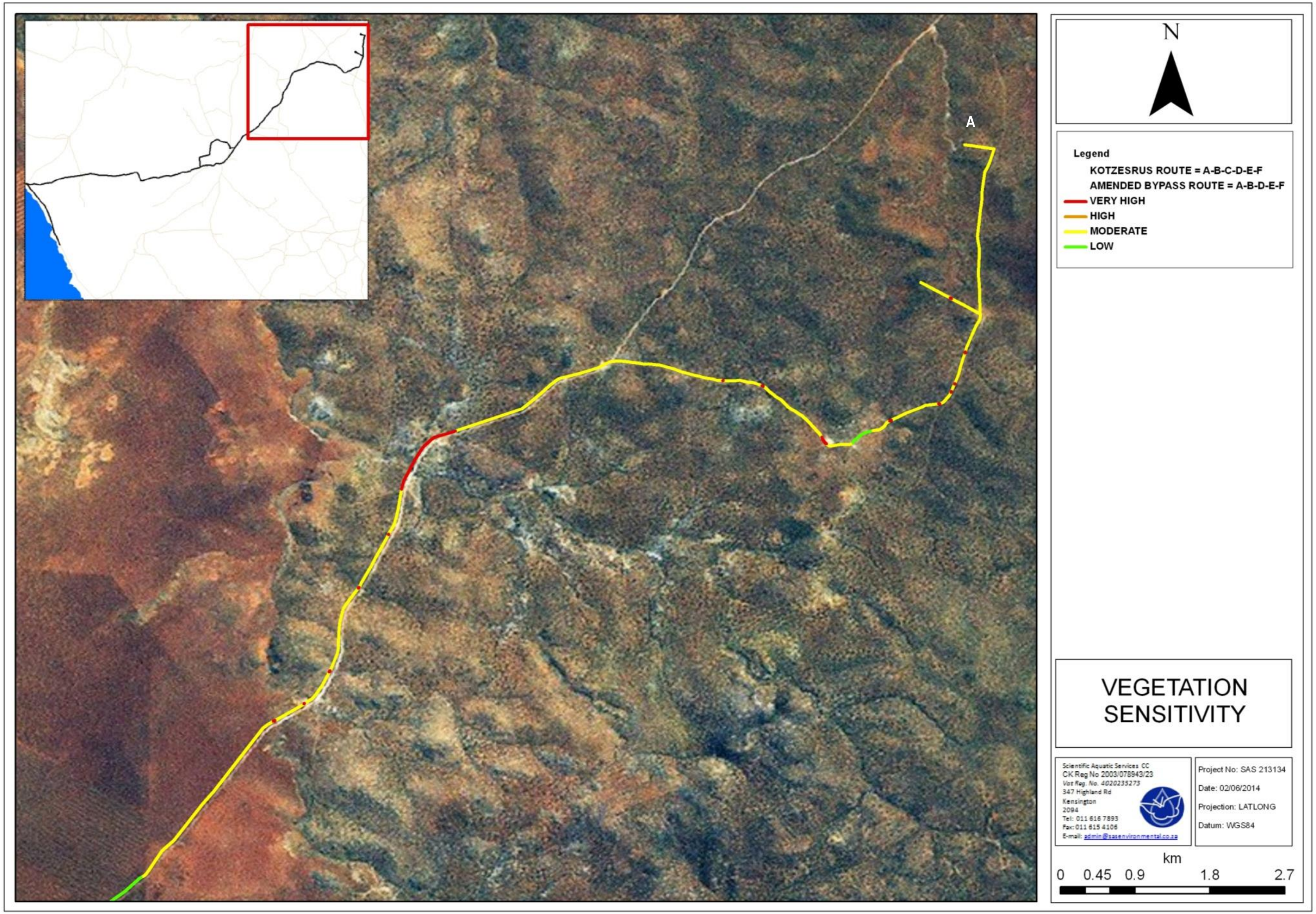

Figure D: Vegetation sensitivity associated with the study area (east)

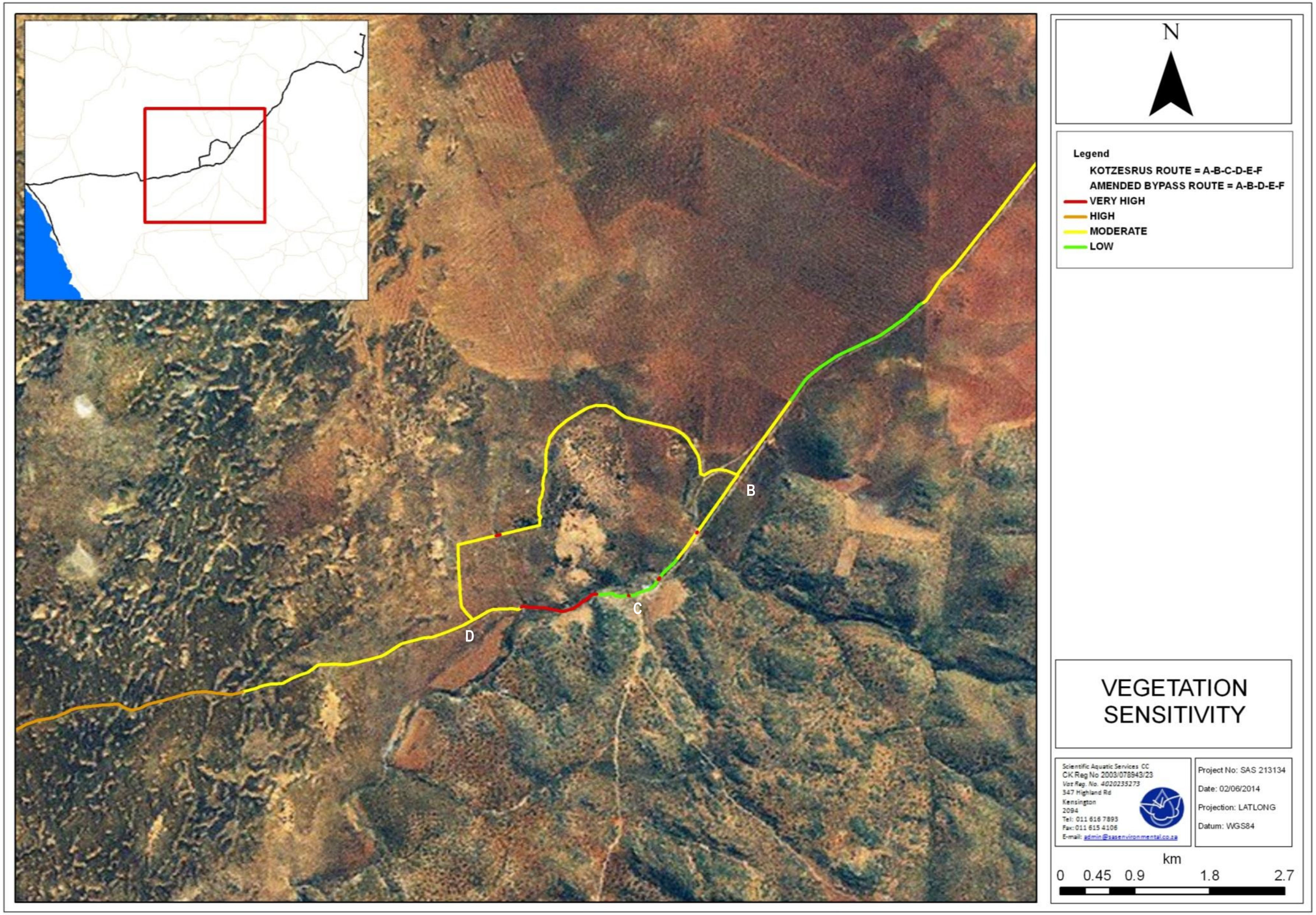

Figure E: Vegetation sensitivity associated with the study area (centre)

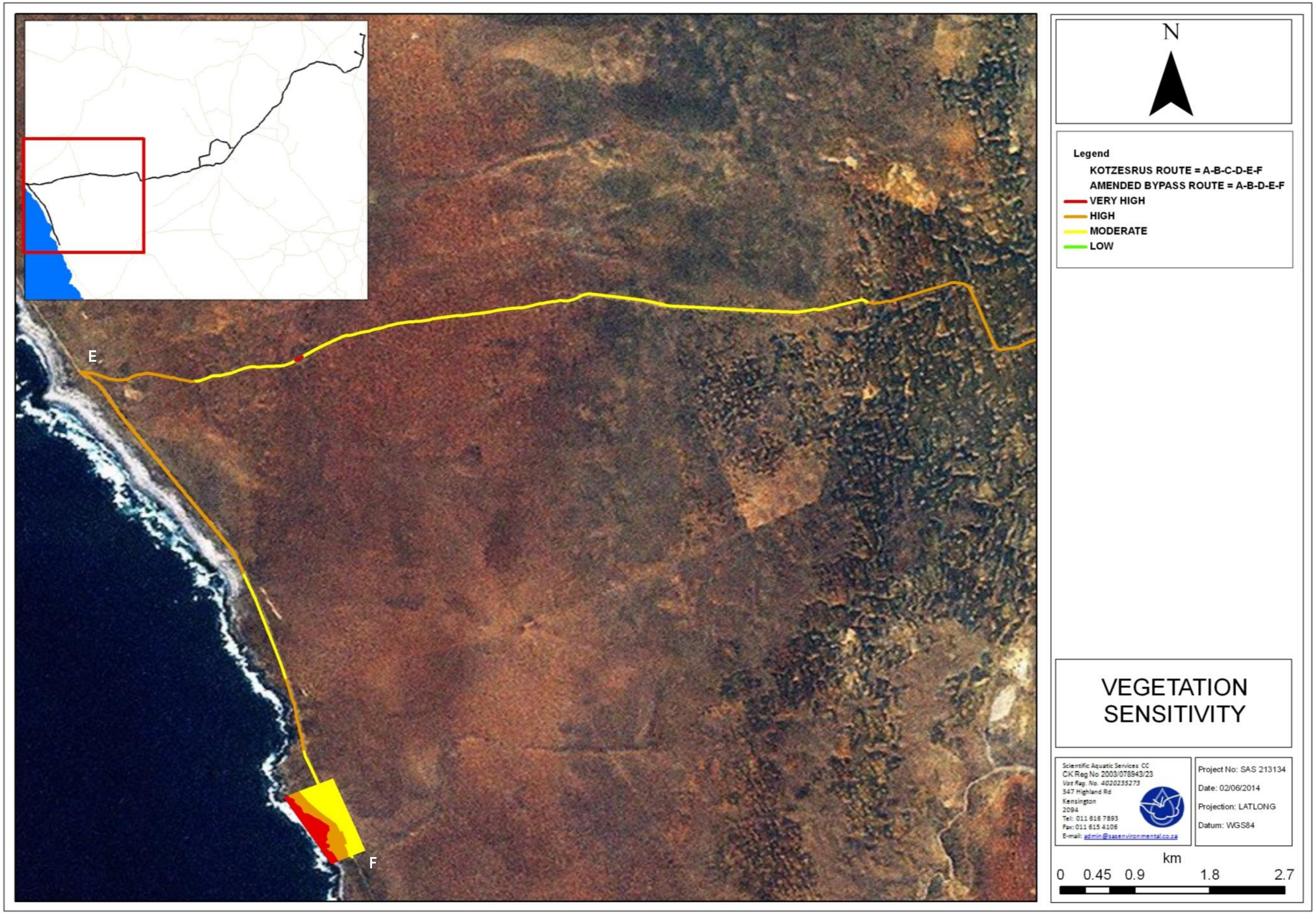

Figure F: Vegetation sensitivity associated with the study area (west)

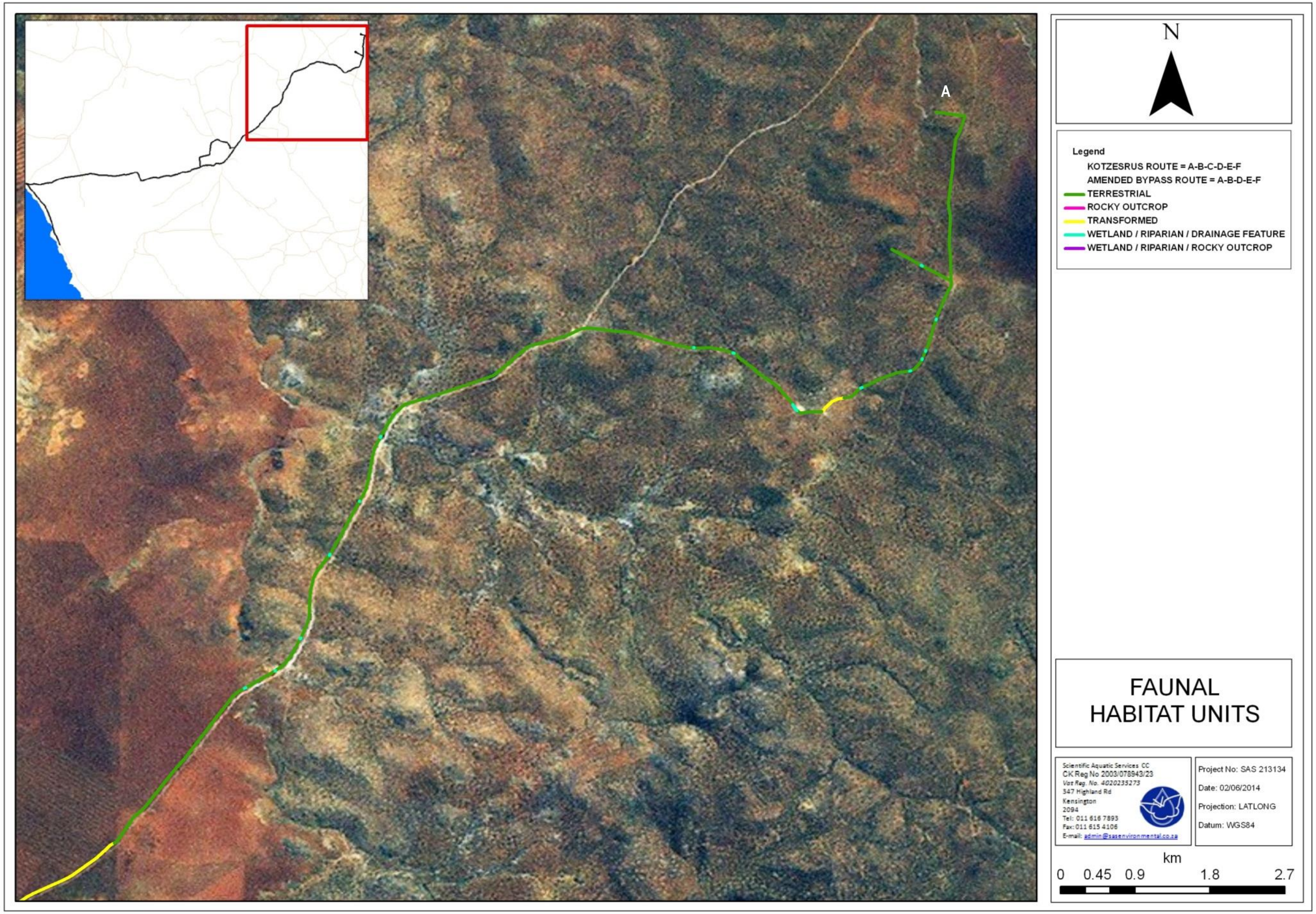

Figure H: Faunal habitat units associated with the study area (east)

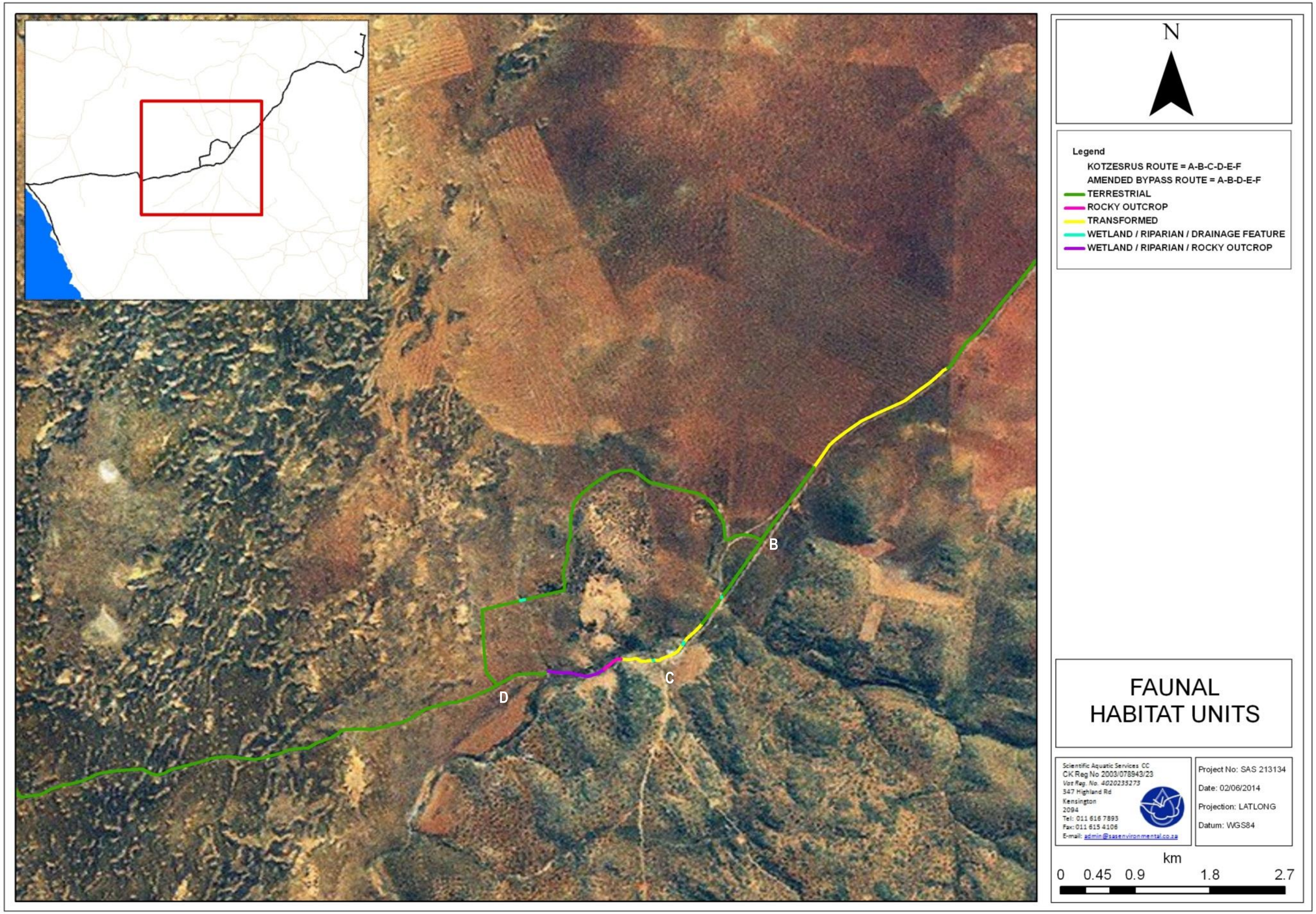

Figure I: Faunal habitat units associated with the study area (centre)

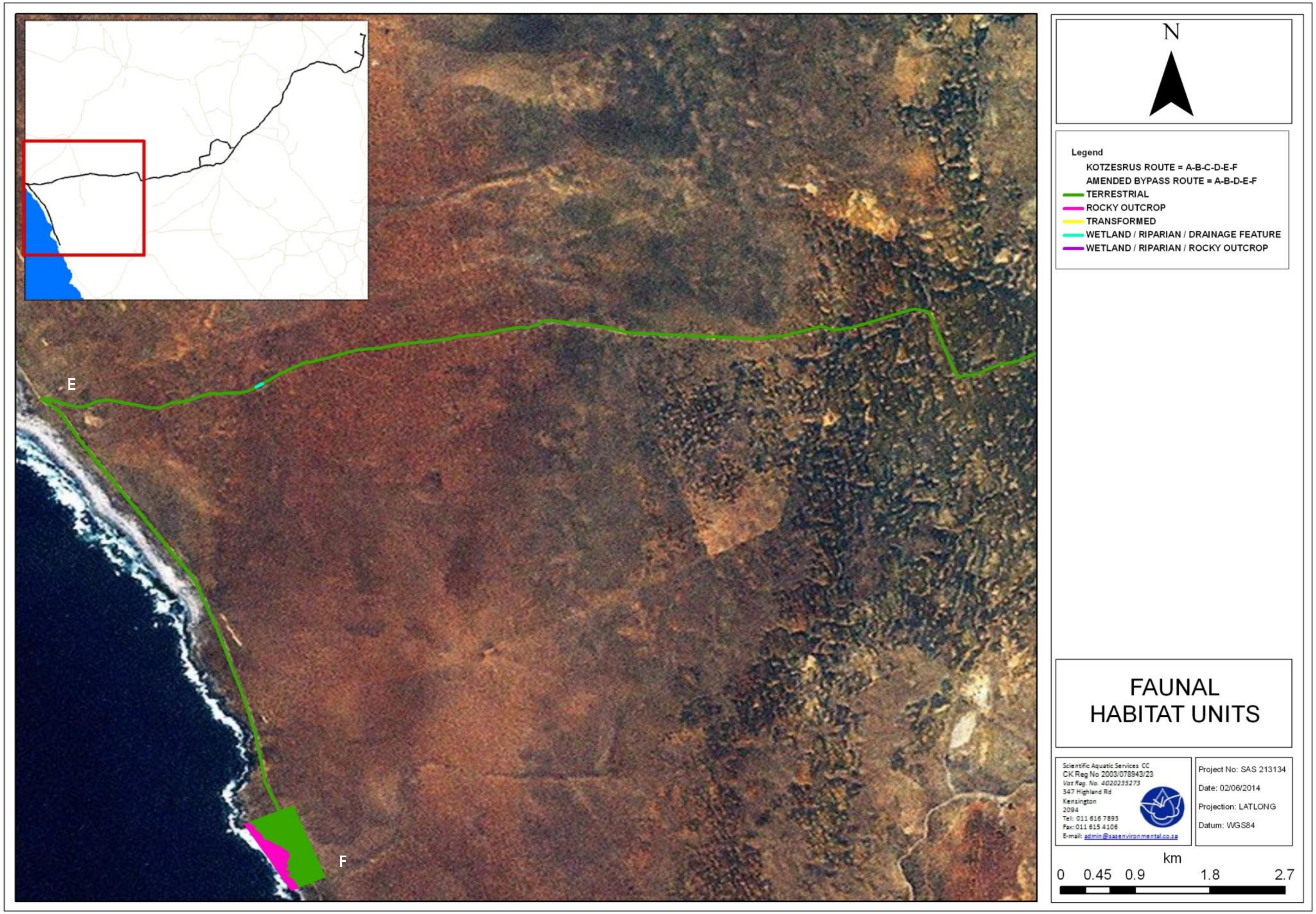

Figure J: Faunal habitat units associated with the study area (west)

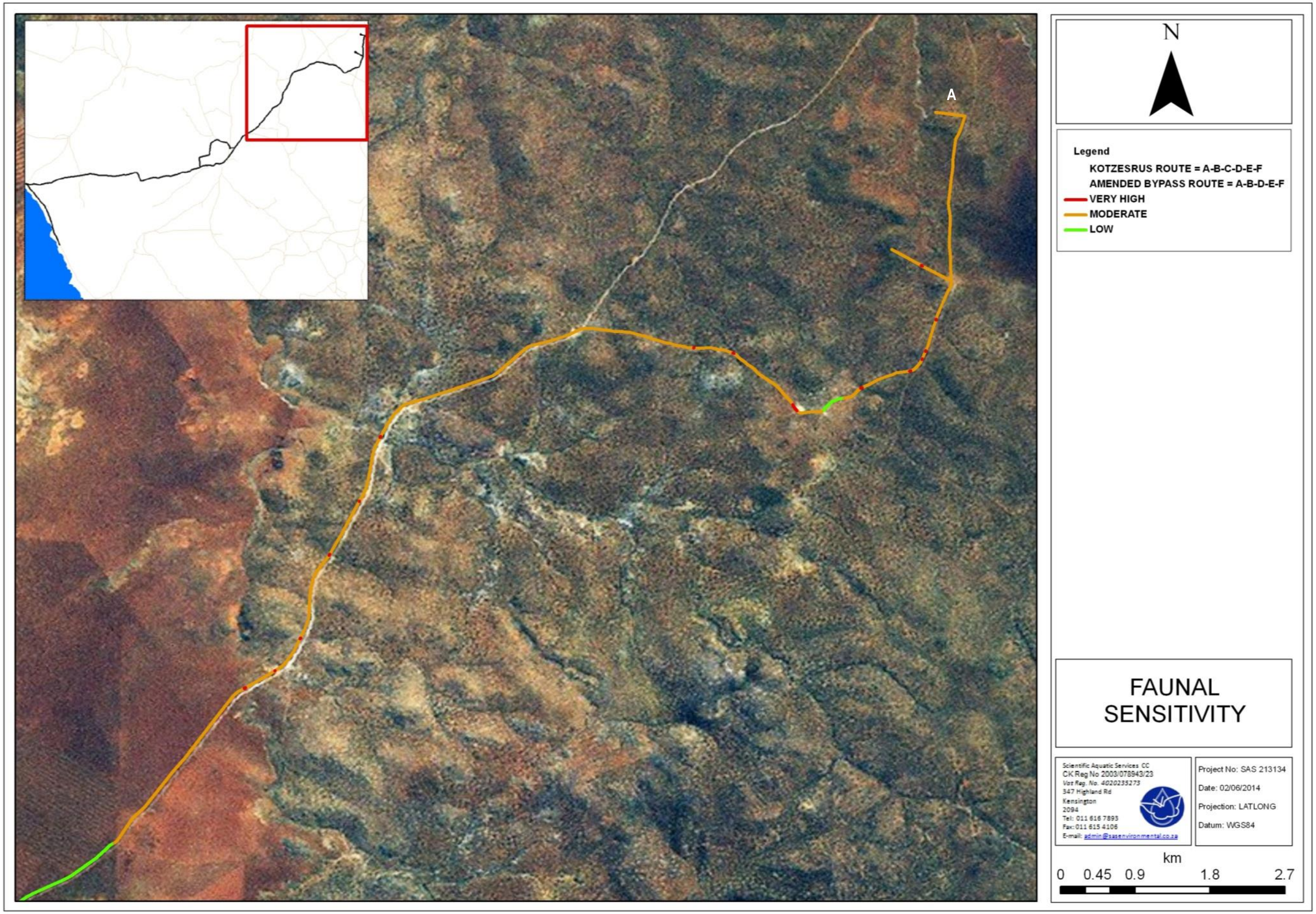

Figure K: Faunal sensitivity associated with the study area (east)

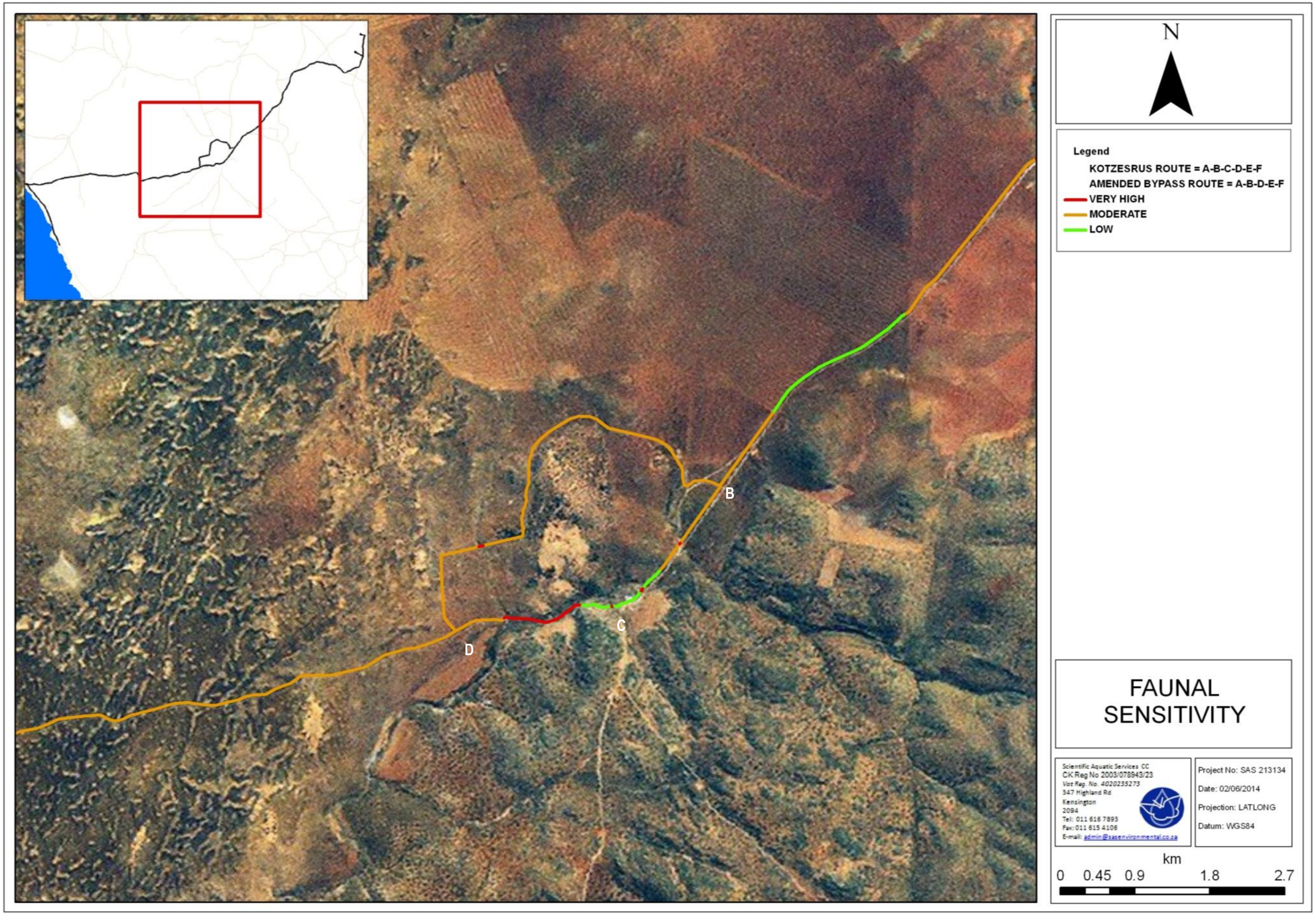

Figure L: Faunal sensitivity associated with the study area (centre)

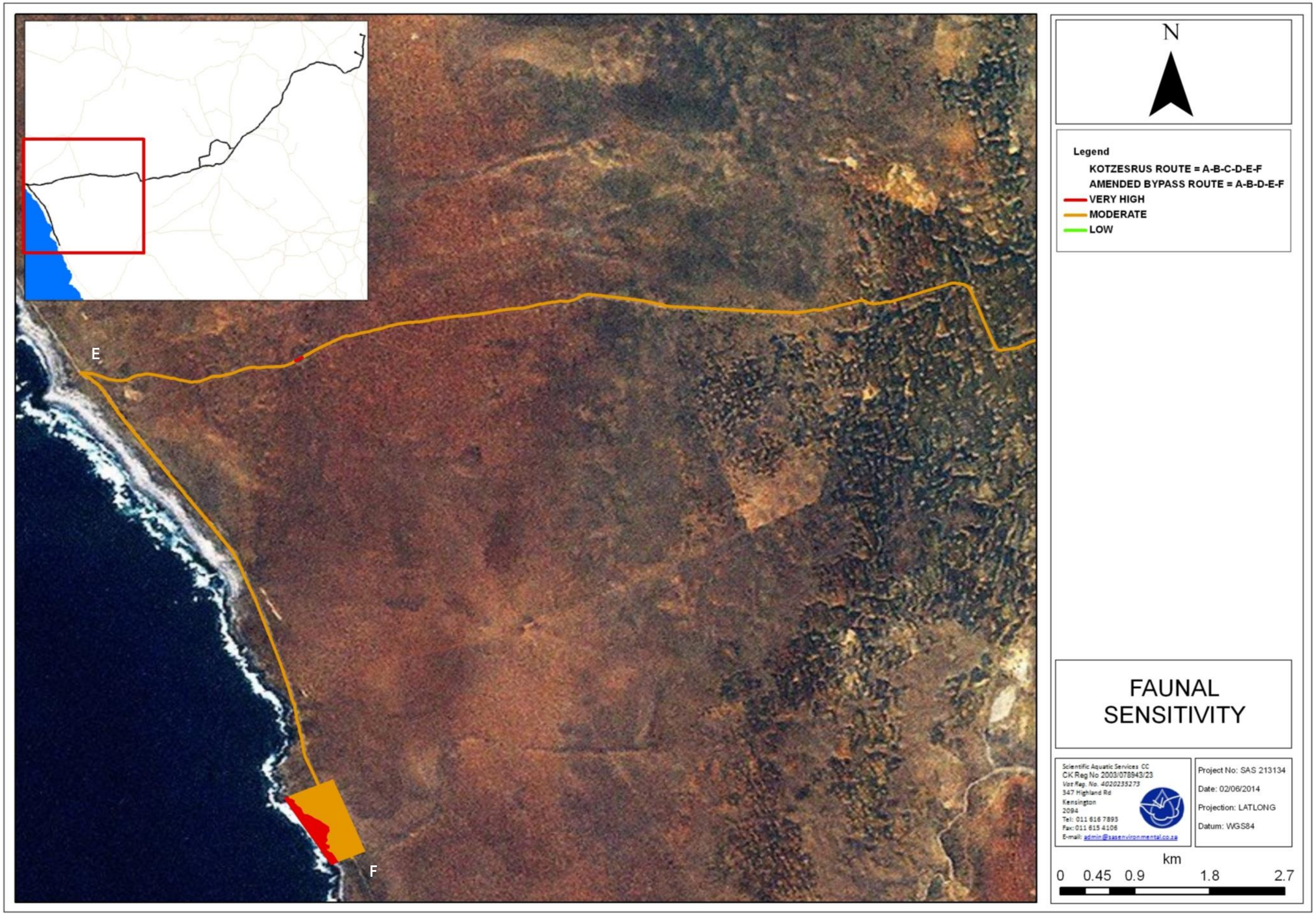

Figure M: Faunal sensitivity associated with the study area (west)

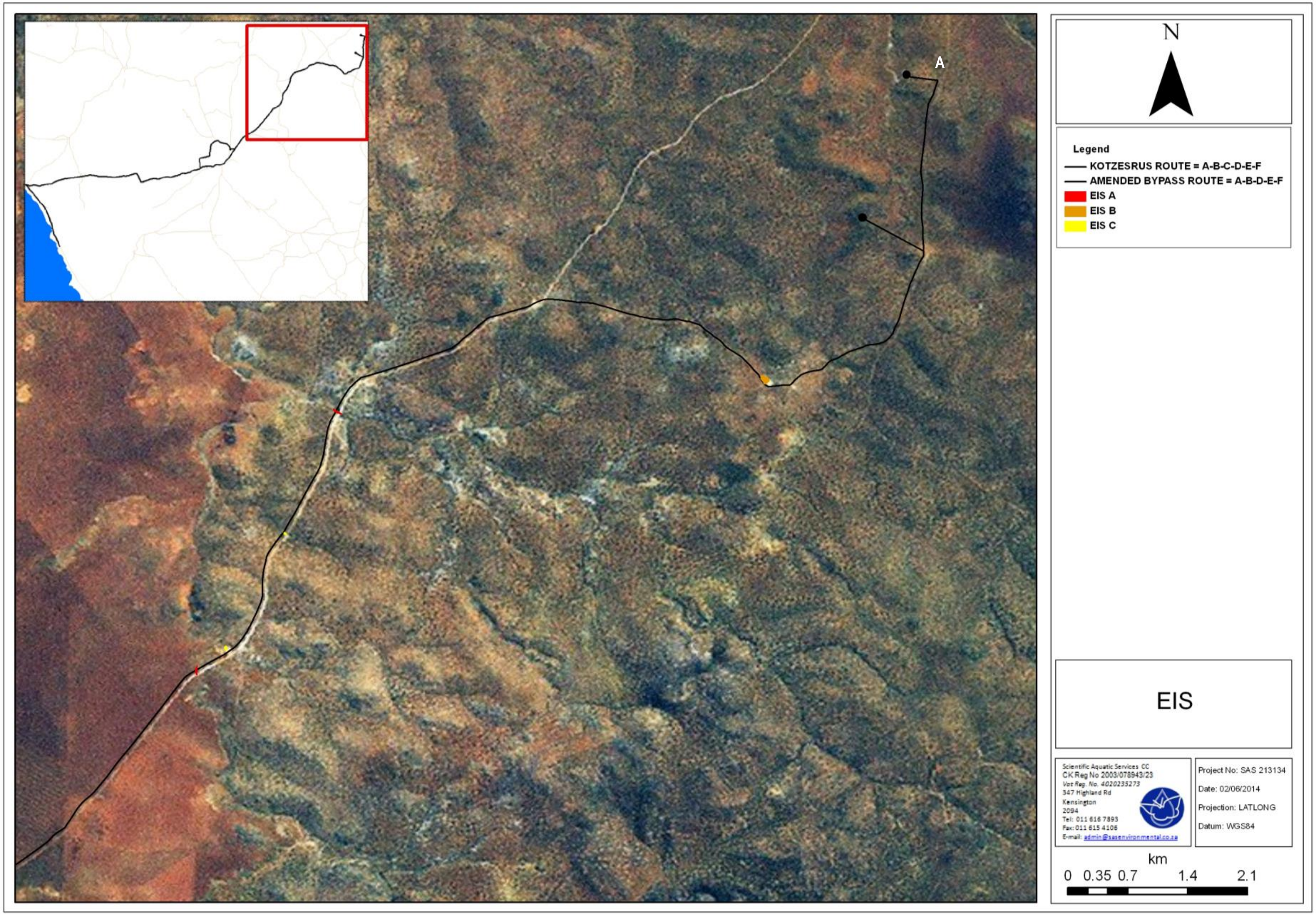

Figure N: EIS map (east)

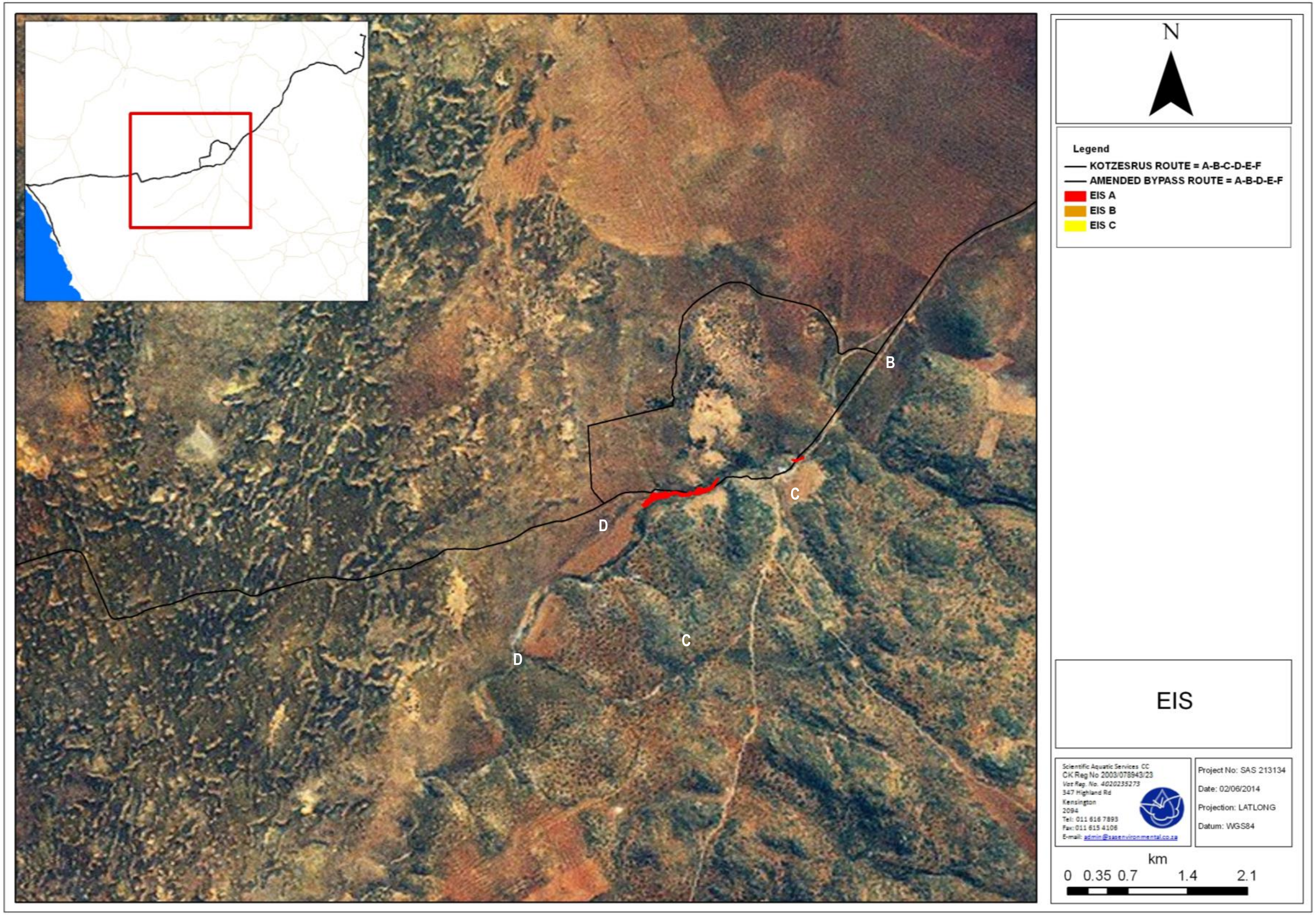

Figure O: EIS map (centre)

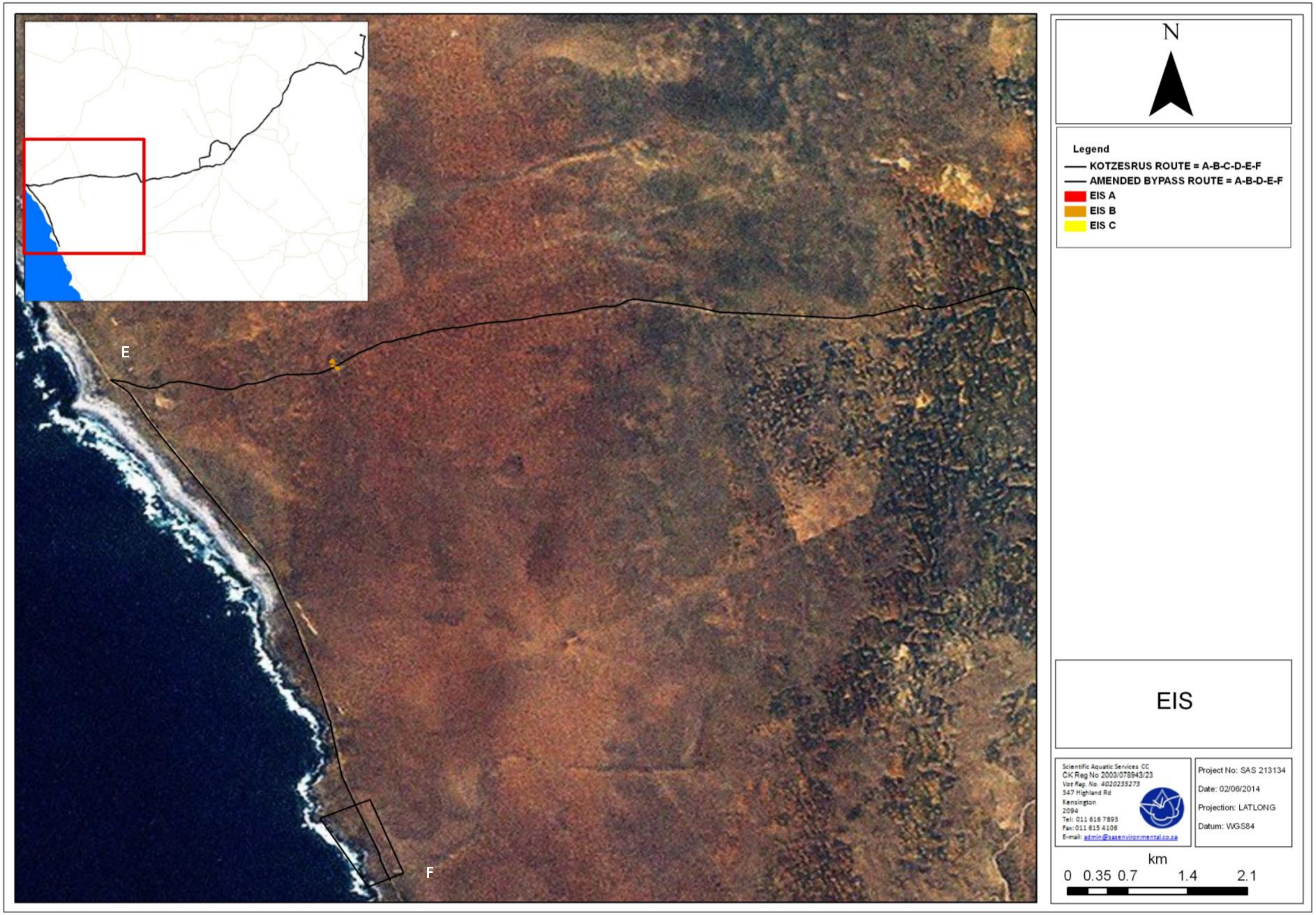

Figure P: EIS map (west)

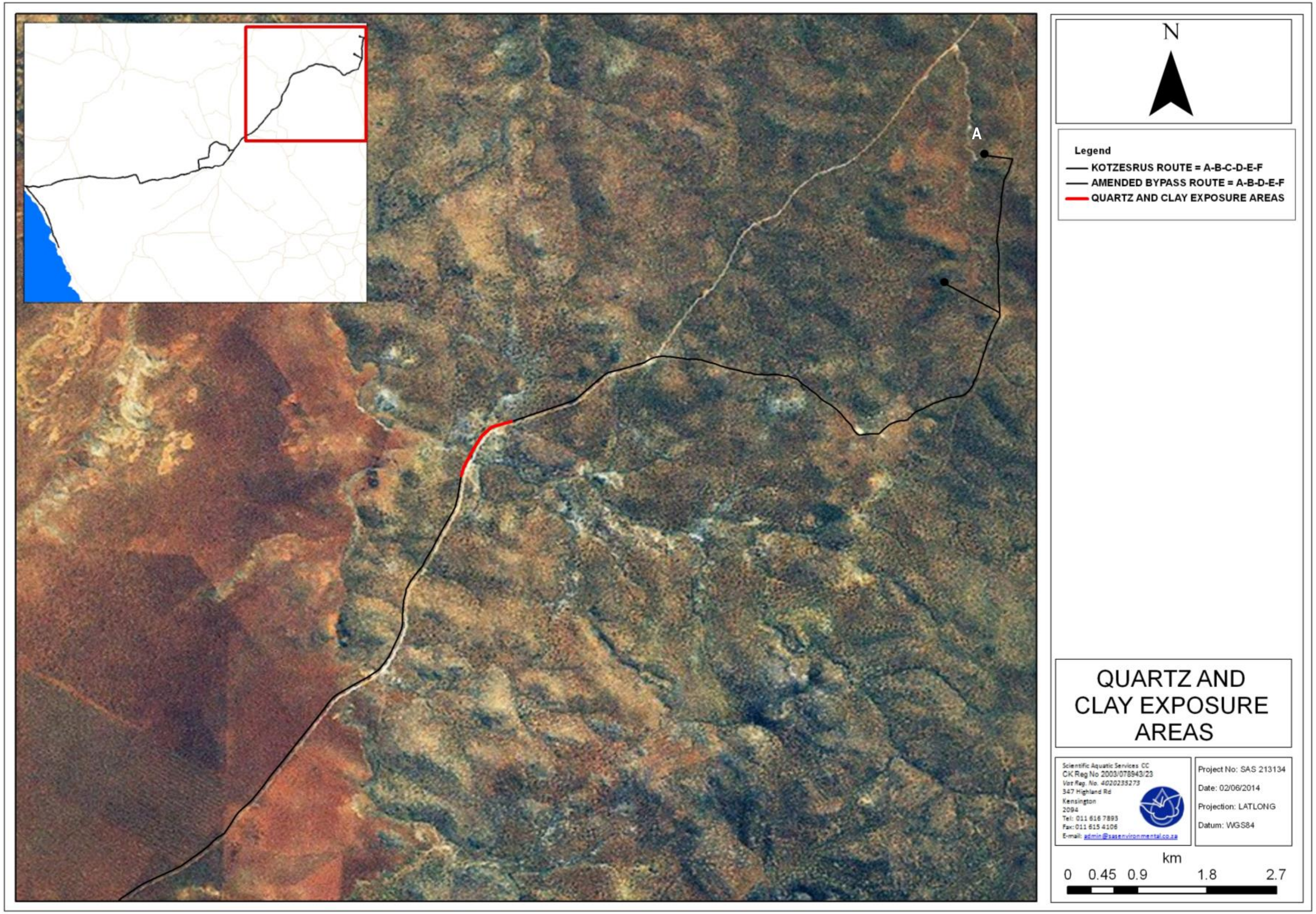

Figure Q: Location of quartz and clay exposure areas along the proposed route.

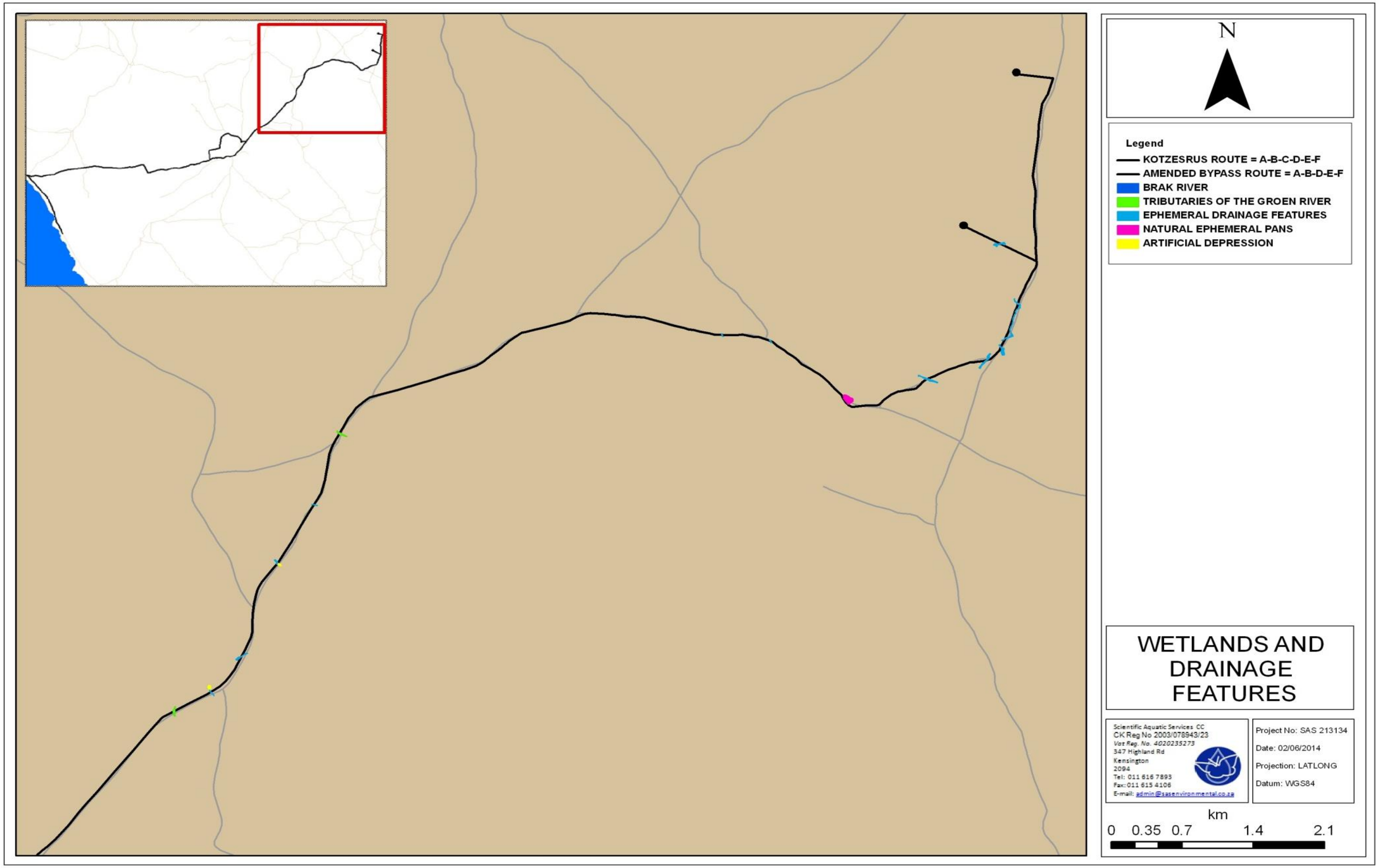

Figure R: Wetlands and drainage features (east).

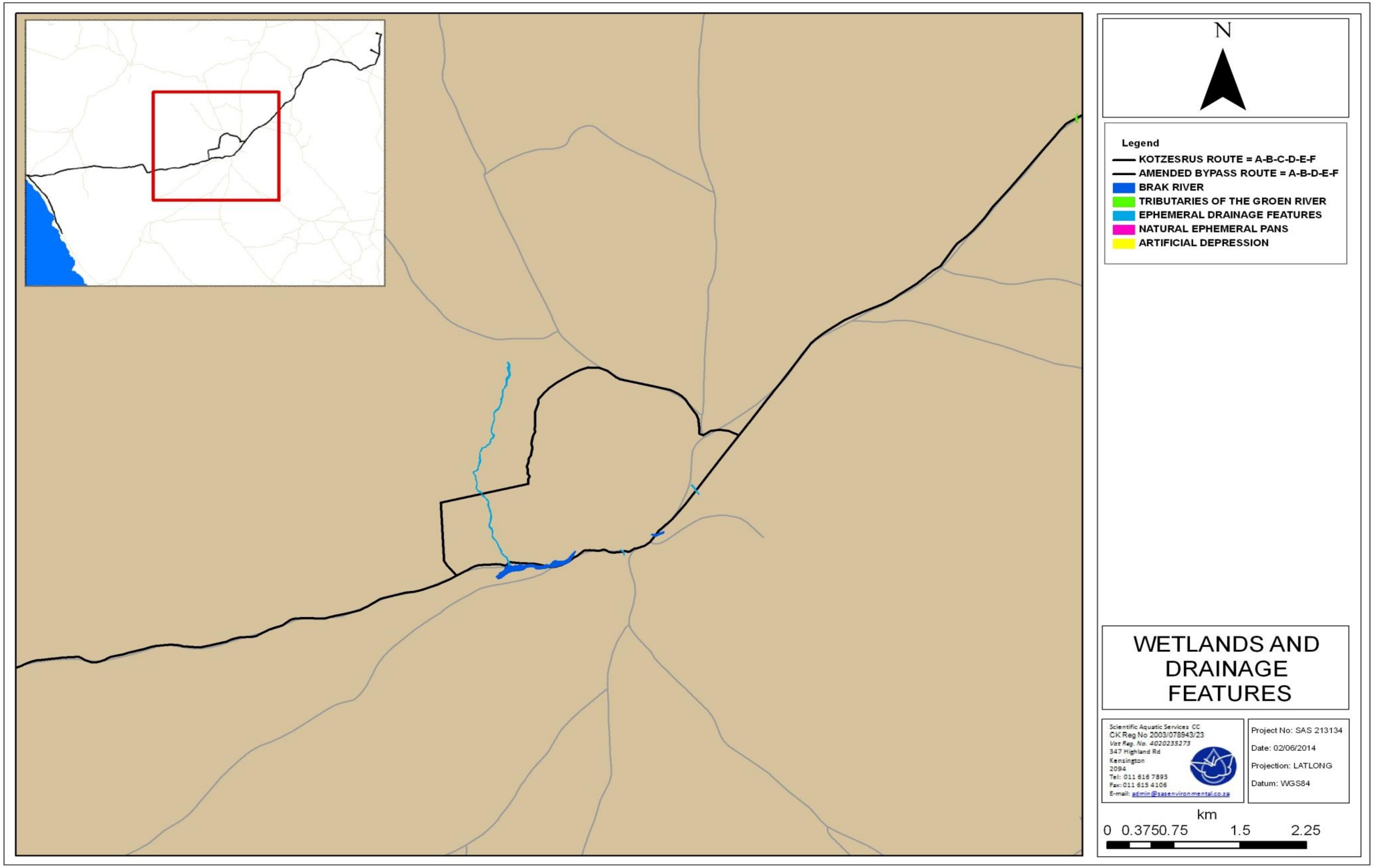

Figure S: Wetlands and drainage features (centre).

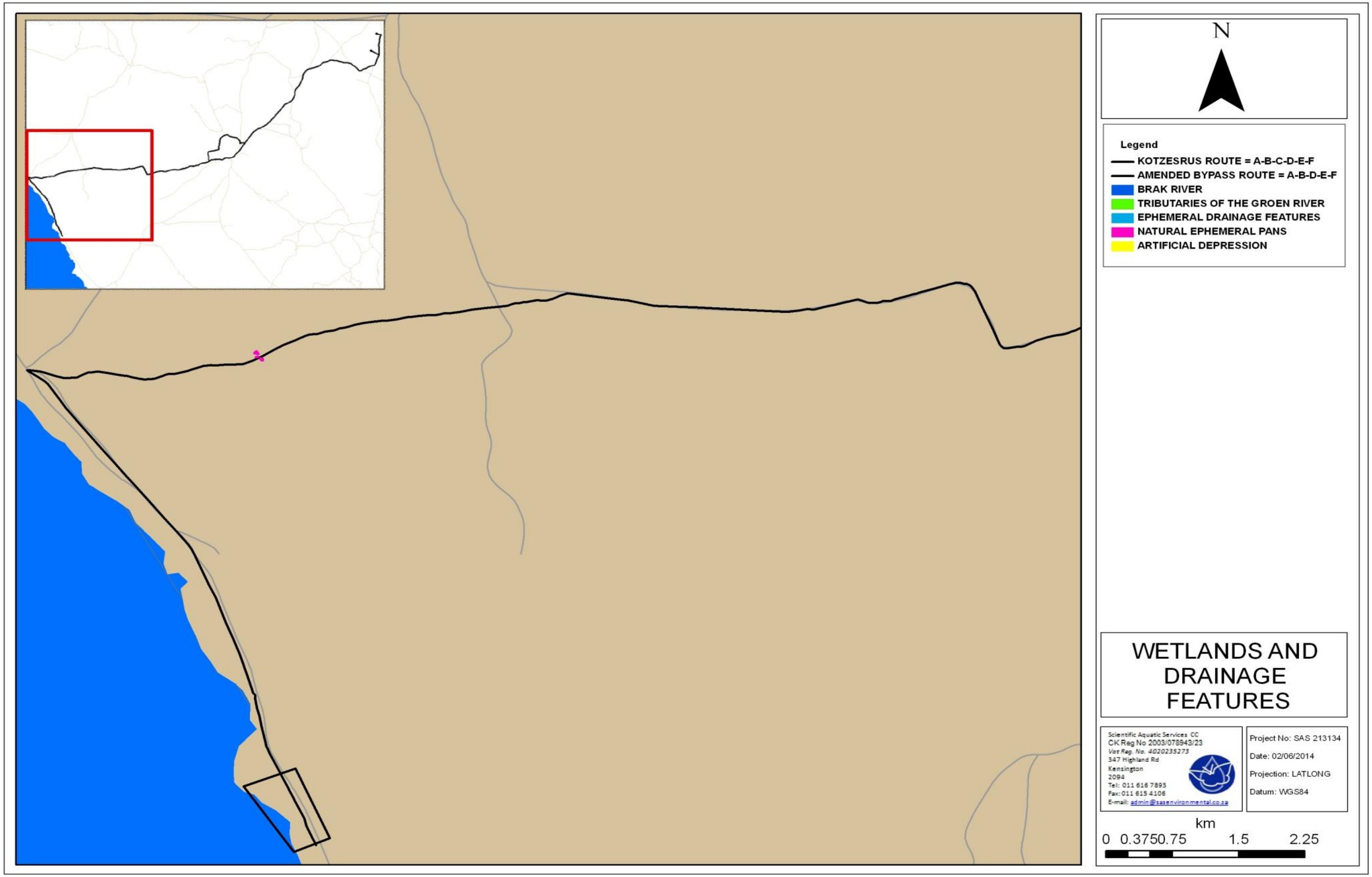

Figure T: Wetlands and drainage features (west).

APPENDIX F

General Good Housekeeping Measures

The list below provides an indication of the general good housekeeping mitigation measures that must be adhered to in order to avoid or reduce general impacts:

Construction Phase

- The boundaries of construction footprint areas are to be clearly defined and it should be ensured that all activities remain within defined footprint areas;
- Wetlands/watercourses falling outside of the construction footprint must be strictly off-limits to construction personnel and vehicles;
- Restrict vehicles to travelling only on designated roadways Do not allow vehicles to indiscriminately drive through open veld areas;
- Implement waste management as contemplated in the Environmental Management Programme;
- Provide appropriate sanitation facilities for the duration of the proposed construction activities and remove all waste to an appropriate facility;
- No dumping of spoil material or waste should take place within high or very high sensitivity habitat units;
- Avoid any discharge of effluents or polluted water into wetlands/watercourses;
- Avoid washing of vehicles or machinery within 50m of wetlands/watercourses;
- Ensure that all areas containing hazardous waste are bunded to ensure that no oil or other waste material contaminate the soils, groundwater or surface water of surrounding wetlands/watercourses;
- Regularly inspect all construction vehicles for leaks;
- Carry out all servicing and refuelling of construction vehicles on a concrete platform with runoff traps and containment. If refuelling takes place in the field use drip trays at all times;
- Treat contaminated soils with appropriate product;
- Remove and appropriately dispose of any contaminated soil and water to a designated dump site as rapidly as possible following contamination;
- Remove all waste, with special mention of waste rock and spoils and remaining construction material from the site on completion of the project;
- Reduce airborne dust at construction sites through:
  - Damping dust generation areas with freshwater;
  - Use of cloth or brush barrier fences;
  - Covering dumps or stockpiles with plastic sheets; and
  - Apply appropriate measures on all dirt roads that service the construction site.
- Do not allow fires for heating and cooking.

Operational Phase

- Limit the footprint area of the maintenance activity to what is absolutely essential in order to minimise environmental damage;
- Wetlands/watercourses falling outside of the maintenance footprint must be strictly off-limits to construction personnel and vehicles;
- Restrict vehicles to travelling only on designated roadways Do not allow vehicles to indiscriminately drive through open veld areas;
- Implement waste management as contemplated in the Environmental Management Programme;
- Provide appropriate sanitation facilities for the duration of the proposed operational activities and remove all waste to an appropriate facility;
- No dumping of waste should take place;
- Avoid any discharge of effluents or polluted water into wetlands/watercourses;
- Avoid washing of vehicles or machinery within 50m of wetlands/watercourses;

- Ensure that all areas containing hazardous waste are bunded to ensure that no oil or other waste material contaminate the soils, groundwater or surface water of surrounding wetlands/watercourses;
- Regularly inspect all operational vehicles for leaks;
- Carry out all servicing and refuelling of operational vehicles on a concrete platform with runoff traps and containment. If refuelling takes place in the field use drip trays at all times;
- Treat contaminated soils with appropriate product;
- Remove and appropriately dispose of any contaminated soil and water to a designated dump site as rapidly as possible following contamination;
- Do not allow fires for heating and cooking.

APPENDIX G

Specialist botanical input to routing of proposed pipeline in area north of Kotzesrus (Helme, 2014).

Available on request

Appendix 4B Marine and Coastal Ecology Impact Assessment

Marine Environmental Impact Assessment for the Seawater Intake Structure and Brine Disposal System of the Proposed Desalination Plant at Volwaterbaai

Prepared for

SRK Consulting (South Africa)(Pty) Ltd

On behalf of

Sedex Desalination (Pty) Ltd

Prepared by

Andrea Pulfrich and Nina Steffani

July 2014

PISCES Environmental Services (Pty) Ltd

Steffani Marine Environmental Consultant

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EXECUTIVE SUMMARY

Sedex Desalination (Pty) Ltd (Sedex Desalination) intends to establish a Sea Water Reverse Osmosis (SWRO) desalination plant with an output capacity of 8 Mm^3/yr on the farm Strandfontein 559 in the Northern Cape, to supply demineralised water via a transfer pipe to the proposed Zandkopsdrift Mine by Sedex Minerals (Pty) Ltd (Sedex Minerals).. Associated with the plant will be a seawater intake structure designed for a maximum of 60 Mm^3/day, and a brine disposal system through which 36.5 Mm^3/day of brine will be discharged back into the sea.

The proposed desalination plant project consists of the following marine components:

- seawater abstraction infrastructure comprising an intake basin, with associated screens and grids and suction inlets installed below the high water mark, and
- a pipeline for disposal of brine into the sea.

As the intake is an open channel intake, there will be a need for extensive pre-treatment of intake water, including the installation of screens, coagulation and flocculation, as well shock-dosing using a chlorine-based biocide to eliminate biological growth in the system. Residual chlorine will be neutralised with sodium metabisulphite before the feedwater passes through the reverse osmosis membranes. The resultant hypersaline brine will be discharged through a pipeline into a gully in the surf-zone.

To quantify the extent, magnitude and duration of impacts associated with the proposed project as part of the marine environmental impact assessment, a description of the baseline environment is provided. Physical components considered include seabed topography, bathymetry and sediments at the study site, a description of the regional waves, tides, currents, water masses and temperature, turbidity and organic inputs. Natural disturbances such as low oxygen events are also covered. Communities occurring on rocky and sandy intertidal and subtidal habitats and within the water column are described, focussing particularly on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the proposed project. Current uses of the marine and coastal environment are mapped and existing environmental impacts are covered.

Following the presentation of the baseline environment, potential issues associated with the proposed project are outlined. Issues were identified both for the construction and the operational phases of the project.

Potential impacts associated with the construction phase are:

- Temporary loss of benthic habitat and associated communities due to laying of the pipeline;
- Short-term impacts on habitat health due to turbidity generated during construction and subsequent deposition of sediments;
- Temporary disturbance of marine biota due to construction activities (especially blasting);
- Impacts to marine water quality and sediments through hydrocarbon pollution by marine construction infrastructure and plant; and
- Contamination of marine waters and sediments by inappropriate disposal of waste materials.

Potential issues associated with the operational phase are:

- Altered flows at the intake and discharge (e.g. entrainment and impingement of biota at the intake, flow distortion/changes at the discharge, and affects on natural sediment dynamics);
- Habitat health impacts/losses resulting from elevated salinity at the brine discharge;
- Discharged effluent potentially having a higher temperature than the receiving environment;
- Biocidal action of residual chlorine in the effluent;
- The effects of co-discharged constituents in the waste-water;
- The removal of particulate matter from the water column where it is a significant food source, as well as changes in phytoplankton production due to changes in nutrients, reduction in light, water column structure and mixing processes, and associated indirect changes in oxygen concentration; and

- Direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent.

A hydrodynamic and water quality model was developed using local wind, wave and atmospheric data. Results of the model provided information on the predicted plume dimensions at the sea surface and near the seabed for a discharge with elevated salinity and the achievable dilutions for antiscalants and other co-discharges.

The modelling results were subsequently used to assess the magnitude, extent and duration of the identified potential impacts associated with the discharge on marine communities in the area.

No impacts of high significance were identified.

One negative impacts of medium significance (before mitigation) associated with the construction phase was identified:

- Disturbance and destruction of intertidal beach macrofauna during pipeline construction as a result of vehicular traffic and excavations.

Five negative impacts of medium significance (before mitigation) associated with the operational phase were identified:

- Increased salinity in the mixing zone affects biota.
- Effects of biocide plume on marine communities in the mixing zone.
- Effects of discharged co-pollutants with backwash water.
- Effects of discharged antiscalants.
- Heavy metals (if present in the brine from corrosion processes) may affect dissolved metal concentrations in the receiving water.

With few exceptions, recommended management actions and mitigation measures will reduce the negative impacts of medium significance to low or very low.

Given the current lack of past and future proposed development along the coastline of the project area, cumulative impacts as well as disturbances to marine or coastal systems or features are expected to be limited.

The recommended mitigation measures for the construction phase of the desalination plant are:

- Keep heavy vehicle traffic associated with pipeline or breakwater construction on the beach to a minimum.
- Restrict vehicles to clearly demarcated access routes and construction areas only.
- All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan.
- Good house-keeping must form an integral part of any construction operations on the beach from start-up.
- All blasting activities should be conducted in accordance with recognised standards and safety requirements.
- Search the area around the blasting area and postpone blasting if turtles, marine mammals or flocks of diving or swimming birds are spotted within a 2-km radius of the blasting point.
- Restrict the number of blasts to the absolute minimum required, and to smaller, quick succession blasts directed into the rock using a time-delay detonation.
- Undertake only one blast per day.

The recommended mitigation measures for the operational phase of the desalination plant are:

- Keep intake velocities below ~0.15 m/s to ensure that fish and other organisms can escape the intake current.
- Install screens to prevent fish from entering the system while still allowing adequate water flow.
- Undertake regular pigging of the intake pipelines.
- Undertake intermittent chlorination of the intake water to prevent bacterial re-growth in the brine.

- Ensure that residual chlorine is suitably neutralised with sodium metabisulfite (SMBS); residual chlorine in the brine discharge must be below 3 µg/ℓ.
- Monitor the brine for dissolved oxygen levels potentially caused by overdosing of SBMS, and aerate if necessary.
- Avoid the use of nutrient-enriching antiscalants, and use antiscalants with low toxicity to aquatic invertebrate and fish species.
- The discharge pipe should be fitted with a diffuser system at its seaward end to ensure rapid and efficient dilution of the effluent with the receiving water, thereby reducing plume footprints near the seabed and minimising impacts on marine ecology.

Monitoring recommendations include:

- Conduct a study on the chemical and physical properties of the raw water at the proposed intake site prior to the design and construction of the desalination plant.
- Once in operation, conduct a study to ensure that the required dilution levels are achieved.
- Undertake toxicity testing of the discharged effluent for a full range of operational scenarios (*i.e.* shock-dosing, etc) to ensure complete confidence in the potential effects of co-discharged constituents and the antiscalant to be used.
- Continuously monitor the effluent for residual chlorine and dissolved oxygen levels.
- Periodically assess bacterial re-growth.
- Regularly monitor the effluent for heavy metals until a profile of the discharge in terms of heavy metal concentrations is determined.
- Check corrosion levels of plant constituent parts and the physical integrity of the intake and outlet pipes and diffuser and replace or modify components if excessive corrosion is identified or specific maintenance is required.
- Implement a monitoring program to study the effects of the discharged brine on the receiving water body and/or intertidal biological communities surrounding the discharge location. Although monitoring of the salinity plume to the validate the model results would be ideal, the high wave energy environment in the project area makes this impractical. Monitoring of the intertidal benthic communities at the impact site, and comparison with communities at a further two reference sites could, however, be used to assess the ecological impacts of the hypersaline plume, and assist in developing a contingency plan that examines the risk of contamination, and considers procedures that must be implimented to mitigate any unanticipated impacts.

ABBREVIATIONS, UNITS AND GLOSSARY

Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
AOC	assimilable organic carbon
BCLME	Benguela Current Large Marine Ecosystem
CIP	Clean in Place
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CSIR	Council for Scientific and Industrial Research
CTD	conductivity-temperature-depth
DAF	Dissolved Air Flotation
DBNPA	2,2-dibromo-3-nitrilopropionamide
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
E	East
EC_{50}	median effective concentration
EDTA	Ethylenediaminetetraacetic acid
EEZ	Exclusive Economic Zone
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
FAMDA	Fishing and Mariculture Development Association
HWM	High Water Mark
IFC	International Finance Corporation
IUCN	International Union for Conservation of Nature
LAT	Lowest Astronomical Tide
LC_{50}	median lethal concentration
LWM	Low Water Mark
MPA	Marine Protected Area
NaOCl	Sodium Hypochlorite
NCDENC	Northern Cape Department of Environment and Nature Conservation
NEMA	National Environmental Management Act
NHRA	National Heritage Resources Act
NOEC	no observed effect concentration
NW	Northwest
NWA	National Water Act
PIM	Particulate Inorganic Matter
PNEC	predicted no effect concentrations
POM	Particulate Organic Matter
ppm	parts per million
ppt	parts per thousand
RO	Reverse Osmosis
RSA DWAF	Republic of South Africa, Department of Water Affairs and Forestry
RSA	Republic of South Africa
SMBS	Sodium metabisulphite
SRK	SRK Consulting (South Africa) Pty Ltd
STPP	Sodium tripolyphosphate
SWRO	Seawater Reverse Osmosis
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TRC	Total Residual Chlorine
TSP	Trisodium phosphate
TSPM	Total Suspended Particulate Matter
TSS	Total Suspended Solids
UNEP	United Nations Environment Programme
US-EPA	United States Environmental Protection Agency

WET	Whole Effluent Toxicity
WHO	World Health Oragnisation

Units used in the report

cm	centimetres
h	hours
ha	hectares
kg	kilogram
km	kilometres
km^2	square kilometres
m	metres
M	Million
mm	millimetres
m^2	square metres
mg/ ℓ	milligrams per litre
psu	practical salinity units which in normal oceanic salinity ranges are the same as $^0/_{00}$
s	seconds
%	percentage
~	approximately
<	less than
>	greater than
°C	degrees centigrade

Glossary

Anti-cyclonic	An extensive system of winds spiralling outward anti-clockwise (in Southern Hemisphere) the from a high-pressure centre.
Barotropic reversals	reversal of constant weather conditions
Bedload	the sediment transported by a current in the form of particles too heavy to be in suspension.
Benthic	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Benthos	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms	Organisms living in or on sediments of aquatic habitats.
Biodiversity	The variety of life forms, including the plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
Biomass	The living weight of a plant or animal population, usually expressed on a unit area basis.
Biota	The sum total of the living organisms of any designated area.
Bivalve	A mollusk with a hinged double shell.
Community structure	All the types of taxa present in a community and their relative abundance.
Community	An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another.
Cyclonic	An atmospheric system characterized by the rapid inward circulation of air masses about a low-pressure centre; circulating clockwise in the Southern Hemisphere
DBNPA	A non-oxidising biocide (2,2-dibromo-3-nitrilopropionamide).
Dilution	The reduction in concentration of a substance due to mixing with water.
Dissolved oxygen (DO)	Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre.

Effluent	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment.
Epifauna	Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement.
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment.
Environmental impact	A positive or negative environmental change (biophysical, social and/or economic) caused by human action.
Environmental quality objective	A statement of the quality requirement for a body of water to be suitable for a particular use (also referred to as Resource Quality Objective).
Euphotic/photic zone	the zone in the ocean that extends from the surface down to a depth where light intensity falls to one percent of that at the surface; i.e. there is to sufficient sunlight for photosynthesis to occur.
Fouling/biofouling	the accumulation of microorganisms, algae and marine invertebrate fauna on wetted and submerged surfaces.
Guideline trigger values	These are the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should ‘trigger’ some action, either further ecosystem specific investigations or implementation of management/remedial actions.
Habitat	The place where a population (e.g. animal, plant, micro-organism) lives and its surroundings, both living and non-living.
Hypoxic	Deficiency in oxygen.
Infauna	Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes.
Intertidal	The area of a seashore which is covered at high tide and uncovered at low tide.
Macrofauna	Animals >1 mm.
Macrophyte	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Meiofauna	Animals <1 mm.
Mariculture	Cultivation of marine plants and animals in natural and artificial environments.
Marine discharge	Discharging wastewater to the marine environment either to an estuary or the surf-zone or through a marine outfall (*i.e.* to the offshore marine environment).
Marine environment	Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions.
Pelagic	of or pertaining to the open seas or oceans; living at or near the surface of ocean.
Pollution	The introduction of unwanted components into waters, air or soil, usually as result of human activity; e.g. hot water in rivers, sewage in the sea, oil on land.
Population	Population is defined as the total number of individuals of the species or taxon.

Recruitment	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion and migration.
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Sludge	Residual sludge, whether treated or untreated, from urban wastewater treatment plants.
Subtidal	The zone below the low-tide level, *i.e.* it is never exposed at low tide.
Supratidal	The zone above the high-tide level.
Surf-zone	Also referred to as the 'breaker zone' where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.
Suspended material	Total mass of material suspended in a given volume of water, measured in mg/ℓ.
Suspended matter	Suspended material.
Suspended sediment	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in mg/ℓ.
Tainting	This refers to the tainting of seafood products as a result of the presence of objectionable chemical constituents which may greatly influence the quality and market price of cultured products.
Taxon (Taxa)	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (e.g. species, genera, families).
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Turbidity	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Turgor	The normal rigid state of fullness of a cell or blood vessel or capillary resulting from pressure of the contents against the wall or membrane.
Vulnerable	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

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1. GENERAL INTRODUCTION

Background

Sedex Minerals (Pty) Ltd (Sedex Minerals) intends to mine a Rare Earth Element deposit and beneficiate the ore to produce a mixed rare earth salt at the Zandkopsdrift Mine, 30 km south of the town of Garies in the Northern Cape Province. Sedex Desalination (Pty) Ltd (Sedex Desalination) proposes to construct a 8 million m^3/yr (Mm^3/yr) seawater desalination plant, including associated infrastructure and services at Volwaterbaai, on the farm Strandfontein 559 in the Northern Cape, (see Figure 1) to supply demineralised water via a transfer pipe to the Zandkopsdrift Mine.

The National Environmental Management Act 107 of 1998, as amended (NEMA), and the Environmental Impact Assessment (EIA) Regulations, 2010 (promulgated in terms of NEMA) warrant that listed activities require Environmental Authorisation from the National Department of Environmental Affairs (DEA) or provincial equivalent, in this case the Northern Cape Department of Environment and Nature Conservation (NCDENC). A Scoping and Environmental Impact Reporting process is required to support an application for Environmental Authorisation. SRK Consulting (South Africa) Pty Ltd (SRK) has been appointed by Sedex Desalination to undertake the Social and Environmental Impact Assessment process required for the proposed desalination plant, in terms of the EIA Regulations. SRK in turn has appointed Pisces Environmental Services (Pisces) to provide the Marine and Coastal Specialist Report and associated marine biological baseline studies.

Scope of Work

The Terms of Reference and principal objectives for the Marine and Coastal Specialist Study, as provided by SRK, are to:

- Undertake a site visit to inspect the immediate and surrounding area associated with the marine infrastructure of the project in order to gather general information on the sandy beach and rocky intertidal ecology of the area;
- Describe the existing marine and coastal baseline characteristics of the study area and place these in a regional context; in doing so highlight sensitive and threatened habitats, and threatened or rare marine fauna and flora;
- Describe pertinent characteristics of the marine environment including, amongst others, the following components:
    - Marine baseline conditions;
    - Waves, tides and currents;
    - Surf-zone currents and processes;
    - Upwelling;
    - Nutrients;
    - Turbidity;
    - Organic inputs;
    - Low oxygen events;
    - Rocky shore communities;
    - Sandy beach communities;
    - Pelagic communities;
    - Marine mammals and seabirds;
    - Extractive and non-extractive users of the area;

    – Future use scenarios

- Review and provide an expert interpretation of all the relevant, available local and international publications and information sources on the disturbances and risks associated with hypersaline effluents;
- Identify and describe all factors resulting from the construction and operation of the desalination plant and associated infrastructure that may influence the marine and coastal environments in the region, based on existing information and data collected during the site visit;
- Assess the impacts of the proposed development on the marine biology of the project area during the construction and operational phases of the project using SRK's prescribed impact assessment methodology;
- Summarise, categorise and rank all identified marine and coastal impacts in appropriate EIA tables, to be incorporated in the overall EIA;
- Identify and describe potential cumulative impacts resulting from the proposed development in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to minimise impacts and/or optimise benefits associated with the proposed project; Provide recommendations for draft a monitoring campaign, if applicable; and
- Compile an Environmental Management Plan (EMP) (or relevant sections of the EMP) for the marine aspects of the construction and operational phases of the intake structure and brine disposal systems.

Approach to the Study

Although the Marine and Coastal Specialist Study largely adopts a desktop approach, qualitative information on the intertidal and shallow subtidal environments collected during the site visit and during exploratory dives at the proposed discharge location is included in the description of the baseline environment. This combined approach is deemed adequate for placing into context the potential impacts associated with a desalination plant of the capacity proposed for this development. Furthermore, the assessment of impacts associated with the brine discharge are based on the results of a numerical modelling study ("the modelling study") undertaken by PRDW, thereby adding confidence to the assessment of the likely extent and duration of the hypersaline effluent footprints under different seasonal oceanographic scenarios.

Structure of the Report

This chapter of the Marine and Coastal Specialist Report describes the effects of the construction and operation of the proposed desalination plant project on the marine and coastal environment, and significance within the context of the receiving environment in the vicinity of Volwaterbaai. The report outlines the approach to the study, assesses impacts identified by marine specialist consultants, and makes recommendations for mitigation, monitoring and management of these impacts. The report is structured as follows:

Section 1: General Introduction - provides a general overview to the proposed project, and outlines the Scope of Work and objectives of the study and the report structure. The assessment methodology is outlined and the assumptions and limitations to the study are given.

Section 2: Project Description relative to the Marine Environment - gives a brief overview of the marine components of the proposed desalination plant, giving some technical detail on the alternative project designs being considered and the volume, nature and water quality of the proposed discharges from the desalination plant.

Section 3: Description of the Marine Environment - describes the receiving biophysical environment that could be impacted by the desalination plant. Existing impacts on the environment are discussed and sensitive and/or potentially threatened habitats or species are identified.

Section 4: Identification of Key Issues and Sources of Potential Environmental Impact - here key issues identified during the public consultation process for the proposed desalination plant project are identified and summarised in terms of the construction phase and operational phase.

Section 5: Assessment of Environmental Impact - identifies and assesses the significance of potential direct, indirect and cumulative environmental impacts on the marine environment associated with the construction and operation of the desalination plant and associated infrastructure, based on information provided by the client and the results of the modelling studies. The environmental acceptability of the development alternatives are discussed, and the environmentally preferred alternative is identified. A comparison between the “no development” alternative and the proposed development alternatives is also included. Mitigation measures and monitoring recommendations are presented.

Section 6: References - provides a full listing of all information sources and literature cited in this report.

Methodology

1.1.1 *Marine Environmental Baseline*

The ecological assessment is limited to a “desktop” approach and thus relies on existing information only. The description of the baseline marine environment was compiled following a literature search and review of all relevant, available local and international publications and information sources on southern African West Coast communities. This was supplemented by quantitative information gathered during a site visit and exploratory dives at the discharge location by the Research Dive Unit at the University of Cape Town. Due to the extreme wave exposure of the coastline the collection of quantitive biological data or detailed bathymetric data from subtidal habitats was not possible. Instead, divers equipped with GoPro® cameras swam transects from the intertidal area to depths of ~8 m, recording the seabed type and its associated communities. This video footage provided valuable information on the seabed type in the vicinity of the outfall, and the subtidal benthic flora and fauna occurring in the area.

1.1.2 *Environmental Impact Assessment*

The identification and description of all factors resulting from the construction and operation of the desalination plant and associated infrastructure that may influence the marine and coastal environments in the region, was based on a review and expert interpretation of all relevant, available local and international publications and information sources on the disturbances and risks associated with coastal construction and the discharge of hypersaline effluents.

1.1.3 *Impact Assessment Methodology*

SRK's prescribed impact assessment methodology was used to assess the significance of potential impacts. Using this methodolgy, the **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was rated as set out below:

Step 1 – The **consequence** rating for the impact was determined by assigning a score for each of the three criteria (A-C) listed below and then **adding** them.

Rating	Definition of Rating	Score
A. *Extent* *– the area over which the impact will be experienced*		
Local	Confined to project or study area or part thereof (e.g. site)	1
Regional	The region, which may be defined in various ways, e.g. cadastral, catchment, topographic	2
(Inter) national	Nationally or beyond	3
B. ***Intensity*** *– the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. ***Duration*** *– the timeframe over which the impact will be experienced and its reversibility*		
Short-term	Up to 2 years (i.e. reversible impact)	1
Medium-term	2 to 15 years (i.e. reversible impact)	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	3 – 4	5	6	7	8 – 9
Consequence Rating	Very low	Low	Medium	High	Very high

Step 2 –The **probability** of the impact occurring is assessed according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Step 3 –The overall **significance** of the impact is determined as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**

	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Step 4 – The **status** of the impact is noted as being either negative or positive.

Step 5 –The level of **confidence** in the assessment of the impact is stated as high, medium or low.

Step 6 – Practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact are identified and described as either:

- **Essential**: best practice measures which must be implemented and are non-negotiable; and
- **Best Practice**: recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Having inserted *Essential* mitigation and optimisation measures, the impact is then re-assessed assuming mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures. *Best practice* measures are also inserted into the impact assessment table, but not considered in the "with mitigation" impact significance rating.

Limitations and Assumptions

The following are the assumptions and limitations of the study:

- The study is based on the **project description made available to the specialists at the time of the commencement of the study** (plant capacities, discharge locations, constituents, volumes, *etc*.). The assessment is restricted to only those constituents specified by Sedex Desalination as being contained within the effluents from the desalination plant.
- The three-dimensional modelling study comprises a near-field model coupled with a wave model used to simulate both the near-field and the far-field dispersion of the brine. It is thus assumed that the resolution in the modelling will provide adequate detail within an approximate 300-m radius of the discharge point.
- The residual oxidising biocide (chlorine) concentration in the effluent stream is assumed to be <3 µg/ℓ, as this is the water guideline value for residual chlorine in brine effluents as published by ANZECC (2000). Furthermore an intermittent discharge has been assumed. As the modelling study did not explicitly model the discharge of a biocide, it is assumed that the residual oxidising biocide concentrations will be managed (*i.e.* the biocide will be neutralised with sodium metabisulfite before the intake water passes the RO membranes) such that a residual biocide concentration of 3 µg/ℓ is not exceeded at the point of discharge at any stage of the treatment process (*i.e.* at any stage during the shock treatment process).
- Some important conclusions and associated assessments and recommendations made in this study are based on results from the detailed three-dimensional modelling study. **The predictions of these models, whilst considered to be robust in terms of the major discharge constituent, need to be validated by field observations**

and subsequent monitoring. If field observations and monitoring, however, fail to mirror predicted results, the forecasted impacts will need to be re-assessed.

- Potential changes in the marine environment such as **sea level rise and/or increases in the severity and frequency of storms related to climate change are not explicitly considered here**. Such scenarios are difficult to assess due to the uncertainties surrounding climate change. Should evidence or more certain predictions of such changes become available, Sedex Desalination should re-assess their development and management plans to include the impacts of these anticipated macroscale changes. However, it is not expected that these climate changes will affect the effluent plume behaviour to the extent that the conclusions of this study will be altered.

2. DESCRIPTION OF THE PROJECT RELATIVE TO THE MARINE ENVIRONMENT

The site for the desalination plant and associated infrastructure is located in Namaqualand, which stretches along the west coast of the Northern Cape and further inland. The proposed desalination plant will be constructed at Volwaterbaai on the Farm Strandfontein 559, approximately 15 km west of the town of Kotzesrus. The location of the plant is approximately 6 km north of the Brak River on a stretch of coastline comprising rocky coastal outcrops interspersed with sandy beaches. From the desalination plant, water supply pipelines, overhead power lines and an access road servicing the plant will be routed along a distance of approximately 42 km to the proposed Zandkopsdrift Mine by Sedex Minerals.

The proposed mine will would have an annual water demand of approximately 8 Mm^3/a, which in this water scarce area is not readily available. Sedex Desalination has thus proposed the desalination of sea water to provide the secure and reliable permanent fresh water supply required by the mine.

A detailed description of the project components are provided in Chapter 3 of the EIA Report for this project. Provided below is a brief description of the infrastructure associated with the proposed project that may have an effect on the marine environment, *i.e*. the seawater abstraction and brine discharge components and installation of pipelines in the coastal zone, including alternatives considered. Details surrounding plant location, bulk water and power supply and the required linear routes between the desalination plant and the mine will be detailed in the overall EIA and their impacts dealt with by other specialists and will not be further discussed here.

2.1 Identification and Selection of Alternatives

The number and size of seawater reverse osmosis desalination (SWRO) plants, as well as the environmental awareness related to such projects is increasing, resulting in increased emphasis on intake (and outfall) design and economics. Intake (and outfall) structures can be the ‘fatal flaw issue’ of new seawater desalination facilities. Whereas the design and manufacturing of the desalination unit itself are well established and approved technical solutions are available, the intake and pre-treatment of the seawater, and the discharge of brine need to be specifically adapted to the particular conditions at the plant site. These can differ over a wide range, as not only the raw water quality, but also aspects such as the geological situation, existing infrastructure and logistics need to be taken into consideration during the design, construction and operation of a desalination plant.

Following a screening process investigating seawater intake, brine discharge and location alternatives for the Sedex Desalination Project, Volwaterbaai was selected as the most favourable site for locating the proposed desalination plant. Due to shallow bedrock depth on the beaches in the project area, the use of beach wells as seawater intake structures was not a viable option. A small-scale open water intake, was thus considered the only feasible alternative of providing feedwater to the plant. In selecting potential sites for locating the intake pipeline, features that create natural gullies or channels to the shore and would thereby minimise the need for intrusive engineering solutions were given preference. Seven potential discharge sites were identified within Volwaterbaai of which Brine 2.5 was selected as most suitable based on engineering considerations, with further refinement to two locations being undertaken. The final site selected (Brine 5) comprises an intertidal gully, which would enable the brine to be discharged below the Lowest Astronomical Tide (LAT). The effluent would therefore be released into a high-energy wave environment, which would facilitate the requirements for achievable dilutions for a surf-zone discharge to be most readily met. The assessment of impacts of the marine infrastructure of the proposed project on marine biota (Section 4) will thus focus only on these single, final preferred alternative locations for the intake and discharge pipelines.

Furthermore, as part of the Feasibility Study for the project, various process and design alternatives were considered, including:

- Alternatives for discharge/disposal of wastes other than brine from the desalination process which could include:
  - Blending with brine for discharge to the sea;
  - Discharge to an on-site wastewater treatment facility;
  - Disposal at tailing facility at Zandkopsdrift Mine; and
  - Disposal to landfill;
- Alternative chemicals used in the desalination process and plant; and
- Pipeline alternatives including:
  - The use of a large single pipeline or multiple (2) smaller pipelines; and
  - Positioning of pipe above ground (either on the surface or elevated) or below ground.

This assessment assumes that:

- Co-pollutants are discharged by blending these with the brine for discharge to sea;
- Only those chemicals specified in the project description will be discharged; and
- The pipelines crossing the coastal zone will be positioned below ground.

The 'no-go' alternative implies that development the desalination plant and its associated infrastructure would not be developed.

2.2 Description of the Marine Infrastructure as part of the Desalination Plant

The marine infrastructure associated with the proposed sea water reverse osmosis (SWRO) desalination plant project consists of two principle components, namely the seawater intake system and the brine discharge system and the associated pipelines in the coastal zone leading to and from the desalination plant.

2.1.1 *Seawater Intake System*

The seawater extraction system would be an open water intake placed inside an existing gully crossing the intertidal zone into the shallow subtidal area (i.e. below the LAT). The system would include:

- Modification to the existing gully to serve as the intake channel;
- A marine intake basin, which would be excavated into the underlying rock within the gully;
- Intake heads and screens;
- Intake pipes;
- Slurry-type seawater extraction pumps;
- A pump station; and
- Pipeline(s) from the pump station to the desalination plant.

The intake basin, with associated screens and grids and suction inlets would be installed below the high water mark (HWM), with all other intake infrastructure above the HWM. The seawater intake structure will be designed for a maximum feedwater abstraction capacity of

~20 Mm^3/annum. To avoid impingement and entrainment of marine organisms water would be drawn into the intake heads at a velocity of <0.15 m/s, be screened through coarse (120 – 150 mm) and fine screens (40 mm) before being pumped to the desalination plant. The installation of the seawater intake infrastructure would require some blasting, excavation and concrete work below the HWM and in the intertidal zone.

Open water intakes typically necessitate the need for extensive pre-treatment of intake water. Behind the screening and sand trap, the seawater pre-treatment will incorporate dissolved air flotation (DAF) and dual media filtration in combination with clarification, coagulation and flocculation. All filtration processes give rise to a waste stream containing the filtered solids and any coagulant (typically $FeCl_3$ and an anionic polymer) used. Sulphuric acid will also be used to lower the pH to the optimal flocculation pH of around 6.9. Media filters generate a waste-water volume of between 3-5% of their treated water throughput, which is blended with other wastes from the system and bled back into the hypersaline effluent (brine) prior to discharge.

The use of a biocide (chlorine) will be required to inhibit biological growth in the intake pipeline and on the screens. An intermittent shock dosing treatment is proposed for this project. To avoid damage to the RO membranes, the chlorine needs to be neutralised with sodium metabisulfite (SMBS) before it can pass through the membranes. Consequently, no residual biocide will be discharged with the brine. An antiscalant (phosphonate) is added to control scaling and inorganic precipitation (including metals) removal on the RO membranes.

A pipe ‘pigging’ system for regular maintenance and cleaning of the seawater supply lines (only intake) would also be installed. This involves the use of a ‘pig’ (bullet-shaped device with bristles), which is introduced into the pipeline which transfers the feed-water from the pump station to the desalination plant to mechanically clean out the structure.

Depending on the quality of the feed-water, the RO membranes will need to be cleaned at intervals of three to six months. The cleaning-in-place (CIP) process typically generates in the order of 134 m^3 of cleaning solution and rinse water per RO train. Therefore, for an 8 Mm^3/yr capacity, the maximum expected volume of cleaning solution and rinse water will be approximately 10 200 m^3/yr. The maximum expected volume of pre-treatment wastes is expected to average 1.18 Mm^3/yr on a continuous basis, with a maximum of ~2 500 m^3 of CIP waste added in batches every two months. These residual streams will be mixed with the DAF sludge and the waste-water would then be blended into and co-discharged to sea with the brine effluent.

2.1.2 *Desalination Process*

The basic process for the treatment of water in the proposed SWRO plant is summarised here for the sake of completeness. Reverse Osmosis (RO) is a membrane filtration process utilised to reduce the salinity of seawater (feed-water). Following pre-treatment, the feed-water is pumped to a seawater buffer storage tank. To overcome the natural osmotic pressure of seawater, it is then pumped at high pressure through to the RO membranes. This process retains the brine (high salinity) on one side of the membranes and allows the water containing very low salinity to pass to the other side. The desalinated water is piped to the potable water tank, and the brine is released back into the ocean through discharge pipes. The recovery rate of product water through the process is typically approximately 40%.

The proposed maximum output capacity of treated water is 8 Mm^3/annum (~22,000 m^3/d). The plant will be capable of performing over a range of temperatures, with the RO feed pressure decreasing if the temperature is above 15 ºC and the required feed pressure increasing when the water temperature is below 15 ºC. The desalination plant would be designed, and the process equipment selected, for continuous operation 24 hours per day, for 350 days per year, with approximately 15 days per year allowed for maintenance. The actual operational time may vary, depending on the fresh water demands of the mine and maintenance requirements of the plant. The anticipated life-span of the desalination plant is a minimum of 30 years, with provisions to expand and renew equipment as and where it is needed.

2.1.3 *Brine Discharge System*

A maximum of 60% of the sea water abstracted will be returned to the sea as brine. The brine disposal system would comprise a brine discharge pipeline routed from the desalination plant, across the intertidal zone to the sea. The brine discharge pipeline would be located within a gully, with the brine outlet positioned below the low water mark (LWM). The brine would either be discharged under gravity feed, or be pumped. At maximum plant capacity, ~12 Mm^3 of brine would be discharged back into the sea annually. To ensure that the brine does not re-circulate and contaminate the feedwater, the discharge pipeline would be located approximately 500 m north of the seawater intake site.

In addition, the discharge system would allow for the discharge of solid waste material (sludge), the pre-treatment waste stream and other co-discharges with the brine. The brine may contain an organic scale inhibitor, which would be an approved chemical for potable water systems and will be bio-degradable. Other chemicals utilised in the pre-treatment and feed water conditioning process become disassociated[1], such as acid for pH conditioning and, possibly, sodium metabisulfite to scavenge available chlorine.

The brine is negatively buoyant and will tend to sink towards the seabed; however the brine temperature will increase slightly over the feed-water temperatures. The brine will be discharged at a velocity of 4 - 6 m/s through a single 0.3-m diameter nozzle located directly above the seabed in approximately 1.2 m water depth, and directed horizontally offshore. The brine will be thus be dispersed into the ambient seawater as a fast moving current.

Table 1 lists the expected composition of the brine effluent and the typical cleaning reagents and pre-treatment chemicals to be used. The brine effluent at the maximum plant capacity is anticipated to have a temperature of between 1 – 2 degree Celsius above the ambient average seawater temperature, a salinity of 66 g/ℓ or psu (based on the maximum feed-water salinity of 36.7 g/ℓ or psu) and a density of 1 050 kg/m^3 with a maximum effluent flow of ~12 Mm^3/yr.

2.1.4 *Temporary Desalination Plant*

As fresh water will be required during construction activities, a temporary containerised desalination plant will be set up at the construction site. The intake and discharge flows from this plant amount to 67 m^3/d and 36.5 m^3/d respectively. The brine will also contain traces (<3 mg/ ℓ) of membrane antiscalant and suspended solids from the backwash waste.

[1] The chemical or biochemical process in which molecules (or ionic compounds such as salts, or complexes) separate or split into smaller particles such as atoms, ions or radicals, usually in a reversible manner.

Table 1: Expected composition and flow of the brine discharge from the proposed desalination plant assuming a maximum annual capacity of 8 Mm^3.

Description	Units	Quantity
Feed-water Intake	m^3/d	54,780
Average brine discharge	m^3/d	32,876
Co-discharge (Pre-treatment Media Filtration Backwash – intermittent and discharged over 24 h)	m^3/d	2,147
Co-discharge (CIP rinse water – 6 x per year only and assumed to be discharged over 12 h at rate of 70 m^3/h)	m^3/d	841 (in 12 h)
Discharge velocity	m/s	4-6
Salinity	mg/ℓ psu	66,000 66
Change in temperature	°C	1 - 2
pH		7.3 – 8.2
Suspended Solids	mg/ℓ	11.67
Phosphonate antiscalant	mg/ℓ	4.7
Chlorine	mg/ℓ	0.002
Sodium bisulphate (SMS)	mg/ℓ	3.14
Spent CIP solution (quarterly and blended in over 12 hours) Peroxyacetic acid Low pH cleaner High pH cleaner	mg/ℓ	 0.006 0.015 0.015
Preservative (sodium metabisulfite) (on shutdown/start-up, and blended in over 12 h)	mg/ℓ	0.028
Coagulant: Ferric Chloride ($FeCl_3$) will precipitate into Ferric Hydroxide, which will be removed as a solid.	mg/ℓ	3.33
Anionic polymer (alternative to $FeCl_3$) *	mg/ℓ	1.67

* The ionic polymer would be used as an alternative to FeCl3 and not in conjunction with it.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

The general location of the proposed desalination plant is at Abrahams Villiers Bay on the farm Strandfontein 559, 15 km west of Kotzesrus in the Northern Cape Province on the west coast of South Africa. For the purpose of this study, the project area encompasses a ~50-km stretch of the coastal and shallow marine habitats from approximately Groenriviermond in the north to the provincial border of the Western Cape in the south (Figure 1). The project area thus falls within the central Benguela region, which extends from Lüderitz in Namibia to Cape Columbine on the Western Cape coast.

Physical Environment

3.1.1 *Sea Surface Temperature, Currents and Circulation Patterns*

An overview of the water masses, and major coastal and oceanic current and circulation patterns along the South African west coast was presented by Shannon & Nelson (1996).

The cool temperate Benguela region (average sea surface temperature 10 - 14°C) is located between two warm current features, namely the Angola Current in the north and the Agulhas current in the south. The southward flowing Angola Current originates from the circular gyre on the Angola Dome, which is a prominent oceanographic feature off the coast of Angola. At the opposite end of the Benguela system, the strong Agulhas Current flows down the eastern South African shelf edge, along the Agulhas Bank past Cape Agulhas, and periodically generates massive, warm 'Agulhas Rings', resulting in substantial heat flux into the central South Atlantic ocean. The Agulhas Current is also capable of rounding Cape Point and generating an episodic, northward-flowing current, which splits near Cape Columbine (33°S) into the offshore Cape Canyon jet, and a northward longshore flow (Figure 2). The surface water of the Agulhas Current is generally >21 °C, and its influence west of Cape Agulhas results in average sea surface temperatures in the southern Benguela of 16 - 20 °C (Shannon 1985).

The Benguela region in contrast is dominated more by wind-driven upwelling and swell events, than by consistent current flows. Currents tend to follow major topographic features, with typical current speeds in the region ranging from 10 - 50 cm/s. Over the southern Benguela region (south of Cape Columbine), there is a southward flow of cold water close inshore near the surface, which occurs during periods of barotropic reversals, and during the winter non-upwelling period (Nelson & Hutchings 1983). There is also a significant southerly poleward flow of sub-thermocline water on the continental shelf and at the shelf break, forming a poleward undercurrent, which becomes more consistent to the south (Nelson 1989, Boyd & Oberholster 1994, Shannon & Nelson 1996) (Figure 2).

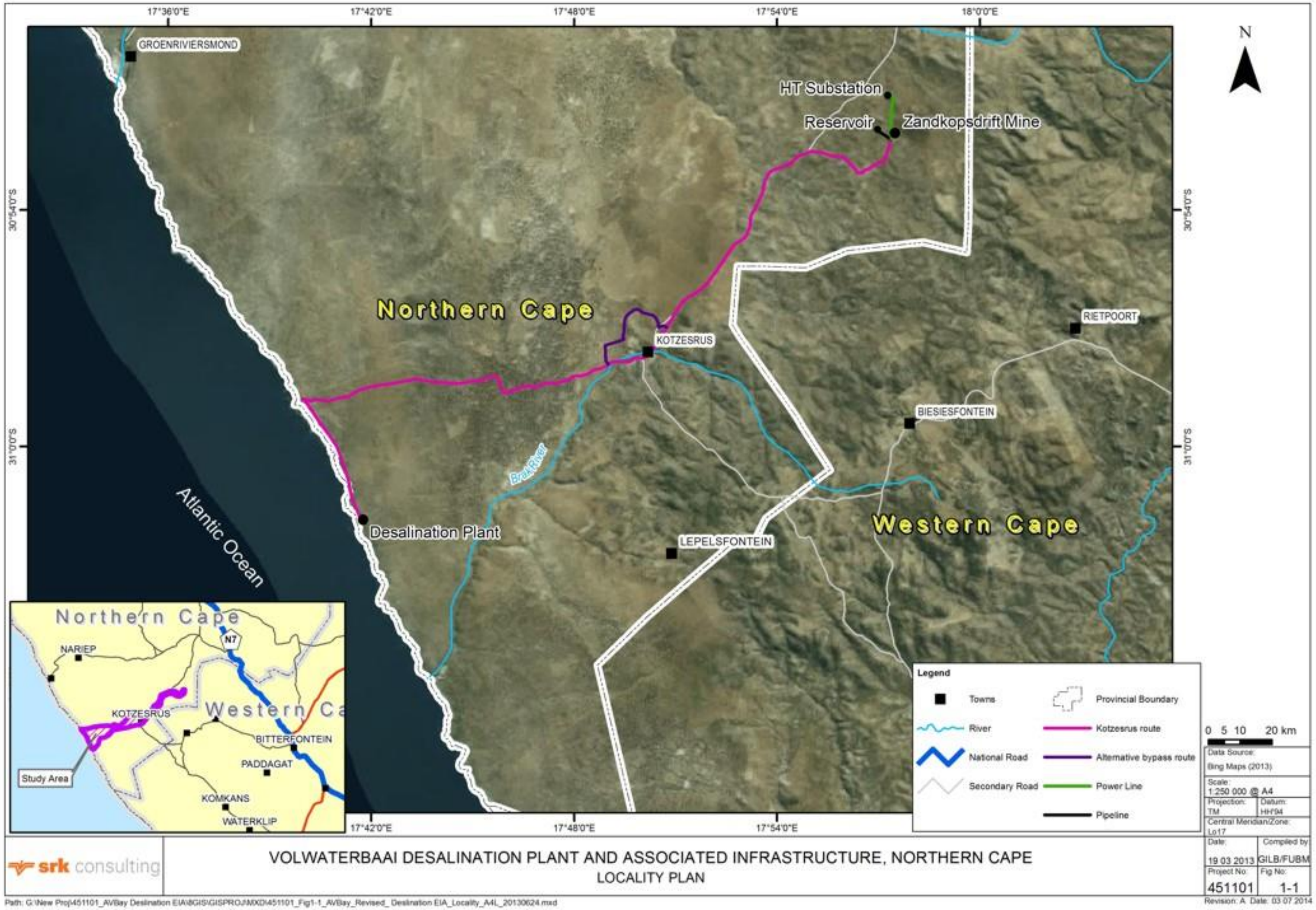

Figure 1: Location map of the proposed desalination plant.

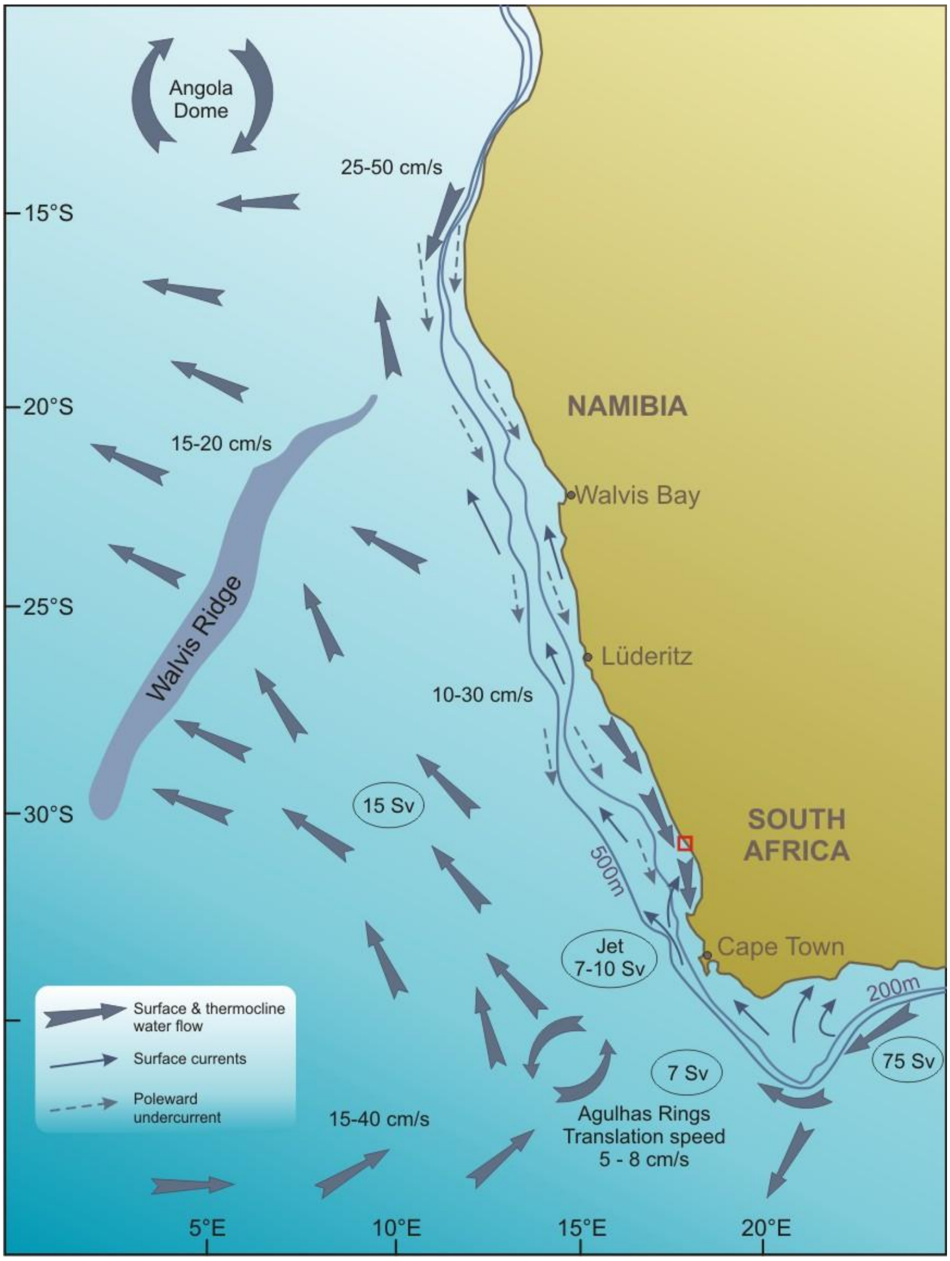

Figure 2: Major features of the predominant circulation patterns and volume flows in the Benguela System, along the southern Namibian and South African west coasts (re-drawn from Shannon & Nelson 1996), in relation to the project area (red square).

The project area falls within the nearshore central Benguela region (Cape Columbine to Lüderitz), which is primarily characterised by variable, northward flowing, longshore surface currents, generated by consistent, strong winds and swells from the south and southwest (Shillington *et al.* 1990, Shannon & Nelson 1996). These nearshore surface currents remain closely aligned with the coastline and the winds, generally flowing in a northerly direction, although periodic reversals can occur. Winds are the main physical driver of the nearshore region, and physical processes are characterised by the average seasonal wind patterns. Substantial episodic changes in these wind patterns can consequently have strong effects on the entire Benguela region.

The prevailing winds along the southern African West Coast are controlled by the South Atlantic subtropical anticyclone, the eastward moving mid-latitude cyclones south of southern Africa, and the seasonal atmospheric pressure field over the subcontinent. The south Atlantic anticyclone is a perennial feature that forms part of a discontinuous belt of high-pressure systems, which encircle the subtropical southern hemisphere. This undergoes seasonal variations, being strongest in the austral summer, when it also attains its southernmost extension, lying south west and south of the subcontinent. In winter, the south Atlantic anticyclone weakens and migrates north-westwards.

These seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, as the southern hemisphere anti-cyclonic high-pressure systems, and the associated series of cold fronts, moves northwards in winter, and southwards in summer (Figure 3). The strongest winds occur in summer, during which winds blow 99% of the time, and gales (winds exceeding 63 km/h or 18 m/s) are frequent. In summer, winds are dominated by southerlies, which occur over 40% of the time, averaging 37 – 55 km/h (10 – 15 m/s) and reaching speeds in excess of 100 km/h. South-easterlies are almost as common, blowing about one-third of the time, and also averaging 37 – 55 km/h. The combination of these southerly/south-easterly winds drives the massive offshore movements of surface water, and the resultant strong upwelling of nutrient-rich bottom waters, which characterise this region in summer.

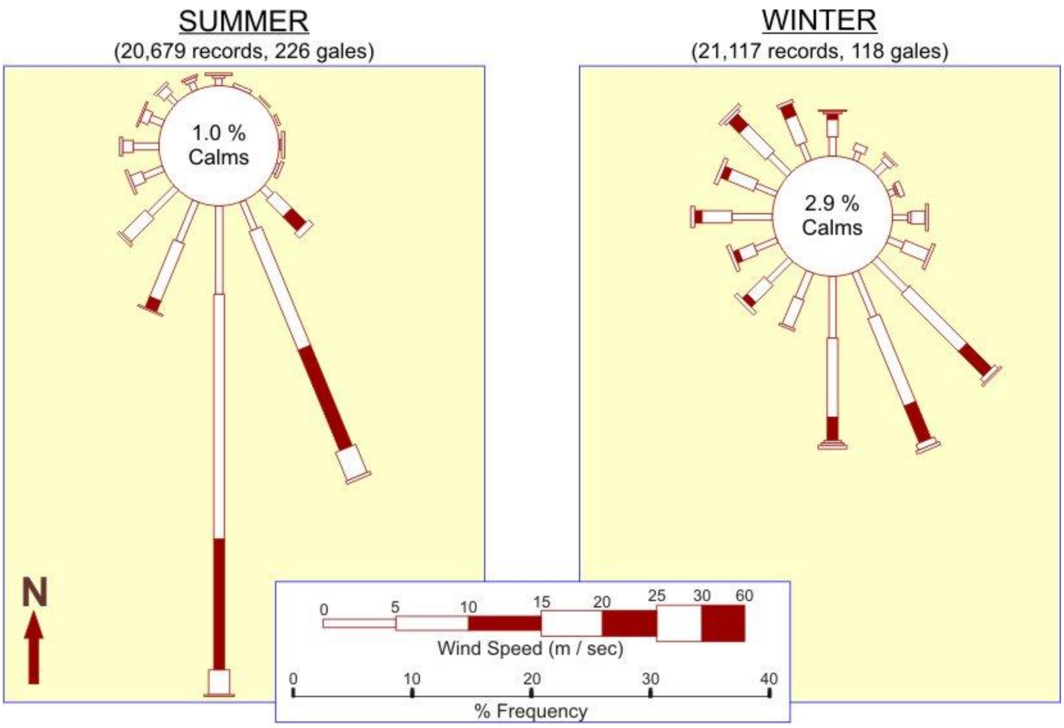

Figure 3: Rose-plots of the distribution of wind strength and direction along the South African west coast between Alexander Bay (29°S) and Saldanha Bay (33° S) during the summer and winter seasons over the period 1960 - 1997. (Data from the SA Data Centre for Oceanography.)

Southerly to south-southeasterly winds continue to dominate the wind pattern during winter, but the closer proximity of the winter cold-front systems also results in a significant south-westerly to north-westerly component (Figure 3). This 'reversal' from the summer condition results in cessation of upwelling, movement of warmer mid-Atlantic water shorewards and breakdown of the strong thermoclines, which typically develop during summer. There are also more calms in winter, occurring about 3% of the time, and wind speeds generally do not reach the maximum speeds of summer. The westerly winds blowing in synchrony with the prevailing south-westerly swell direction in winter, however, usually result in far heavier swell conditions.

3.1.2 *Waves and Tides*

Most of the west coast of southern Africa is classified as exposed, experiencing strong wave action, rating between 13 - 17 on the 20 point exposure scale (McLachlan 1980). West- to north-facing embayments are limited and most of the coastline is therefore impacted by heavy south-westerly swells generated in the roaring forties, as well as significant sea waves generated locally by the prevailing moderate to strong southerly winds characteristic of the region. The coastline south of Groen River mouth in which the project area is located is particularly exposed, being rated as “exposed” and “extremely exposed” (Steffani 2001).

The wave regime along the southern African west coast shows only moderate seasonal variation in direction, with virtually all swells throughout the year coming from the southwesterly to southerly direction (Figure 4). Winter swells are strongly dominated by those from the southwest to south-southwest, which occur almost 80% of the time, and typically exceeding 2 m in height, averaging about 3 m, and often attaining over 5 m. With wind speeds capable of reaching 100 km/h (during heavy winter south-westerly storms, winter swell heights can exceed 10 m). The dominant peak energy period for waves is ~12 seconds, although longer period swells occur about 30% of the time.

Summer swells tend to be smaller on average, typically around 2 m with a more pronounced southerly swell component. These southerly swells tend to be wind-induced, with shorter wave periods (~8 seconds), and are generally steeper than swell waves. The wind-induced southerly waves are relatively local and work together with the strong summer southerly winds to cause the northward-flowing nearshore surface currents, which results in substantial nearshore sediment mobilisation and northwards transport. In common with the rest of the southern African coast tides along the Namaqualand coast and in the project area are semi-diurnal.

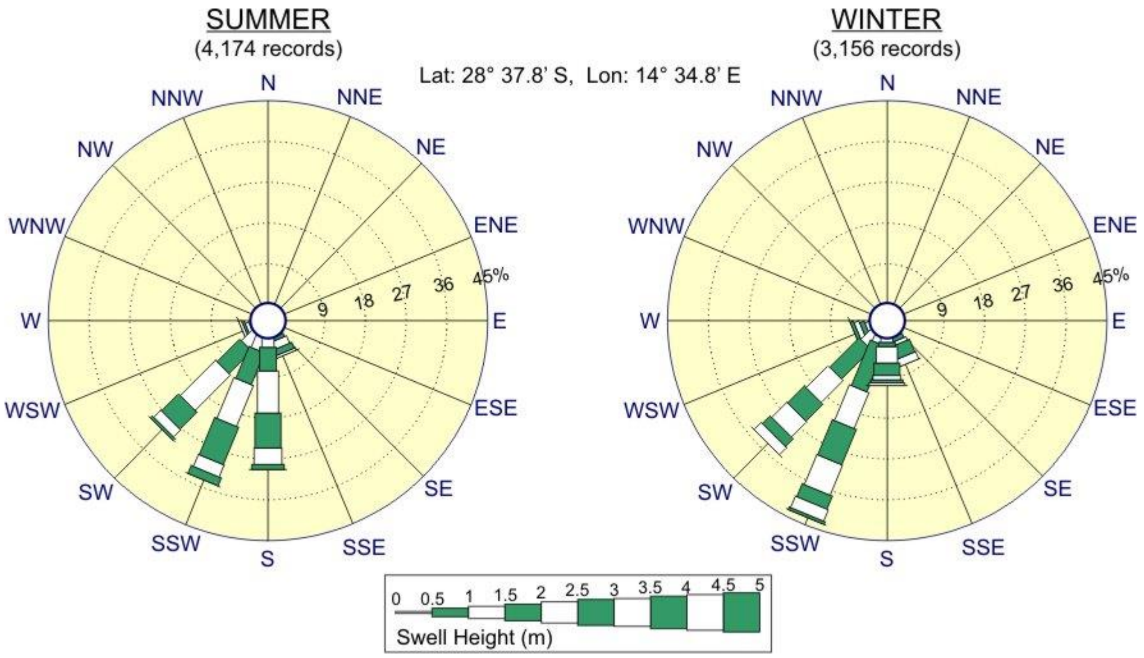

Figure 4: Rose-plots of the distribution of swell height and direction measured by a wave-rider buoy moored in 175 m water depth, 180 km offshore, west of the Orange River mouth, over the summer and winter seasons during March 1998 - April 1999 (redrawn from CSIR 2000).

3.1.3 *Upwelling and Plankton Production*

Coastal, wind-induced upwelling is the principle physical process that shapes the marine ecology of the Benguela region. The prevailing longshore, equatorward winds move nearshore surface water northwards and offshore. To balance the displaced water, cold, deeper water wells up inshore. Although the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns, the most intense upwelling tends to occur where the shelf is narrowest and the wind strongest. The largest and most intense upwelling cell is in the vicinity of Lüderitz, and upwelling can occur there throughout the year (Shannon & O'Toole 1998, Shillington 2003). Several secondary upwelling cells occur, of which the Namaqua cell is centred around Hondeklip Bay (30°S), and the Cape Columbine (33°S) and Cape Point (34°S) upwelling cells are located further south (Figure 5). Upwelling in these secondary cells is seasonal, with maximum upwelling occurring between September and March. The project area is located in the southern portion of the Hondeklip Bay cell, which can during strong upwelling events extend as far south as Lamberts Bay, and is thus likely to be periodically influenced by upwelling-related processes (Figure 6). During the winter months westerly winds result in relaxation of upwelling and often warmer surface water temperatures (Lutjeharms & Meeuwis 1987).

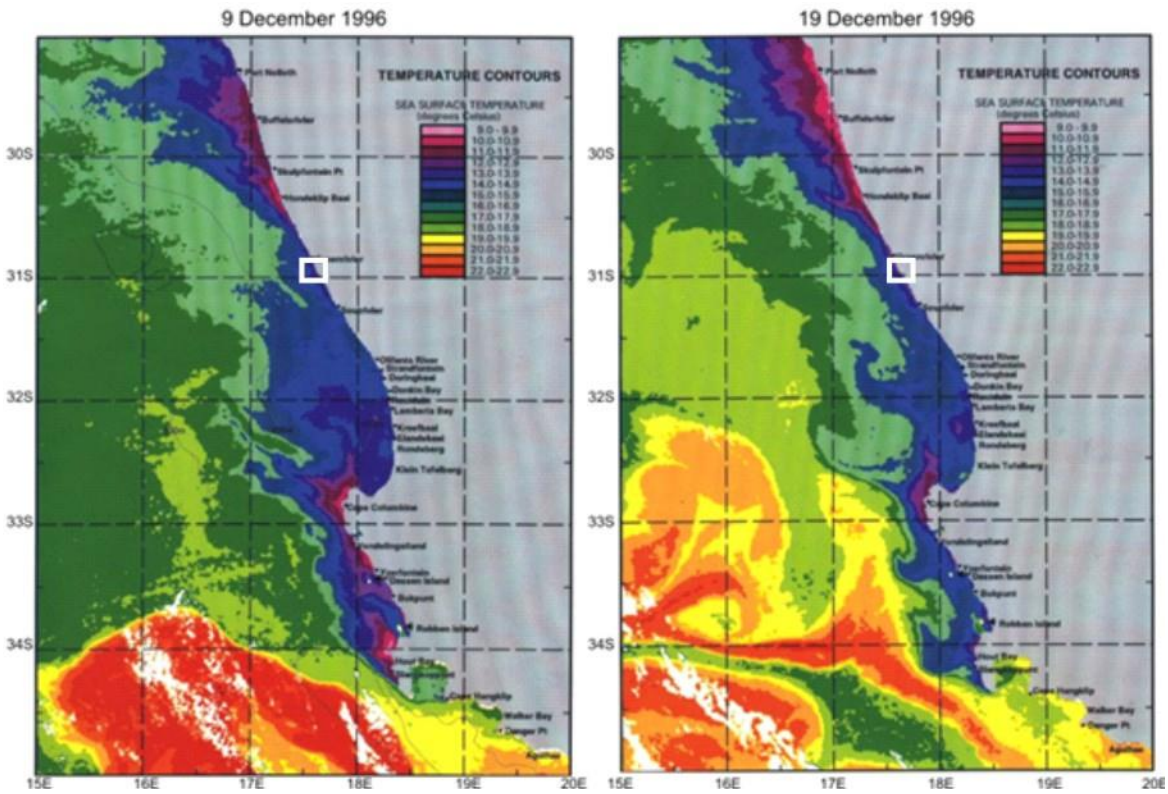

Figure 5: Satellite sea-surface temperature images showing upwelling intensity along the South African west coast and the influence of the Agulhas current on temperatures on the southwest coast (from Lane & Carter 1999). The white block denotes the project area.

During upwelling the comparatively nutrient-poor surface waters are displaced by deep water rich in inorganic nutrients, thereby supporting substantial seasonal primary phytoplankton production (Chapman & Shannon 1985). This, in turn, serves as the basis for a rich food chain up through zooplankton, pelagic baitfish, to predatory fish, marine mammals and seabirds. High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters, resulting in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays.

Biological decay of plankton blooms can, however, lead to “black tide” events, as the available dissolved oxygen is stripped from the water during the decomposition process. Subsequent anoxic decomposition by sulphur reducing bacteria can result in the formation and release of hydrogen sulphide (Pitcher & Calder 2000). Sulphur eruptions are, however, uncommon along the South African coastline, primarily occurring north of Lüderitz, in Namibia.

3.1.4 *Organic Inputs*

The Benguela upwelling region is an area of particularly high natural productivity, with extremely high seasonal production of phytoplankton and zooplankton. These plankton blooms in turn serve as the basis for a rich food chain up through pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (snoek), mammals (primarily seals and dolphins) and seabirds (jackass penguins, cormorants, pelicans, terns and others). All of these species are subject to natural mortality, and a proportion of the annual production of all these trophic levels, particularly the plankton communities, die naturally and sink to the seabed.

Balanced multispecies ecosystem models have estimated that during the 1990s the Benguela region supported biomasses of 76.9 tons/km^2 of phytoplankton and 31.5 tons/km^2 of zooplankton alone (Shannon *et al*. 2003). Thirty six percent of the phytoplankton and 5% of the zooplankton are estimated to be lost to the seabed annually. This natural annual input of millions of tons of organic material onto the seabed off the southern African West Coast has a substantial effect on the ecosystems of the Benguela region. It provides most of the food requirements of the particulate and filter-feeding benthic communities that inhabit the sandy-muds of this area, and results in the high organic content of the muds in the region. As most of the organic detritus is not directly consumed, it enters the seabed decomposition cycle, resulting in subsequent depletion of oxygen in deeper waters.

3.1.5 *Low Oxygen Events*

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations with <40% saturation occurring frequently (e.g. Visser 1969; Bailey *et al*. 1985). The low oxygen concentrations are attributed to nutrient remineralisation in the bottom waters of the system, the absolute rate of which is dependent upon the net organic material build-up in the sediments, with the carbon rich mud deposits playing an important role. (Chapman & Shannon 1985). As the mud on the shelf is distributed in discrete patches, there are corresponding preferential areas for the formation of oxygen-poor water. The two main areas of low-oxygen water formation in the southern Benguela region are in the Orange River Bight and St Helena Bay (Chapman & Shannon 1985; Bailey 1991; Shannon & O’Toole 1998; Bailey 1999; Fossing *et al*. 2000) (Figure 6). The spatial distribution of oxygen-poor water in each of the areas is subject to short- and medium-term variability in the volume of hypoxic water that develops. De Decker (1970) showed that the occurrence of low oxygen water off Lambert’s Bay is seasonal, with highest development in summer/autumn. Bailey & Chapman (1991), on the other hand, demonstrated that in the St Helena Bay area daily variability exists as a result of downward flux of oxygen through thermoclines and short-term variations in upwelling intensity. Subsequent upwelling processes can move this low-oxygen water up onto the inner shelf, and into nearshore waters, often with devastating effects on marine communities.

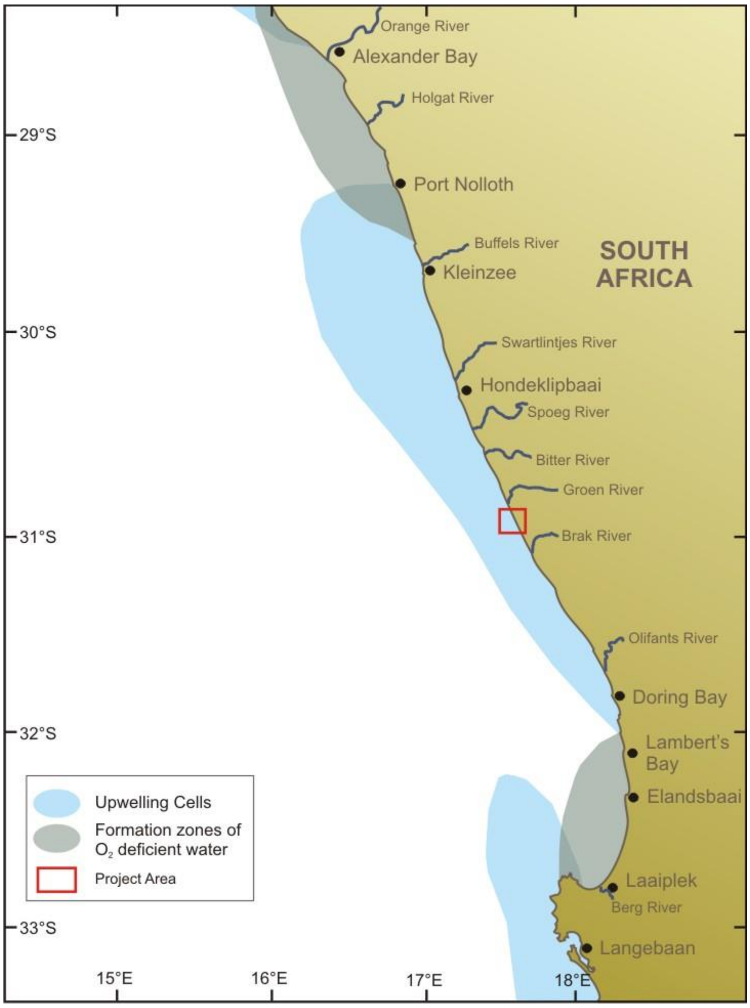

Figure 6: Upwelling centres and formation zones of oxygen deficient water on the West Coast in relation to the project area (red block).

Periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities leading to large-scale stranding of rock lobsters, and mass mortalities of marine biota and fish (Newman & Pollock 1974; Matthews & Pitcher 1996; Pitcher & Calder 2000; Cockcroft *et al*. 2000) (Figure 7). The development of anoxic conditions as a result of the decomposition of huge amounts of organic matter generated by algal blooms is the main cause for these mortalities and walkouts. The blooms develop over a period of unusually calm wind conditions when sea surface temperatures where high. Algal blooms usually occur during summer-autumn (February to April) but can also develop in winter during the 'berg' wind periods, when similar warm windless conditions occur for extended periods. Low-oxygen events have, however, not been reported from the region between Groen River mouth and Sout River mouth in which the project area is located.

Figure 7: Mass stranding, or 'walk-out' of rock lobsters that occurred at Elands Bay on the South African west coast in February 2002 (Photo from http://www.waterencyclopedia.com).

3.1.6 *Turbidity*

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulate matter. Total Suspended Particulate Matter (TSPM) can be divided into Particulate Organic Matter (POM) and Particulate Inorganic Matter (PIM), the ratios between them varying considerably. The POM usually consists of detritus, bacteria, phytoplankton and zooplankton, and serves as a source of food for filter-feeders. Seasonal microphyte production associated with upwelling events will play an important role in determining the concentrations of POM in coastal waters. PIM, on the other hand, is primarily of geological origin consisting of fine sands, silts and clays. Off Namaqualand, the PIM loading in nearshore waters is strongly related to natural inputs from the Orange River or from 'berg' wind events. Although highly variable, annual discharge rates of sediments by the Orange River is estimated to vary from 8 - 26 million tons/yr (Rogers 1979). 'Berg' wind events can potentially contribute the same order of magnitude of sediment input as the annual estimated input of sediment by the Orange River (Shannon & Anderson 1982; Zoutendyk 1992, 1995; Shannon & O'Toole 1998; Lane & Carter 1999). For example, a 'berg' wind event in May 1979 described by Shannon and Anderson (1982) was estimated to have transported in the order of 50 million tons of sand out to sea, affecting an area of 20,000 km^2.

Concentrations of suspended particulate matter in shallow coastal waters can vary both spatially and temporally, typically ranging from a few mg/ℓ to several tens of mg/ℓ (Bricelj & Malouf 1984; Berg & Newell 1986; Fegley *et al*. 1992). Field measurements of TSPM and PIM concentrations in the Benguela current system have indicated that outside of major flood events, background concentrations of coastal and continental shelf suspended sediments are generally <12 mg/ℓ, showing significant long-shore variation (Zoutendyk 1995). Considerably higher concentrations of PIM have, however, been reported from southern African West Coast waters under stronger wave conditions associated with high tides and storms, or under flood conditions. During storm events, concentrations near the seabed may even reach up to 10,000 mg/ℓ (Miller & Sternberg 1988). In the vicinity of the Orange River mouth, where river outflow strongly influences the turbidity of coastal waters, measured concentrations ranged from 14.3 mg/ℓ at Alexander Bay just south of the mouth (Zoutendyk 1995) to peak values of 7,400 mg/ℓ immediately upstream of the river mouth during the 1988 Orange River flood (Bremner *et al*. 1990).

The major source of turbidity in the swell-influenced nearshore areas off the West Coast is the redistribution of fine inner shelf sediments by long-period Southern Ocean swells. The current velocities typical of the Benguela (10-30 cm/s) are capable of resuspending and transporting considerable quantities of sediment equatorwards. Under relatively calm wind conditions, however, much of the suspended fraction (silt and clay) that remains in suspension for longer periods becomes entrained in the slow poleward undercurrent (Shillington *et al*. 1990; Rogers & Bremner 1991).

Superimposed on the suspended fine fraction, is the northward littoral drift of coarser bedload sediments, parallel to the coastline. This northward, nearshore transport is generated by the predominantly south-westerly swell and wind-induced waves. Longshore sediment transport varies considerably in the shore-perpendicular dimension, being substantially higher in the surf-zone than at depth, due to high turbulence and convective flows associated with breaking waves, which suspend and mobilise sediment (Smith & Mocke 2002).

On the inner and middle continental shelf, the ambient currents are insufficient to transport coarse sediments typical of those depths, and re-suspension and shoreward movement of these by wave-induced currents occur primarily under storm conditions. Data from a Waverider buoy at Port Nolloth have indicated that 2-m waves are capable of re-suspending medium sands (200 µm diameter) at ~10 m depth, whilst 6-m waves achieve this at ~42 m depth. Low-amplitude, long-period waves will, however, penetrate even deeper. Most of the sediment shallower than 90 m can therefore be subject to re-suspension and transport by heavy swells (Lane & Carter 1999).

Biological Environment

The study area lies within the relatively uniform cool Namaqua marine biogeographic region, which extends from Cape Point to Lüderitz in Namibia (Emanuel *et al.* 1992; Lombard *et al.* 2004)(Figure 8). The major force driving the ecology of this region is coastal upwelling, predominantly occurring in the spring/summer period when the south-easterly is the prevailing wind. The upwelling process supplies inorganic nutrients to the euphotic zone supporting high biological productivity (see previous section). This coast is, however, characterized by low marine species richness and low endemicity (Awad *et al.* 2002).

The biota of nearshore marine habitats on the West Coast are relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. The benthic communities within this region are largely ubiquitous, particular only to substrate type (i.e. hard vs. soft bottom), exposure to wave action, or water depth. Habitats specific to the study area include:

- Sandy intertidal and subtidal substrates,
- Intertidal rocky shores and subtidal reefs, and
- The water body

The biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability - even at small scales. No rare or endangered species have been recorded (Awad *et al.* 2002). Consequently, this review describes 'typical' biological communities, focussing on dominant, commercially important and conspicuous species only.

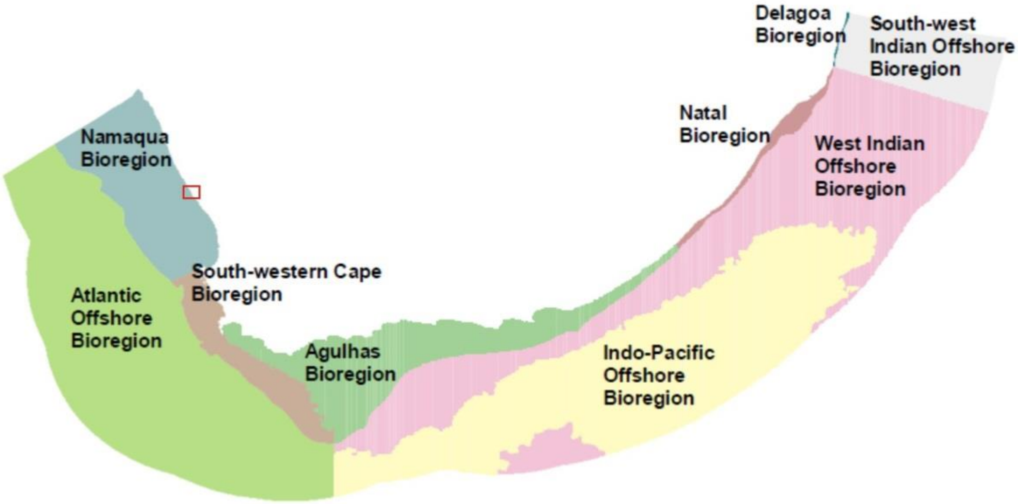

Figure 8: The South African inshore and offshore bioregions in relation to the proposed Volwaterbaai desalination plant area (red rectangle) (adapted from Lombard et al. 2004).

3.1.7 *Sandy Substrate Habitats and Biota*

The benthic biota of soft bottom substrates constitutes invertebrates that live on, or burrow within, the sediments, and are generally divided into megafauna (>10 cm), macrofauna (animals >1 mm) and meiofauna (<1 mm).

Intertidal Sandy Beaches

Although the coastline of the study area is highly dominated by rocky shores, there are some isolated pocket beaches between the rocky outcrops. Longer beaches occur south of the Brak River mouth and ~3.5 km to the north of the proposed desalination plant site. Sandy beaches are one of the most dynamic coastal environments. The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size, which is termed beach morphodynamics. Three morphodynamic beach types are described: dissipative, reflective and intermediate beaches (McLachlan *et al.* 1993). Generally, dissipative beaches are relatively wide and flat with fine sands and high wave energy. Waves start to break far from the shore in a series of spilling breakers that 'dissipate' their energy along a broad surf zone. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches have low wave energy, and are coarse grained (>500 µm sand) with narrow and steep intertidal beach faces. The relative absence of a surf-zone causes the waves to break directly on the shore causing a high turnover of sand. The result is depauperate faunal communities. Intermediate beach conditions exist between these extremes and have a very variable species composition (McLachlan *et al.* 1993, Jaramillo *et al.* 1995, Soares 2003). This variability is mainly attributable to the amount and quality of food available. Beaches with a high input of e.g. kelp wrack have a rich and diverse drift-line fauna, which is sparse or absent on beaches lacking a drift-line (Branch & Griffiths 1988). As a result of the combination of typical beach characteristics, and the special adaptations of beach fauna to these, beaches act as filters and energy recyclers in the nearshore environment (Brown & McLachlan 1990).

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch & Griffiths (1988) is used below (Figure 9), supplemented by data from various publications on West Coast sandy beach biota (e.g. Bally 1987, Brown *et al.* 1989, Soares *et al.* 1996, 1997, Nel 2001, Nel *et al*. 2003, Soares 2003, Branch *et al.* 2010, Harris 2012). The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. Due to the exposed nature of the coastline in the study area, most beaches are of the intermediate to reflective type. The supralittoral zone is situated above the high water spring (HWS) tide level, and receives water input only from large waves at spring high tides or through sea spray. This zone is characterised by a mixture of air breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on kelp deposited near or on the driftline. Terrestrial species include a diverse array of beetles and arachnids and some oligochaetes, while semi-terrestrial fauna include the oniscid isopod *Tylos granulatus*, and amphipods of the genus *Talorchestia*. The intertidal zone or mid-littoral zone, has a vertical range of about 2 m. This mid-shore region is characterised by the cirolanid isopods *Pontogeloides latipes*, *Eurydice* (*longicornis*=) *kensleyi*, and *Excirolana natalensis*, the polychaetes *Scolelepis squamata*, *Orbinia angrapequensis*, *Nepthys hombergii* and *Lumbrineris tetraura*, and amphipods of the families Haustoridae and Phoxocephalidae (Figure 10). In some areas, juvenile and adult sand mussels *Donax serra* may also be present in considerable numbers.

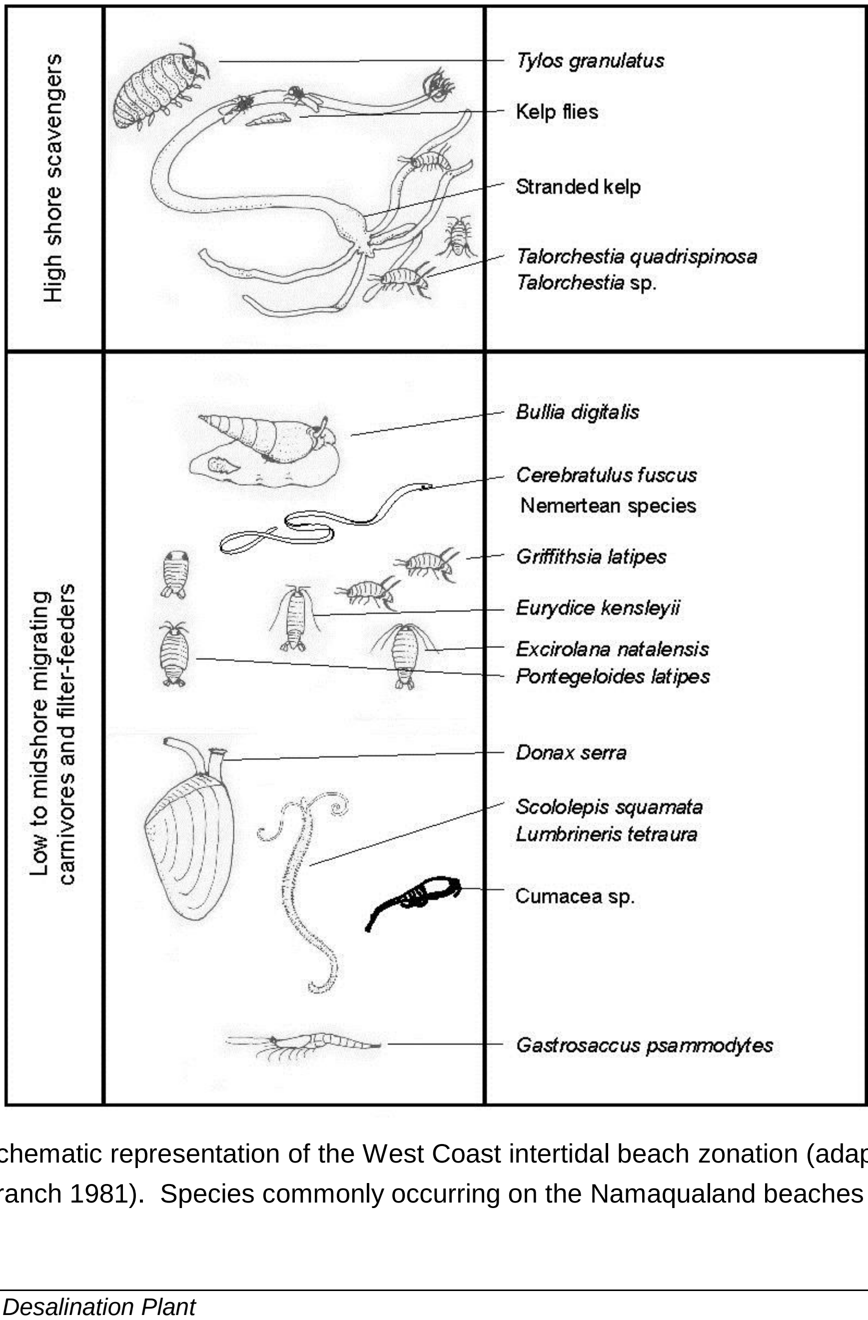

Figure 9: Schematic representation of the West Coast intertidal beach zonation (adapted from Branch & Branch 1981). Species commonly occurring on the Namaqualand beaches are listed.

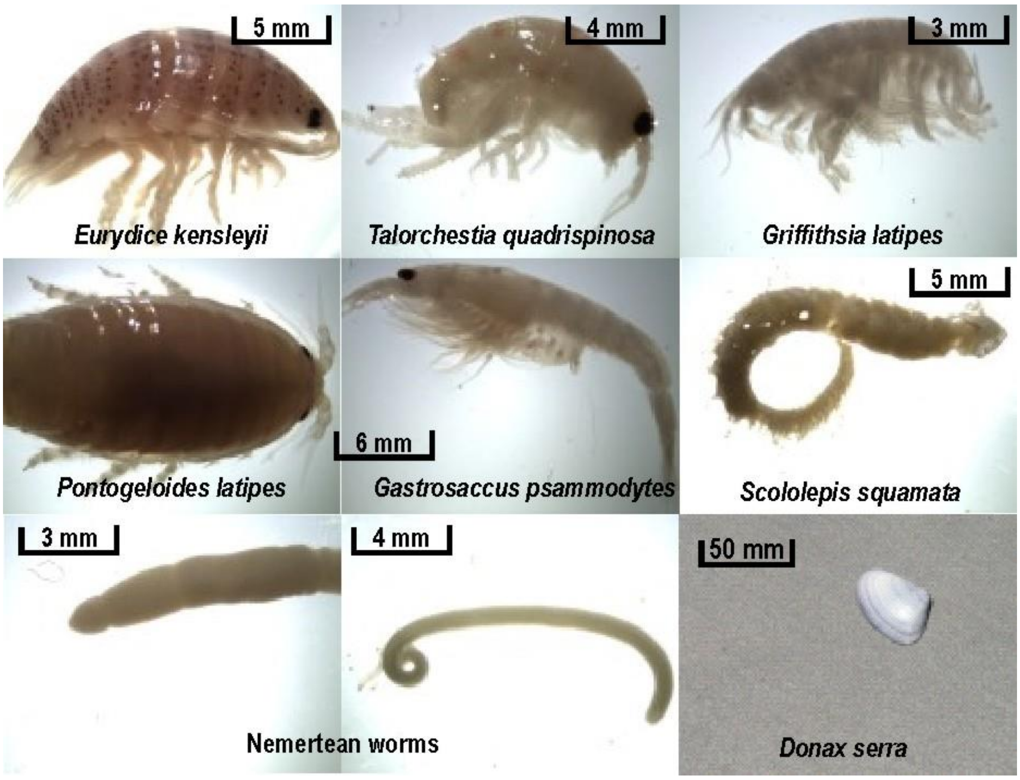

Figure 10: Common beach macrofaunal species occurring on exposed West Coast beaches.

3.1.8 *Rocky Substrate Habitats and Biota*

The following general description of the intertidal and subtidal habitats for the West Coast is based on Field *et al.* (1980), Branch & Branch (1981), Branch & Griffiths (1988) and Field & Griffiths (1991). It is supplemented by the descriptions of Steffani (2001), Blamey (2003), Pulfrich *et al.* (2003a), and Steffani & Branch (2003a, b, 2005), specific to the Groen River coastline. The biological communities of rocky intertidal and subtidal reefs are generally ubiquitous throughout the southern African West Coast region, being particular only to wave exposure, turbulence and/or depth zone.

Intertidal Rocky Shores

Several studies on the west coast of southern Africa have documented the important effects of wave action on the intertidal rocky-shore community. Specifically, wave action enhances filter-feeders by increasing the concentration and turnover of particulate food, leading to an elevation of overall biomass despite a low species diversity (McQuaid & Branch 1985, Bustamante & Branch 1995a, 1996a, Bustamante *et al.* 1997). Conversely, sheltered shores are diverse with a relatively low biomass, and only in relatively sheltered embayments does drift kelp accumulate and provide a vital support for very high densities of kelp trapping limpets, such as *Cymbula granatina* that occur exclusively there (Bustamante *et al.* 1995b). In the subtidal, these differences diminish as wave exposure is moderated with depth.

West Coast rocky intertidal shores can be divided into five zones on the basis of their characteristic biological communities: The Littorina, Upper Balanoid, Lower Balanoid, Cochlear/Argenvillei and the Infratidal Zones. These biological zones correspond roughly to zones based on tidal heights (Figure 11 and Figure 12). Tolerance to the physical stresses associated with life on the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce these five zones.

Supralittoral fringe or Littorina zone - The uppermost part of the shore is the supralittoral fringe, which is the part of the shore that is most exposed to air, perhaps having more in common with the terrestrial environment. The supralittoral is characterised by low species diversity, with the tiny periwinkle *Afrolittorina knysnaensis*, and the red alga *Porphyra capensis* constituting the most common macroscopic life.

Upper Mid-littoral or Upper Balanoid zone - The upper mid-littoral is characterised by the limpet *Scutellastra granularis*, which is present on all shores. The gastropods *Oxystele variegata*, *Nucella dubia*, and *Helcion pectunculus* are variably present, as are low densities of the barnacles *Tetraclita serrata*, *Octomeris angulosa* and *Chthalamus dentatus*. Flora is best represented by the green algae *Ulva* spp.

Lower Mid-littoral or Lower Balanoid zone - Toward the lower shore, biological communities are determined by exposure to wave action. On sheltered and moderately exposed shores, a diversity of algae abounds with a variable representation of: green algae – *Ulva* spp, *Codium* spp.; brown algae – *Splachnidium rugosum*; and red algae – *Aeodes orbitosa*, *Mazzaella (=Iridaea) capensis*, *Gigartina polycarpa* (=*radula*), *Sarcothalia* (=*Gigartina*) *stiriata*, and with increasing wave exposure *Plocamium rigidum* and *P. cornutum*, and *Champia lumbricalis*. The gastropods *Cymbula granatina* and *Burnupena* spp. are also common, as is the reef building polychaete *Gunnarea capensis*, and the small cushion starfish *Patiriella exigua*. On more exposed shores, almost all of the primary space can be occupied by the dominant alien invasive mussel *Mytilus galloprovincialis*. First recorded in 1979 (although it is likely to have arrived in the late 1960's), it is now the most abundant and widespread invasive marine species spreading along the entire West Coast and parts of the South Coast (Robinson *et al.* 2005). *M. galloprovincialis* has partially displaced the local mussels *Choromytilus meridionalis* and *Aulacomya ater* (Hockey & Van Erkom Schurink 1992), and competes with several indigenous limpet species (Griffiths *et al.* 1992, Steffani & Branch 2003a, b). Recently, another alien invasive has been recorded, the acorn barnacle *Balanus glandula*, which is native to the west coast of North America where it is the most common intertidal barnacle. The presence of *B. glandula* in South Africa was only noticed a few years ago as it had always been confused with the native barnacle *Cthamalus dentatus* (Simon-Blecher *et al.* 2008). There is, however, evidence that it has been in South Africa since at least 1992 (Laird & Griffith 2008). At the time of its discovery, the barnacle was recorded from 400 km of coastline from Elands Bay to Misty Cliffs near Cape Point (Laird & Griffith 2008). As it has been reported on rocky shores south of Lüderitz in Namibia (Pulfrich 2013), it is likely that it occurs in the study area. When present, the barnacle is typically abundant at the mid zones of semi-exposed shores.

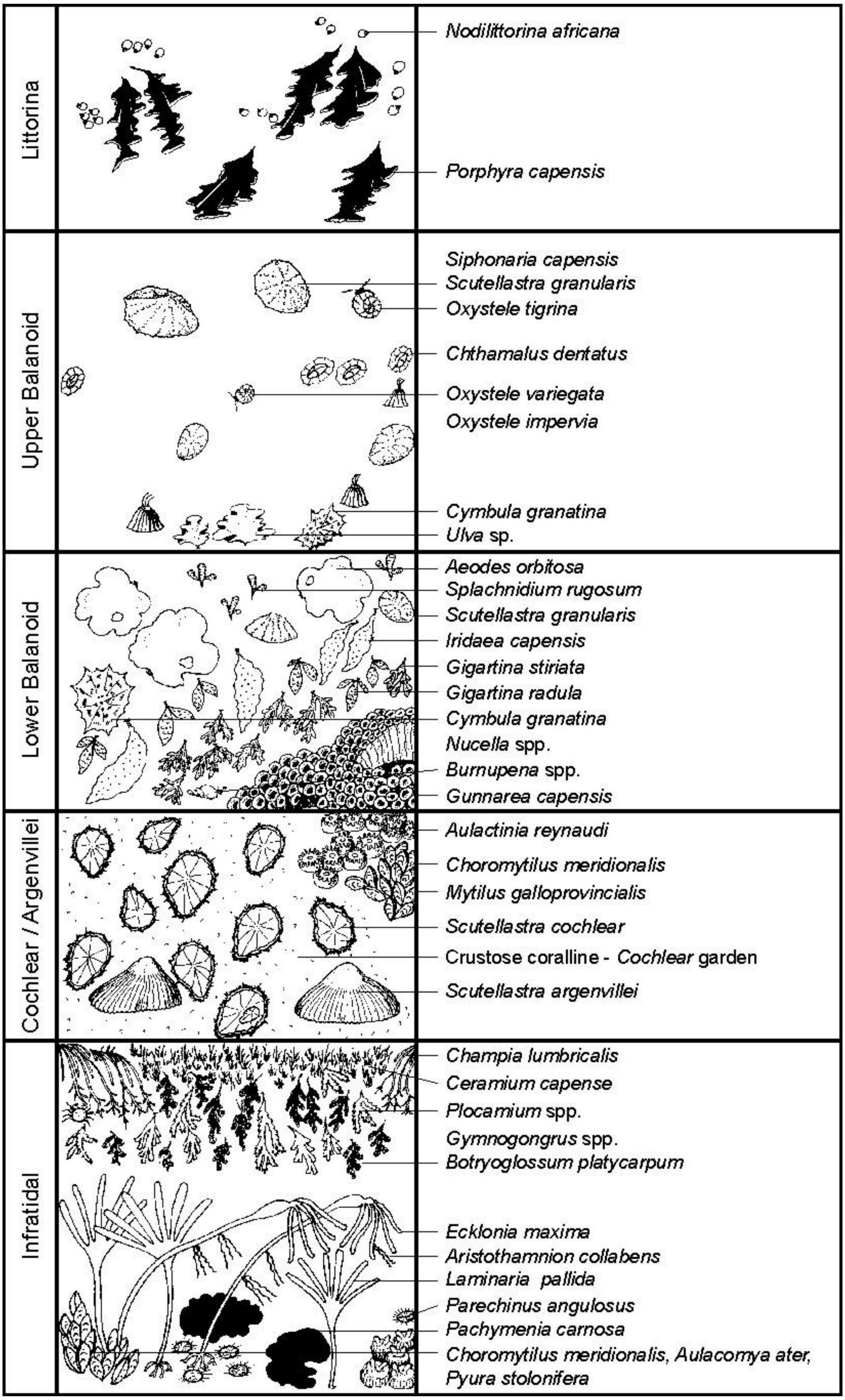

Figure 11: Schematic representation of the West Coast intertidal zonation. Species commonly occurring north of the Olifants River mouth are listed (adapted from Branch & Branch 1981).

Figure 12: Typical rocky intertidal zonation on the southern African west coast.

Sublittoral fringe or Argenvillei zone - Along the sublittoral fringe, the large kelp-trapping limpet *Scutellastra argenvillei* dominates forming dense, almost monospecific stands achieving densities of up to 200/m^2 (Bustamante *et al.* 1995). Similarly, *C. granatina* is the dominant grazer on more sheltered shores, also reaching extremely high densities (Bustamante *et al.* 1995). On more exposed shores *M. galloprovincialis* dominates. There is evidence that the arrival of the alien *M. palloprovincialis* has led to strong competitive interaction with *S. argenvillei* (Steffani & Branch 2003a, b, 2005). The abundance of the mussel changes with wave exposure, and at wave-exposed locations, the mussel can cover almost the entire primary substratum, whereas in semi-exposed situations it is never abundant. As the cover of *M. galloprovincialis* increases, the abundance and size of *S. argenvillei* on rock declines and it becomes confined to patches within a matrix of mussel bed. As a result exposed sites, once dominated by dense populations of the limpet, are now largely covered by the alien mussel. Semi-exposed shores do, however, offer a refuge preventing global extinction of the limpet. In addition to the mussel and limpets, there is variable representation of the flora and fauna described for the lower mid-littoral above, as well as the anemone *Aulactinia reynaudi*, numerous whelk species and the sea urchin *Parechinus angulosus*. Some of these species extend into the subtidal below.

Very recently, the invasion of west coast rocky shores by another mytilid, the small *Semimytilus algosus*, was noted (de Greef *et al.* 2013). It is hypothesized that this species has established itself fairly recently, probably only in the last ten years. Its current range extends from the Groen River mouth in the north to Bloubergstrand in the south. Where present, it occupies the lower intertidal zone, where they completely dominate primary rock space, while *M. galloprovincialis* dominates higher up the shore. Many shores on the West Coast have thus now been effectively partitioned by the three introduced species, with *B. glandula* colonizing the upper intertidal, *M. galloprovincialis* dominating the mid-shore, and now *S. algosus* smothering the low-shore (de Greef *et al.* 2013).

Rocky Subtidal Habitat and Kelp Beds
Biological communities of the rocky sublittoral can be broadly grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. This shift in communities is not knife-edge, and rather represents a continuum of species distributions, merely with changing abundances.

From the sublittoral fringe to a depth of between 5 and 10 m, the benthos is largely dominated by algae, in particular two species of kelp. The canopy forming kelp *Ecklonia maxima* extends seawards to a depth of about 10 m. The smaller *Laminaria pallida* forms a sub-canopy to a height of about 2 m underneath *Ecklonia*, but continues its seaward extent to about 30 m depth, although further north up the west coast increasing turbidity limits growth to shallower waters (10-20 m) (Velimirov *et al.* 1977, Jarman & Carter 1981, Branch 2008). *Ecklonia maxima* is the dominant species in the south forming extensive beds from west of Cape Agulhas to north of Cape Columbine, but decreasing in abundance northwards. *Laminaria* becomes the dominant kelp north of Cape Columbine and thus in the project area, extending from Danger Point east of Cape Agulhas to Rocky Point in northern Namibia (Stegenga *et al.* 1997, Rand 2006).

Kelp beds absorb and dissipate much of the typically high wave energy reaching the shore, thereby providing important partially-sheltered habitats for a high diversity of marine flora and fauna, resulting in diverse and typical kelp-forest communities being established (Figure 13). Through a combination of shelter and provision of food, kelp beds support recruitment and complex trophic food webs of numerous species, including commercially important rock lobster stocks (Branch 2008).

Figure 13: The canopy-forming kelp *Ecklonia maxima* provides an important habitat for a diversity of marine biota (Photo: Geoff Spiby).

Growing beneath the kelp canopy, and epiphytically on the kelps themselves, are a diversity of understorey algae, which provide both food and shelter for predators, grazers and filter-feeders associated with the kelp bed ecosystem. Representative under-storey algae include *Botryocarpa prolifera*, *Neuroglossum binderianum*, *Botryoglossum platycarpum*, *Hymenena venosa* and *Rhodymenia* (=*Epymenia*) *obtusa*, various coralline algae, as well as subtidal extensions of some algae occurring primarily in the intertidal zones (Bolton 1986). Epiphytic species include *Polysiphonia virgata*, *Gelidium vittatum (=Suhria vittata)* and *Carpoblepharis flaccida*. In particular, encrusting coralline algae are important in the under-storey flora as they are known as settlement attractors for a diversity of invertebrate species. The presence of coralline crusts is thought to be a key factor in supporting a rich shallow-water community by providing substrate, refuge, and food to a wide variety of infaunal and epifaunal invertebrates (Chenelot *et al.* 2008).

The sublittoral invertebrate fauna is dominated by suspension and filter-feeders, such as the mussels *Aulacomya ater* and *Choromytilus meriodonalis*, and the Cape reef worm *Gunnarea capensis*, and a variety of sponges and sea cucumbers. Grazers are less common, with most herbivory being restricted to grazing of juvenile algae or debris-feeding on detached macrophytes. The dominant herbivore is the sea urchin *Parechinus angulosus*, with lesser grazing pressure from limpets, the isopod *Paridotea reticulata* and the amphipod *Ampithoe humeralis*. The abalone *Haliotis midae*, an important commercial species present in kelp beds south of Cape Columbine is naturally absent north of Cape Columbine (but see section 1.3.7). Key predators in the sub-littoral include the commercially important West Coast rock lobster *Jasus lalandii* and the octopus *Octopus vulgaris*. The rock lobster acts as a keystone species as it influences community structure *via* predation on a wide range of benthic organisms (Mayfield *et al.* 2000). Relatively abundant rock lobsters can lead to a reduction in density, or even elimination, of black mussel *Choromytilus meriodonalis*, the preferred prey of the species, and alter the size structure of populations of ribbed mussels *Aulacomya ater*, reducing the proportion of selected size-classes (Griffiths & Seiderer 1980). Their role as predator can thus reshape benthic communities, resulting in large reductions in taxa such as black mussels, urchins, whelks and barnacles, and in the dominance of algae (Barkai & Branch 1988, Mayfield 1998).

Of lesser importance as predators, although numerically significant, are various starfish, feather and brittle stars, and gastropods, including the whelks *Nucella* spp. and *Burnupena* spp. Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii*, two tone finger fin *Chirodactylus brachydactylus*, red fingers *Cheilodactylus fasciatus*, galjoen *Dichistius capensis*, rock suckers *Chorisochismus dentex* and the catshark *Haploblepharus pictus* (Branch *et al.* 2010).

There is substantial spatial and temporal variability in the density and biomass of kelp beds, as storms can remove large numbers of plants and recruitment appears to be stochastic and unpredictable (Levitt *et al.* 2002, Rothman *et al.* 2006). Some kelp beds are dense, whilst others are less so due to differences in seabed topography, and the presence or absence of sand and grazers.

Due to their importance as recruitment, nursery, and feeding grounds for numerous species, including the commercially important rock lobster *J. lalandii*, kelp beds are considered a medium sensitivity habitat.

3.1.9 *Site-specific Description*

An underwater qualitative inspection of the discharge location at Volwaterbaai was undertaken by a team of divers equipped with GoPro® cameras. The divers swam transects from the intertidal area to depths of ~8 m, recording the seabed type and its associated communities. This video footage identified that within ~70 m of the shore (~4 m depth), the seabed was dominated by relatively fine sand, with the only organisms recorded being fat plough shells (*Bullia laevissima*). Large accumulations of macerated red and brown algae occurred just above the seabed, which in shallower water became aggitated by wave action resulting in a dense algal 'soup'. The nearshore area was characterised by large boulders and flat reef, often covered in a thin veneer of sand. The reef was covered by crustose coraline algae, mussels (*Choromytilus meridionals*) and sea anemones (*Aulactinia reynaudi*) (all of which are tolerant of frequent sand inundation), with only sparse growth of foliose red algae. This suggests that the seaward edge of the rocky coastline is strongly influenced by seasonal sand inundation and subsequent erosion. The reefs in the surf-zone where characterised by *C. meridionalis*, *A. reynaudi*, the Cape reef worm *Gunnarea capensis,* the limpet *Scutellastra argenvillei*, a diversity of foliose red algae and the kelp *Laminaria pallida*. Sand was prevalent on and between the reefs, and kelp fronds and the green alga *Caulerpa filliformis* protruding from the sand suggested that the shallow subtidal areas had recently become inundated by mobile sediments.

3.1.10 *The Water Body*

The study area is located in the southern Benguela ecosystem and, as there are few barriers to water exchange, pelagic communities are typical of those of the region. The pelagic communities are typically divided into plankton, fish, and marine mammals (seals, dolphins and whales).

Plankton

Plankton range from single-celled bacteria to jellyfish, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton (Figure 14).

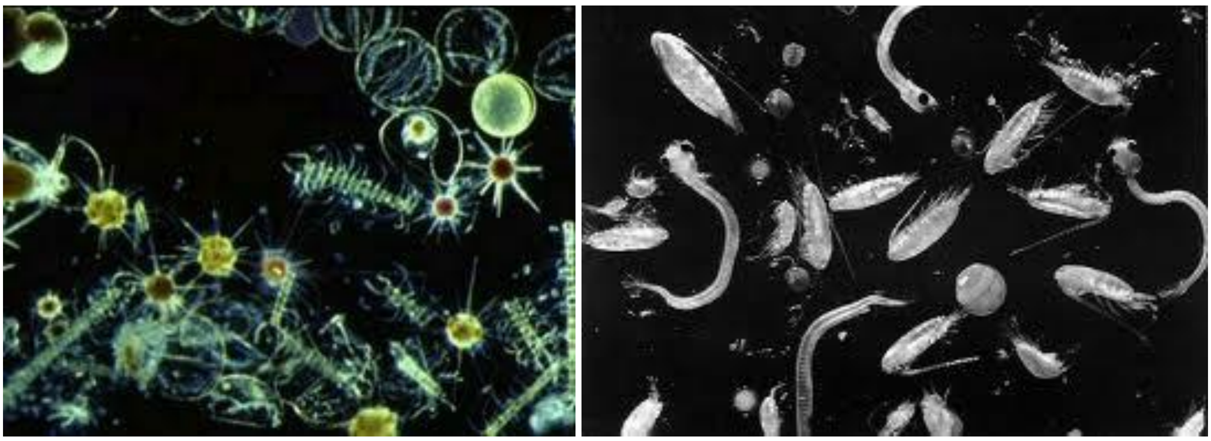

Figure 14: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

The phytoplankton includes diatoms, dinoflagellates, coccolithophorids and microflagellates. Phytoplankton biomass in the southern Benguela is generally high in summer during the upwelling season, but also quite extensive in the autumn and spring, with diatoms generally dominating inshore and small flagellates offshore (Barlow *et al.* 2005). Maximum diatom concentrations are found in the upper 10 m and thereafter decrease with an increase in depth. Common and widely distributed diatom species include *Asterionella glacialis*, *Leptocylindrus danicus*, *Minidiscus trioculatus*, *Skeletonema costatum*, *Thalassionema nitzschioides* and a number of *Navicula*, *Nitzschia* and *Thalassiosira* species. The most common member of the microflagelattes is a species of *Pyramimonas*. Dinoflagellates are represented by several members of the genus *Gyrodinium*, *Ceratium*, *Protoperidilium* amongst others. Also present in the area are toxic dinoflagellate species such as *Alexandrium catenella* and various members of the genus *Dinophysis*, which can cause mass mortalities of fish, shellfish, marine mammals, seabirds and other animals (Pitcher & Calder 2000).

Zooplankton is characterised by pelagic crustaceans (e.g. copepods, cumaceans, hyperiid amphipods, chaetognaths, mysids, euphausiids), invertebrate larvae (e.g. bivalve, polychaete, *etc*.), pelagic cnidarians, and ichthyoplankton. Crustaceans often contribute greatest to the total zooplankton with copepods (e.g. *Calanus* spp., *Centropages* spp., *Metridia* spp.) being the most common organisms in the zooplankton (Verheye & Richardson 1998, Hutchings *et al.* 2006). Ichthyoplankton constitutes the eggs and larvae of fish. Long-term changes in the southern Benguela include a significant increase in zooplankton over the past five decades, with a decline since 1995 linked to a concomitant increase in pelagic fish biomass as the main predators on zooplankton (Hutchings *et al.* 2006).

Fish

Small pelagic species that occur in the area include the sardine (*Sardinops sagax*), anchovy (*Engraulis encrasicolus*), juvenile Cape horse mackerel (*Trachurus trachurus capensis*), and round herring (*Etrumeus whiteheadi*). Although these species generally occur within the 200 m contour, they may often be found very close inshore (Pecquerie *et al.* 2004). Demersal fish include deep water (*Merluccius paradoxus*), shallow water hake (*M. capensis*) and kingklip (*Genypterus capensis*), and St Joseph shark (*Callorhinchus capensis*) in shallow inshore waters. Linefish species include (juvenile) snoek (*Thyrsites atun*), silver kob (*Argyrosomus inodorus*), white steenbras (*Lithognathus lithognathus*), blacktail (*Diplodus sargus*), white stumpnose (*Rhabdosargus globiceps*), Hottentot (*Pachymetopon blochii*), geelbek (*Atractoscion aequidens*) and galjoen (*Dichistius capensis*).

The surf-zone and outer turbulent zone habitats of sandy beaches are considered to be important nursery habitats for marine fishes (Modde 1980, Lasiak 1981, Kinoshita & Fujita 1988, Clark *et al.* 1994). However, the composition and abundance of the individual assemblages seems to be heavily dependent on wave exposure (Blaber & Blaber 1980, Potter *et al*. 1990, Clark 1997a, b). Surf-zone fish communities off the South African West Coast have relatively high biomass, but low species diversity. Typical surf-zone fish include harders (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*) (Figure 15), Cape sole (*Heteromycteris capensis*), Cape gurnard (*Chelidonichthys capensis*), False Bay klipfish (*Clinus latipennis*), sandsharks (*Rhinobatos annulatus*), eagle ray (*Myliobatis aquila*), and smooth-hound (*Mustelus mustelus*) (Clark 1997b).

Figure 15: Common surf-zone fish include the harder (left, photo: aquariophil.org) and the white stumpnose (right, photo: easterncapescubadiving.co.za).

Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii*, twotone fingerfin (*Chirodactylus brachydactylus*), red fingers (*Cheilodactylus fasciatus*), galjoen (*Dichistius capensis*), rock suckers (*Chorisochismus dentex*), maned blennies (*Scartella emarginata*) and the catshark (*Haploblepharus pictus*) (Sauer *et al.* 1997; Brouwer *et al*. 1997; Branch *et al*. 2010). Several additional species of fish are also commonly caught in gill-nets set over rocky reef areas between the Orange River and Cape Columbine. Species of importance include harder (*Liza richardsonii*), pilchard (*Sardinops sagax*), strepie (*Sarpa salpa*), houndsharks (*Mustelus mustelus*) and cowsharks (*Notorynchus cepedianus*) (K. Hutchings, UCT, pers. comm.).

Seabirds

Large numbers of pelagic seabirds exploit the pelagic fish stocks of the Benguela system. Of the 49 species of seabirds that occur in the Benguela region, 14 are defined as resident, 10 are visitors from the northern hemisphere and 25 are migrants from the southern Ocean. The area between Cape Point and the Orange River supports 38% and 33% of the overall population of pelagic seabirds in winter and summer, respectively. 14 species of seabirds breed in southern Africa; Cape Gannet, African Penguin, four species of Cormorant, White Pelican, three Gull and four Tern species. The breeding areas are distributed around the coast with islands being especially important. The number of successfully breeding birds at the particular breeding sites varies with food abundance.

Birds endemic to the region and liable to occur most frequently in the project area include Cape Gannets (*Morus capensis*), Kelp Gulls (*Larus dominicanus*), African Penguins (*Spheniscus demersus*), African Black Oystercatcher (*Haematopus moquini*) (Figure 16, left), Bank (*Phalacrocorax neglectus*), Cape (*Phalacrocorax capensis*) and Crowned Cormorants (*Phalacrocorax coronatus*) (Figure 16, right), and Hartlaub's Gull (*Larus hartlaubii*). Of these the Black oystercatcher and Bank cormorant are rare. The breeding success of African Black Oystercatcher is particularly susceptible to disturbance from off-road vehicles as they nest and breed on beaches between the Eastern Cape and southern Namibia. Caspian (*Hydroprogne caspia*) and Damara (*Sterna balaenarum*) terns are likewise rare and breed in the study area, especially in the wetland and saltpan areas associated with the Olifants River estuary.

Most of the breeding seabird species forage at sea with most birds being found relatively close inshore (10 - 30 km), although African Penguins and Cape Gannets are known to forage up to 60 km and 140 km offshore, respectively.

Figure 16: The African Black Oystercatcher (Left, photo: patrickspilsbury.blogspot.com) and Crowned Cormorant (right, photo: savoels.za.net) occur in the Island Point area.

Marine Mammals
The marine mammal fauna of the West Coast comprises between 28 and 31 species of cetaceans (whales and dolphins) and four species of seals of which the Cape fur seal *Arctocephalus pusillus* is the most common.

The Cape fur seal (Figure 17, left) is the only species of seal resident along the west coast of Africa, occurring at numerous breeding and non-breeding sites on the mainland and on nearshore islands and reefs (see Figure 19). Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989). There are three Cape fur seal breeding colonies within the broader study area: at Kleinzee (incorporating Robeiland), at Bucchu Twins near Alexander Bay and at Elephant Rocks near the Olifants River mouth. The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African Coast (Wickens 1994). The colony at Buchu Twins, formerly a non-breeding colony, has also attained breeding status (M. Meyer, SFRI, pers. comm.). Non-breeding colonies occur at Strandfontein Point (~5 km north or the Groen River mouth) and on Bird Island at Lamberts Bay. All have important conservation value since they are largely undisturbed at present.

Dusky dolphin (*Lagenorhynchus obscurus*) and Heaviside's dolphin (*Cephalorhynchus heavisidii*) (Figure 17, right) are resident year round throughout the Benguela ecosystem coastal waters (Findlay *et al.* 1992, Elwen 2008, Elwen *et al*. 2010). Whale species that may be sighted in the area include southern Right whale (*Balaena glacialis*), Humpback whale (*Megaptera novaeangliae*), and Killer whale (*Orcinus orca*), along with Antarctic Minke (*Balaenoptera acutorostrata*) and Bryde's (*B. brydei*) whales (Best 2007). Whales occurring in the nearshore regions of the project area will largely be transitory.

Figure 17: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich)(left) and the endemic Heaviside's Dolphin *Cephalorhynchus heavisidii* (right) (Photo: De Beers Marine Namibia).

Beneficial Uses

3.1.11 *Rock Lobster Fishery*

The West Coast rock lobster *Jasus lalandii* is a valuable resource of the South African West Coast and consequently an important income source for West Coast fishermen. Following the collapse of the rock-lobster resource in the 1970s, fishing has been controlled by a Total Allowable Catch (TAC), a minimum size, restricted gear, a closed season and closed areas

(Crawford *et al.* 1987, Melville-Smith & Van Sittert 2005). The West Coast rock lobster fishery in Zone A (Port Nolloth & Hondeklipbaai) is seasonally restricted to the period 1 October to the last day in April. Management of the resource is geographically specific, with the TAC annually allocated by Area. The study area falls within Area 2 of the commercial rock lobster fishing zones that extends from Kleinzee to the mouth of the Brak River. The TAC for the season 2013/14 has been set at 2167.06 tons.

Commercial catches of rock lobster in Area 2 are confined to shallower water (<30 m) with almost all the catch being taken in <15 m depth. Actual rock-lobster fishing, however, takes place only at discrete suitable reef areas along the shore within this broad depth zone. Lobster fishing is conducted from a fleet of small dinghies/bakkies. The majority of these work directly from the shore within a few nautical miles of the harbours, with only 30% of the total numbers of bakkies partaking in the fishery being deployed from larger deck boats. As a result, lobster fishing tends to be concentrated close to the shore within a few nautical miles of Port Nolloth and Hondeklip Bay. Rock lobster landings for the fishing season 2008/09 and 2009/10 for the sub-areas 1 and 2 of Area 2 are provided inTable 2.

Table 2: Actual rock-lobster Catch (kg) for subareas 1 and 2 of Area 2 for the 2008/09 and 2009/2010 fishing seasons (Data source: Rock Lobster Section, DAFF).

Area/subarea	Actual Catch 2008/09	Actual Catch 2009/10	Actual Catch 2010/11	Actual Catch 2011/12	Actual Catch 2012/13
2/1	937	1,286	2,246	1,683	--
2/2	--	--	--	--	--

3.1.12 *Kelp Collecting*

The West Coast is divided into numerous seaweed concession areas (Figure 18). Access to a seaweed concession is granted by means of a permit from the Fisheries Branch of the Department of Agriculture, Forestry and Fisheries (DAFF) to a single party for a period of five years. The seaweed industry was initially based on sun dried beach-cast seaweed, with harvesting of fresh seaweed occurring in small quantities only (Anderson *et al.* 1989). The actual level of beach-cast kelp collection varies substantially through the year, being dependent on storm action to loosen kelp from subtidal reefs (Table 3). Further south, around Cape Columbine, permits also allow the harvesting of live kelp by hand from a boat.

Table 3: Beach-cast collections (in kg dry weight) for kelp concessions north of Lamberts Bay (Data source: Seaweed Section, DAFF).

Concession Number	Concession Holder	2005	2006	2007	2008	2009	2010	2011	2012	2013
13	Eckloweed Industries	65,898	94,914	122,095	61,949	102,925	53,927	40,511	43,297	20,485
14	Eckloweed Industries	165,179	145,670	79,771	204,365	117,136	166,106	72,829	151,561	97,283
15	Rekaofela Kelp	10,300	19,550	0	23,646	0	0	0	160,500	36,380
16	Rekaofela Kelp	35,920	28,600	84,445	16,804	0	0	0	156,000	24,000
18	FAMDA	0	0	0	0	0	0	0	0	0
19	Premier Fishing	0	0	0	0	0	0	0	0	0

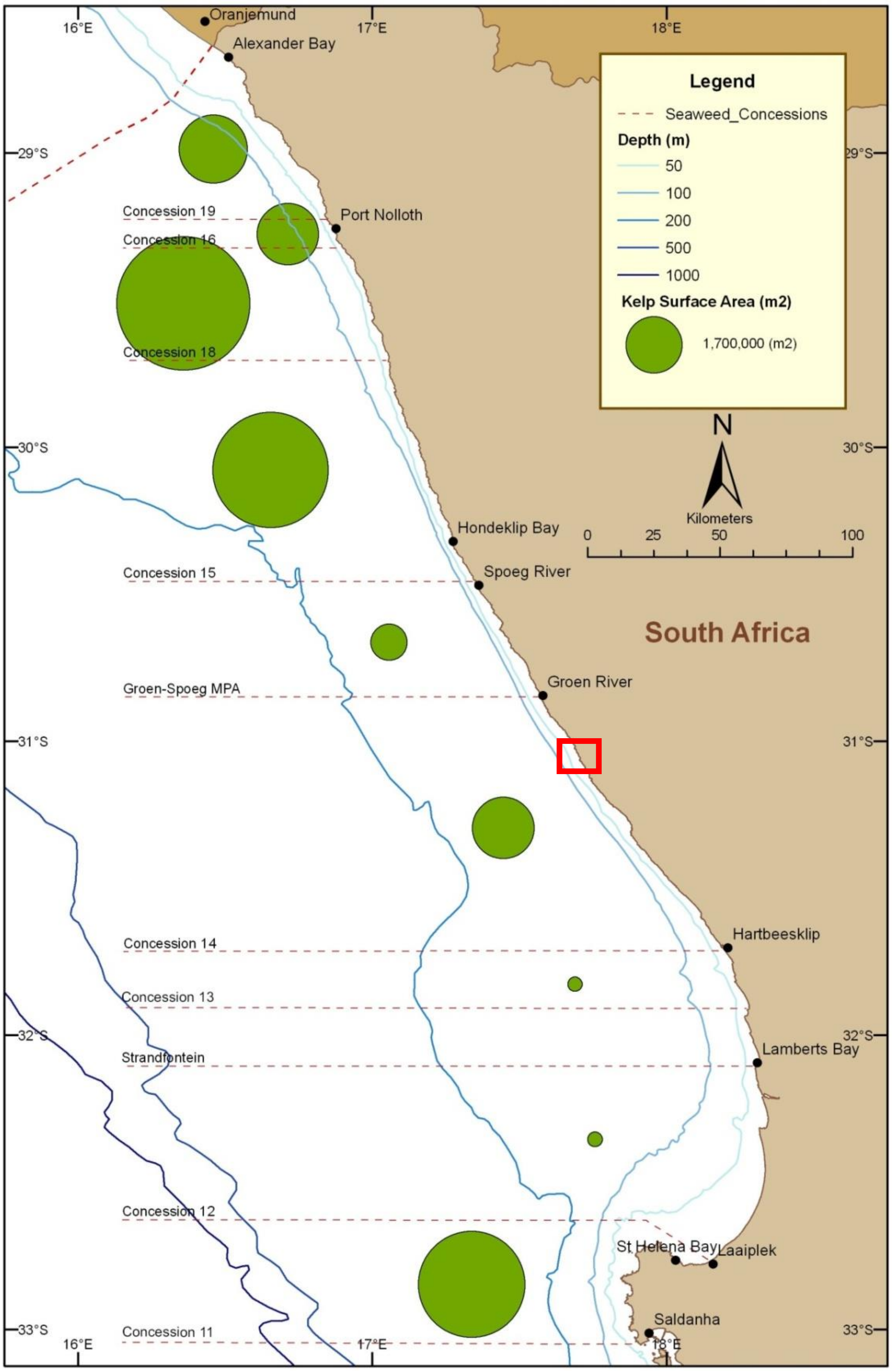

Figure 18: Estimated kelp bed area in the South African kelp concessions between the Orange River mouth and Cape Columbine (from Penney *et al.* 2007) in relation to the proposed project area (red polygon).

Permit holders collect beach casts of both *Ecklonia maxima* and *Laminaria pallida* from the driftline of beaches. The kelp is initially dried just above the high water mark before being transported to drying beds in the foreland dune area. The dried product is ground and used for agricultural purposes, or exported for production of alginic acid (alginate).

3.1.13 *Linefishing*

Commercial linefishing is conducted from a variety of vessels ranging from large deckboats to tiny rock lobster bakkies, most of which operate very close to the shore. In Namaqualand, the boats belong mostly to the rock lobster fishery, with most of the fishing undertaken during the rock lobster closed season. As with the rock lobster fishery, linefishing effort is centred around the harbours in the area. The main species targeted by the line-fishermen are snoek, yellowtail, hottentot and galjoen (Sauer & Erasmus 1997). The estimated annual linefish catch on the West Coast is 6,000 tons of which only 10% is contributed from inshore and offshore fishing in the northern regions. Sauer and Erasmus (1997) estimated that the inshore linefish catch along the Northern Cape coast amounts to <5t/km/year.

The landings and effort in the linefishery show distinct seasonality, influenced to a large extent by the availability of the target species. Of the species targeted by the linefishery, the hottentot is available to the fishermen throughout the year. The occurrence of snoek is more seasonal with the fish being more abundant during late summer and autumn. Yellowtail show a similar seasonality with catches peaking in March/April. Catches of galjoen are limited to the winter months, there being a closed season from 15 October to the end of February.

Clark *et al.* (2002) identified approximately 330 fishers in the area between Port Nolloth and Doring Bay. The increase in the number of artisanal fishers in the region since the 2002 survey is unknown, but in the interim many of these fishers will have received official recognition and have been granted small scale commercial or “interim relief” rights.

From 2002 to 2004, the Northern Cape provincial government initiated a small scale experimental fishery off Port Nolloth and Hondeklip Bay which targeted hake, kingklip, snoek, and St Joseph shark in the near-shore zone (www.northern-cape.co.za).

3.1.14 *Recreational Fisheries*

Recreational and subsistence fishing on the West Coast is small in scale when compared with the south and east coasts of South Africa. The population density in Namaqualand is low, and poor road infrastructure and ownership of much of the land by diamond mining companies in the northern parts of the West Coast has historically restricted coastal access to the towns and recreational areas of Port Nolloth, McDougall’s Bay, Hondeklip Bay and the Groen River mouth.

Recreational linefishing is confined largely to rock and surf angling in places such as Brand-se-Baai and the more accessible coastal stretches in the regions. Boat angling is not common along this section of the coast due to the lack of suitable launch sites and the exposed nature of the coastline. Fishing effort has been estimated at 0.12 angler/km north of Doring Bay. These fishers expended effort of approximately 200,000 angler days/year with a catch-per-unit-effort of 0.94 fish/angler/day (Brouwer *et al.* 1997, Sauer & Erasmus 1997). Target species consist mostly of hottentot, white stumpnose, kob, steenbras and galjoen, with catches being used for domestic consumption, or sold.

Recreational rock lobster catches are made primarily by diving or shore-based fishing using baitbags. Hoop-netting for rock lobster from either outboard or rowing boats is not common along this section of the coast (Cockcroft & McKenzie 1997). The majority of the recreational take of rock lobster is made by locals resident in areas close to the resource. Due to the remoteness of the area and the lack of policing, poaching of rock lobsters both by locals as well as seasonal visitors is becoming an increasing problem. Large numbers of rock lobsters are harvested in sheltered bays along the Namaqualand coastline by recreational divers who disregard bag-limits, size-limits or closed seasons. This potentially has serious consequences for the sustainability of the stock in the area.

3.1.15 *Marine Protected Areas (MPAs)*

'No-take' MPAs offering protection of the Namaqua biozones (sub-photic, deep-photic, shallow-photic, intertidal and supratidal zones) are absent northwards from Cape Columbine (Emanuel *et al*. 1992, Lombard *et al*. 2004). The only existing conservation area in the broader project area in which restrictions apply is the McDougall's Bay rock lobster sanctuary near Port Nolloth, which is closed to commercial exploitation of rock lobsters. Rocky shore and sandy beach habitats are generally not particularly sensitive to disturbance and natural recovery occurs within 2-5 years. However, much of the Namaqualand coastline has been subjected to decades of disturbance by shore-based diamond mining operations (Penney *et al*. 2007). These cumulative impacts and the lack of biodiversity protection has resulted in most of the coastal habitat types being assigned a threat status of 'critically endangered' (Lombard *et al*. 2004; Sink *et al*. 2012) (Table 4). Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan has been developed for the West Coast with the objective of identifying coastal and offshore priority focus areas for MPA expansion (Majiedt *et al*. 2013). To this end, nine focus areas have been identified for protection on the West Coast between Cape Agulhas and the South African – Namibian border. Those within the broad project area shown in Figure 19.

Table 4: Ecosystem threat status for marine and coastal habitat types in Namaqualand (adapted from Sink *et al*. 2011)

Habitat Type	Threat Status
Namaqua Boulder shore	Critically Endangered
Namaqua Exposed Rocky Coast	Least Threatened
Namaqua Inshore Hard Grounds	Critically Endangered
Namaqua Inshore Reef	Critically Endangered
Namaqua Island-associated	Critically Endangered
Namaqua Mixed Shore	Endangered
Namaqua Muddy Inshore	Vulnerable
Namaqua Sandy Inshore	Critically Endangered
Namaqua Sheltered Rocky Coast	Critically Endangered
Namaqua Very Exposed Rocky Coast	Vulnerable
Namaqua Hard Inner Shelf	Least Threatened
Namaqua Inner Shelf Reef	Critically Endangered
Namaqua Muddy Inner Shelf	Least Threatened
Namaqua Sandy Inner Shelf	Least Threatened

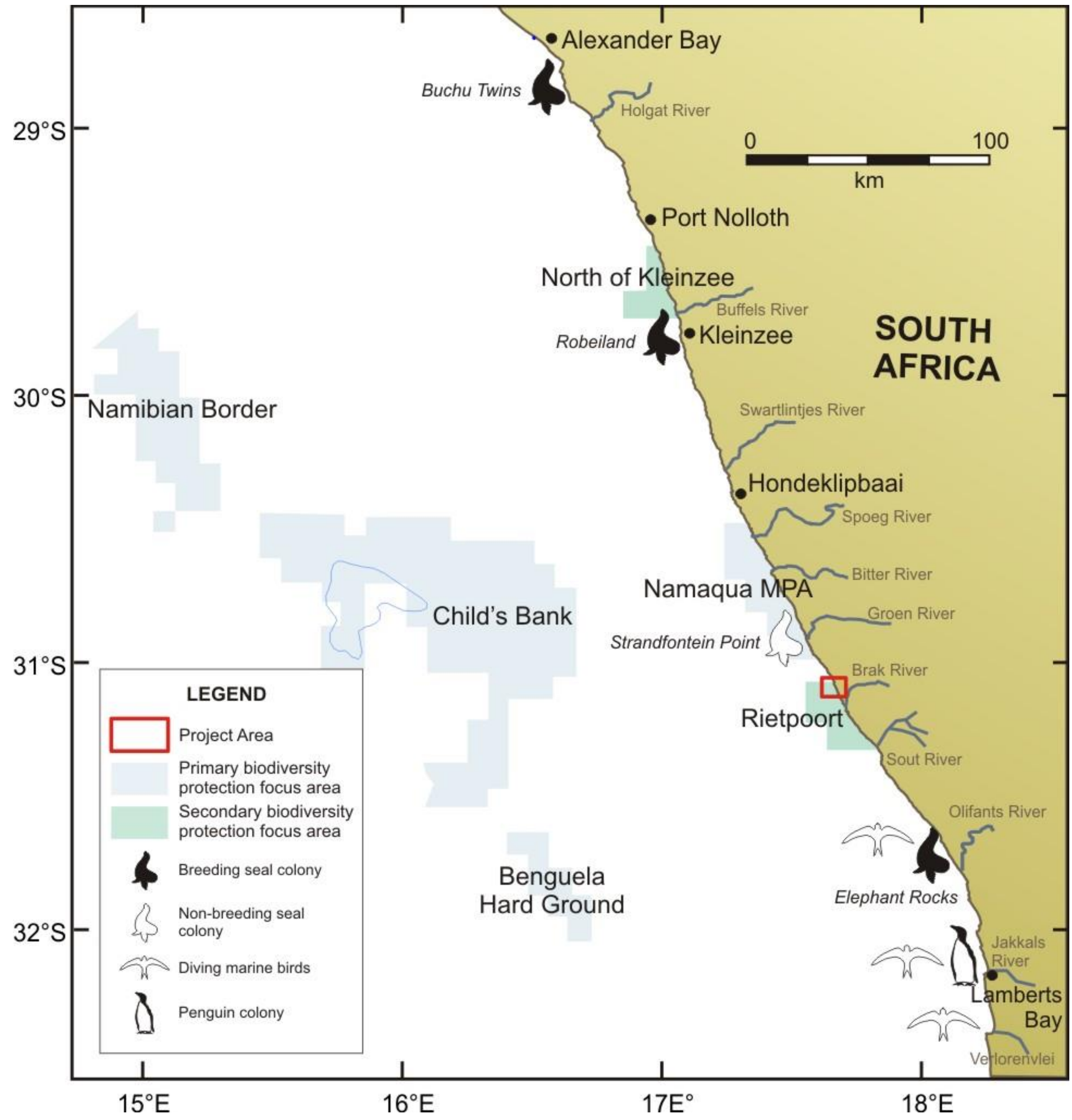

Figure 19: Project - environment interaction points on the West Coast, illustrating the location of seabird and seal colonies and priority areas for biodiversity protection in relation to the proposed project area.

Of principal importance is the proposed Namaqua MPA, which stretches between the Groen and Spoeg Rivers and adjacent to the Namaqua National Park. This area meets habitat targets for 14 habitat types including Critically Endangered habitat types such as Namaqua Inshore Reef, Namaqua Inshore Hard Grounds and Namaqua Sandy Inshore. The proposed project area falls within the Rietpoort secondary focus area, which extends from the Sout River to just north of the Brak River, and contributes to targets for nine habitat types, all of which are also included in the Proposed Namaqua MPA focus area. The Critically Endangered habitats in this area are Namaqua Sandy Inshore and Namaqua Sheltered Rocky Coast. Significantly this area is the only stretch of the Northern Cape coastline that is in a good habitat condition as very little mining has taken place although there are rights holders with leases (see below).

3.1.16 *Marine Diamond Mining*

In 1994 the Department of Minerals and Energy established formal diamond-mining concessions covering the continental shelf off the west coast of South Africa between the Orange River mouth and Cape Columbine. The concessions are grouped into Land, Surf-zone and Marine Concession Areas (Figure 20). The description below is summarised from Penney *et al.* (2007).

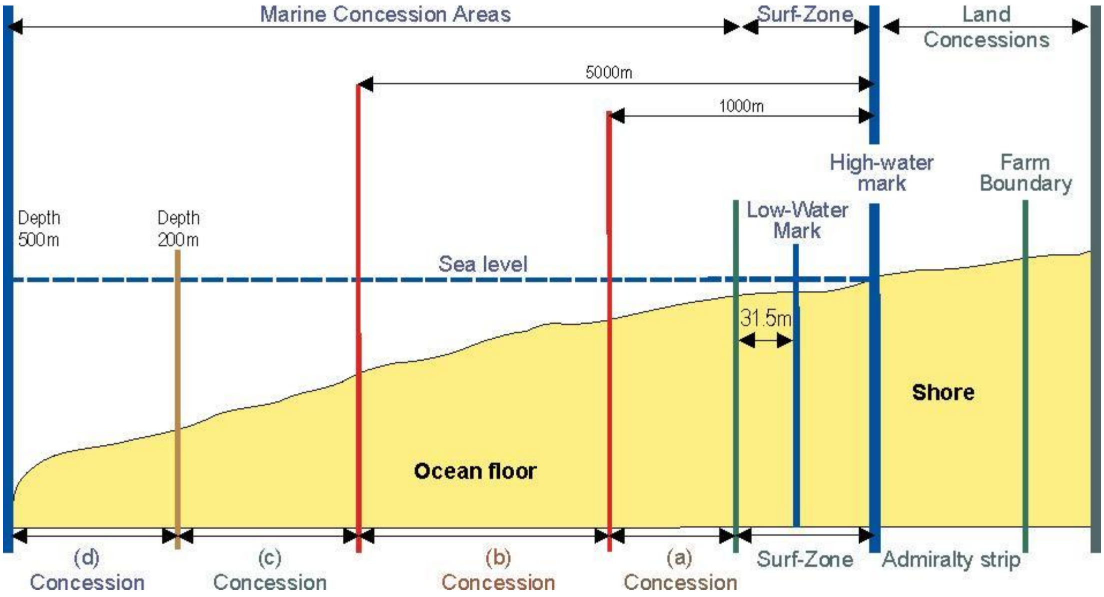

Figure 20: Diagram of the onshore and offshore boundaries of the South African (a) to (d) marine diamond mining concession areas.

Terrestrial concessions along the coast of Namaqualand and the Northern Cape are held by De Beers Namaqualand Mines (Pty) Ltd, Alexkor Limited (a public Company with the state as sole share-holder) and the Trans Hex Group (Pty) Ltd (Figure 21). De Beers operates from just south of Port Nolloth to slightly north of the Olifants River, while the Alexkor concession extends from the De Beers border to the Orange River mouth. The concessions operated by the Trans Hex Group (Pty) Ltd are located at Hondeklip Bay and at the Olifants River mouth.

The marine concession areas are split into four or five zones (Surf zone and (a) to (c) or (d)-concessions), which together extend from the high water mark out to approximately 500 m depth (Figure 21). The area considered for the desalination plant overlaps with 9(a) which was held by Namagroen Prospecting & Investment (Pty) Ltd; the lease area is in the process of a conversion (Majiedt *et al.* 2013).

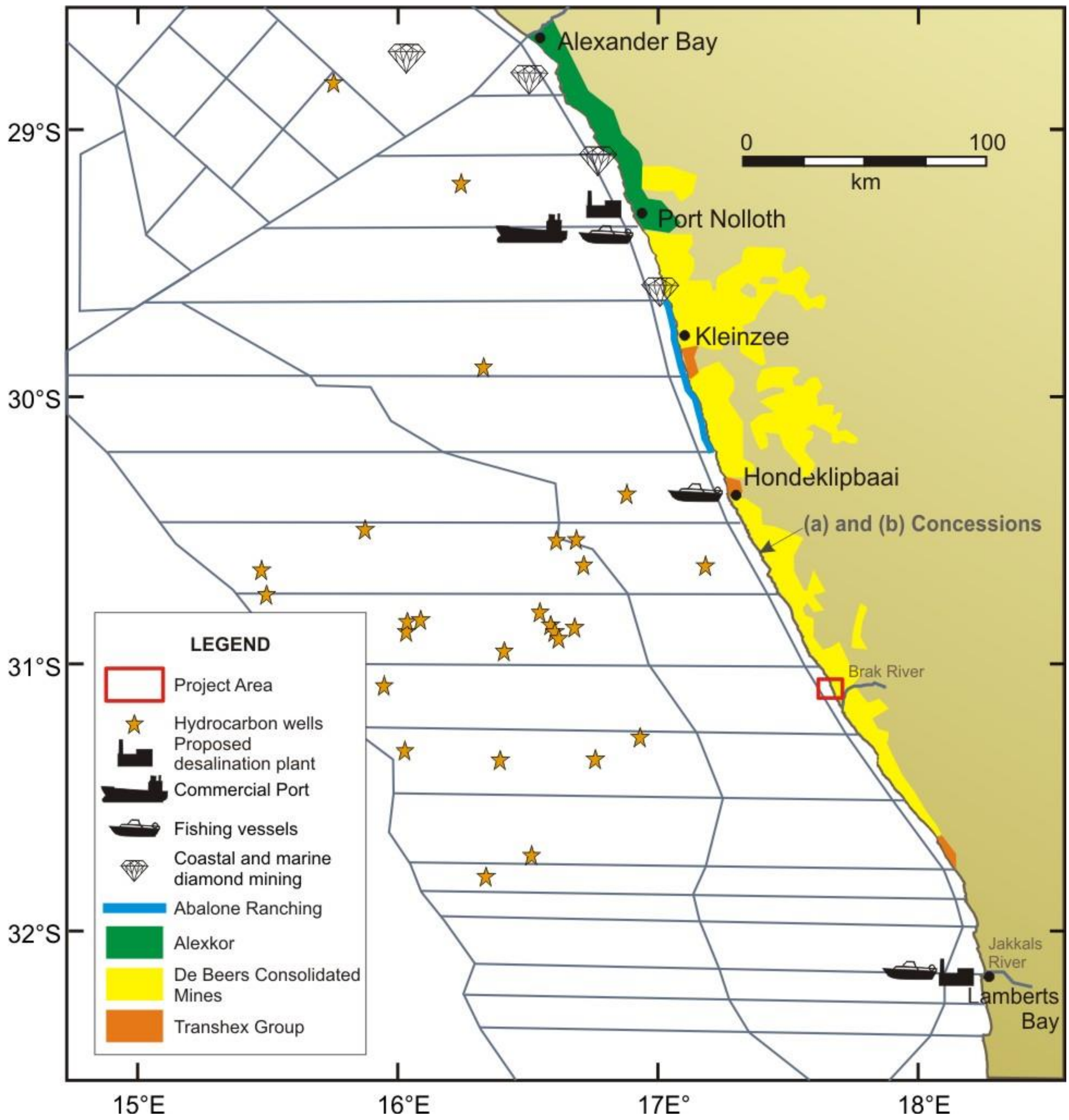

Figure 21: Project - environment interaction points on the West Coast, illustrating the marine diamond mining concessions, the terrestrial concessions held by various mining companies, proposed desalination plants and the Port Nolloth Sea Farm experimental abalone ranching area.

Nearshore shallow-water mining is typically conducted by divers using small-scale suction hoses operating either directly from the shore or from converted fishing vessels in small bays and out to ~30 m depth. Diver-assisted mining is largely exploratory and highly opportunistic in nature, being dependent on suitable, calm sea conditions. The typically exposed and wave-dominated nature of the west coast effectively limits the periods in which mining can take place to a few days per month. Sea conditions also control where safe operations can be conducted, as these often have to be in areas with some shelter from waves. As sea conditions vary enormously over small spatial and temporal scales, it is impossible to sequentially mine a concession from one end to the other. While some (typically calmer) sites may be systematically worked out over a sustained period of time, others are repeatedly revisited when conditions permit.

As shore-based divers cannot excavate a gravel depth much more than 0.5 m, mining rates are low, being only about 35 m^2 worked by each contractor per year. Because of the tidal cycle and limitations imposed by sea conditions, such classifiers usually operate for less than 4 hours per day for an average of 5-6 days per month, although longer periods may be feasible in certain protected areas.

Vessel-based diver-mining contractors usually work in the depth range immediately seaward of that exploited by shore-based divers, targeting gullies and potholes in the sub-tidal area usually just behind the surf-zone. A typical boat-based operation consists of a 10 - 15 m vessel, with the duration of their activities limited to daylight hours for 3 - 10 diving days per month. Estimated mining rates for vessel-based operations range from 300 m^2-1,000 m^2/year.

Over the past few years there has been a substantial decline in small-scale diamond mining operations along the Namaqualand coast due to the global recession and depressed diamond prices. Some vessels still operate out of Alexander Bay and Port Nolloth, but activity out of Hondeklip Bay has all but ceased.

3.1.17 *Hydrocarbons*

The South African continental shelf and economic exclusion zone (EEZ) have similarly been partitioned into Licence blocks for petroleum exploration and production activities. Exploration has included extensive 2D and 3D seismic surveys and the drilling of numerous exploration wells, with ~40 wells having been drilled in the Namaqua Bioregion since 1976 (Figure 21). The majority of these occur in the Ibhubesi gas field in Block 2A. Prior to 1983, technology was not available to remove wellheads from the seafloor and currently 35 wellheads remain on the seabed.

3.1.18 *Development Potential of the Marine Environment in the Project Area*

The economy of the Namaqualand region is dominated by mining. However, with the decline in the mining industry and the closure of many of the coastal mines, the economy of the region is declining and jobs are being lost with potential devastating socio-economic impacts on the region. The Northern Cape provincial government has recognized the need to investigate alternative economic activities to reduce the impact of minerals downscaling and has commissioned a series of baseline studies of the regional economy (Britz & Hecht 1997, Britz *et al.* 1999, 2000, Mather 1999). These assessments concluded that fishing and specifically mariculture offer a significant opportunity for long term (10+ years) sustainable economic development along the Namaqualand coast. The major opportunities cited in these studies include hake and lobster fishing (although the current trend in quota reduction is likely to limit development potentials), seaweed harvesting and aquaculture of abalone, seaweeds, oysters and finfish. The Northern Cape provincial government is facilitating the development of the fishing and mariculture sectors by means of a holistic sector planning approach and has in partnership with a representative community and industry based Fishing and Mariculture Development Association (FAMDA), developed the Northern Cape Province Fishing and Mariculture Sector Plan. This plan forms part of the 'Northern Cape - Fishing and Mariculture Sector Development Strategy' (www.northern-cape.gov.za, accessed December 2013) whereby implementation of the plan will be coordinated and driven by FAMDA.

Abalone ranching (*i.e.* the release of abalone seeds into the wild for harvesting purposes after a growth period) has been identified as one of the key opportunities to develop in the short- to medium-term and consequently the creation of abalone ranching enterprises around Hondeklip Bay and Port Nolloth forms part of the sector plan's development targets (www.northern-cape.gov.za). In the past, experimental abalone ranching concessions have been granted to Port Nolloth Sea Farms (PNSF) in sea mining areas 5 and 6 (Figure 21), effectively a 60-km strip of coastline, and to Ritztrade in the Port Nolloth area (www.northern-cape.co.za). These experimental operations have shown that although abalone survival is highly variable depending on the site characteristics and sea conditions, abalone ranching on the Namaqualand coast has the potential for a lucrative commercial business venture (Sweijd *et al.* 1998, de Waal 2004). As a result, the government publication 'Guidelines and potential areas for marine ranching and stock enhancement of abalone *Haliotis midae* in South Africa' (GG No. 33470, Schedule 2, April 2010) identified broad areas along the South African coastline that might be suitable for abalone ranching. Along the Northern Cape coast, four specific zones were marked, separated by 6-13 km wide buffer zones. Currently, applications for abalone ranching projects have been submitted and permits for pilot projects for some of the zones have been granted. The proposed development site for the desalination plant and marine infrastructure is approximately 50-60 km south of the southern-most ranching zone in the Northern Cape.

Besides abalone sea-ranching, several other potential projects were identified in the sector plan. Most of these are land-based aquaculture projects (e.g. abalone and oyster hatcheries in Port Nolloth and abalone grow-out facility in Hondeklip Bay), but included was a pilot project to harvest natural populations of mussels and limpets in the intertidal coastal zone along the entire Northern Cape coast. The objective of the project was to determine the stock levels and to ascertain what percentage of the biomass of each species can be sustainably harvested, as well as the economic viability of harvesting the resource.

4. LEGISLATIVE AND PERMITTING REQUIREMENTS

The legislative requirements associated with the proposed development are detailed in the Scoping Report for the project and will be covered in Chapter 2 of the EIA. These will not be repeated in detail here, but for the sake of completeness are summarised below.

4.1 South African Legislation

Listed below are the regulatory requirements specific to the coastal zone and marine environment:

- National Environmental Management Act 107 of 1998, as amended (NEMA);
- National Water Act 36 of 1998 (NWA);
- National Environmental Management: Biodiversity Act 10 of 2004 (NEM:BA);
- National Environmental Management: Integrated Coastal Management Act 24 of 2008 (NEM:ICMA);
- Marine Living Resources Act: Act 18 of 1998 (MLRA); and
- National Environmental Management: Off-road Vehicle Regulations 1399.

4.2 International Standards and Guidelines

In addition to the national legislations, there are international standards, protocols and guidelines that are applicable for a desalination plant project:

- In August 2007, the Department of Water Affairs & Forestry (DWAF 2007) of South Africa published the "*Guidelines for the evaluation of possible environmental impacts during the development of seawater desalination processes*". This document gives general guidance on the assessment procedure, lists possible environmental impacts which can be expected during implementation of seawater desalination, and provides recommendations for specialist and monitoring studies.
- The International Finance Corporation, a member of the World Bank Group, has developed operational policies (IFC 1998) that, inter alia, require that an impact assessment is undertaken within the country's overall policy framework and national legislation, as well as international treaties, and that natural and social aspects are to be considered in an integrated way. IFC has further published Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') containing guidelines and standards applicable to projects discharging industrial wastewater (IFC 2007). The EHS Guidelines contain the performance levels and measures that are normally acceptable to IFC and are generally considered to be achievable in new facilities at reasonable costs by existing technology. The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice, as defined in IFC's Performance Standard 3 on Pollution Prevention and Abatement (IFC 2006). This Performance Standard has the objective to avoid and minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities. It outlines a project approach to pollution prevention and abatement in line with internationally disseminated pollution prevention and control technologies and practices. In addition, Performance Standard 3 promotes the private sector's ability to integrate such technologies and practices as far as their use is technically and financially feasible and cost-effective in the context of a project that relies on commercially available skills and resources.
- Other guidance documents are those by the California Coastal Commission (Seawater Desalination and the California Coastal Act, 2004), the United Nations Environmental Programme (UNEP 2008) and the World Health Organisation (WHO

2008) that include international best practices and principles such as the precautionary approach and describe how design and construction approaches can mitigate likely impacts.
- The Rio Declaration on Environment and Development (1992), which calls for use of EIA as an instrument of national decision making (Principle 17). Moreover, it establishes important principles for sustainable development that should be reflected in EIAs, such as the application of the precautionary principle (Principle 15, whereby, where there is uncertainty in the nature and severity of a potential impact, conservative assumptions are made with respect to the significance and potential severity of the impact being assessed).

As signatory to the Convention of Biological Diversity and Convention to Combat Desertification, South Africa is committed to the preservation of rare and endemic species, and to provide protection for ecosystems and natural life-support processes within the country's boundaries. As a signatory of the United Nations Law of the Sea Convention of 1982, South Africa is required to adopt legislation to reduce marine pollution from seabed activities in the Exclusive Economic Zone (EEZ) and on the continental shelf, and from land-based sources.

4.3 Water Quality Guidelines

Environmental quality objectives need to be set for the marine environment, based on the requirements of the site-specific marine ecosystems, as well as other designated beneficial uses (both existing and future) of the receiving environment. The identification and mapping of marine ecosystems and the beneficial uses of the receiving marine environment provide a sound basis from which to derive site-specific environmental quality objectives (Taljaard *et al*. 2006). To ensure that these are practical and effective management tools, they need to be set in terms of measurable target values, or ranges for specific water column and sediment parameters, or in terms of the abundance and diversity of biotic components.

The *South African Water Quality Guidelines for Coastal Marine Waters* (DWAF 2005) provide recommended target values (as opposed to standards) for a range of substances, but these are not exhaustive. Therefore, in setting site-specific environmental quality objectives, the information contained in the DWAF guideline document should be supplemented by additional information obtained from published literature, best available international guidelines (*e.g*. ANZECC 2000; World Bank 1998), and site-specific data and information (*e.g*. obtained through numerical modelling outputs). Recommended target values are also reviewed and summarized in the Benguela Current Large Marine Ecosystem (BCLME) document on water quality guidelines for the BCLME region (CSIR 2006). Recommended target values extracted from these guidelines are provided in Table 5.

Mixing Zones

A mixing zone is the area around an effluent discharge point where the effluent is actively diluted with the water of the receiving environment. This zone usually encompasses the near-field and mid-field regions of dilution to allow for the plume to mix throughout the water column. Within the mixing zone, no water quality criteria for physical and chemical stressors are defined (with the exception of a select few contaminants that may potentially bioaccumulate). Instead, these water quality criteria ('trigger values') are defined at the boundary of the mixing zone to ensure the quality of nearby waters does not deteriorate as a result of the effluent discharge. The boundaries of a proposed mixing zone are typically defined according to an estimated distance from the discharge point at which point defined water quality guidelines will be met, as predicted by numerical modelling of the discharge.

Table 5: Water quality guidelines for the discharge of a high-salinity brine into the marine environment.

VARIABLE	SOUTH AFRICA (DWAF 2005)	AUSTRALIA/NEW ZEALAND (ANZECC 2000)	WORLD BANK [a] (World Bank 1998)	US ENVIRONMENTAL PROTECTION AGENCY (EPA 2006)
Zone of impact / mixing zone	To be kept to a minimum, the acceptable dimensions of this zone informed by the EIA and requirements of licensing authorities, based on scientific evidence.	No guideline found	100 m radius from point of discharge for temperature	No guideline found
Temperature	The maximum acceptable variation in ambient temperature is ± 1°C	Where an appropriate reference system is available, and there are sufficient resources to collect the necessary information for the reference system, the median (or mean) temperature should lie within the range defined by the 20%ile and 80%ile of the seasonal distribution of the ambient temperature for the reference system.	< 3°C above ambient at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.	No guideline found
Salinity[b]	33 – 36 psu	Low-risk trigger concentrations for salinity are that the median (or mean) salinity should lie within the 20%ile and 80%ile of the ambient salinity distribution in the reference system(s). The old salinity guideline (ANZECC 1992) was that the salinity change should be <5% of the ambient salinity.	No guideline found	No guideline found
Total residual Chlorine	No guideline, however, deleterious effects recorded for concentrations as low as 2 – 20 µg/ ℓ. A conservative trigger value is <2 µg/ℓ.	3 µg Cl/ℓ measured as total residual chlorine (low reliability trigger value at 95% protection level, to be used only as an indicative interim working level) (ANZECC 2000)[c]	0.2 mg/ℓ at the point of discharge prior to dilution	Long-term and short-term water quality criteria for chlorine in seawater are 7.5 µg/l and 13 µg/l, respectively

VARIABLE	SOUTH AFRICA (DWAF 2005)	AUSTRALIA/NEW ZEALAND (ANZECC 2000)	WORLD BANK [a] (World Bank 1998)	US ENVIRONMENTAL PROTECTION AGENCY (EPA 2006)
Total residual dibromonitrilopropionamide (DBNPA)	No guideline exists, suggest values ranging between 0.035 mg/ ℓ and 0.070mg/ ℓ	No guideline found	No guideline found	No guideline found
Dissolved oxygen (DO)	For the west coast, the dissolved oxygen should not fall below 10 % of the established natural variation. For the south and east coasts the dissolved oxygen should not fall below 5 mg/ℓ (99 % of the time) and below 6 mg/ℓ (95 % of the time)	Where an appropriate reference system is available, and there are sufficient resources to collect the necessary information for the reference system, the median lowest diurnal DO concentration for the period for DO should be >20%ile of the ambient dissolved oxygen concentration in the reference system(s) distribution. The trigger value should be obtained during low flow and high temperature periods when DO concentrations are likely to be at their lowest.	No guideline found	No guideline found
Nutrients	Waters should not contain concentrations of dissolved nutrients that are capable of causing excessive or nuisance growth of algae or other aquatic plants or reducing dissolved oxygen concentrations below the target range indicated for dissolved oxygen (see above)	Default trigger values of PO_4-P: 100 µg/ℓ NO_x-N: 50 µg/ℓ NH_4^+-N: 50 µg/ℓ for the low rainfall southern Australian region (Table 3.3.8 in ANZECC 2000)	No guideline found	No guideline found
Chromium	8 µg/ℓ (as total Cr)	Marine moderate reliability trigger value for chromium (III) of 10 µg./ℓ with 95% protection Marine high reliability trigger value for chromium (VI) of 4.4 µg/ℓ at 95% protection.	0.5 mg/ℓ (total Cr) for effluents from thermal power plants	1 100 µg/ℓ for highest concentration at brief exposure without unacceptable effect 50 µg/ℓ highest concentration at continous exposure without unacceptable effect

VARIABLE	SOUTH AFRICA (DWAF 2005)	AUSTRALIA/NEW ZEALAND (ANZECC 2000)	WORLD BANK [a] (World Bank 1998)	US ENVIRONMENTAL PROTECTION AGENCY (EPA 2006)
Iron	No guideline found	Insufficient data to derive a reliable trigger value. The current Canadian guideline level is 300 µg/ℓ	1.0 mg/ℓ for effluents from thermal power plants	No guideline found
Molybdenum	No guideline found	Insufficient data to derive a marine trigger value for molybdenum. A low reliability trigger value of 23 µg/ℓ was adopted to be used as indicative interim working levels.	No guideline found	No guideline found
Nickel	25 µg/ℓ (as total Ni)	7 µg/ℓ at a 99% protection level is recommended for slightly-moderately disturbed marine systems.	No guideline found	74 µg/ℓ for highest concentration at brief exposure without unacceptable effect 8.2 µg/ℓ highest concentration at continous exposure without unacceptable effect

[a] The World Bank guidelines are based on maximum permissible concentrations at the point of discharge and do not explicitly take into account the receiving environment, *i.e*. no cognisance is taken of the fact of the differences in transport and fate of pollutants between, for example, a surf-zone, estuary or coastal embayment with poor flushing characteristics and an open and exposed coastline. It is for this reason that we include in this study other generally accepted Water Quality guidelines that take the nature of the receiving environment into account.

[b] The ANZECC (2000) Water Quality guideline for salinity is less stringent than, but roughly approximates, the South African Water Quality guideline that requires that salinity should remain within the range of 33 psu to 36 psu (=ΔS of approximately 1 psu). Scientific studies have shown that effects on marine biota are primarily observed for increases of >4 psu above ambient level. ΔS 1 psu and 4 psu have been chosen for assessment purposes.

[c] In case of chlorine "shocking", which involves using high chlorine levels for a short period of time rather than a continuous low-level release, the target value is a maximum value of 2 mg/ℓ for up to 2 hours, not to be repeated more frequently than once in 24 hours, with a 24-hour average of 0.2 mg/ℓ (The same limits would apply to bromine and fluorine).

5. IDENTIFICATION OF KEY ISSUES AND SOURCES OF POTENTIAL ENVIRONMENTAL IMPACT

Construction activities associated with the development of the desalination plant project will be focussed in three main areas:

- submerged intake and discharge pipelines;
- the transfer pipeline, powerline and access routes between the desalination plant and the mine; and
- the desalination plant itself.

This Marine and Coastal Specialist Study will deal with the first point only, as well as with the implementation of a temporary desalination plant required during construction.

Potential impacts on the marine environment were identified in the early stages of the proposed desalination plant project and these were supplemented by key issues raised during the scoping process. These are briefly summarised below in terms of the construction, commissioning, operation and decommissioning phase, and then discussed in more detail in Section 5.

Construction Phase

The potential impacts associated with the construction of feedwater intake and brine discharge structures into the marine environment are related to:

- Onshore construction (human activity, air, noise and vibration pollution, dust, blasting, disturbance of coastal flora and fauna) (to be dealt with by others); and
- Construction and installation of intake and discharge pipelines through the intertidal zone (construction site, pipe lay-down areas, trenching in the marine environment, vehicular traffic on the beach and consequent disturbance of intertidal and subtidal biota).

The desalination plant including the pump station will be constructed a set-back distance from the existing shoreline. Consequently, issues associated with the location of the plant and pump station, and the associated pipelines leading to and from these constructions are not deemed to be of relevance to the marine environment, and will be dealt with by other specialist studies. However, infrastructure extending into the sea will potentially impact on intertidal and shallow subtidal biota during the construction phase in the following ways:

- Temporary loss of benthic habitat and associated communities due to preparation of the seabed for pipeline laying and associated activities;
- Possible temporary short-term impacts on habitat health due to turbidity generated during construction;
- Temporary disturbance of marine biota, particularly shore birds, turtles and marine mammals, due to construction activities (blasting);
- Possible impacts to marine water quality and sediments through hydrocarbon pollution by marine construction infrastructure and plant; and
- Potential contamination of marine waters and sediments by inappropriate disposal of spoil and/or surplus rock from construction activities, used lubricating oils from marine machinery maintenance and human wastes, which could in turn lead to impacts upon marine flora, fauna and habitat.

Construction activities associated with the desalination plant are anticipated to last for a period of 18 months.

Commissioning Phase

Once construction has been completed, it will take about 2 months to commission the new desalination plant. During the commissioning phase, seawater will be pumped into the plant at up to peak production rates. However, any fresh water produced will be combined with the brine and discharged. Once the produced water is of suitable quality, it will be used for construction purposes instead of that produced by the temporary modular desalination plant. As the discharge will have a salinity equivalent to that of normal seawater, it will not have an environmental impact during the commissioning phase.

It may be necessary to discard the membrane storage solution and rinse the membranes before plant start-up. If the storage solution contains a biocide or other chemicals, which may be harmful to marine life and this solution is discharged to the sea, local biota and water quality may be affected.

Operational Phase

The key issues and major potential impacts are mostly associated with the operational phase. The key issues related to the presence of pipeline infrastructure and brine discharges into the marine environment are:

- Altered flows at the intake and discharge resulting in ecological impacts (e.g. entrainment and impingement of biota at the intake, and flow distortion/changes at the discharge);
- Potential for habitat health impacts/losses resulting from elevated salinity in the vicinity of the brine discharge;
- The effect of the discharged effluent potentially having a higher temperature than the receiving environment;
- Biocidal action of residual chlorine and/or other non-oxidising biocides such as dibromonitrilopropionamide (DBNPA) in the effluent;
- The effects of co-discharged constituents in the brine;
- The removal of particulate matter from the water column where it is a significant food source, as well as changes in phytoplankton production due to changes in nutrients, reduction in light, water column structure and mixing processes; and
- Direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent, and indirect changes in dissolved oxygen content of the water column and sediments due to changes in phytoplankton production as a result of nutrient input.

Additional engineering design considerations, not strictly constituting issues to be considered within this Marine and Coastal Specialist Study, include:

- Structural integrity of the intake and outfall pipelines;
- Potential re-circulation of brine effluent;
- Pipeline maintenance and replacement requirements; and
- Water quality of feed-waters that should include consideration of possible deteriorating water quality (particularly sediments that may be stirred up during storms, or large-scale hypoxia in bottom waters), that may require specific mitigation measures or planned flexibility in the operations of the desalination plant.

During the scoping phase of the project, the following additional issues relevant to the marine environment were raised by Interested and Affected Parties:

- Discharging brine into the surf zone, which is generally considered a sensitive environment, is not desirable; as a general principle, brine should be discharge at a point further out to sea; and

- Cumulative impacts need to be considered and monitoring of the receiving environment over the long-term may be required.

Decommissioning Phase

The minimum anticipated life of the desalination plant is approximately 30 years. The individual RO modules will be replaced as and when required during this period. No decommissioning procedures or restoration plans have been compiled at this stage, as it is envisaged that the plant will be refurbished rather than decommissioned after the anticipated 30 year lifespan. In the case of decommissioning the pipeline will most likely be left in place. The potential impacts during the decommissioning phase are thus expected to be minimal in comparison to those occurring during the operational phase, and no key issues related to the marine environment are identified at this stage. As full decommissioning will require a separate EIA, potential issues related to this phase will not be dealt with further in this report.

6. ASSESSMENT OF ENVIRONMENTAL IMPACT

The sources of potential impacts and key issues identified in terms of the construction, commissioning, and operational phases of the proposed SWRO plant relating to potential risks to the marine environment are discussed in detail and assessed below.

Construction of Intake and Discharge Structures

6.1.1 *Disturbance of the Coastal Zone*

The use of intake structures and discharge pipelines in the engineering designs for the desalination plant is unavoidable, but will involve considerable disturbance of the high-shore, intertidal and shallow subtidal habitats during the construction and installation process. The intake and outfall points of the desalination plant pipelines will be located below the low water mark, in the surf-zone.

The intake structure will involve the excavation of an intake channel and basin to a depth of 3 - 3.5 m below mean sea level. This will require trenching and blasting of the bedrock in the intertidal and shallow subtidal zones. The brine discharge pipeline will be placed in a rocky gully and similarly be trenched or encased in concrete to to provide stability on the seabed and adequately protect it where it crosses the surf-zone. Obviously, the physical removal of sediments or bedrock in the intake channel and basin and discharge pipeline trench, and disposal thereof into the surf-zone will result in the total destruction of the associated benthic biota. Mobile organisms such as fish, shore birds and marine mammals, on the other hand, are capable of avoiding the construction area and although severely disturbed, should not be significantly affected by the excavation activities.

Individual pipeline sections will be fabricated by the supplier and transported to site. This will require a sufficiently large and relatively flat onshore area (immediately inland of the final pipeline position) where the pipes can be stockpiled and prepared. Coastal vegetation and associated fauna at the pipeline construction sites will almost certainly be severely disturbed or removed. The pipe sections will subsequently be butt-welded together into long strings, placed in the trenches and subsequently covered with concrete and rock. Boulders and sediments will be turned over in the process and the associated biota will most likely be eliminated. Any shorebirds feeding and/or roosting in the area will also be disturbed and displaced for the duration of construction activities.

Despite this unavoidable disturbance of the intertidal and shallow subtidal habitats, the activities would remain localised and confined to within a hundred metres of the construction site. Provided the construction activities are all conducted concurrently, the duration of the disturbance should also only be limited to a period of about 18 months. Active rehabilitation of intertidal communities is not possible, but rapid natural recovery of disturbed habitats in the turbulent intertidal and surf-zone areas can be expected. Furthermore, the exposed pipeline will serve as a new ‘hard-bottom’ substrate for colonisation by marine benthic communities. The ecological recovery of marine habitats is generally defined as the establishment of a successional community of species, which progresses towards a community that is similar in species composition, population density and biomass to that previously present (Ellis 1996). In general, communities of short-lived species and/or species with a high reproduction rate (opportunists) may recover more rapidly than communities of slow growing, long-lived species. Opportunists are usually small, mobile, highly reproductive and fast growing species and are the early colonisers. Habitats in the nearshore wave-base regime, which are subjected to frequent disturbances, are typically inhabited by these opportunistic species (Newell *et al.* 1998). Recolonisation will start rapidly after cessation of trenching, and species numbers may recover within short periods (weeks) whereas biomass often remains reduced for several years (Kenny & Rees 1994, 1996).

Studies on the disturbance of beach macrofauna and rocky shore communities on the southern African West Coast by shore beach mining activities and shore-based diamond diving operations have ascertained that, provided physical changes to beach morphology and rocky intertidal zones are kept to a minimum, biological 'recovery' of disturbed areas will occur within 2-5 years (Nel *et al*. 2003; Pulfrich *et al*. 2003; Pulfrich *et al*. 2004). Disturbed subtidal communities within the wave base (<40 m water depth) might recover even faster (Newell *et al*. 1998; Pulfrich & Penney 2001).

Disturbance of the intertidal and subtidal rocky shore during installation of the intake and discharge pipelines is consequently deemed of high intensity within the immediate vicinity of the construction sites, with impacts persisting over the short- to medium-term and is considered to be of **MEDIUM** significance without mitigation. The implementation of mitigation would reduce the significance to **LOW**.

Impact: Distrubance and destruction of marine biota through alteration and disturbance of the coastal zone during construction

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Medium-term 2	**Medium** 6	Definite	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Restrict disturbance of the intertidal and subtidal areas to the smallest area possible. • Lay pipeline in such a way that required rock blasting is kept to a minimum. • Restrict traffic on upper shore to minimum required. • Restrict traffic to clearly demarcated access routes and construction areas only. **Best practice mitigation measures:** • Have good house-keeping practices in place during construction.								
With mitigation	Local 1	High 3	Short-term 1	**Low** **5**	Definite	**LOW**	**– ve**	High

6.1.2 *Pollution and Accidental Spills*

Construction activities in the intertidal zone will involve extensive traffic on the shore by heavy vehicles and machinery, as well as the potential for accidental spillage or leakage of fuel, chemicals or lubricants. Any release of liquid hydrocarbons has the potential for direct, indirect and cumulative effects on the marine environment through contamination of the water and/or sediments. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton, pelagic eggs and fish larvae, and habitat loss or contamination (CSIR 1998; Perry 2005). Many of the compounds in petroleum products have been known to smother organisms, lower fertility and cause disease in aquatic organisms. Hydrocarbons are incorporated into sediments through attachment to fine dust particles, sinking and deposition in low turbulence areas. Due to differential uptake and elimination rates filter-feeders particularly mussels can bioaccumulate organic (hydrocarbons) contaminants (Birkeland *et al*. 1976).

Concrete work will be required in the intertidal and shallow subtidal zones during construction and installation of the pipelines. As cement is highly alkaline, wet cement is strongly caustic, with the setting process being exothermic. Excessive spillage of cement in the intertidal area may thus potentially increase the alkalinity of the water column with potential sublethal or lethal effects on marine organisms.

During construction (and also during operation), litter can enter the marine environment. Inputs can be either direct by discarding garbage into the sea, or indirectly from the land when litter is blown into the water by wind. Marine litter is a cosmopolitan problem, with significant implications for the environment and human activity all over the world. Marine litter travels over long distances with ocean currents and winds. It originates from many sources and has a wide spectrum of environmental, economic, safety, health and cultural impacts. It is not only unsightly, but can cause serious harm to marine organisms, such as turtles, birds, fish and marine mammals. Considering the very slow rate of decomposition of most marine litter, a continuous input of large quantities will result in a gradual increase in litter in coastal and marine environment. Suitable waste management practices should thus be in place to ensure that littering is avoided.

Potential hydrocarbon spills and pollution in the intertidal zone during installation of the intake and discharge pipelines is thus deemed of medium intensity within the immediate vicinity of the construction sites, with impacts persisting over the short- to medium-term. The impact is therefore assessed to be of **LOW** significance without mitigation. With the implementation of mitigation measures, impacts would become **INSIGNIFICANT**.

Impact: Detrimental effects on marine biota through accidental hydrocarbon spills and litter in the coastal zone during construction

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Medium-term
2</td><td>Low
5</td><td>Probable</td><td>LOW</td><td>– ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Conduct a comprehensive environmental awareness programme amongst contracted construction personnel.
• For equipment maintained in the field, oils and lubricants to be contained and correctly disposed of off-site.
• Maintain vehicles and equipment to ensure that no oils, diesel, fuel or hydraulic fluids are spilled.
• Vehicles should have a spill kit (peatsorb/ drip trays) onboard in the event of a spill.
• No mixing of concrete in the intertidal zone.
• Regularly clean up concrete spilled during construction.
• No dumping of excess concrete or mortar on the sea bed.
• Ensure regular collection and removal of refuse and litter from intertidal areas.

Best practice mitigation measures:
• Have good house-keeping practices in place during construction.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Possible</td><td>INSIGNIFI-CANT</td><td>– ve</td><td>High</td></tr>
</table>

6.1.3 *Increased Turbidity*

Excavating operations and disturbance and turnover of sediments and boulders in the intertidal and/or surf zone will result in increased suspended sediments in the water column and physical smothering of biota by the discarded sediments. The effects of elevated levels of particulate inorganic matter and depositions of sediment have been well studied, and are known to have marked, but relatively predictable effects in determining the composition and ecology of intertidal and shallow subtidal benthic communities (e.g. Zoutendyk & Duvenage 1989, Engledow & Bolton 1994, Iglesias *et al.* 1996, Slattery & Bockus 1997). Increased suspended sediments in the surf-zone and nearshore can potentially affect light penetration and thus phytoplankton productivity and algal growth, load the water with inorganic suspended particles, which may affect the feeding and absorption efficiency of filter-feeders, and can cause scouring.

Rapid deposition of material from the water column will have a smothering effect. Some mobile benthic animals inhabiting soft-sediments are capable of migrating vertically through more than 30 cm of deposited sediment (Newell *et al*. 1998). Sand inundation of reef habitats was found to directly affect species diversity whereby community structure and species richness appears to be controlled by the frequency, nature and scale of disturbance of the system by sedimentation (Seapy & Littler 1982, Littler *et al*. 1983, Schiel & Foster 1986, McQuaid & Dower 1990, Santos 1993, Airoldi & Cinelli 1997 amongst others). For example, frequent sand inundation may lead to the removal of grazers thereby resulting in the proliferation of algae (Hawkins & Hartnoll 1983; Littler *et al*. 1983; Marshall & McQuaid 1989; Pulfrich *et al.* 2003a, 2003b).

Construction activities required for the installation of the intake and discharge pipelines for the Volwaterbaai desalination plant will be highly localised. The impact of the resulting sediment plumes is likewise expected to be localised and of short duration (only for a couple of hours to a few days after cessation of excavation activities). As the biota of sandy and rocky intertidal and subtidal habitats in the wave-dominated nearshore areas of southern Africa are well adapted to high suspended sediment concentrations, periodic sand deposition and resuspension, impacts are expected to occur at a sublethal level only.

Elevated suspended sediment concentrations in nearshore waters due to construction activities is thus deemed of low intensity within the immediate vicinity of the construction sites, with impacts persisting over the short-term only. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation. As elevated suspended sediment concentrations are an unavoidable consequence of construction activities in the intertidal zone, no direct mitigation measures, other than the no-project alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices.

Impact: Reduced physiological functioning of marine organisms due to increased turbidity of nearshore waters during excavations

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Definite</td><td>VERY LOW</td><td>– ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• No dumping of construction materials in the intertidal and subtidal zones.

Best practice mitigation measures:
• Have good house-keeping practices in place during construction.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Probable</td><td>VERY LOW</td><td>– ve</td><td>High</td></tr>
</table>

Impact: Smothering of benthos through redeposition of suspended sediments

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Definite	**VERY LOW**	**– ve**	High
Essential mitigation measures: • No dumping of construction materials in the intertidal and subtidal zones. **Best practice mitigation measures:** • Have good house-keeping practices in place during construction.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**– ve**	High

6.1.4 *Construction Noise and Blasting*

During pipeline trenching operations, noise and vibrations from excavation machinery may have an impact on surf-zone biota, marine mammals and shore birds in the area. Noise levels during construction are generally at a frequency much lower than that used by marine mammals for communication (Findlay 1996), and these are therefore unlikely to be significantly affected. Additionally, the maximum radius over which the noise may influence is very small compared to the population distribution ranges of surf-zone fish species, resident cetacean species and the Cape fur seal. Both fish and marine mammals are highly mobile and should move out of the noise-affected area (Findlay 1996). Similarly, shorebirds and terrestrial biota are typically highly mobile and would be able to move out of the noise-affected area.

Trenching of the pipeline and construction of the intake basin will require blasting to attain the required depths. As details of the probable blast levels, blasting practice and duration of the blasting required to ensure adequate depth for the intake basin, and suitable burial of the pipeline have not yet been determined, the assessment that follows is generic only. Effects of underwater blasting on marine organisms have received extensive coverage in the formal peer-reviewed scientific literature (see Lewis 1996 and Keevin & Hempen 1997 for references), as well as in various assessments for seismic surveys, underwater construction and weapons testing. The following impact description is based on two reviews on the subject provided in Lewis (1996) and Keevin & Hempen (1997).

Explosives generate chemical energy, which is released as physical, thermal, and gaseous products. The most important of these for marine organisms is the physical component which, as a shock wave, passes into the surrounding medium. Depending on the blasting practice, some of the energy may escape into the water column, and it is this shock wave that is the primary cause of damage to aquatic life at, or some distance from the shot point. Thermal energy dissipation, in contrast, is generally limited to the immediate vicinity (<10 m) of the exploding material, and in shallow water gaseous products produce minor shock wave amplitudes.

The nature of the shock wave generated by the blast depends on the type of explosive used. Relatively low energy explosives such as black powder are slow burning and produce a shock wave with a shallow rise height. Dynamite and other high explosives have a rapid detonation velocity and produce a more abrupt shock wave. Consequently, high explosives have more dramatic effects on marine organisms.

Two damage zones are associated with an underwater explosion:

- an immediate kill zone of relatively limited extent, but within which all animals are susceptible to damage through disruption of their body tissues by the pressure wave generated by the explosion, and
- a more extensive remote damage zone in which damage is caused by negative pressure pulses, generated when the compression wave is reflected from an air-water interface. The negative pulses act on gas bodies within the organism inducing injuries such as haemorrhaging and contrusions of the gastro-intestinal tract (mammals and birds) or rupture of swimbladders in fish.

Keevin & Hempen (1997) and Lewis (1996) provide information on blast-effects on a variety of shallow water (<10 m) organisms. Appendix A.1 provides a summary of these effects focussing on the marine macrophytic algae, major invertebrate macrofaunal taxa, fish, turtles and marine mammals that may occur in the blast area off the desalination plant site.

From this summary, the following can be gleaned:

- Any effects on macrophytes through blasting would be limited to the immediate vicinity of the charges.
- Marine invertebrates appear to be relatively immune to blast effects in terms of obvious injury or mortalities, suggesting that any blast-effects are likely to remain confined to the immediate area of blasting.
- In fish, the swim bladder is the organ most frequently damaged through blasting, potentially leading to high mortality in the immediate area of blasting. In contrast, fish species that do not posses swim bladders seem to be largely immune to underwater explosions. Egg and fish larvae may also be affected by underwater explosions, but impact ranges seem to be restricted to the immediate vicinity of the blasting. Although injury or mortality of fish and/or their eggs and larvae in the immediate area of the blasting is likely to occur, the probability of the blasting programme having a measurable effect at the population level on fish in the study area is judged to be unlikely, as surf-zone and nearshore species along the Namaqualand coastline are widely distributed.
- The limited information available on blasting effects on swimming and diving birds suggests that mortality occurs primarily within the immediate vicinity (< 10 m) of the blast.
- Effects on sea turtles may occur up to a distance of 1 km from the underwater explosion. Although occurring in the study area, turtles are infrequent visitors in the shallow nearshore regions.
- Similar to fish, injuries to marine mammals generated by underwater explosions are primarily trauma of various levels to organs containing gas, and mortality can occur in the immediate area around the blasting. Given the generally low numbers of seals in the study area relative to the overall population size any population level mortality effects, or injuries that may be caused are judged to be insignificant. Seals and scavenging birds may, however, be attracted to the blasting area by stunned and dead fish following a blast. Although occurring in the study area, whales and dolphins are infrequent visitors in the shallow nearshore regions, being more common further offshore. However, Heaviside's Dolphin and the Common Bottlenose Dolphin occur in shallow waters (<50 m) and could be vulnerable to detonations.

It is recommended that the area around the blasting site be visually searched before blasting commences and blasting postponed should a marine mammal, sea turtle or flocks of swimming and diving birds be spotted within a 2-km radius around the blasting point. The blasting programme should also be scheduled to allow seals and other scavengers feeding on dead fish to have left the area before the next blasting event. The probability of the proposed blasting programme having a measurable effect on sea turtles or marine mammals in the study area is unlikely if these recommendations are strictly adhered to.

Disturbance and injury to marine biota due to construction noise is thus deemed of low intensity within the immediate vicinity of the construction sites, with impacts persisting over the very short-term only. In the case of blasting, however, the impact would be of high intensity, but also persist over the very short-term only. Without mitigation, the impacts of construction noise and blasting are therefore assessed to be of **VERY LOW** and **LOW** significance, respectively. The implementation of mitigation would reduce the significance to **VERY LOW** in both cases. As the noise associated with construction is unavoidable, no direct mitigation measures, other than the no-project alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices.

As details of the probable blast levels, blasting practice and duration of the blasting required have not yet been finalised, confidence in the assessment of this impact is rated as medium.

Impact: Disturbance of shore birds and marine biota through construction noise

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Probable	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Restrict construction noise and vibration-generating activities to the absolute minimum required. **Best practice mitigation measures:** • Have good house-keeping practices in place during construction.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**– ve**	High

Impact: Disturbance of and injury to shore birds and marine biota through blasting

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	High 3	Short-term 1	**Low** 5	Definite	**LOW**	**– ve**	Medium
Essential mitigation measures: • Restrict blasting to the absolute minimum required (one blast per day). • Use blasting methods which minimise the environmental effects of shock waves through the use of smaller, quick succession blasts directed into the rock. • Avoid onshore blasting during the breeding season of shore-birds. • Undertake visual observation prior to blasting to ensure there are no marine mammals and turtles present in the immediate vicinity (approximately 2-km radius). **Best practice mitigation measures:** • Development of a responsible blasting schedule.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**– ve**	Medium

6.1.5 *Installation of Structures*

Installation of the intake basin and pipelines will effectively eliminate any (sandy or rocky) biota in the structural footprint, and reduce the area of seabed available for colonisation by marine benthic communities. Although the loss of substratum as a result of the intake basin and pipelines constitutes a negative impact, it will be temporary only, as the structures themselves will provide an alternative substratum for colonising communities. Assuming that the hydrographical conditions around the structures will not be significantly different to those on the seabed, a similar community to the one previously present can be expected to develop, thereby constituting a positive impact.

The composition of the fouling community on artificial structures depends on the age (length of time immersed in water) and the composition of the substratum, and usually differs from the communities of nearby natural rocky reefs (Connell & Glasby 1999; Connell 2001). Colonization of hard substratum goes through successional stages (Connell & Slayter 1977). Early successional communities are characterized by opportunistic algae (e.g. *Ulva* sp., *Enteromorpha* sp.). These are eventually displaced by slower growing, long-lived species such as mussels, sponges and/or coralline algae, and mobile organisms, such as urchins and lobsters, which feed on the fouling community. With time, a consistent increase in biomass, cover and number of species can usually be observed (Bombace *et al*. 1994; Relini *et al.* 1994; Connell & Glasby 1999). Depending on the supply of larvae and the success of recruitment, the colonization process can take up to several years. For example, a community colonising concrete blocks in the Mediterranean was found to still be changing after five years with large algae and sponges in particular increasing in abundance (Relini *et al*. 1994). Other artificial reef communities, on the other hand, were reported to reach similar numbers of species (but not densities and biomass) to those at nearby artificial reefs within eight months (Hueckel *et al*. 1989).

The elimination of marine benthic communities in the structural footprint is an unavoidable consequence of the installation of intake and discharge structures, and no direct mitigation measures, other than the no-project alternative, are possible. The initial negative impacts are, however, deemed of low intensity within the immediate vicinity of the construction sites. Furthermore, the negative impacts persist over the short-term only as the new structures will offer a new settling ground for hard bottom species and will be rapidly colonised. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation.

Impact: Elimination of benthic communities through loss of substratum in structural footprint

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Definite</td><td>VERY LOW</td><td>– ve/ + ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• No direct mitigation possible other than the no-project alternative.

Best practice mitigation measures:
• Leave pipeline in place post closure to prevent unnecessary disturbance of the seabed and associated communities.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Definite</td><td>VERY LOW</td><td>– ve/ + ve</td><td>High</td></tr>
</table>

6.1.6 *Water Supply during Construction*

As fresh water will be required for construction of the desalination plant and associated infrastructure, and no viable sources are available for this purpose, a containerised desalination plant will be temporarily used to supply fresh water during the construction phase. Water will be abstracted from the sea via a submersible pump positioned in a tidal pool close to the shore and be conveyed to the temporary desalination plant via a 50 mm pipe. The temporary plant will be fitted with external sand filters, feedwater and filtered water tanks. Although the desalination process will differ slightly from that for the main plant, it is based on the same principles, and the waste streams will be similar to those described below for the operational phase of the main desalination plant. The intake and discharge flows from this plant will amount to 67 m^3/d and 36.5 m^3/d, respectively. The brine will contain traces of membrane antiscalant, $FeCl_3$ and suspended solids from the backwash waste (~18% of the brine volumes discharged daily), and will be discharged into the surf-zone as a single waste stream via a 50 mm pipe. The impacts of this temporary, low volume discharge into the turbulent surf-zone environment are deemed to be **INSIGNIFICANT**.

Disturbance of the intertidal area during installation of the temporary desalination plant is similarly expected to be **INSIGNIFICANT**, primarily amounting to the 80 m^2 footprint of the fenced in area above the high water mark enclosing the plant.

Impact: Installation and operation of temporary desalination plant during construction

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Improbable	**INSIGNIFI-CANT**	**– ve**	High
Essential mitigation measures: • Keep footprint of the temporary desalination plant in the coastal zone to the absolute minimum required. • Ensure that brine and co-pollutants are discharge into the surf-zone below the low water mark. **Best practice mitigation measures:** • Use low-toxicity chemicals as far as practicable.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

Operational Phase

6.1.7 *Impingement and Entrainment*

Intake of water directly from the ocean, be it through a submerged intake structure located offshore at the end of an intake pipeline or *via* a channel to an intake basin as is the case for the Volwaterbaai desalination plant, will result in loss of marine species as a result of impingement and entrainment. Impingement refers to injury or mortality of larger organisms (e.g. fish, jellyfish) that collide with and are trapped by intake screens, whereas entrainment refers to smaller organisms that slip through the screens and are taken into the plant with the feed water. Impingement mortality is typically due to suffocation, starvation, or exhaustion due to being pinned up against the intake screens or from the physical force of the rakes used to clear screens of debris. The significance of impingement is related primarily to the location of the intake structure and is a function of intake velocity. The reduction of the average intake velocity of the feedwater to ~0.1 - 0.15 m/s, which is comparable to background currents in the oceans and has been implemented for the Volwaterbaai desalination plant, will allow mobile organisms to swim away from the intake under these flow conditions (UNEP 2008). The intake of large quantities of seawater may also affect water circulation, especially in areas such as gullies and rockpools that are characterised by weak natural currents and waves.

While using screens reduces impingement, entrainment effects are likely to remain, as most of the entrained organisms are too small to be screened out without significantly reducing the intake water volume. Entrained material includes holoplanktic organisms (permanent members of the plankton, such as copepods, diatoms and bacteria) and meroplanktic organisms (temporary members of the plankton, such as juvenile shrimps and the planktonic eggs and larvae of invertebrates and fish). Mortality rates of organisms entering desalination plants in the feedwater are likely to be 100% since the seawater is forced, at high pressure, through filters or membranes to remove particles, including the small organisms that are taken in with the feed-water. Furthermore, the feed-water will be treated with a biocide specifically designed to eliminate and kill entrained biota.

Although the mortality caused by entrainment may affect the productivity of coastal ecosystems, the effects are difficult to quantify (UNEP 2008; WHO 2007). Planktic organisms show temporal and spatial variations in species abundance, diversity and productivity, but it can be assumed that species common in the Benguela region will be prevalent in the surface waters of the project area. Furthermore, plankton species have rapid reproductive cycles. Due to these circumstances it seems unlikely that the operation of a single desalination facility of the capacity proposed at Volwaterbaai will have a substantial negative effect on the ability of plankton organisms to sustain their populations. The entrainment of eggs and larvae from common invertebrate and fish species will also unlikely adversely affect the ability of these species to reproduce successfully. The reproduction strategy of these species is to produce a large number of eggs and larvae, of which only a small percentage reaches maturity due to natural mortality (such as starvation of larvae or failure to settle in a suitable location). For example, an entrainment study for a RO Pilot Plant in San Francisco Bay showed that the estimated effects of fish larvae entrainment were minimal and indicated little potential for population-level effects (Tenera Environmental 2007). The significance of entrainment is related both to the location of the intake, as well as the overall volume of feed-water required. As the feed-water volumes required for the Volwaterbaai desalination plant are comparatively small, impingemnet and entrainment impacts are unlikely to be of significance.

A further issue of potential concern, is the removal of particulate matter from the water column, where it is a significant source of food for surf-zone and nearshore communities. For the comparatively small feed-water volumes required for the Volwaterbaai desalination plant this is unlikely to be of significance, as the surf-zone in the study area is particularly productive, and particulate organic matter frequently accumulates on the shore as foam and scum.

Algal blooms, which typically develop during periods of unusually calm wind conditions when sea surface temperatures are high (February to April), can negatively impact source water quality and may result in elevated organics in the source water and accelerated biofouling of RO installations. Red tides may result in the release of algal toxins of small molecular weight, which may impact product water quality. These are, however, typically effectively removed during the reverse osmosis process. Abstraction of the feed-water at depth and a reduced intake velocity can minimise the entrance of algal material in open water intakes (UNEP 2008). For the current project, the feed-water will be abstracted from an open channel in the surf-zone. As the coastline of the study area is characterised by high wave energy, algal wrack often accumulates in large quantities in intertidal gullies and may thus similarly accumulate in the feed-water intake channel. Furthermore, the diver survey undertaken as part of the project also identified high concentrations of macerated macroalgae in the water column in the surf-zone. This algal material could likewise accumulate in the intake channel, clog the screens at the intake box and negatively impact source water quality through elevated organics.

Considering the comparatively low feed-water volumes required for this project and the fact that feed-water will be abstracted from an intertidal gully, the loss of marine species through impingement and entrainment is deemed of low intensity, but with impacts persisting over the operational life time of the plant. The impact is therefore assessed to be of **LOW** significance both without and with mitigation.

Impact: Loss of marine species through impingement and entrainment

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Definite	**LOW**	**– ve**	High
Essential mitigation measures: • Adjust intake velocities to <0.15 m/s. • Ensure installation of screens on the end of the intake pipes, or the use of a screen box or shroud. **Best practice mitigation measures:** • Although an entrainment and impingement study is typically recommended for large desalination plants, the comparatively low volumes of feed-water to be extracted from the surf-zone for this project would not justify such a study.								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Probable	**LOW**	**+ ve**	High

6.1.8 *Flow Distortion*

The potential of scouring of sediment around the discharge outlet is a serious design issue for an effluent system discharging high volumes into a shallow receiving water body (Carter & van Ballegooyen 1998). For the current project, however, the comparatively low brine volumes and their discharge into the highly turbulent surf-zone are such that the potential impacts on bottom sediments are expected to be limited, and will unlikely be detectable above those resulting from natural wave action. The hydrodynamic modelling study undertaken as part of this project (PRDW 2014) identified that the discharge would generate a current up to 100 m from the discharge point, but as the current speeds as a result of the discharge are similar to those generated by the waves and winds, scour of seabed sediments would be limited to within 20 m of the discharge point. Furthermore, the location and orientation of the discharge pipeline in the gully is unlikely to distort sediment transport pathways in the nearshore environment beyond those controlled by wave action. Should any impacts associated with flow distortion be detectable, they would be of low intensity within the immediate vicinity of the discharge. Despite persisting over the operational life time of the plant, the impact is deemed to be **INSIGNIFICANT** when seen in context with the highly dynamic natural sediment movements typical of the coastline.

Impact: Potential flow distortion around the discharge outlet

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Improbable	**INSIGNIFI-CANT**	**– ve**	High
Essential mitigation measures: • No mitigation measures deemed necessary. **Best practice mitigation measures:** • Design outlet velocities so as to minimise the potential for flow distortion.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low 3**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

6.1.9 *Desalination Plant Effluents*

During operation, the desalination plant will discharge a high-salinity brine into the surf-zone through a single outfall pipeline. Due to its increased salinity (~1.7 times that of seawater), the brine is denser (heavier) than the surrounding seawater and would sink towards the seabed and be advected away from the discharge point in the near-bottom layers of the water column, flowing down-slope (*i.e.* offshore) into deeper water. For the proposed discharge, the jet stream from the pipe end would be utilised to accelerate the brine directly into the oncoming rolling waves, thereby ensuring rapid mixing with the surrounding seawater. In the shallow gully, the effluent plume may reach the surface. Depending on the discharge velocity, the volumes of brine being discharged and the local environmental conditions, thorough mixing throughout the water column is expected, but depending on the degree of mixing, the diluted brine may again sink towards the seabed and continue to dilute due to natural mixing processes. The region where the brine settles to the seafloor is termed the "near field" or "sacrificial mixing zone" as it represents an area in which large changes in water quality, sediments or biota can be expected. In other words, contaminant concentrations will be such that they will result in changes beyond natural variation in the natural diversity of species and biological communities, rates of ecosystem processes and abundance/biomass of marine life. Although the surf-zone carries a significant amount of turbulent energy, it has a limited capacity to transport the brine to the open ocean. If the mass of the saline discharge exceeds the threshold of the surf-zone's salinity load transport capacity, the excess salinity would begin to accumulate in the surf-zone and could ultimately result in a long-term salinity increment in this zone beyond the level of tolerance of the aquatic life (WHO 2007). This salinity threshold mixing/transport capacity of the surf-zone was determined using hydrodynamic modelling.

Under the design specifications for the Volwaterbaai desalination plant project, the feed-waters will be drawn from an intake basin in the intertidal area and is expected to be well mixed (i.e. no thermocline expected). Although no specific heating of the intake water will be done, piping of water prior to it entering the desalination plant may potentially result in a slight elevation in temperature. This potential increase is assumed to be in the range of +1 to 2°C above ambient water temperature. On discharge, the slightly heated, dense effluent would sink towards the seabed where the receiving water masses may potentially have lower temperatures than the brine. However, discharge into the oncoming waves will ensure rapid dispersal throughout the water column, and no changes in absolute or mean temperatures of the receiving water are expected. Only under conditions of extreme calm, when the receiving waters may be stratified, would a thermal foorprint be expected. The brine will also contain traces of biocide and other chemical residuals from RO membrane cleaning processes. Table 1 (pg 11) lists the expected composition of the brine effluent as known at the time of compilation of this Specialist Study.

<u>Salinity</u>

All marine organisms have a range of tolerance to salinity, which is related to their ability to regulate the osmotic balance of their individual cells and organs to maintain positive turgor pressure. Aquatic organisms are commonly classified in relation to their range of tolerance as stenohaline (able to adapt to only a narrow range of salinities) or euryhaline (able to adapt to a wide salinity range), with most organisms being stenohaline.

Salinity changes may affect aquatic organisms in two ways:

- direct toxicity through physiological changes (particularly osmoregulation), and
- indirectly by modifying the species distribution.

Salinity changes can also cause changes to water column structure (e.g. stratification) and water chemistry (e.g. dissolved oxygen saturation and turbidity). For example, fluctuation in the salinity regime has the potential to influence dissolved oxygen concentrations, and changes in the stratification could result in changes in the distribution of organisms in the water column and sediments. Behavioural responses to changes in salinity regime can include avoidance by mobile animals, such as fish and macro-crustaceans, by moving away from adverse salinity and avoidance by sessile animals by reducing contact with the water by closing shells or by retreating deeper into sediments.

However, in marine ecosystems adverse effects or changes in species distribution are anticipated more from a reduction rather than an increase in salinity (ANZECC 2000), and most studies undertaken to date have investigated effects of a decline in salinity due to an influx of freshwater, or salinity fluctuations in estuarine environments, where most of the fauna can be expected to be of the euryhaline type. As large-scale desalination plants have only been in operation for a short period of time, very little information exists on the long-term effects of hypersaline brine on organisms in coastal marine systems (Al-Agha & Mortaja 2005). However, from the limited studies that have been published, it has been observed that salinity has a toxic effect on numerous organisms dependant on specific sensitivities (Mabrook 1994; Eniev *et al*. 2002), and by upsetting the osmotic balance, can lead to the dehydration of cells (Kirst 1989; Ruso *et al.* 2007).

Sub-lethal effects of changed salinity regimes (or salinity stress) can include modification of metabolic rate, change in activity patterns, slowing of development and alteration of growth rates (McLusky 1981; Moullac *et al*. 1998), lowering of immune function (Matozzo *el al*. 2007) and increased mortality rates (Fagundez & Robaina 1992). The limited data available include a reported tolerance of adults of the mussel *Mytilus edulis* of up to 60 psu (Barnabe 1989), and successful fertilization (Clarke 1992) and development (Bayne 1965) of its larvae at a salinity of up to 40 psu. The alga *Gracilaria verrucosa* can tolerate salinity ranges from 9-45 psu (Engledow & Bolton 1992). The shrimp *Penaeus indicus* was capable of tolerating a salinity range of 1 to 75 psu if allowed an acclimation time of around 48 hours (McClurg 1974), the oyster *Crassostrea gigas* tolerated salinities as high as 44 psu (King 1977), and the shrimp *Penaeus monodon* survived in 40 psu saline water (Kungvankij *et al*. 1986a, b, cited in DWAF 1995). Chen *et al*. (1992) reported a higher moulting frequency in juveniles of the prawn *Penaeus chinensis* at a salinity of 40 psu. Lethal effects were reported for seagrass species: for example, salinities of 50 psu caused 100% mortality of the Mediterranean seagrass *Posidonia oceanica*, 50% mortality at 45 psu, and 27% at 40 psu. Salinity concentrations above 40 psu also stunted plant growth and no-growth occurred at levels exceeding 48 psu (Latorre 2005). The high saline concentration can also lead to an increase of water turbidity, which is likely to reduce light penetration, an effect that might disrupt photosynthetic processes (Miri & Chouikhi 2005). The increased salt concentration can reduce the production of plankton, particularly of invertebrate and fish larvae (Miri & Chouikhi 2005). One of the main factors of a change in salinity is its influence on osmoregulation, which in turn affects uptake rates of chemical or toxins by marine organisms. In a review on the effects of multiple stressors on aquatic organisms, Heugens *et al*. (2001) summarise that in general metal toxicity increases with decreasing salinity, while the toxicity of organophosphate insecticides increases with increasing salinity. For other chemicals no clear relationship between toxicity and salinity was observed. Some evidence, however, also exists for an increase in uptake of certain trace metals with an increase in salinity (Roast *et al*. 2002; Rainbow & Black 2002).

Very few ecological studies have been undertaken to examine the effects of high salinity discharges from desalination plants on the receiving communities. One example is a study on the macrobenthic community inhabiting the sandy substratum off the coast of Blanes in Spain (Raventos *et al.* 2006). The brine discharge from this plant was approximately 33,700 m^3/d, nearly an order of magnitude higher than that considered for the Volwaterbaai desalination plant. Visual census of the macrobenthic communities were carried out at two control points (away from the discharge outlet) and one impacted (at the discharge outlet) location several times before and after the plant began operating. No significant variations attributable to the brine discharges from the desalination plant were found. This was partly attributed to the high natural variability that is a characteristic feature of seabeds of this type, and also to the rapid dilution of the hypersaline brine upon leaving the discharge pipe. Other studies, however, indicated that brine discharges have led to reductions in fish populations, and to die-offs of plankton and coral in the Red Sea (Mabrook 1994), and to mortalities in mangrove and marine angiosperms in the Ras Hanjurah lagoon in the United Arab Emirates (Vries *et al.* 1997). Salinity increases near the outfall of a SWRO plant on Cyprus were reported to be responsible for a decline of macroalgae forests, and echinoderm species vanished from the discharge site (Argyrou 1999 cited in UNEP 2008).

Research conducted on abalone (*Haliotis diversicolor supertexta*) has shown that they experience significant mortality at salinities greater than 38 psu (Cheng & Chen 2000). Cheng *et al.* (2004) demonstrated that salinity stress affects the immune system of abalone, making them more vulnerable to bacterial infection. The immune capabilities in bivalve molluscs (e.g. the clam *Chamelea gallina*, Matozzo *et al.* 2007) and crustaceans (e.g. the prawn *Allacrobrachium rosenbergii*, Chen & Chen 2000) have also been shown to be compromised by changes in salinity. The Indian spider lobster *Panulirus homarus*, suffered from a depressed immune system when exposed to salinities over 45 psu, subsequently resulting in 100% mortality (Verghese *et al*. 2007). Desalination plants therefore have the potential to impact on the viability of fishing industries, if the brine accumulates beyond the optimal range for commercially important species.

The South African Water Quality guidelines (DWAF 1995) set an upper target value for salinity of 36 psu. The paucity of information on the effects of increased salinity on marine organisms makes an assessment of the high salinity plume difficult. However, this guideline seems sufficiently conservative to suggest that no adverse effects should occur for salinity <36 psu. At levels exceeding 40 psu, however, significant effects are expected, including possible disruptions to molluscan bivalves (e.g. mussels/oysters/clams) and crustacean (and possibly fish) recruitment as salinities >40 psu may affect larval survival (e.g. Bayne 1965; Clarke 1992). This applies particularly to the larval stages of fishes and benthic organisms in the area, which are likely to be damaged or suffer mortality due to osmotic effects, particularly if the encounter with the discharge effluent is sudden.

In the case of the proposed desalination plant at Volwaterbaai, the brine, which will have a salinity of ~66 psu, will be discharged into the turbulent surf-zone where the effluent would be expected to be rapidly diluted. Toxic effects of elevated salinities are likely to be experienced only by a very limited range of sensitive species, which may consequently be excluded from the sacrificial zone and/or the discharge gully. Most intertidal and shallow subtidal species are likely to experience sub-lethal effects only, if at all, and these would be restricted to within the immediate vicinity (i.e. within the discharge gully) of the outfall. As benthic communities within this region are largely ubiquitous and naturally highly variable at temporal and spatial scales, the loss or exclusion of sensitive species within the highly localised area around the outfall can be considered insignificant in both a local and regional context.

Figures 22 and 23 (pg 77) summarise the results from the hydrodynamic modelling study pertinent to the marine ecological assessment. The three-dimensional hydrodynamic modelling undertaken as part of this project provided detailed outputs for a plant capacity of 6 Mm^3/annum and 8 Mm^3/annum. The model results are only applicable to a discharge *via* a single port located directly above the seabed and directed horizontally offshore, with an exit velocity of 4 to 6 m/s. For this ecological assessment, the maximum proposed plant capacity of 8 Mm^3/annum was assumed, and the assessment undertaken for the 'worst-case' conditions identified by the model. The assessment has thus taken a conservative approach, as under typical wind and wave conditions the observed effluent footprints would be considerably reduced or undetectable.

The model results for the 8 Mm^3/annum desalination plant indicated that the maximum salinity footprint where the water quality guideline of ΔS 1 psu would be exceeded, occurs within 75 m of the discharge point at the water surface and within 250 m of the discharge point at the seabed (Figure 22). This, however, is achieved only under 'worst-case' conditions during a very calm period for a very short time (1% of the time).

For most of the year, plume dimensions are far smaller, with the brine footprint at the surface never exceeding water quality guidelines, whereas at the seabed a 1 psu change in salinity is met within 50 m of the discharge point for 50% of the time. As would be expected, brine footprints are comparatively small during the typically rough conditions along the coastline of the study area, with plume footprints near the seabed extending beyond 100 m from the discharge point only during rare calm sea conditions. Under calm conditions the brine is not sufficiently mixed within the gully and remains close to the seabed due to its greater density. The plume thus extends through the narrow surf-zone, potentially pooling in seabed depressions, and thereby resulting in a much more extensive footprint. Frequent strong wind or storm events that are typical for this coastline are, however, likely to prevent any long term cumulative build up of high–density saline pools at the seafloor. Any detrimental effects on marine organisms would thus be sub-lethal and transient, and unlikely to be detectable above natural environmental perturbations.

The effects of elevated salinities on the physiological functioning of marine organisms is considered to be of medium intensity and dispersion modelling results indicate that effects will remain localised (within a maximum of 250 m under transient, 'worst-case' conditions, but typically within 50 m). Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of **MEDIUM** significance without mitigation. Mitigation in the form of suitable engineering designs to ensure adequate dispersion and dilution of the brine in the receiving surf-zone environment would reduce the significance to **LOW**.

Impact: Reduced physiological functioning of marine organisms due to elevated salinity

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (29x), thereby limiting increased salinities to the minimum achievable mixing zone only. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Possible	**LOW**	**- ve**	High

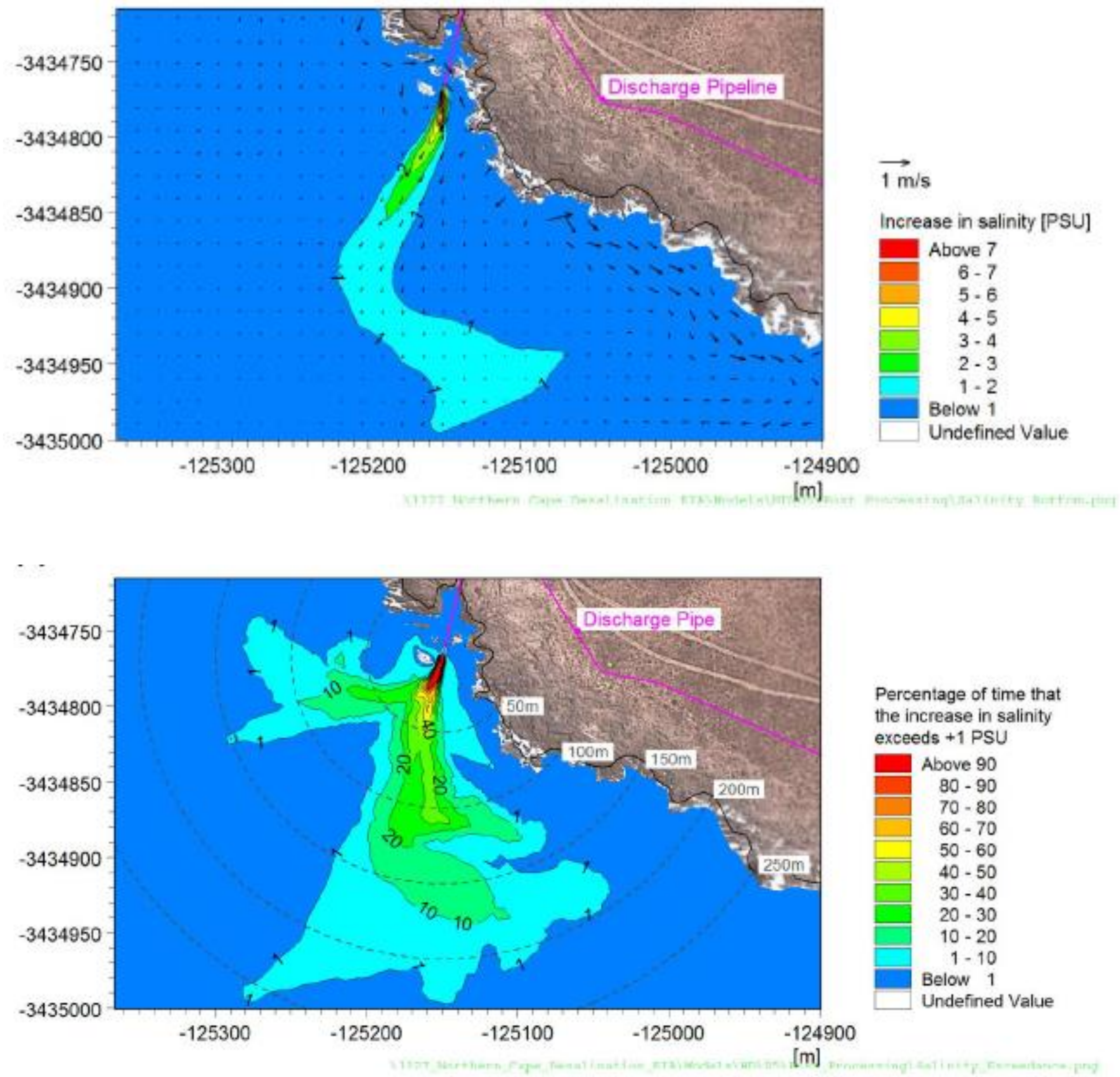

Figure 22: Maximum salinity footprints near the seabed during periods of extreme calm (Top), and the percentage of time that the increase in salinity exceeds the water quality guidelines of 1 psu (Bottom) for a discharge from a plant of 8 Mm^3/annum capacity (Source: PRDW 2014).

Avoidance of the brine footprint by marine organisms is considered to be of low intensity and would remain confined to the mixing zone. Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of **LOW** significance without mitigation, reducing to **VERY LOW** significance with the implementation of mitigation.

Impact: Avoidance behaviour by invertebrates, fish and marine mammals of the discharge area

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Probable	**LOW**	**– ve**	High
Essential mitigation measures: • Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (29x), thereby limiting increased salinities to the minimum achievable mixing zone only. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Possible	**VERY LOW**	**- ve**	High

<u>Temperature</u>

Generally, there is no heating process of the intake water in RO desalination plants. However, the temperature of the feed water may increase slightly during its passage through the pipelines and the plant. Such an increase is not expected to exceed 2°C.

Bamber (1995) defined four categories for direct effects of thermal discharges on marine organisms:

- Increases in mean temperature;
- Increases in absolute temperature;
- High short term fluctuations in temperature; and
- Thermal barriers.

<u>Increased mean temperature</u>

Changes in water temperature can have a substantial impact on aquatic organisms and ecosystems, with the effects being separated into two groups:

- influences on the physiology of the biota (e.g. growth and metabolism, reproduction timing and success, mobility and migration patterns, and production); and
- influences on ecosystem functioning (e.g. through altered oxygen solubility).

The impacts of increased temperature have been reviewed in a number of studies along the West Coast of South Africa (e.g. Luger *et al*. 1997; van Ballegooyen & Luger 1999; van Ballegooyen *et al*. 2004, 2005). A synthesis of these findings is given below.

Most reports on adverse effects of changes in seawater temperature on southern African West Coast species are for intertidal (e.g. the white mussel *Donax serra*) or rocky bottom species (e.g. abalone *Haliotis midae*, kelp *Laminaria pallida*, mytilid mussels, Cape rock lobster *Jasus lalandii*). Cook (1978) specifically studied the effect of thermal pollution on the commercially important rock lobster *Jasus lalandii*, and found that adult rock lobster appeared reasonably tolerant of increased temperature of +6°C and even showed an increase in growth rate. The effect on the reproductive cycle of the adult lobster female was, however, more serious as the egg incubation period shortened and considerably fewer larvae survived through the various developmental stages at +6°C above ambient temperature. Zoutendyk (1989) also reported a reduction in respiration rate of adult *J. lalandii* at elevated temperatures.

Other reported effects include an increase in biomass of shallow water hake *Merluccious capensis* and West Coast sole *Austroglossus microlepis* at 18°C (MacPherson & Gordoa 1992) but no influence of temperatures of <17.5°C on chub-mackerel *Scomber japonicus* (Villacastin-Herroro *et al*. 1992). In contrast, 18°C is the lower lethal limit reported for larvae and eggs of galjoen *Distichius capensis* (Van der Lingen 1994).

Internationally, a large number of studies have investigated the effects of heated effluent from coastal power stations on the open coast. These concluded that at elevated temperatures of <5°C above ambient seawater temperature, little or no effects on species abundances and distribution patterns were discernable (van Ballegooyen *et al*. 2005). On a physiological level, however, some adverse effects were observed, mainly in the development of eggs and larvae (e.g. Cook, 1978, Sandstrom *et al*. 1997; Luksiene *et al*. 2000).

The South African Water Quality Guidelines recommend that the maximum acceptable variation in ambient temperature should not exceed 1°C (DWAF 1995), which is an extremely conservative value in view of the negligible effects of thermal plumes on benthic assemblages reported elsewhere for a ΔT of +5°C or less.

All benthic species have preferred temperature ranges and it is reasonable to expect that those closest to their upper limits (*i.e.* boreal as opposed to temperate) would be negatively affected by an increase in mean temperature. The sessile biota in the Benguela region are, however, naturally exposed to wide temperature ranges due to surface heating and rapid vertical mixing of the water column and intrusions of cold bottom shelf water into the system. It can thus be assumed that the biota in these waters are relatively robust and well-adapted to substantial natural variations in temperature.

The application of the ANZECC (2000) water quality guideline (that requires that the median temperature in the environment with an operational discharge should not lie outside the 20 and 80 percentile temperature values for a reference location or ambient temperatures observed prior to the construction and operation of the proposed discharge), may be more appropriate to the high temperature variability conditions in the study area. Conditions in the surf-zone are, however, expected to be well mixed and thermoclines would not be expected.

Although not modelled for the current study, no discernible temperature footprint would be expected as temperature differences between the brine and receiving waters are expected to be <2°C. There would thus be compliance with both the South African Water Quality Guidelines (DWAF 1995) as well as the ANZECC (2000) guidelines.

Increased absolute temperature

The maximum observed sea surface temperature in the region typically is <18°C. Strong wind events and wave action in the surf-zone are likely to mix the water column to such an extent that the bottom waters will have similar water temperatures to the surface waters. The discharged brine will not be heated above this naturally occurring maximum temperature and therefore an increase in absolute temperature is not expected and is not further assessed here.

Short term fluctuations in temperature and thermal barriers

Temperature fluctuations are typically caused by variability in flow or circulation driven by frequently reversing winds or tidal streams. For example, Bamber (1995) described faunal impoverishment in a tidal canal receiving hot water effluent where the temperature variability was ~12°C over each tidal cycle. As noted above, although likely well mixed by surf-zone turbulence, the receiving waters in the area may vary rapidly in temperature, and the ecological effects of potential brine-induced changes of <2°C in temperature are therefore not further assessed.

For thermal barriers to be effective in limiting or altering marine organism migration paths they need to be persistent over time and cover a large cross-sectional area of the water body. The predictions for the brine plume distributions indicate that neither condition will be met in the study area. Over and above this, there are no known migration pathways in the system. This effect can therefore be considered insignificant.

The effects of elevated temperature on marine communities is considered to be of low intensity. Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of **VERY LOW** significance without mitigation. Mitigation in the form of suitable engineering designs to ensure adequate dispersion and mixing of the effluent in the receiving surf-zone environment would reduce the probablility of the impact occurring but maintain the significance at **VERY LOW**.

Impact: Reduced physiological functioning of marine organisms due to elevated temperature

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Possible	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (29x), thereby limiting potential thermal footprints to the mixing zone only. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effleunt to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Improbable	**VERY LOW**	**- ve**	High

Dissolved Oxygen

Dissolved oxygen (DO) is an essential requirement for most heterotrophic marine life. Its natural levels in seawater are largely governed by local temperature and salinity regimes, as well as organic content. Coastal upwelling regions are frequently exposed to hypoxic conditions owing to extremely high primary production and subsequent oxidative degeneration of organic matter. Along the southern African west coast, low-oxygen waters are a feature of the Benguela system.

Hypoxic water (<2 ml O_2/ℓ) has the potential to cause mass mortalities of benthos and fish (Diaz & Rosenberg 1995). Marine organisms respond to hypoxia by first attempting to maintain oxygen delivery (e.g. increases in respiration rate, number of red blood cells, or oxygen binding capacity of haemoglobin), then by conserving energy (e.g. metabolic depression, down regulation of protein synthesis and down regulation/modification of certain regulatory enzymes), and upon exposure to prolonged hypoxia, organisms eventually resort to anaerobic respiration (Wu 2002). Hypoxia reduces growth and feeding, which may eventually affect individual fitness. The effects of hypoxia on reproduction and development of marine animals remains almost unknown. Many fish and marine organisms can detect, and actively avoid hypoxia (e.g. rock lobster “walk-outs”). Some macrobenthos may leave their burrows and move to the sediment surface during hypoxic conditions, rendering them more vulnerable to predation. Hypoxia may eliminate sensitive species, thereby causing changes in species composition of benthic, fish and phytoplankton communities. Decreases in species diversity and species richness are well documented, and changes in trophodynamics and functional groups have also been reported. Under hypoxic conditions, there is a general tendency for suspension feeders to be replaced by deposit feeders, demersal fish by pelagic fish and macrobenthos by meiobenthos (see Wu 2002 for references). Further anaerobic degradation of organic matter by sulphate-reducing bacteria may additionally result in the production of hydrogen sulphide, which is detrimental to marine organisms (Brüchert *et al*. 2003).

Because oxygen is a gas, its solubility in seawater is dependent on salinity and temperature, whereby temperature is the more significant factor. Increases in temperature and/or salinity result in a decline of dissolved oxygen levels. The temperature of the effluent is not significantly elevated in relation to the intake water temperature, and a reduction in dissolved oxygen is thus only expected as a result of the elevated salinity of the brine. For example, saturation levels of dissolved oxygen in seawater decrease with rising salinity from 5.69 ml/ℓ at 15˚C and 35 psu, to 4.54 ml/ℓ at for example 67.5 psu (DWAF 1995), not taking into account any biological use of oxygen due to respiration, oxidation and degradation. In summer months the surface water may reach temperatures of 23°C, and the saturation level of DO in the brine at this temperature would decline from 4.91 ml/ℓ at 35 psu to 3.97 ml/ℓ at 67.5 psu. These approximate calculations for example brine of 67.5 psu translate into a 19-20% reduction of DO in the brine. The South African Water Quality Guidelines for Coastal Marine Waters (DWAF 1995) state that for the west coast, the dissolved oxygen should not fall below 10% of the established natural variation. A potential difference in DO concentration of 20% is within the natural variability range of the waters in the Benguela, and the potential for a reduction in dissolved oxygen levels will also drastically reduce within a few meters of the outlet as the receiving water body is very shallow and therefore likely to be well mixed.

Near-bottom waters on the southern African West Coast are often characterised by hypoxic conditions as a result of decomposition of organic matter and low-oxygen water generation processes. A decrease in DO levels in the discharged brine is thus not of great concern. Cumulative effects may occur though during such low oxygen events but compared to the potentially large footprint of the natural hypoxic water masses, the footprint of the effluent itself will be minimal.

As discussed above, the expected changes in dissolved oxygen are associated with both direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the effluent being discharged. However, indirect changes in dissolved oxygen content of the water column and sediments due to changes in hydrodynamic and ecosystem functioning in the area are also possible. For example, oxygen concentrations may change (particularly in the bottom waters and in the sediments) due to changes in phytoplankton production as a result of changes in nutrient dynamics (both in terms of changes in nutrient inflows and vertical mixing of nutrients) and subsequent deposition of organic matter. Several of the scale control additives typically used in desalination plant operations have the potential to act as nutrients for plants (e.g. sodium tripolyphosphate and trisodium phosphate). In principle the phosphate can act as a plant nutrient and thus increase algal growth (Lattemann & Höpner 2003), however, phosphate generally is not limiting in marine environments, unless there are significant inputs of nitrogen (nitrates, ammonia), which is the limiting nutrient in such systems.

A critical factor that also needs to be taken into account is that oxygen depletion in the brine might occur through the addition of sodium metabisulfite (SMBS), which is commonly used as a neutralizing agent for chlorine (Lattemann & Höpner 2003) (see below). SBMS is an oxygen scavenger and if not properly dosed, can severely deplete the dissolved oxygen in the discharged water. In such cases, aeration of the effluent is recommended prior to discharge, in which case, the brine may in fact have a higher DO concentration than the receiving water body during natural low oxygen events.

The effects of reduced dissolved oxygen concentrations on marine communities are considered to be of medium intensity and effects will likely remain localised. Impacts will, however, persist in the very short-term only, as 1) plankton blooms (should they occur) in response to elevated nutrients would be ephemeral only, and 2) accidental overdosing of SMBS would occur intermittently only, despite dechlorination being practiced over the life time of the plant. The impact is therefore assessed to be **INSIGNIFICANT**.

Impact: Reduced physiological functioning of marine organisms due to reduced dissolved oxygen concentrations

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Possible</td><td>INSIGNIFI-CANT</td><td>– ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Avoid overdosing with SMBS or aerate effluent prior to discharge.

Best practice mitigation measures:
• Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effleunt to ensure compliance with water quality guidelines.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
</table>

<u>Pretreatment of Intake Waters</u>

Chemical pretreatment of the intake water and periodical cleaning of the RO membranes is essential in the effective operation of desalination plants. Pretreatment and cleaning include treatment against biofouling, suspended solids and scale deposits. The type of pretreatment system used is determined primarily by the intake type (e.g. pretreatment for open water intake is generally more complex and comprehensive than that for sub-surface intakes) and the feed-water quality.

The main components of the pretreatment system for the Volwaterbaai desalination plant are:

- Control of biofouling by addition of an oxidising (chlorine-based) or non-oxidising (e.g. DBNPA) biocide, and dechlorination with sodium metabisulfite (in the case of chlorine-based products),
- Removal of suspended material by coagulation and membrane filtration (*i.e* ultrafiltration membrane),
- Control of scaling by acid addition (lowering the pH of the incoming seawater) and/or dosing of special ‘antiscalant’ chemicals,
- Cartridge filters as a final protection barrier against suspended particles and microorganisms before the RO units.

The open channel intake basin design is likely to necessitate high pre-treatment and screen maintenance to reduce the intake of extensive algal growth, floating debris, grease and oil, thus increasing the amount of biocides and/or chemicals co-discharged with the brine.

Biocides

Chlorination of the intake water is undertaken to ensure that the pumping systems (e.g. intake pipe and membranes) are maintained free of biofouling organisms. For example, larvae of sessile organisms (e.g. mussels, barnacles) can grow in the intake pipe, and impede the intake flow of the feed-water. Biofouling of the membranes by algae, fungi and bacteria can rapidly lead to the formation and accumulation of slimes and biofilms, which can increase pumping costs and reduce the lifespan of the membranes.

There are two main groups of biocides: the oxidising biocides and the non-oxidising biocides. The classification is based on the mode of biocidal action against biological material. Oxidising biocides include chlorine and bromine-based compounds and are non selective with respect to the organisms they kill. Non-oxidising biocides are more selective, in that they may be more effective against one type of micro-organisms than another. A large variety of active ingredients are used as non-oxidising biocides, including quaternary ammonium compounds, isothiazolones, halogenated bisphenols, thiocarbamates as well as others. In desalination plants, the non-oxidising Dibromonitrilopropionamide (DBNPA) is frequently used as an alternative to an oxidising biocide. DBNPA has extremely fast antimicrobial action and rapid degradation to relatively non-toxic end products. A summary of its environmental fate is included in Appendix A.3.

For the Volwaterbaai desalination plant, it is proposed that either sodium hypochlorite (NaOCl) or chlorine gas will be used as an oxidising biocide. The chlorine-based biocide will be added intermittently at the plant's intake structure as shock dosages of 10 minute duration every 4 hours.

Before the feed-water enters the RO units, residual chlorine needs to be neutralised with sodium metabisulfite (SMBS) to avoid membrane damage, as RO membranes are typically made from polyamide materials which are sensitive to oxidising chemicals such as chlorine. As a consequence, chlorine concentration will be very low to non-detectable in the brine effluent of the plant and is thus assumed to be below the 3 µg/ℓ limit as permitted by ANZECC (2000), which provides the most conservative guideline value (Table 5).

Compliance with the guidelines is thus expected, but for the sake of completeness a summary of chlorine chemistry and its potential effects on the receiving environment is provided in Appendix A.2. This serves to highlight the importance of assuring that chlorine is at all times sufficiently neutralised before discharge of the brine.

The effects of residual chlorine on marine communities are considered to be of high intensity, but effects will likely remain localised. Impacts will persist over the medium-term as impacted marine communities will recover within 2-5 years. The impact is therefore assessed to be of **MEDIUM** significance without mitigation, but would reduce to **INSIGNIFICANT** with mitigation.

Impact: Detrimental effects on marine organisms due to residual chlorine levels

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	High 3	Medium-term 2	**Medium** **6**	Definite	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Implement shock dosing of biocide in preference to continual dosing. • Dechlorinate effluent prior to discharge with sodium metabisulphite (SMBS). • Undertake 'pigging' of intake and discharge pipelines to reduce the need for and costs of biocides. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

A major disadvantage of chlorination is the formation of organohalogen compounds (e.g. THMs, see Appendix A.2). However, as only a few percent of the total added chlorine is recovered as halogenated by-products, and as by-product diversity is high, the environmental concentration of each substance can be expected to be relatively low. Dechlorination will further considerably reduce the potential for by-product formation. Nonetheless, there is some evidence that chlorinated-dechlorinated seawater increased mortality of test species and chronic effects of dechlorinated seawater were observed, which were assumed to be due to the presence of halogenated organics formed during chlorination (see UNEP 2008 for references).

The effects of halogenated by-products on marine communities are considered to be of medium intensity, but effects will be chronic and endure over the long-term. As only a very small percentage of the chlorine will transform into toxic by-products that cannot be eliminated by dechlorination, the impact is assessed to be of **LOW** significance both without and with mitigation.

Impact: Chronic effects on marine organisms due to formation of halogenated by-products

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Improbable	**LOW**	**– ve**	High
Essential mitigation measures: • No direct mitigation is possible as chlorine chemistry is complex and type and concentrations of by-product formation cannot be predicted. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Medium 2	Long-term 3	**Medium** **6**	Improbable	**LOW**	**- ve**	High

De-chlorination

SMBS is a powerful reducing agent that reduces hypobromous acid (HOBr) to hydrobromic acid (HBr) and is in turn oxidised to sulfate. Although the reaction products are non-hazardous, SMBS may cause oxygen depletion if dosing is not adjusted properly. However, SMBS rapidly reacts with free chlorine but has a much slower reaction with naturally occurring dissolved oxygen. The reaction chemistry involved also means that SMBS can remove less oxygen from the seawater than the quantity of chlorine they are capable of removing. In case of overdosing with SMBS and resultant low oxygen levels, aeration of the effluent, prior to discharge may be necessary.

As marine communities in the Benguela system are adapted to naturally occurring hypoxia, the effect is considered to be of medium intensity, of localised extent and persisting over the short-term only. The impact is therefore assessed to be **INSIGNIFICANT** without mitigation, as well as with mitigation.

Impact: Reduction in dissolved oxygen concentrations as a result of dechlorination

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Possible</td><td>INSIGNIFI-CANT</td><td>– ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Implement shock dosing of biocide in preference to continual dosing.
• Avoid over-dosing of SMBS.
• Aerate the effluent prior to discharge.

Best practice mitigation measures:
• Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effleunt to ensure compliance with water quality guidelines.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Low
1</td><td>Short-term
1</td><td>Very Low
3</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
</table>

Bacterial re-growth

Excessive bacterial re-growth in the brine after chlorination is a further concern. For example, this was reported for a RO desalination plant in Egypt (Diab 2002), where bacterial counts in the brine were 7-10 times higher than those in the feed-water thereby posing potential health risks to marine biota as well as users of the marine environment (e.g. swimmers, surfers, divers). Besides inadequate maintenance of the plant and an ineffective cleaning in place (CIP) process, excessive bacterial aftergrowth has also been attributed to the use of continuous chlorination. The reason for this ineffectiveness is that chlorination results in the breakdown of high molecular dissolved organics into nutrients, thus forming assimilable organic carbon (AOC). In addition, microorganisms subject to low levels of biocides often exude extracellular polysaccharides as a protective biofilm that increases their survival rate. Both, the availability of surplus nutrients and the survival of some microorganisms can cause a heavy re-growth in desalination systems following chlorination (UNEP 2008). For most large RO facilities, continuous chlorination has proven ineffective and has been replaced by intermittent shock chlorination. Shock dosing is also proposed for this project. In severe cases of biogrowth, additional shock treatment may become necessary to re-establish low bacterial numbers from time to time. Sodium metabisulfite is most commonly used for this purpose, with a typical application of 500-1 000 mg/ℓ for 30 minutes (Redondo & Lomax 1997). It has to be noted though that SMBS reduces bacterial numbers by oxygen depletion and is therefore only effective against aerobic microorganisms, while some other bacteria might survive in anaerobic conditions.

The health risks associated with excessive bacterial re-growth following chlorination are considered to be of low intensity, will likely remain localised, but may persist over the life time of the plant. The impact is therefore assessed to be of **VERY LOW** significance without mitigation, but would reduce to **INSIGNIFICANT** with mitigation.

Impact: Excessive bacterial re-growth in the brine after chlorination

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Possible	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Use intermittent shock dosing with a biocide to avoid bacterial resistance to the biocide. • Monitor the brine for excessive bacterial re-growth and if necessary use SMBS shock dosing to reduce bacterial numbers (note that the brine will be oxygen depleted after this treatment and needs to be aerated before discharge). **Best practice mitigation measures:** • Ensure efficient CIP process and adequate maintenance of plant. • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

Co-discharged Waste-water Constituents

In addition to the biocide dosing, the pretreatment of the feed-water includes the removal of suspended solids, the control of scaling, and the periodical cleaning of the RO membranes (CIP). Specifications and volumes of cleaning chemicals that may be used in the pretreatment and CIP process and may be co-discharged with the brine effluent are listed in Table 1. As different chemicals are suited for different types of membranes, exact specifications for the additives will only be known once the desalination plant operator has been appointed and the membrane type decided on. Manufacturers of RO membranes will provide relevant information in product manuals and are likely to offer consultation with regard to pretreatment and CIP chemicals. This section thus describes the use and effects of cleaning chemicals that are used conventionally in desalination plants with an open water intake.

Flocculants

Ferric chloride ($FeCl_3$) will be used as primary coagulant or flocculant in the pretreatment system. When added to water, a hydrolysis reaction produces an insoluble ferric hydroxide precipitate that binds non-reactive molecules and colloidal solids into larger aggregations that can then be more easily settled or filtered from the water before it passes through to the RO membranes. Dosing of sulfuric acid to establish slightly acidic pH values and addition of coagulant aids such as polyelectrolytes can enhance the coagulation process. Polyelectrolytes are organic substances with high molecular masses (like polyacrylamide) that help to bridge particles together. The dosage of coagulants and coagulant aids is normally correlated with the amount of suspended material in the intake water. It can range between < 1 and 30 mg/ℓ for coagulants and between 0.2 and 4 mg/ℓ for polyelectrolytes. The resulting ferric hydroxide floc is retained when the seawater passes through the filter beds. The filters are backwashed on a periodic basis (few times every day), using filtered seawater or permeate water, to clean the particulate material off the filters. This produces a sludge that contains mainly sediments and organic matter, and filter coagulant chemicals. If co-discharged to the sea, ferric chloride may cause discoloration of the receiving water, and the sludge discharge may lead to increases in turbidity and suspended matter and has blanketing effects (Sotero-Santos *et al.* 2007, Lattemann & Höpner 2003). As a pro-active measure in favour of direct discharge to the sea, the sludge (mixed with other cleaning waste solutions) should be treated in an on-site sludge handling facility where it can be neutralised, and the solids removed and recycled or transported to a landfill site. The remaining waste-water could then be blended into and co-discharged with the brine effluent. Residual ferric hydroxide in the brine would thus be minimal to non-detectable.

After passing through the filter beds, the feed-water is put through a Dissolved Air Flotation (DAF) tank. DAF is a water treatment process that clarifies waters by the removal of suspended matter such as oil or solids. The removal is achieved by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. Best practice involves keeping the supernatant water together with other cleaning waste-water, and treating this in the sludge handling facilities prior to drip-feeding the neutralised waste flows into the brine effluent.

Figure 23 summarises the results from the hydrodynamic modelling study pertinent to the assessment of potential impacts of co-pollutants in the brine on the marine ecology. The three-dimensional hydrodynamic modelling undertaken provided detailed outputs for a plant capacity of 6 Mm^3/annum and 8 Mm^3/annum. The model results are only applicable to a discharge *via* a single port located directly above the seabed and directed horizontally offshore, with an exit velocity of 4 to 6 m/s. For this assessment, the maximum proposed plant capacity of 8 Mm^3/annum was assumed, and the assessment undertaken for the 'worst-case' condition identified by the model. The assessment of co-pollutants has thus taken a conservative approach, as under typical wind and wave conditions the observed co-pollutant footprints would be considerably reduced or undetectable. The model results for typical dilutions and dispersion of co-pollutants in the brine showed similar footprints for a dilution factor of 30, to those obtained for salinity.

The effects on marine communities of discharging co-pollutants with the brine are considered to be of medium intensity, will remain localised (within a maximum of 250 m under transient, 'worst-case' conditions, but typically within 50 m), but would persist over the life time of the plant. The impact is therefore assessed to be of **MEDIUM** significance without mitigation, but would reduce to **VERY LOW** with mitigation.

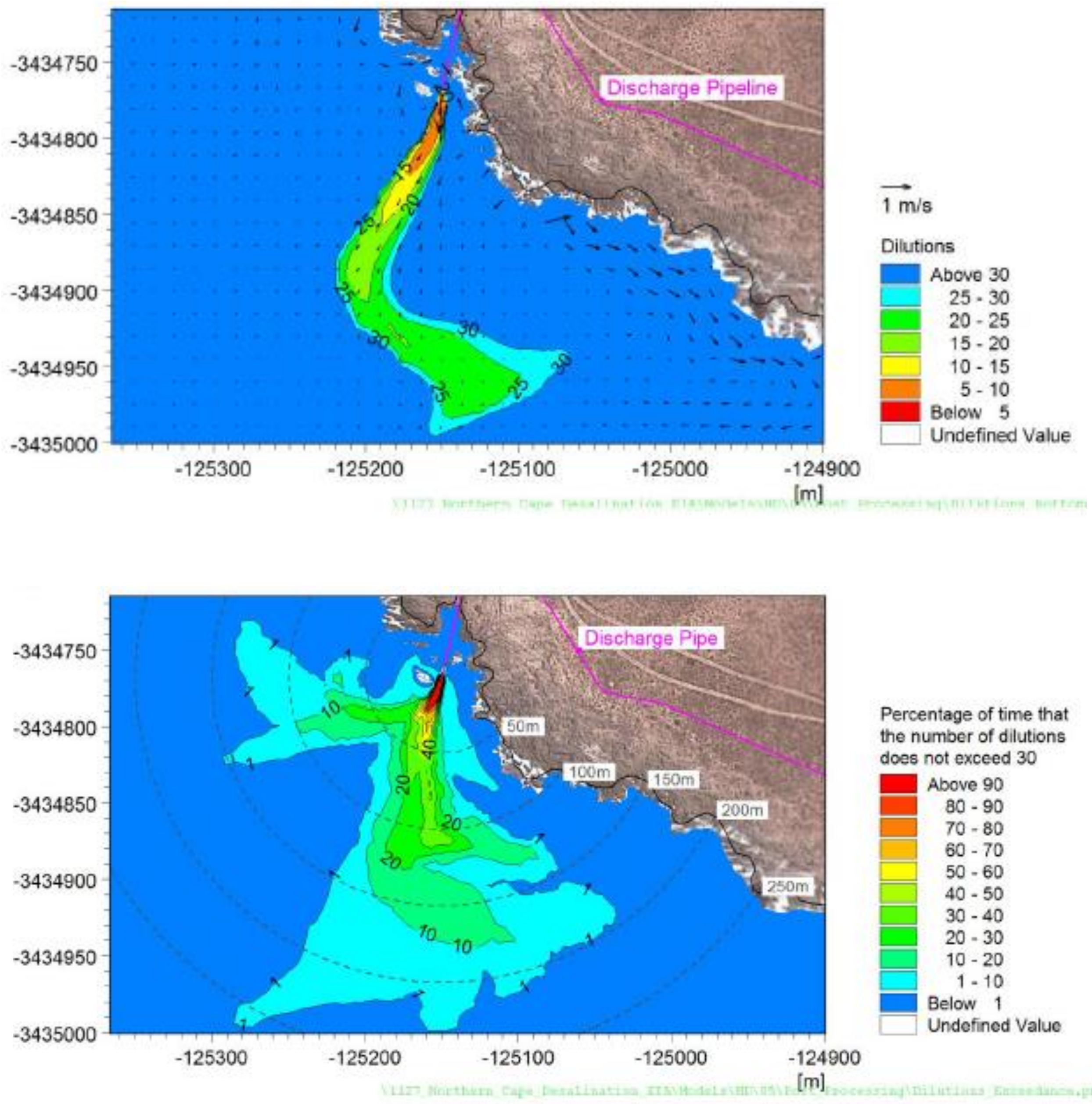

Figure 23: Maximum footprints near the seabed for achievable dilutions of co-pollutants in the brine during periods of extreme calm (Top), and the percentage of time that the number of dilutions does not exceeds 30x (Bottom) for a discharge from a plant of 8 Mm^3/annum capacity (Source: PRDW 2014).

Impact: Detrimental effects on marine organisms through discharge of co-pollutants in backwash waters

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Use low-toxicity chemicals as far as practicable. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Improbable	**LOW**	**- ve**	High

Antiscalants

Scaling on the inside of tubes or on RO membranes impairs plant performance. Antiscalants are commonly added to the feed-water in desalination plants to prevent scale formation. The main representatives of antiscalants are organic, carboxylic-rich polymers such as polyacrylic acid and polymaleic acid. Acids and polyphosphates are still in use to a limited degree but are generally on the retreat as they can cause eutrophication (see for example Shams *et al.* 1994). Polyphosphate antiscalants are easily hydrolysed to orthophosphate, which is an essential nutrient for primary producers. Their use may cause a nutrient surplus and an increase in primary production at the discharge site, through formation of algal blooms and increased growth of macroalgae (DWAF 2007). When the organic material decays, this in turn can lead to oxygen depletion.

In contrast, phosphonate and organic polymer antiscalants have a low toxicity to aquatic invertebrate and fish species, but some substances exhibit an increased toxicity to algae (see UNEP 2008 for reference). The typical antiscalant dosing rate in desalination plants (1–2 mg/ℓ), however, is a factor of 10 lower than the level at which a chronic effect was observed (20 mg/ℓ), and it is 10 to 5,000 times lower than the concentrations at which acutely toxic effects were observed. Phosphonate will be used as the antiscalant for the Volwaterbaai desalination plant, with predicted antiscalant concentration in the brine of 4.7 mg/ ℓ, which is still far below chronic effects level. Due to the antiscalants capability of binding nutrients they may, however, interfere with the natural processes of dissolved metals in seawater following discharge (see UNEP 2008 for reference). Some of these metals may be relevant micronutrients for marine algae.

The effects on marine communities of discharging antiscalants with the brine are considered to be of medium intensity, will remain localised (within a maximum of 250 m under transient, 'worst-case' conditions, but typically within 50 m), but would persist over the life time of the plant. The impact is therefore assessed to be of **MEDIUM** significance without mitigation, but would reduce to **VERY LOW** with mitigation.

Impact: Detrimental effects on marine organisms through discharge of antiscalants in backwash waters

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Limit the use of scale-control additives to minimum practicable quantities. • Avoid antiscalants that increase nutrient levels (e.g. polyphosphate antiscalants)., • Select an antiscalant that has relevant eco-toxicological testing. • Conduct Whole Effluent Toxicity (WET) testing of the brine effluent. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Improbable	**VERY LOW**	**- ve**	High

Cleaning in Place Chemicals

Despite feed-water pretreatment, membranes may become fouled by biofilms, accumulation of suspended matter and scale deposits, necessitating periodic cleaning. The cleaning intervals (CIP) of RO membranes are typically three to six months depending on the quality of the plant's feed-water (Einav *et al*. 2002). The cleaning interval currently suggested for the proposed desalination plant is four times per year. The chemicals used are mainly weak acids and detergents. Alkaline cleaning solutions (pH 11-12) are used for removal of silt deposits and biofilms, whereas acidified solutions (pH 2-3) remove metal oxides and scales. Further chemicals such as detergents, oxidants, complexing agents and/or non-oxidising biocides for membrane disinfection, are often added to improve the cleaning process. These additional chemicals are usually generic types or special brands recommended by the membrane manufacturers. Common cleaning chemicals include Sulphuric acid, Ethylenediaminetetra-acetic acid (EDTA), Sodium tripolyphosphate (STPP), and Trisodium phosphate (TSP), and Dibromonitrilopropionamide (DBNPA) as the non-oxidising biocide. Appendix A.3 provides a short summary of the environmental fates and effects of these chemicals.

After the cleaning process is complete and the cleaning agents have been circulated through the membranes, the membranes are rinsed with product water several times. For the Volwaterbaai desalination plant project, it is proposed that the residual membrane cleaning solution and rinse water will be blended with the other residual streams from the DAF and filtration systems, and drip-fed into the brine effluent. Generally, the toxicity of the various chemicals used in the pre-treatment and CIP process (aside from biocides) is relatively low (see Appendix A.3), and none of the products are listed as tainting substances (DWAF 1995).

The effects on marine communities of discharging CIP chemicals with the brine are considered to be of low intensity and will likely remain localised (within a maximum of 250 m under transient, ‘worst-case’ conditions, but typically within 50 m). As discharge will be intermittent, effects are likely to persist over the short-term only. The impact is therefore assessed to be of **VERY LOW** significance without mitigation, and would reduce to **INSIGNIFICANT** with mitigation.

Impact: Detrimental effects on marine organisms or ambient seawater pH through discharge of residual cleaning solutions used periodically for cleaning in place

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Collect residual cleaning solutions and membrane filter washes and neutralize and remove solids before discharge. • Use low-toxicity chemicals as far as practicable. • Conduct Whole Effluent Toxicity (WET) testing of the brine effluent. **Best practice mitigation measures:** • Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Possible	**Insignificant**	**- ve**	High

For assessment purposes, the hydrodynamic model used dilution target values of 30-times dilution. These are merely nominal conservative required dilutions that provide indicative results for potential co-discharges. The assumption here is that the respective water quality guidelines will be sufficiently stringent for required dilutions of 30 to be necessary. The model outputs, however, could be re-processed assuming any specified thresholds deemed to be representative of the pollutant of concern. In that sense the modelling approach utilised was entirely generic and scalable. The footprints in Figure 23 and the assessments are based on 30 times dilution contours.

The maximum distance from the discharge point where the required dilution of 30 was not achieved for 1% of the time (or approximately 7 hours per month) occur near the seabed during periods of extreme calm and are ~250 m. Although the reported maximum footprint is relatively large, it represents the worst-case scenarios and will only occur for a very short periods under certain weather conditions (very calm conditions). It is unlikely that in such short time a surplus of nutrients will lead to a significant increase in algal production, or in the case of antiscalants, to a noticeable reduction in micronutrients. Mitigating measures include discharge of the brine through a diffuser, and the avoidance of polyphosphate antiscalants. A Whole Effluent Toxicity test of the discharged brine is recommended to more reliably assess the impact of any co-discharged constituents and to calculate the required dilution rate.

Heavy Metals

The brine from a desalination plant often contains low amounts of heavy metals that pass into solution when the plant's interior surfaces corrode. In RO plants, non-metal equipment and stainless steels are typically used. The RO brine may therefore contain traces of iron, nickel, chromium and molybdenum, but contamination levels are generally low (Hashim & Hajjaj 2005; Lattemann & Höpner 2003). Heavy metals tend to enrich in suspended material and finally in sediments, so that areas of restricted water exchange and soft bottom habitats impacted by the discharge could be affected by heavy metal accumulation. Many benthic invertebrates feed on this suspended or deposited material, with the risk that metals are enriched in their bodies and passed on to higher trophic levels. At this stage, no assessment of the potential concentration of heavy metals can be provided, as it is an incidental by-product of desalination plant processes. It is therefore recommended that limits are established for heavy metal concentrations in the brine discharges (see Table 5 for guideline values), and the brine regularly monitored to avoid exceedance of these limits.

The effects on marine communities of heavy metals in the brine from corrosion processes are considered to be of medium intensity, but will likely remain localised. As heavy metals can accummulate in the sediments, the effects would persist in the long-term. The impact is therefore assessed to be of **MEDIUM** significance without mitigation, and would reduce to **VERY LOW** with mitigation.

Impact: Detrimental effects on marine organisms of heavy metals from corrosion processes

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local 1	Medium 2	Long-term 3	**Medium** 6	Probable	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Design the plant to reduce corrosion to a minimum by ensuring that dead spots and threaded connections are eliminated. Corrosion resistance is considered good when the corrosion rate is <0.1 mm/a (UNEP 2008). **Best practice mitigation measures:** • Implement a water quality monitoring programme to ensure compliance with water quality guidelines.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Improbable	**VERY LOW**	**- ve**	High

6.1.10 *Cumulative Impacts*

Anthropogenic activities in the coastal zone can result in complex immediate and indirect effects on the natural environment. Effects from disparate activities can combine and interact with each other in time and space to cause incremental or cumulative effects. Cumulative effects can also be defined as the total impact that a series of developments, either present, past or future, will have on the environment within a specific region over a particular period of time (DEAT IEM Guideline 7, Cumulative effects assessment, 2004).

To define the level of cumulative impact in the intertidal and subtidal environment, it is therefore necessary to look beyond the environmental impacts of the current project and consider also the influence of other past or future developments in the area.

The coastline of the project area has in the past been targeted by shore-based, diver-assisted diamond mining operations. As sea conditions control where safe operations can be conducted, these are typically limited to small bays and gullies with some shelter from waves. In mining target areas, intertidal and subtidal organisms are damaged or destroyed by movement of mining equipment, removal of boulders from subtidal gullies into the intertidal zone or into rock piles, discard of tailings and the general activities of the contractors around the mining unit (Parkins & Branch 1995, 1996, 1997; Pulfrich 1998a; Pulfrich *et al.* 2003a). This mining-related disturbance is very localised being limited to a scale of 10s of metres around each individual operation. While recovery of the intertidal and subtidal communities occurs within 2-5 years, physical alteration of the shoreline in ways that cannot be remediated by swell action, such as deposition of large piles of pebbles and boulders, can be more or less permanent.

As the intake and discharge pipelines for the proposed desalination plant are located in relatively sheltered gullies, there is a strong possibility that these have in the past been targeted by diamond divers. On face value, however, the selected locations for pipeline installation do not appear significantly different from other similar habitats in the general area, suggesting that if they had indeed been targeted by shore-based divers in the past, impacts to the intertidal area were temporary only. Cumulative effects with the proposed development are thus highly unlikely.

The proposed development by Forest Oil of gas infrastructure and a desalination plant on the northern portion of Farm Strandfontein 559 has been withdrawn. The development now involves a subsea pipeline linking the iBhubesi Gas Field with a proposed onshore gas receiving facility at the Ankerlig Power Station at Atlantis north of Cape Town. The subsea pipeline will be routed along the 200 m depth contour, well offshore of the proposed Volwaterbaai development and no synergistic effects between the projects are expected. Therefore, given the current lack of past and future proposed development along the coastline of the project area, cumulative impacts as well as disturbances to marine or coastal systems or features are expected to be limited.

Conclusions and Recommendations

The main marine impacts associated with the proposed desalination plant at Volwaterbaai are related to the construction of the intake and outfall structures during the construction phase, the intake of feed water from, and consequent discharge of a high-salinity brine back into the ocean during the operational phase.

6.1.11 *Environmental Acceptability*

The environmental acceptability of the proposed development is outlined below.

<u>Construction Phase</u>

Construction activities as part of the proposed development will severely impact the rocky shore and nearshore habitats and their associated communities, but the impacts will be highly localised and confined to the immediate construction area. The installation of the intake and discharge structures will result in considerable disturbance of the high-shore, intertidal and shallow subtidal habitats at the construction site. The construction will involve substantial excavation activities on the intertidal rocky shore and in the surf-zone, as well as extensive traffic on the shore by heavy vehicles and machinery, and the potential for associated hydrocarbon spills. Although the activities in the intertidal zone will be localised and confined to within a hundred metres of the construction site, the boulders and sediments will be completely turned over in the process and the associated macrofauna will almost certainly be entirely eliminated. Rock blasting will be necessary to remove existing bedrock to the required depth, resulting in disturbance of coastal and marine biota. The physical removal of sediments or bedrock in the trench will result in the total destruction of the associated sessile benthic biota. Excavating operations will also result in increased suspended sediments in the water column and physical smothering of macrofauna by the discarded sediments. However, provided construction activities are not phased over an extended period, the shoreline is not repeatedly disturbed through persistent activities and suitable post-construction rehabilitation measures are adopted (e.g. track rehabilitation, Removal of foreign construction materials which may hamper recovery of biota, backfilling excavations above mean sea level with the excavated material as trenching progresses, so as to maintain the original shore profile as far as possible). the macrofaunal communities are likely to recover in the short-to medium-term. The benthic communities of these shores are highly variable, on both spatial and temporal scales, and subject to dramatic natural fluctuations, particularly as a result of episodic disturbances such as unusual storms, and low oxygen events. As a consequence, the benthos is considered to be relatively resilient, being well-adapted to the dynamic environment, and capable of keeping pace with rapid biophysical changes (McLachlan & De Ruyck 1993). The highly localised, yet significant impacts over the short term thus need to be weighed up against the long-term benefits of the desalination plant.

Operational Phase

The key potential impacts on the marine environment of the proposed desalination plant are mostly associated with the operational phase. The impacts involve impingement and entrainment of biota at the intake point, and impacts associated with water quality due to pre-treatment of feed-water and discharge of the brine effluent..

The open channel intake considered for this project will result in impingement and entrainment of biota. Careful designing of the intake with appropriate screens can reduce impingement substantially and should be implemented. The entrainment of biological matter and suspended matter, however, cannot be eliminated and will require substantial pre-treatment of the feed-water, which has environmental as well as operational cost consequences for the desalination plant.

The need for pre-treatment of the feed water will also result in the use of chlorination to prevent biofouling of the pipelines and screens, and the use of other cleaning materials, which will be co-discharged with the reject brine. Impacts associated with the brine discharge thus include:

- the effect of elevated salinities in the discharged effluent;
- the effect of the effluent potentially having a higher temperature than the receiving environment;
- biocidal action of residual chlorine in the effluent (residual chlorine will be neutralized with sodium metabisulfite before the feed-water reaches the RO membranes);
- the effects of co-discharged constituents in the brine;
- the removal of particulate matter from the water column where it is a significant food source, as well as changes in phytoplankton production due to changes in nutrients, water column structure and mixing processes; and
- direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent (especially if sodium bisulfate is used to neutralize residual chlorine), and indirect changes in dissolved oxygen content of the water column and sediments due to changes in phytoplankton production as a result of nutrient input.

It is particularly important that the development of a coherent density flow of brine along the seabed is avoided by ensuring complete mixing in the surf-zone at the point of discharge. Consequently, the effluent must be discharged in an area of relatively high wave energy where regular mixing of the water column can be expected as a result of the exposed nature of the coastline. Careful consideration of available technologies and processes in the plant design for the proposed desalination plant is thus the key issue that will allow the selection of the least environmentally damaging option for feed-water treatment, cleaning of plant components and brine disposal, thereby reducing discharges of hazardous components into the environment and ensuring adequate and rapid dilution of the effluent in the receiving water.

The hydrodynamic modelling results indicate that under average sea conditions, the predicted plume footprint is limited in spatial extent to no more than 50 m from the discharge point. Although this may extend to up to 250 m from the discharge point under extremely calm conditions, these will be transient only and are predicted to occur only 1% of the time.

6.1.12 *Recommendations*

General Recommendations relevant to Desalination Plants

The experience of existing operational desalination plants and the considerable research in the field of desalination techniques has shown that careful planning and design of the plant is vital for successful long-term plant operation (Campbell & Jones 2005; WHO 2007; UNEP 2008). From a systems engineering perspective, three criteria drive the design of a seawater reverse osmosis plant, namely, quality of feedwater, reverse osmosis membrane specification, and water quality of permeate (Jones 2008). From a marine environmental perspective, feed-water quality is the most critical issue as the quality is largely determined by the type of intake system used. As the first step in the pre-treatment process, the type of intake structure used is a key component, as it will affect a range of source water quality parameters and will ultimately impact the performance of downstream treatment facilities. Ultimately, the choice of intake technology determines the amount of biological and suspended material pumped into the plant, and the level of chemical pollution co-discharged with the brine. Many recent studies and reviews have advocated the use of sub-surface intakes where possible (Lattemann & Höpner 2003; WHO 2007; Peters *et al.* 2007; Peters & Pintó 2008; National Water Comission 2008; Pankratz 2008), as these have the advantage that the overlaying sediment acts as a natural filter, thereby significantly reducing impingement and entrainment effects. This in turn protects downstream equipment, enhances process performance and reduces the capital and operating costs of the pre-treatment system. The implementation of sub-surface intakes, however, depends on local geological conditions, and in this case, the rocky nature of the coastline dictates that this option is not feasible.

Mitigation Measures

The essential mitigation measures are listed below for both the construction and operational phases of the desalination plant.

Construction Impacts

Heavy vehicle traffic associated with construction and pipeline installation must be kept to a minimum, and be restricted to clearly demarcated access routes and construction areas only. All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan. Good house-keeping must form an integral part of any construction operations on the beach from start-up, including, but not limited to:

- drip trays under all vehicles parked on the beach;
- no vehicle maintenance or refuelling on beach;
- oil spill contingency plan for accidental oil spills;
- accidental diesel and hydrocarbon spills to be cleaned up accordingly; and
- no concrete mixing on the shore.

All blasting activities must be conducted in accordance with recognised standards and safety requirements. The area around the blasting site should be visually searched before blasting commences, and the blasting postponed should a marine mammal, sea turtle and/or flocks of swimming and diving birds be spotted within a 2-km radius around the blasting point. Following a previous blast, stunned or dead fish may attract seals and scavenging birds. The blasting programme should be scheduled to allow seals to have left the area before the next blasting event. The number of blasts should be restricted to the absolute minimum required, and should consist of smaller, quick succession blasts directed into the rock using a time-delay detonation.

Operational Impacts

Seawater Intake

There are several alternative design or mitigation measures that can completely avoid or reduce the impact of impingement. Intake velocities should be kept below ~0.15 m/s to ensure that fish and other organisms can escape the intake current. This can be achieved through a combination of pumping rates and intake design as is the case for the proposed desalination plant at Volwaterbaai. Further mitigation options involve screens, which prevent the intake of fish and wrack while still allowing adequate water flow.

Furthermore, manual cleaning of the intake channel, screen box and intake and seawater delivery pipelines will be necessary as marine growth, scaling and sediment settlement will occur. Most marine pipelines employ a pigging system for regular maintenance cleaning, in which a ‘pig’ (bullet-shaped device with bristles) is introduced into the pipeline to mechanically clean out the structure. The pigging device is introduced at the intake structure and allowed to travel to the pump station, from where it is retrieved. For the discharge pipeline, it is introduced in the desalination plant, and is removed again on the seaward side.

Chlorination of the intake water is undertaken intermittently to ensure that the intake pipeline and feed-water pumping systems remain free of biofouling organisms. However, as the RO membranes are sensitive to oxidizing chemicals, neutralisation of residual chlorine, with sodium metabisulfite (SMBS), is necessary if membrane damage is to be avoided.

Scaling of the plant pipelines and RO membranes is controlled by the addition either of acid or specific antiscalant chemicals. Acids and polyphosphates cause eutrophication through formation of algal blooms and macroalgae, and should therefore be avoided. The preferred alternative would be to use phosphonate and organic polymer antiscalants, which have a low toxicity to aquatic invertebrate and fish species. These are proposed for the Volwaterbaai desalination plant. Depending on the membrane type, the antiscalant product should preferably be one for which relevant eco-toxicological testing has already been undertaken.

The recommendations provided above are in line with best practice for desalination plants of the capacity proposed at Volwaterbaai. Essential mitigation measures would comprise the use of low toxicity phosphonate and organic polymer antiscalants.

Discharges

During commissioning of the desalination plant, it may be necessary to discard the membrane storage solution and rinse the membranes before plant start-up. If the membrane storage solution contains a biocide or other chemicals these must either be neutralised before being discharged to sea, or the storage solution disposed of at an appropriate waste disposal facility.

Sedex Desalination have specified that traces of residual chlorine in the brine discharge will be below 3 µg/ℓ (ANZECC (2000) guideline levels) as chlorine will be neutralised with sodium metabisulfite (SMBS). As marine organisms are extremely sensitive to residual chlorine, it is vital to ensure that the residual chlorine concentration in the discharged brine is at all times reduced to a level below that which may have lethal or sublethal effects on the biota, particularly the larval stages. Should the exceedance of the recommended guideline (<3 µg/ℓ) be a more persistent or recurrent event, there could be serious implications for marine biota in the discharge gully and the plant would need to be closed down until the problem has been rectified.

The use of SMBS during dechlorination is, however, associated with oxygen depletion in the effluent if overdosing occurs, as the substance is an oxygen scavenger. Shock dosing with SMBS is also an effective way of eliminating re-growth of aerobic bacteria in the discharge pipelines. Aeration of the effluent prior to discharge is therefore recommended, prefereably with a permanent aeration system. Alternatively, if a permanent *in situ* effluent monitoring system is in place, aeration can be undertaken intermittently when monitoring results detect unacceptably low dissolved oxygen levels in the effluent.

If DBNPA were to be used as alternative to chlorine, mitigation measures to ensure low residuals of DBNPA in any discharge to the marine environment include appropriate design of the brine basin so as to ensure greater and sufficient dilution of the DBNPA residuals in the effluent stream and higher degradation rate before discharge. A better option would be carefully monitored dosing to ensure minimal DBNPA concentrations in the discharge.

The solids generated by the filtration, backwash and CIP processes will be mixed with the DAF sludge and the waste-water would then be blended into and co-discharged to sea with the brine effluent.

6.1.13 *Monitoring Recommendations*

Monitoring plays a key role in ensuring that plant operations function as intended and achieve the provision of water with minimal environmental impacts. It includes validation, operational monitoring, verification and surveillance. Validation is the process of obtaining evidence that control measures are capable of operating as required, in other words it should confirm that specific pieces of equipment achieve accepted performance standards. Operational monitoring is the planned series of observations or measurements undertaken to assess the ongoing performance of individual control measures in preventing, eliminating or reducing hazards. Operational monitoring will normally be based on simple and rapid procedures such as measurement of turbidity and chlorine residuals or inspection of the distribution system integrity. Verification provides assurance that a system as a whole is providing safe water while surveillance reviews compliance with identified guidelines standards and regulations.

<u>Recommendations for Validation</u>

International guidelines (WHO 2007; UNEP 2008) recommend that, prior to the design and construction of the desalination plant, a study be conducted on the chemical and physical properties of the raw water. A thorough raw water characterisation at the proposed intake site should include an evaluation of physical, microbial and chemical characteristics, meteorological and oceanographic data, and aquatic biology. Seasonal variations should also be taken into account. The study should consider all constituents that may impact plant operation and process performance including water temperature, total dissolved solids (TDS), total suspended solids (TSS), membrane scaling compounds (calcium, silica, magnesium, barium, etc.) and total organic carbon (TOC). Many of these data were collected for the area during the pre-feasibility phase of the project.

Once the desalination plant is in full operation, a monitoring program should be implemented to ensure that the required level of dilution (as predicted by the numerical modelling) is in fact achieved. Typical brine and thermal footprints should ideally be confirmed, both to assess the performance of the discharge system and validate the numerical model predictions. As there are no suitable launch sites in the Volwaterbaai area and sea conditions typically prevent vessel operations in the nearshore, such an approach is not considered feasible. Considering the high costs associated with implementing such monitoring, and the uncertainty of obtaining sufficient quantitative information on a regular basis, a validation monitoring program is thus not recommended.

To ensure complete confidence in the potential effects of the antiscalant to be used in the desalination plant and that the co-discharged waste-water constituents are being managed to concentrations that will not have significant environmental impacts, it will be necessary to undertake toxicity testing of the discharge for a full range of operational scenarios (*i.e.* shock-dosing, etc). Such sampling and Whole Effluent Toxicity (WET) testing need only be undertaken for the duration and extent necessary to determine an effluent profile under all operational scenarios.

<u>Recommendations for Operational Monitoring</u>

To quantify the full impact of the brine discharge on the marine environment, all affected habitats and/or communities should be monitored before and during the discharge. However, prior research has indicated that this is impractical, impossible or simply unnecessary. Monitoring should rather focus on what are likely to be the most sensitive, significantly affected and/or representative species, communities or resources. The proposed discharge area includes two principal kinds of habitat - subtidal unconsolidated sediments and reefs, and intertidal rocky shores. In both cases a suite of standard, and widely accepted techniques have been developed for the monitoring of invertebrate communities associated with these habitats. The nature of the marine environment in the Volwaterbaai area, however, makes the design and successful implementation of a subtidal monitoring program for this project particularly difficult. An initial diving survey has established that the habitat in the vicinity of the outlet consists of a mixture of sandy and rocky habitats. Typical tools for sampling of sandy biota (e.g. suction sampler, van Veen grab) are therefore not suitable, and a quantitative, visual census of the benthic communities by suitably qualified scientific divers is the only feasible alternative. The exposed nature of the coastline in combination with the naturally high sediment load in nearshore waters, however, results in extremely poor visibility at the seabed. Experience has shown that such conditions persist even during periods of calm weather and low sea swell. For example, despite careful preparation and close observation of the weather and sea conditions, it was not possible to establish a well informed and quantitative baseline in the area due to typically high wave conditions at the study sites. Under such persistent conditions, the results of visual census diving surveys will lack the resolution required to identify any changes in the biota that might be associated with the brine discharge. Considering the high costs associated with implementing diving surveys, and the uncertainty of obtaining sufficient quantitative information a monitoring program reliant on diving surveys is thus not recommended.

A monitoring program of intertidal rocky shore communities is, however, feasible. It is thus highly recommended that Sedex Desalination consider implementing a structured before-after/control-impact monitoring program (Underwood 1992, 1993, 1994), which would commence prior to the start of construction and continue for at least 5 years following the commencement of brine discharge. The results of such a monitoring program will not only inform on the extent and magnitude of the construction impacts for the desalination plant, but also the cumulative effects of the brine discharge.

Although it is predicted that residual chlorine levels in the discharge will be below guideline levels, continuous monitoring of the effluent for residual chlorine and dissolved oxygen levels is essential. Should residual chlorine be detected in the brine, SMBS dosing should immediately be increased. This may in turn lead to reduced oxygen levels in the effluent requiring aeration of the brine before discharge. Furthermore, bacterial re-growth should be periodically assessed (every 6 months) and if high bacterial numbers are encountered in the brine, shock-dosing with SMBS should be undertaken. Continuous monitoring of oxygen levels would then indicate whether aeration of the effluent is necessary.

The waste brine often contains low amounts of heavy metals from corrosive processes, which tend to enrich in suspended material and finally in the marine sediments. It is recommended that the effluent be monitored regularly (every 6-12 months) for heavy metals until a profile of the discharge in terms of heavy metal concentrations is determined. These heavy metal concentrations in the brine effluent would then need to be assessed based on existing guidelines (DWAF 1995; ANZECC 2000). A summary of these guidelines is provided in Table 4. An inspection program at similar intervals (6-12 months) to check corrosion levels of plant constituent parts and the physical integrity of the intake and outlet pipes and diffuser should be implemented and components replaced or modified if excessive corrosion is identified or specific maintenance is required.

Recommendations for Surveillance Reviews

A monitoring program should be developed to study the effects of the discharged brine on the receiving water body, particularly as monitoring of the affected subtidal benthic communities is in this case not feasible. This recommendation is reinforced by the *Guidelines for Environmental Evaluation for Seawater Desalination* which has recently been published by the *Department of Water Affairs and Forestry* (DWAF 2007), in which it is stated that it is essential that the effects of the discharge of brine into any water body be monitored according to a monitoring program performed at 6-monthly intervals over a period of approximately 4 years. This monitoring program would validate numerical modelling results and/or ecological assessments based on these (see above). Depending on initial results, reduced monitoring (*i.e.* annually) may be acceptable. This monitoring will include measurement of the main water quality parameters such as temperature, salinity and dissolved oxygen as a minimum.

This information should be used to develop a contingency plan that examines the risk of contamination, and considers procedures that must be implimented to mitigate any unanticipated impacts (e.g. mixing zone larger than expected under certain conditions).

However, as there are no suitable launch sites in the Volwaterbaai area and sea conditions typically prevent vessel operations in the nearshore, the success of implementing such monitoring cannot be guaranteed.

7. CONCLUSIONS AND RECOMMENDATIONS

The impact assessment (Section 5 above) identified that the marine environment will be impacted to some degree during both the construction and operational phases of the proposed Volwaterbaai desalination plant.

One negative impacts of medium significance (before mitigation) associated with the construction phase was identified:

- Disturbance and destruction of intertidal beach macrofauna during construction as a result of vehicular traffic and excavations.

Five negative impacts of medium significance (before mitigation) associated with the operational phase were identified:

- Increased salinity in the mixing zone affects biota.
- Effects of biocide plume on marine communities in the mixing zone.
- Effects of discharged co-pollutants with backwash water.
- Effects of discharged antiscalants.
- Heavy metals (if present in the brine from corrosion processes) may affect dissolved metal concentrations in the receiving water.

With few exceptions, recommended management actions and mitigation measures will reduce the negative impacts of medium significance to low.

The recommended mitigation measures for the construction phase of the desalination plant are:

- Keep heavy vehicle traffic associated with construction on the shore to a minimum.
- Restrict vehicles to clearly demarcated access routes and construction areas only.
- All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan.
- Good house-keeping must form an integral part of any construction operations on the beach from start-up.
- All blasting activities should be conducted in accordance with recognised standards and safety requirements.
- Search the area around the blasting area and postpone blasting if turtles, marine mammals or flocks of diving or swimming birds are spotted within a 2-km radius of the blasting point.
- Restrict the number of blasts to the absolute minimum required, and to smaller, quick succession blasts directed into the rock using a time-delay detonation.
- Undertake only one blast per day.

The recommended mitigation measures for the operational phase of the desalination plant are:

- Keep intake velocities below ~0.15 m/s to ensure that fish and other organisms can escape the intake current.
- Install screens to prevent fish from entering the system while still allowing adequate water flow.
- Undertake regular pigging of the intake pipelines.
- Undertake intermittent chlorination of the intake water to prevent bacterial re-growth in the brine.
- Ensure that residual chlorine is suitably neutralised with sodium metabisulfite (SMBS); residual chlorine in the brine discharge must be below 3 µg/ℓ.

- Monitor the brine for dissolved oxygen levels potentially caused by overdosing of SMBS, and aerate if necessary.
- Avoid the use of nutrient-enriching antiscalants, and use antiscalants with low toxicity to aquatic invertebrate and fish species.
- The discharge pipe should be fitted with a suitable diffuser system at its seaward end to ensure rapid and efficient dilution of the effluent with the receiving water, thereby reducing plume footprints near the seabed and minimising impacts on marine ecology. The design of the diffuser and discharge rates would meet the requirements of the South African Marine Water Quality Guidelines and the Operational Policy for the Disposal of Land-derived Water containing Waste to the Marine Environment insofar as they are applicable to this type of installation.

Monitoring recommendations include:

- Conduct a study on the chemical and physical properties of the raw water at the proposed intake site prior to the design and construction of the desalination plant.
- Once in operation, conduct a study to ensure that the required dilution levels are achieved.
- Undertake toxicity testing of the discharged effluent for a full range of operational scenarios (*i.e.* shock-dosing, etc) to ensure complete confidence in the potential effects of co-discharged constituents and the antiscalant to be used.
- Continuously monitor the effluent for residual chlorine and dissolved oxygen levels.
- Periodically assess bacterial re-growth.
- Regularly monitor the effluent for heavy metals until a profile of the discharge in terms of heavy metal concentrations is determined.
- Check corrosion levels of plant constituent parts and the physical integrity of the intake and outlet pipes and diffuser and replace or modify components if excessive corrosion is identified or specific maintenance is required.
- Implement a monitoring program to study the effects of the discharged brine on the receiving water body and/or intertidal biological communities surrounding the discharge location. Although monitoring of the salinity plume to validate the model results would be ideal, the high wave energy environment in the project area makes this impractical. Monitoring of the intertidal benthic communities at the impact site, and comparison with communities at a further two reference sites could, however, be used to assess the ecological impacts of the hypersaline plume, and assist in developing a contingency plan that examines the risk of contamination, and considers procedures that must be implimented to mitigate any unanticipated impacts.

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Appendix A:

1. Potential Effects of Blasting
2. Seawater Chlorination Chemistry and Associated Potential Impacts
3. Summary of Chemistry and Environmental Fate of Certain Desalination Plant Cleaning Chemicals and Biocides

A.1 Potential Effects of Blasting

The laying of the intake and discharge pipeline will require blasting. Keevin & Hempen (1997) and Lewis (1996) provide information on blast-effects on a variety of shallow water (<10 m) organisms. Below follows a summary of these effects focussing on the marine macrophytic algae, major invertebrate macrofaunal taxa, fish, turtles and marine mammals that may occur in the blast area off the desalination plant site.

<u>Macrophytes</u>

Smith (1996) measured blast effects on three species of algae, and found that both physical and physiological damage can occur within 10.5 m of a 2 kg explosive charge. Mortality (=biomass loss) was limited to within 8.5 m whilst depressions in photosynthetic rates post-blast occurred at all distances observed: 2.5 m – 10.5 m from the blast. This indicates that any disruptions to algal beds through blasting would be limited to the immediate vicinity of the charges.

<u>Invertebrates</u>

Due to the lack of gas bodies, marine invertebrates appear to be relatively immune to blast effects in terms of obvious injury or mortalities. Keevin & Hempen (1997) reported that oysters (*Ostrea virginica*) exposed to a 136.1 kg charge of TNT (high explosive) in open water had 100% survival at distances ranging from 7.6 - 122 m from the blast. Crabs (*Callinectes sapidus*) also showed high survival rates when exposed to a 90.7 kg open water charge, with mortalities ranging from 28% at a distance of 15.2 m from the blast, to 11% at a distance of 75 m. At 110 m from the charge, crab mortalities were zero. In a study by CSIR (1997) in Saldanha Bay, mud prawns (*Upogebia capensis*) suspended in perforated, thin walled plastic bags at 0.5 m, 30 m, 70 m and 120 m from six short interval (millisecond) 22.5 kg high explosive blasts in stemmed shot holes, showed no mortalities, and were actively swimming immediately after the blasts. In contrast, Keevin & Hempen (1997) reported 55% mortality in crabs exposed within 38 m - 15 m to a 13.6 kg blast in open water. Sublethal injuries in crabs, including carapace rupture, have been observed within metres to similarly moderately sized blasts (Keevin & Hempen 1997). This suggests that the blast-effects on invertebrates are likely to remain confined to the construction area and minimal far-field effects are likely to occur. Consequently deleterious impacts of underwater blasting on the invertebrate macrofauna in the vicinity of the pipeline are considered to be insignificant should they occur.

<u>Fish</u>

The swim bladder in fish is the organ most frequently damaged by shock (pressure) waves generated by underwater explosions (Lewis 1996, and authors cited therein). Post-mortem examinations of fish killed by underwater explosions generally show traumatic rupture of swim bladders and associated damage to adjacent organs including kidney, liver and spleen (Keevin & Hempen 1997). Further evidence of the role of the swim bladder in blast trauma is offered by the different apparent sensitivities to underwater explosions of physoclistous and physostomus fish species. The former have their swim bladder attached to the circulatory system and it consequently responds slowly to pressure changes, whereas the latter have the swim bladder ducted to the oesophagus with a relatively rapid pressure equalization response. Consequently physoclistic fish species, such as white bass (*Morone chrysops*) appear to be more sensitive to blasts than physostomus species such as trout (*Salmo* sp). Further factors moderating susceptibility to mortality and injury due to blast effects include body shape and overall size. In general thick bodied cylindrical fish, e.g. *Sphyraena* spp. (barracuda), are less susceptible to injury than more laterally compressed species such as Sparidae (Fitch & Young 1948). Furthermore, Yelverton *et al.* (1975) found that higher shock wave intensity was required to kill larger than smaller fish of the same species.

Fish species that do not posses swim bladders (e.g. sharks and rays, some bony fish such as sea chub *Girella* spp, scorpion fish *Scorpaena* and *Scorpaenicthys* sp., and soles such as *Trinectes* sp.) appear to be largely immune to underwater explosions. For example, Goertner *et al.* (1994) found that *Trinectes* were not killed beyond a distance of 1 m from an open water charge of 4.5 kg of the high explosive pentolite.

Hill (1978) has developed equations predicting lethal ranges and safe distances for fish exposed to open water explosions. Input information for these includes:

- Typical size (weight) of the fish species likely to be exposed to the charges
- Depth of the target fish in the water column
- Depth of the detonation, and
- Weight of the charge.

Keevin & Hempen (1997) provide nomograms based on Hill's (1978) equations for estimating ranges from these variables. Following Hill's (1978) recommendations ranges calculated from the nomograms should be doubled to account for possible energy focusing effects of shallow water. Given the fact that surf-zone and nearshore species along the Namaqualand coastline are widely distributed, the probability of the blasting programme having a measurable effect at the population level on fish in the study area is judged to be unlikely and therefore of low impact.

Based on exposures of anchovy eggs and larvae to a small charge size of 50 g TNT, Kostyuchenko (1973) concluded that fish eggs and pre-air bladder inflation fish larvae suffer pathological injury from underwater explosions, but effect ranges appear to be relatively small (< 20 m). The *'Guidelines for the use of explosives in Canadian Fisheries waters'* (Wright, cited in Keevin & Hempen 1997) utilise a wider range of data and define a peak particle velocity of 13 mm/s as the critical threshold. These data allow the calculation of setback distances for fish spawning areas according to the regression equation:

Setback distance (m) = 1.806 (charge wt in kg) + 34.61

It is assumed that fish eggs and larvae will be widely distributed along the Namaqualand coastline. Given the small area in which effects would possibly be generated, the probability of the proposed blasting programme having a measurable effect on fish eggs and larvae on a population level in the study area is unlikely.

Birds

Information on the effects of underwater blasting on swimming and diving birds is limited to experiments on ducks (Lewis 1996). Mortality occurred primarily within the immediate vicinity (< 10 m) of the blast, as a result of extensive pulmonary haemorrhaging and ruptured livers, kidneys, airsacs and eardrums. Birds beyond 20 m from the blast were largely uninjured. Lewis (1996) presents underwater blast criteria for birds on and beneath the water surface, from which safe and lethal ranges can be estimated.

In the case of underwater explosions, shock waves above the water surface are considered highly unlikely (O'Keeffe & Young 1984), and impacts on shore-birds can therefore be expected to be insignificant. Blasting on the shoreline, however, are likely to result in flight responses in nesting birds (Wambach *et al.* 2001), and resting or feeding flocks on the shore.

Turtles

A number of studies have demonstrated that sea turtles are killed and injured by underwater explosions (Duronslet *et al.* 1986; Gitschlag 1990; Gitschlag & Herozeg 1994; Gitschlag & Renaud 1989; Klima *et al*. 1988; O'Keeffe & Young 1984). Experiments undertaken to document the effects of underwater explosions on sea turtles, found that animals placed at intervals between 200-900 m from an explosive removal of an oil platform suffered averted cloaca and vasodilation, and in extreme cases lost consciousness, and if left in the water may have drowned. Carapace fractures in Loggerhead turtles which surfaced within minutes of a detonation have also been reported, as have extensive internal damage, particularly to the lungs.

Young (1991) developed the following equation to estimate sea turtle safe ranges, but as there has been no study establishing the relationship between underwater explosive pressures and mortality, this should be used for preliminary planning purposes only.

$R = 222\ W^{1/3}$

Where R = range in m and W = charge weight in kg.

There are no data on non-lethal damage from underwater explosions or delayed mortality, both of which may have a greater impact on sea turtle populations than immediate death from explosions.

Although occurring in the study area, turtles are infrequent visitors in the shallow nearshore regions. It is recommended that the area around the blasting area be searched before blasting commences, and to postpone blasting if a sea turtle is spotted. Given the small area in which effects would possibly be generated, the probability of the proposed blasting programme having a measurable effect on turtles in the study area is unlikely if the above recommendation is adhered to.

Marine Mammals

Similar to fish, injuries to mammals generated by underwater explosions are primarily trauma of various levels to organs containing gas, such as lungs, ears, and the intestinal tract. Empirical evidence on seals suggests that close proximity to charges can result in mortality, with observations of seals being killed by an 11.4 kg dynamite charge exploded 23 m away (Hanson 1954, cited in Keevin & Hempen 1997). Empirical observations on blast effects on other mammals have allowed the formulation of quantitative relationships between explosive charge size and safe distances. Keevin & Hempen (1997) provide such relationships derived from Young (1991) and Hill (1978). Using three input variables, namely depth of the target animal, depth of detonation and weight of the charge, the safe distances from the predicted maximum charges can be estimated in terms of seal mortality and sub-lethal injury. Note that seals outside of the lethal range but within zero effect range limit may suffer blast injuries such as lung haemorrhaging or ear drum rupture (Hill 1978). However, animals are expected to recover unaided; *i.e.* no human intervention should be required.

Given the relatively small lethal range and the generally low numbers of seals in the study area relative to the overall population size any population level mortality effects, or injuries that may be caused are judged to be insignificant.

Although occurring in the study area, whales and dolphins are infrequent visitors in the shallow nearshore regions, being more common further offshore. Because of their large sizes the risk of pathological injuries that may be caused by the proposed blasting appears to be constrained because of limited effect ranges. Young (1991) gives the following safe ranges for dolphins and whales, the equations indicating a reduction in sensitivity to underwater explosions with increasing size:

Juvenile dolphin	$R = 576\ W^{0.28}$
Dolphin	$R = 434\ W^{0.28}$
6m Whale	$R = 327\ W^{0.28}$

Where R = range in m and W = charge weight in kg.

Due to the limited effect ranges and the distributions of whales and dolphins in the region any effects of the proposed blasting programme at the respective population levels are considered to be insignificant. As specified under South African environmental laws, disturbance of whales should be avoided. If whales are present in the blast area, disturbance cannot be ruled out. Consequently mitigation of the possible disturbance effect is required. It is recommended to visually search the area around the blasting area before blasting commences and to postpone the blasting should a whale be spotted.

A.2. Seawater Chlorine Chemistry and Associated Potential Impacts

The chemistry associated with seawater chlorination when using chlorine-based products is complex and only a few of the reactions are given below, summarised from ANZECC (2000), Lattemann & Höpner (2003) and UNEP (2008). Chlorine does not persist for extended periods in water but is very reactive. Its by-products, however, can persist for longer. The addition of sodium hypochlorite to seawater results in the formation of hypochlorous acid:

$$NaOCl + H_2O \rightarrow HOCl + Na^+ + OH^-$$

Hypochlorous acid is a weak acid, and will undergo partial dissociation as follows:

$$HOCl \rightarrow H^+ + OCl^-$$

In waters of pH between 6 and 9, both hypochlorous acid and hypochlorite ions will be present; the proportion of each species depending on the pH and temperature of the water. Hypochlorous acid is significantly more effective as a biocide than the hypochlorite ion.

In the presence of bromide (Br-), which like chloride is a natural component of seawater (average bromide concentration in seawater is 67 mg/ℓ), chlorine instantaneously oxidises bromide to form hypobromous acid and hypobromite (HOBr):

$$HOCl + Br^- \rightarrow HOBr + Cl^{--}$$

Hypobromous acid is also an effective biocide. It is worth noting that, for a given pH value, the proportion of hypobromous acid relative to hypobromite is significantly greater than the corresponding values for the hypochlorous acid - hypochlorite system. Thus, for example, at pH 8 (the pH of seawater), hypobromous acid represents 83% of the bromine species present, compared with hypochlorous acid at 28%. Hypobromous acid can also disproportionate into bromide and bromated, which is accelerated by sunlight.

In natural waters, chlorine can undergo a range of reactions in addition to those discussed above, leading to the formation of a range of by-products. The reaction of chlorine with organic constituents in aqueous solution can be grouped into several types:

(a) Oxidation,
where chlorine is reduced to chloride ion, e.g. $RCHO + HOCl \rightarrow RCOOH + H^+ + Cl^-$

(b) Addition,
to unsaturated double bonds, e.g. $RC = CR' + HOCl \rightarrow RCOHCClR'$

(c) Substitution,
to form N-chlorinated compounds, e.g. $RNH_2 + HOCl \rightarrow RNHCl + H_2O$
or C-chlorinated compounds, e.g. $RCOCH_3 + 3HOCl \rightarrow RCOOH + CHCl_3 + 2H_2O$

Chlorine substitution reactions can lead to the formation of organohalogen compounds, such as chloroform, and, where HOBr is present, mixed halogenated and brominated organic compounds. The number of by-products can hardly be determined due to many possible side reactions. A major component, however, are the trihalomethanes (THMs) such as bromoform. Concentrations of other halogenated organics are considerably lower and usually in the nanogram per liter range. Substances of anthropogenic origin in coastal waters, especially mineral oil or diesel fuels, may give rise to compounds like chlorophenols (some of which can taint fish flesh at concentrations as low as 0.001 mg/ℓ (DWAF 1995)) or chlorobenzenes. However, THMs such as bromoform account for most of the compounds.

A number of other source water characteristics are likely to have an impact on the concentrations of organic by-products present in brine water discharges: natural organic matter in water is the major precursor of halogenated organic by-products, and hence the organic content of the source water (often measured as total organic carbon, TOC) may affect the concentration of by-products formed. In general, the higher the organic content of the source water, the higher the potential for by-product formation. The ammonia concentration is likely to affect the extent of by-product formation, through reaction with chlorine to form chloramines. Although seawater generally contains low concentrations of ammonia than freshwater, under certain conditions (dependent on chlorine dose: ammonia nitrogen concentration) it can compete with bromide for the available chlorine to form monochloramine. In addition, hypobromous acid can react with ammonia to form bromamines. Although the sequence of reactions is complex, it is likely that the reaction of either hypochlorous or hypobromous acid with ammonia to form halamines will reduce organic by-product formation during the chlorination of seawater. Chlorine can also react with nitrogen-containing organic compounds, such as amino acids to form organic chloramines. The pH of the incoming feed water water could also affect the nature of the by-products formed. In general, while variations in pH are likely to affect the concentrations of individual by-products, the overall quantity formed is likely to remain relatively constant. Little is known about the biocidal properties of these compounds.

Paradoxically, chlorine chemistry thus establishes that no free chlorine is found in chlorinated seawater where bromide oxidation is instantaneous and quantitative. However, the chlorinated compounds, which constitute the combined chlorine, are far more persistent than the free chlorine. After seawater chlorination, the sum of free chlorine and combined chlorine is referred to as total residual chlorine (TRC).

Marine organisms are extremely sensitive to residual chlorine, making it a prime choice as a biocide to prevent the fouling of marine water intakes. Many of the chlorinated and halogenated by-products that are formed during seawater chlorination (see above) are also carcinogenic or otherwise harmful to aquatic life (Einav *et al.* 2002, Lattemann & Höpner 2003). Values listed in the South African Marine Water Quality Guideline (DWAF 1995) show that 1500 µg/ℓ is lethal to some phytoplankton species, 820 µg/ℓ induced 50% mortality for a copepod and 50% mortality rates are observed for some fish and crustacean species at values exceeding 100 µg/ℓ (see also ANZECC 2000). The lowest values at which lethal effects are reported are 10 – 180 µg/ℓ for the larvae of a rotifer, followed by 23 µg/ℓ for oyster larvae (*Crassostrea virginica*). Sublethal effects include valve closure of mussels at values <300 µg/ℓ and inhibition of fertilisation of some urchins, echiuroids, and annelids at 50 µg/ℓ. Eppley *et al.* (1976) showed irreversible reductions in phytoplankton production, but no change in either plankton biomass or species structure at chlorine concentrations greater than 10 µg/ℓ. Bolsch & Hallegraeff (1993) showed that chlorine at 50 µg/ℓ decreased germination rates in the dinoflaggelate *Gymnodinium catenatum* by 50% whereas there was no discernable effect at 10 µg/ℓ. This indicated that particularly the larval stages of some species may be vulnerable to chlorine pollution. The minimum impact concentrations reported in the South African Water Quality Guidelines are in the range 2 to 20 µg/ℓ at which fertilisation success in echinoderm (e.g. sea urchin) eggs is reduced by approximately 50% after 5 minute exposures.

A.3. Environmental Fate of Cleaning Chemicals used in the CIP Process

The membranes in the desalination plant will need periodical cleaning (CIP = Cleaning in Place) to remove any biofouling. The currently suggested cleaning interval for the proposed desalination project is three times per year. Typical cleaning chemicals include weak acids, detergents, oxidants, complexing agents and/or non-oxidising biocides for membrane disinfection. These chemicals are usually generic types or special brands recommended by the membrane manufacturers. The exact list of chemicals used will only be known once the desalination plant operator has been appointed. Common cleaning chemicals, however, include Sulphuric acid, Ethylenediaminetetra-acetic acid (EDTA), Sodium tripolyphosphate (STPP), and Trisodium phosphate (TSP), and Dibromonitrilopropionamide (DBNPA) as non-oxidising biocide. Below follows a short summary of the environmental fates and effects of these chemicals.

Sulphuric acid (H_2SO_4) is used for pH adjustment in the desalination process to reduce the pH for the acid-wash cycle. It is a strong mineral acid that dissociates readily in water to sulphate ions and hydrated protons, and is totally miscible with water. At environmentally relevant concentrations, sulphuric acid is practically totally dissociated, sulphate is at natural concentrations and any possible effects are due to acidification. This total ionisation also implies that sulphuric acid, itself, will not adsorb on particulate matters or surfaces and will not accumulate in living tissues (http://www.chem.unep.ch/irptc/sids/oecdsids/7664939.pdf). Sulphuric acid can be acutely toxic to aquatic life *via* reduction of water pH. Most aquatic species do not tolerate pH lower than 5.5 for any extended period. No guideline values are available for this substance but *No Observed Effect Concentration* (NOEC) values were developed from chronic toxicity tests on freshwater organisms and range from 0.058 mg/ℓ for fish populations to 0.13 mg/ℓ for phytoplankton and zooplankton populations, respectively (http://www.chem.unep.ch /irptc/sids/oecdsids/7664939.pdf). As seawater is highly buffered, the limited sulphuric acid discharges are not expected to have significant impacts in the marine environment. The pH of the effluent is predicted to be between 7.3 and 8.2.

EDTA is an aminopolycarboxylic salt that is used as a chelating agent to bind or capture trace amounts of iron, copper, manganese, calcium and other metals. In water treatment systems, EDTA is used to control water hardness and scale-forming calcium and magnesium ions to prevent scale formation. Because of the ubiquitous presence of metal ions, it has to be assumed that EDTA is always emitted as a metal complex, although it cannot be predicted which metal will be bound. EDTA will biodegrade very slowly under ambient environmental conditions but does photodegrade. EDTA is not expected to bioaccumulate in aquatic organisms, adsorb to suspended solids or sediments or volatilize from water surfaces (European Union Risk Assessment Report 2004). Toxicity tests on aquatic organisms have shown that adverse effects occur only at higher concentrations (the lowest concentrations at which an adverse effect was recorded is 22 mg/ℓ) (European Union Risk Assessment Report 2004). On the other hand, if trace elements like Fe, Co, Mn, and Zn are low in the natural environment, an increased availability of essential nutrients caused by the complexing agent EDTA is able to stimulate algal growth. Heavy metal ions in the water are complexed by free EDTA, and a comparison of the toxicity of those compared to the respective uncomplexed metals and free EDTA have shown a reduction in toxicity by a factor of 17 to 17000 (Sorvari & Sillanpää 1996). Experiments (albeit with significantly higher trace metal concentrations than are typically observed in the environment) indicate that EDTA decreases the accumulation of metals such as Cd, Pb and Cu, however the absorption of Hg by mussels is seemingly promoted through complexation with EDTA (Gutiérrez-Galindo 1981, as cited in the European Union Risk Assessment Report 2004). Potential promotion of the accumulation of metals in sediments is unlikely to be a concern as in high concentrations EDTA prevents the adsorption of heavy metals onto sediments and even can remobilise metals from highly loaded sediments (European Union Risk Assessment Report 2004). Within the framework of marine risk assessment, the European Union has published a risk assessment report in which a *Predicted No Effect Concentration* (PNEC) of 0.64 mg/ℓ was calculated (European Union Risk Assessment Report 2004). The EDTA concentration expected in the brine is 0.013 mg/ℓ and lies thus under the PNEC value.

Sodium tripolyphosphate (STPP, $Na_5P_3O_{10}$) is the sodium salt of triphosphoric acid. It is a typical ingredient of household cleaning products, and is thus commonly present in domestic waste-waters. STPP is an inorganic substance that when in contact with water (waste-water or natural aquatic environment) is progressively hydrolysed by biochemical activity, finally to orthophosphate. Acute aquatic ecotoxicity studies have shown that STPP has a very low toxicity to aquatic organisms (all EC/LC_{50} are above 100 mg/ℓ) and is thus not considered as environmental risk (HERA 2003). The final hydrolysis product of STPP, orthophosphate, however, can lead to eutrophication of surface waters due to nutrient enrichment. However, phosphate as a nutrient is not limiting in marine environments unless there are significant inputs of nitrogen (nitrates, ammonia), which is the limiting nutrient in the marine environment. Depending on the presence of cationic ions, STPP can, in addition to the hydrolysis into orthophosphate, precipitate in the form of insoluble calcium, magnesium or other metal complex species (HERA 2003).

Trisodium phosphate (TSP) (Na_3PO_4) is a highly water-soluble cleaning agent. When dissolved in water it has an alkaline pH. The phosphate can act as a plant nutrient, and can thus increase algal growth, however, as noted above, phosphate as a nutrient is not limiting in marine environments unless there are significant inputs of nitrogen.

The non-oxidising biocide DBNPA, which could potentially be added during the RO cleaning process, or may be an alternative to chlorine based biocides, has extremely fast antimicrobial action and rapid degradation to relatively non-toxic end products (US EPA 1994). The ultimate degradation products formed from both chemical and biodegradation processes of DBNPA include ammonia, carbon dioxide, and bromide ions. Degradation end products (e.g. ammonia) will seemingly not be problematic in the marine environment, however, it is the specific biocidal action of residual DBNPA in the effluent streams that is the major concern. The dominant degradation pathway of DBNPA involves reaction with nucleophilic substances or organic material invariably found in water. Additional degradation reactions include hydrolysis, reaction with soil, and breakdown through light (US EPA 1994). The uncatalyzed hydrolysis of DBNPA proceeds via decarboxylation to the generation of an array of degradation products. These degradates include dibromoacetonitrile, dibromoacetamide, dibromoacetic acid, monobromoacetamide, monobromonitrilo-propionamide, monobromoacetic acid, cyanoacetic acid, cyanoacetamide, oxoacetic acid, oxalic acid, and malonic acid. The rate of hydrolysis is a function of pH and temperature, and increasing either or both pH and temperature will increase the decomposition rate. For instance, at pH 5 the half-life of DBNPA is 67 days as opposed to 63 hours at pH 7 and 73 minutes at pH 9. In natural waters (seawater has a pH of 8), DBNPA hydrolyses rapidly (half life < five hours) into the above mentioned degradates which continue to degrade rapidly by aerobic and anaerobic aquatic metabolism (US EPA 1994). Although the hydrolysis and aquatic photolysis rate is rapid under aquatic conditions, the primary degradation pathway is through aerobic and anaerobic metabolism. In aerobic and anaerobic aquatic metabolism studies, DBNPA degraded with a half-life of <four hours, with a further rapid decrease of the degradate concentrations (US EPA 1994). Exposure to sunlight is a futher factor increasing the rate of decomposition which results in the formation of inorganic bromide ion. For example, the half-life of DBNPA was reported to be approximately 7 days when exposed to sunlight even at a pH of 4 (Dow Chemicals, Fact Sheet No. 253-01464-06/18/02). Aquatic toxicological studies have shown that DBNPA appears to be moderately toxic to estuarine fish and shrimp, highly toxic to estuarine mysids and very highly toxic to estuarine shellfish and larvae. It must be noted though that, due to the fast degradation of DBNPA, toxic effects are generally acute occurring within 24 hours of exposure, and chronic effects will not occur. Due to the rapid degradation of DBNPA in natural waters, some risk assessment studies have concluded that the use of DBNPA in cooling systems (once through and recirculating sytems) does not pose an unacceptable risk to the environment (Klaine et al., 1996). Mitigation measures to ensure low residuals of DBNPA in any discharge to the marine environment include appropriate design of the brine basin so as to ensure greater and sufficient dilution of the DBNPA residuals in the effluent stream before discharge.

A.4 References for Appendices

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